GAUGEMETER FOR STRIP MILLS.

By R. B. SIMS, B.Sc., A.M.I.Mech.E.

INSTRUMENTS for measuring the thickness of rolled strip, at present available, may be grouped into two categories. The more straightforward are the contact type, in which the strip is passed between the anvils of a micrometer, one of which is fixed while the other is displaced relatively to it by the strip as it varies in thickness. The movement of this anvil is amplified and displayed to the mill operator, usually by a simple electrical circuit. The second class of instrument, of more recent introduction, consists of a source of radiation on one side of the strip and a device on the other side for measuring the amount of radiation passing through. From this measurement an estimate may be made of the amount of absorption, which is proportional to the mass of the strip material per unit area, and hence the thickness may be calculated.

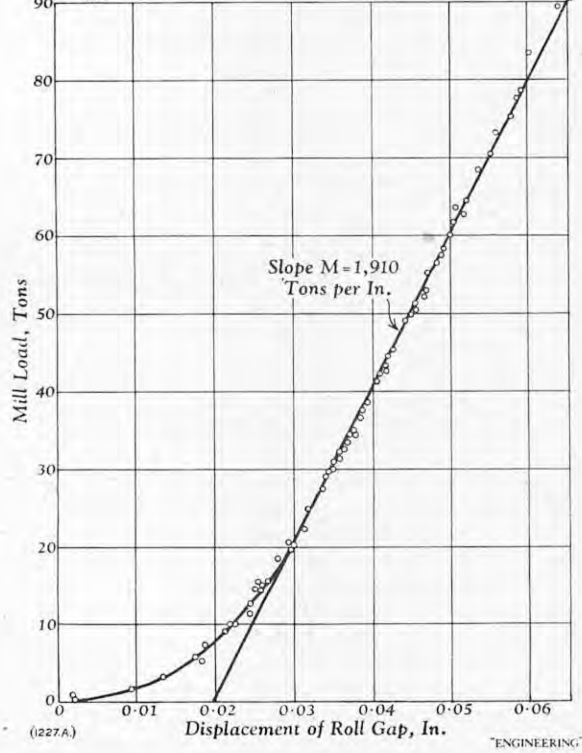
The contact type of thickness gauge, when properly designed and installed, is capable of a very high accuracy when the strip is moving relatively slowly under moderate to high tension, but at high strip speeds the instrument is liable to vibrate, causing the meter to indicate spurious fluctuations in gauge. This is particularly noticeable when strip is rolled full at the edges, the resultant "riffling" causing the micrometer to bounce in its mounting. The contact type, which has only been applied to cold mills, is also limited to the measurement of strip gauge near the edges. The time lags in these instruments need not be very large, but, as the measuring head cannot be mounted close to the roll gap, there is a delay between the rolling of off-gauge strip and its indication. This may give rise to successive over-corrections and under-corrections when the instrument is used to control the strip gauge either manually or automatically.

The radiation type of gauge is considerably more costly than the contact type, but it has the advantage that it can be used to indicate thickness at the hot mill. The cheaper types use sources of β radiation for steel strip up to 0·050 in. thick, but for heavier gauges γ radiation must be used. The type which has found greatest favour in American steelworks uses an X-ray tube of between 50 and 100 kV rating as a source, and these are very costly indeed. Moreover, the X-ray tube has only a limited life. The accuracy of the radiation-type gauges is approximately $\pm$ 2 per cent. if they are adjusted frequently, and, in the case of the radioactive source, a response time of about one second is required for a sufficient number of counts to ensure this accuracy. They also possess an indicating delay, being fixed well away from the roll gap.

Probably the greatest objection to all these gauges is the fact that they work close to the strip and are easily damaged by a cobble. The contact type is usually placed on the strip when the mill is nearly up to speed, and is taken off again before deceleration so that the end of the coil does not strike the instrument; yet it is at the onset of acceleration and at the end of deceleration that off-gauge variation is greatest.

The gaugemeter* described below was designed to meet some of these objections. It is strictly a contact gauge, using the mill rolls as the micrometer anvils, but the measurement of strip thickness is indirect, being derived from a measurement of initial roll setting and mill load. Since all the measuring apparatus is well away from the strip, it cannot be damaged by a cobble, and the circuit is simple and robust. It may have a very fast response, depending only on the design of the indicating circuit, and off-gauge is indicated as soon as it occurs, because the rolls themselves make the measurement. The meter is also accurate and relatively inexpensive. There are certain limitations to its use, which are described below.

Fig. 1.



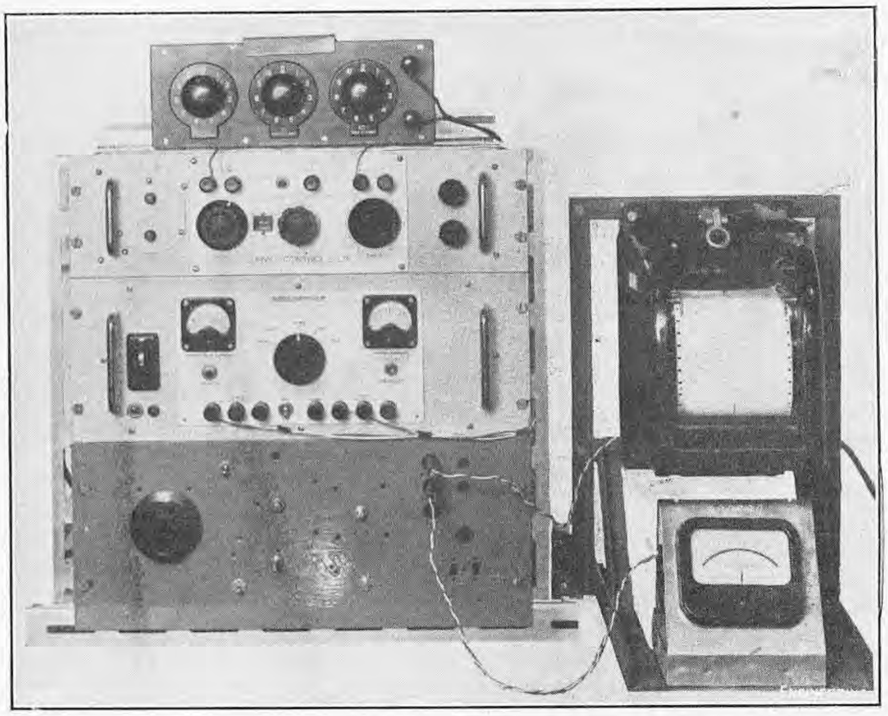


FIG. 2.

THEORY OF THE INSTRUMENT.

Before a pass is taken on a strip in a rolling mill, the gap between the rolls is set by the mill operator to some value less than the desired thickness of the rolled strip. This distance, usually termed the roll setting, will be denoted here by S_0. In mills rolling thin wide strip, the rolls are often forced together under a preload. The linear displacement of the screws, after the rolls have come together, will also be termed the roll setting, and will be written negatively.

The separating force exerted by the plastically deforming strip on the rolls separates them against the elastic contraint of the mill components, and the rolls themselves deform under the load. The strip is thus able to leave the mill at a greater thickness than the roll setting. Since these distortions in the mill are elastic, they obey Hooke's Law and there is a linear relationship between the roll load, F, and the difference between the rolled strip thickness, h, and the roll setting, S_0, which may be written* in the form

$$F = M\,(h - S_0). \qquad (1)$$

where M is the elastic constant of the mill. If F is measured in tons and h and S_0 in inches, then M has the dimensions of tons per inch and is the load in the roll gap required to part the rolls by one inch.

This linear relationship is demonstrated in Fig. 1, herewith, where strips of varying thickness were rolled at a fixed roll setting in the experimental mill of the British Iron and Steel Research Association, and the roll loads plotted against rolled strip thickness. The slope of the line is equal to M and is 1,910 tons per inch for the experimental mill. It will be seen that the relationship is linear except at loads less than about 20 tons, where a marked curvature begins. It is thought that this is due to mis-mating of the mill components. The curve is repeatable, and, as it occurs at loads below the normal working load of the mill, it may be allowed for in the design of the instrument. The significance of this fact will be discussed later.

Returning to equation (1), this may be re-written in the form

$$\frac{F}{M} + S_0 = h \qquad (2)$$

and if electrical quantities proportional to $\frac{F}{M}$ and S_0 can be obtained and added together, a measure of strip thickness will be obtained. Where a wide range of products is rolled in a mill, an accurate indication of strip thickness is difficult to obtain on a single indicating meter. The difference between the thickness rolled h, and the thickness required h', may be displayed, and the overall accuracy of the instrument increased. If $h = h' + \Delta h$, then equation (1) becomes

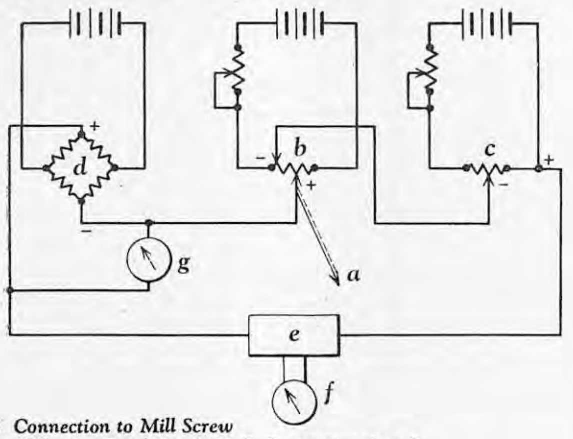
$$\frac{F}{M} + S_0 - h' = \Delta h \qquad (3)$$

* Patent applications have been filed for this instrument in the United Kingdom and abroad.

* "Principles of Continuous Gauge Control in Sheet and Strip Rolling," by W. C. F. Hessenberg, M.A., and R. B. Sims, B.Sc., A.M.I.Mech.E., *Proc. I. Mech. E.* (A), vol. 166, page 75.

GAUGEMETER FOR STRIP MILLS.

Fig. 3. BASIC CIRCUIT OF PROTOTYPE.



a Connection to Mill Screw
b Slidewire Providing E.M.F. Proportional to S_0
c " " " " to h'
d Loadmeter
e D.C. Amplifier
f Centre-Zero Meter Indicating Δh
g Meter Indicating Load
(1227.C.) "ENGINEERING"

Fig. 4. CHANGE IN STRIP THICKNESS v. AMPLIFIER OUTPUT.

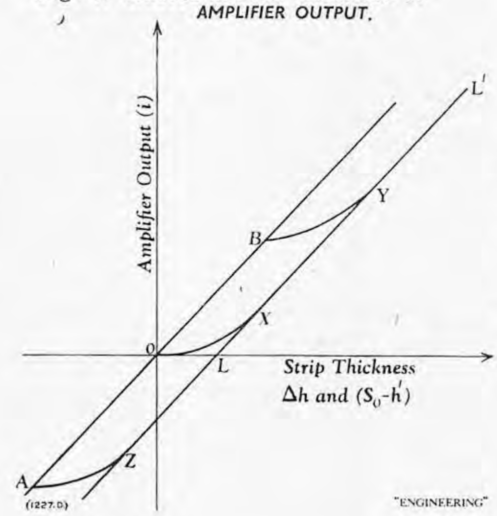


Fig. 5.

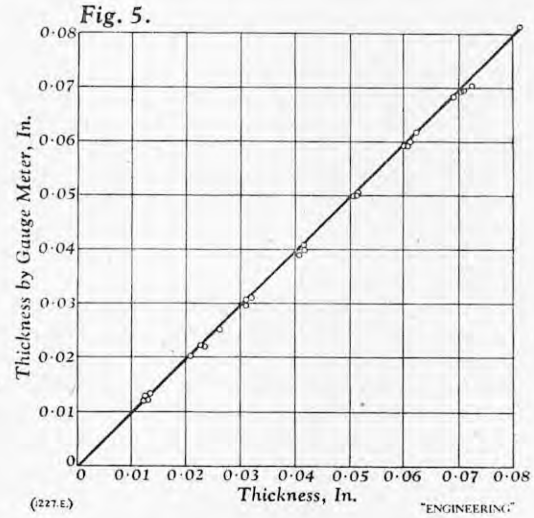


Fig. 6.

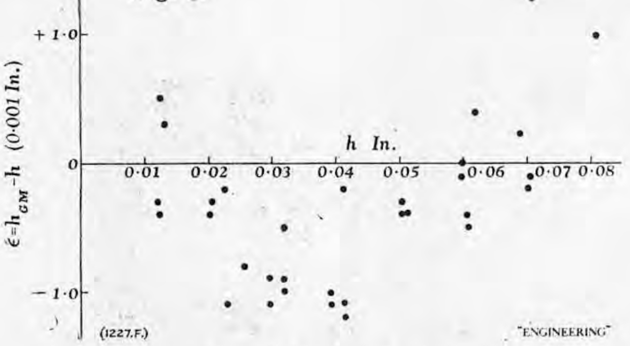
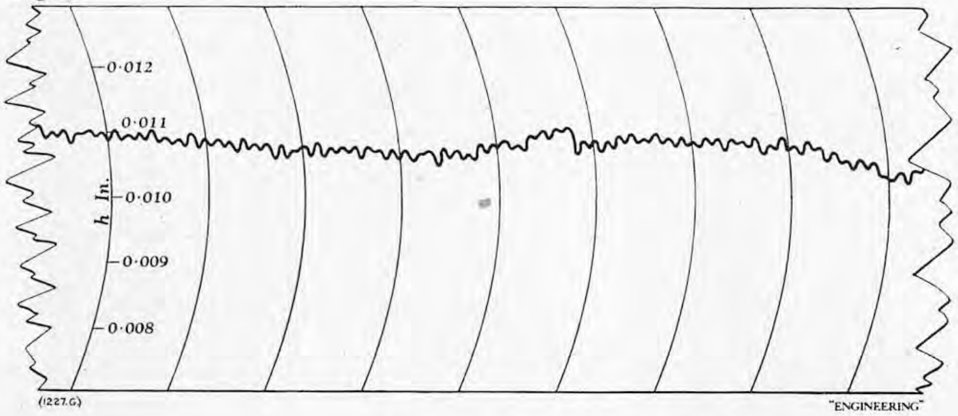


Fig. 7.



and an additional quantity proportional to $S_0 - h'$ must be added to signals proportional to $\frac{F}{M}$ and S_0 to obtain a measure of off-gauge.

THE PROTOTYPE INSTRUMENT.

The prototype apparatus, in the construction and testing of which the author was assisted by Mr. D. F. Arthur, B.Sc., was built to indicate the thickness of strip rolled in the British Iron and Steel Research Association experimental mill, is shown in Fig. 2, herewith, and its electrical circuit is illustrated diagrammatically in Fig. 3. The slidewire *b*, attached directly to the mill screw *a*, provided a measure of the roll setting S_0 from the known pitch of the thread and the amount of angular rotation of the screw. It carried an adjustable zero which enabled the slidewire to indicate negative roll settings. It was connected in series with a decade resistance box *c*, providing an electromotive force proportional to the required thickness h', and with two loadmeters, *d*, of the B.I.S.R.A. type,* connected to indicate total load, thus providing a measure of the quantity $\frac{F}{M}$. A high-impedance stable direct-current amplifier, *e*, of the interruptor type was used in the prototype circuit, and the output indicated on the meter *f* the departure of the strip thickness from the required gauge. A meter *g*, indicating mill load, was included in the circuit.

In Fig. 4, on this page, the line A O B represents the output of the amplifier for a change in the quantity $S_0 - h'$. It will pass through the origin when $S_0 = h'$ or when $h' = 0$, and the rolls are just touching. In this condition, if load is applied, the output will increase along the line O X Y due to the addition of the signal proportional to $\frac{F}{M}$ from the loadmeters. From O to X the output is non-linear, but it is linear above the point X, which represents a load of about 20 tons (the critical load) on the rolls of the experimental mill. If this experiment is repeated at points A and B when the rolls are preloaded and parted, respectively, it will be found that the output is linear when the mill load exceeds the critical load, but is displaced a fixed distance O L from the origin, which depends only on the mill characteristics.

It is possible, therefore, to arrange the electrical circuit so that the line Z X Y shall pass through the origin, when the meter will indicate accurately values of Δh when the mill load exceeds the critical load. The gaugemeter must be adjusted, therefore, to suit the mill characteristics when it is installed. The electrical circuit shown in Fig. 3 provides adjustment for matching the quantity $\frac{F}{M}$ with the roll setting and thickness controls, and there is a single adjustment to correct for zero changes in S_0, occurring during normal usage due to roll changing, wear, etc.

The zero of the instrument will also drift, due to thermal changes in the mill. It would be unaffected if the mill heated up uniformly, but when a mill is started up from cold the rolls and necks will be heated to temperatures in excess of the mill frame. Until the mill has reached thermal equilibrium, the zero of the equipment must be checked by setting the value of h' on the instrument to zero and compressing the rolls together under a load greater than the critical value. If the indicating meter does not read zero, the zero of the gaugemeter may easily be reset by altering the zero of the S_0 slidewire.

The gaugemeter will indicate accurately the thickness at one or both edges of the strip, or a mean thickness across the width of the strip, provided that the loaded rolls do not possess appreciable residual camber, due either to bending, thermal effects or wear. In most efficient strip mills this condition is fulfilled, otherwise strip would be produced with a heavy centre or edges. A calibration of the prototype against the average strip thickness, measured by a contact strip micrometer, is shown in Fig. 5, herewith. The correlation is very close, particularly when it is remembered that the instrument was constructed quite roughly from standard laboratory equipment. The distribution of error in the gaugemeter against the contact micrometer, shown in Fig. 6, herewith, is less than 0·0005 in. The greatest single error is +0·0012 in., and there are errors of approximately −0·001 in. at strip thickness between 0·025 in. and 0·040 in. These are due to imperfections in the resistors and contacts of the prototype equipment. In Fig. 7 is shown a record taken of strip thickness when rolling strip in coil form. A record may be obtained along the whole length of the coil without risk of damage by a cobble, by the end of the strip, or by coil breakage under tension in a cold mill. The indication is unaffected in accuracy by strip shape or variations in tension.

THE INDUSTRIAL INSTRUMENT.

A rugged industrial instrument is now being designed, in which a number of modifications have been made from the prototype. In a production mill, the screws must be lifted occasionally far in excess of their normal travel in order to change the work rolls and the back-up rolls, and the industrial equipment is fitted with a drive which will allow for such large changes in the roll setting. The amplifier will drive up to ten meters, indicating the departure of the strip from gauge, and this will be useful in the continuous hot mill. It is also hoped, by using specially wound resistors, to obtain a greatly improved accuracy.

* "Loadmeter for Industrial Mills," by R. B. Sims, J. A. Place and A. D. Morley, ENGINEERING, vol. 173, page 116 (1952).

The potential advantages of this instrument to the mill operator are considerable. It is relatively inexpensive, and, apart from measuring strip thickness, it will also indicate continuously the load on the rolls, from which many useful production data may be obtained. The components attached to the mill, the slidewire and the loadmeters, are removed from the strip and so cannot be damaged by it, and they may be made robust and reliable; a set of loadmeters have completed a year's continuous operation in a large cold strip mill. The more delicate electrical and electronic components may be housed in safety at some distance from the mill. They are no more complex than any of the self-balancing potentiometric recorders now widely used on the steel-making side of the works, and should have much the same serviceability. One of the two disadvantages—the inability to indicate variations in gauge across the strip—is shared by other strip-measuring instruments; except, perhaps, the radiation types, which must be specially designed for the task. The other disadvantage, the change in zero with temperature changes in the mill structure, may be corrected quickly and easily, and, from current mill practice, the correction would not appear to be large or rapidly fluctuating once the mill has become warmed up.

LITERATURE.

Proceedings of a Second Symposium on Large-Scale Digital Calculating Machinery.

Harvard University Press, Cambridge 38, Massachusetts, U.S.A. [Price 8 dols.]; and Oxford University Press (Geoffrey Cumberlege), Amen House, Warwick-square, London, E.C.4. [Price 52s. net.]

FOLLOWING completion of the Mark III computing machine by the Harvard Computation Laboratory, for subsequent use at the Dahlgren proving grounds, a Second Symposium on Large-Scale Digital Calculating Machinery was held in September, 1949, under the combined auspices of the Bureau of Ordnance of the United States Navy Department and Harvard University. The *Proceedings*, now published, contain a mass of useful information, in 40 papers directed to various aspects of the subject, including methods of numerical analysis, and the solution of special problems in physics, applied mechanics, economics, and social science. The separate contributions to the Symposium fall into five main groups, of which that on recent developments is of particular interest to those responsible for the design and improvement of these mechanical aids to computation. While it is hardly possible to mention each of the papers presented, that read by Mr. E. G. Andrews, on the Bell Computer, Model VI, merits notice because of the complete avoidance of the use of conventional vacuum tubes in this machine. Again, the contribution by Mr. W. S. Elliott, of Elliott Brothers (London), Limited, under the title of "The Present Position of Computing-Machine Development in England," serves to emphasise the difference between the methods of approach to the development of large calculating machines by workers in the United States, on the one hand, and in this country on the other. A subsequent section of the book explains how mercury delay lines, magnetic delay lines, and electrochemical storage components and relays have been employed for the purpose of providing an adequate high-speed storage device. While general-purpose machines formed the principal type under discussion on this occasion, the authors of two of the papers showed that, in certain cases, notably those of industry and government, special-purpose machines offered the advantage of low cost for each function performed. The point is further emphasised by Mr. W. W. Woodbury, in his description of a machine built by the International Business Machines Corporation for Northrop Aircraft, Incorporated, in which the aim was to construct a simple, yet reliable, machine for special purposes.

In addition to papers on numerical methods and analysis, of direct value to advanced students of applied mathematics, there are others of potential value to physicists in search of information on the utility of these machines in the solution of problems associated with the study of the birefringence produced by viscous flow, the trajectories of cosmic-ray particles, and the interaction of atomic electrons with electro-magnetic radiation. The part of the book of most interest to students of engineering and allied subjects consists of five papers, devoted to the use of computing machines in research for the oil industry, and more especially in aeronautical research. In the latter of these applications, the reader will find evidence of noteworthy advances in several directions, as is to be inferred from the prediction of Mr. E. T. Wilmers, in his paper entitled "Problem of Aircraft Dynamics," to the effect that the complete solution of the now separate problems of flutter, aerodynamic stability, and servo-mechanism performance of an airframe may soon be found in terms of the complete frequency-response spectrum for a particular aircraft. Mr. H. W. Emmons, too, makes an instructive contribution to this branch of technology, in the description of his attempt to solve the whole problem of combustion in a form that will permit a careful check of the stream lines and the position of the flame-front with those obtained experimentally. The various contributors to the Symposium succeed admirably in providing a valuable survey.

Mechanical Biology: Announcing the Discovery of Twelve Biological Rules or Laws.

By THE REV. P. H. FRANCIS, M.A. The Mitre Press, Mitre Chambers, Mitre-street, London, E.C.3. [Price 30s. net.]

THE theme of this book is that all mechanical appliances are copies of some feature of human or animal bodies. To support this contention, the author considers a large number of weapons and games implements, ranging from crossbows to croquet mallets. His method may be indicated by referring to the club. He looks upon the head of a club as a substitute for the fist of the man who wields it and the shaft of the club as an extension of his arm. To liken the head and shaft of a club to the fist and arm of the user is a pardonable analogy, although it is not clear that it is a valuable one. When, however, the analogy is pushed to the extent of contending that "the human prototype" of a cartridge case is "the skin of the right hand palm and parts of the fingers," it becomes absurd. The overworked analogy leads up to the statement that "a useful mechanical contrivance cannot be made that is not a copy of a contrivance of the body." For the purpose of supporting this remarkable assertion, a mass of interesting information about primitive and historic weapons has been assembled, but the conclusions which the author has drawn from it may not be shared by many of his readers.

His analogy between a petrol engine and the human machine is not novel, but an inference to which it leads certainly is. A cardinal tenet of his doctrine is that the "contrivance of the body" is always more efficient than the mechanical copy, but he has to recognise that "a motor car or an aeroplane can travel faster than any creature." The difficulty presented by this circumstance is met by his statement that "Nature is not interested in speed . . . no doubt she could have given her creatures great speeds, if her plans had required it," with the added rash prophecy that "probably the speeds of mechanical vehicles of the future will correspond more closely to the speeds of creatures." In these remarks, the author is endowing Nature with a personality and entering a pantheistic sphere into which we shall not attempt to follow him.

Tables of Chemical Kinetics: Homogeneous Reactions.

Circular 510 of the National Bureau of Standards. The Superintendent of Documents, United States Government Printing Office, Washington 25, D.C., U.S.A. [Price 4.00 dols.]

THIS massive volume of 730 pages, forming part of a co-operative effort to supplement and correct data published in 1926 in the International Critical Tables and sponsored by various national and international scientific bodies, has been prepared under the auspices of the National Bureau of Standards, the Committee on Tables of Constants of the National Research Council, and Princeton University. It presents a critically evaluated compilation of the available factual numerical data on rates and rate constants of homogeneous chemical reactions. The reactions covered include rearrangement-isomerisation, condensation-solvolysis, exchange-substitution, elimination, dissociation-decomposition, association-addition, and oxidation-reduction. Successive columns list the reaction, amount of reactant, temperature, rate constant and, in appropriate cases, the nature and amount of addend, defined mass-action law, frequency factor, activation energy and entropy, with comments and literature references. Wherever necessary, the original data have been recalculated to ensure conformity with the definitions of units set out in the introduction. Each table starts on a fresh sheet and is designated by a six-digit number, the first two digits referring to the type of reaction, the third to the phase of the homogeneous reaction—gaseous (1), liquid (2), or solid (3). The second three-digit group of the table number refers to the types of substances involved. Within each table the order is usually that of increasing complexity of the key reactant; thus, for organic compounds in the order of increasing numbers of carbon atoms, while substituted derivatives are arranged in an order corresponding to that of the periodic system. The paper casing of the volume can be removed and the sheets have been punched for incorporation in a standard loose-leaf binder to enable additional sheets to be added and revised sheets substituted as these become available. These comprehensive tables provide the physical chemist with an indispensable source of reference.

Hydraulics and Its Applications.

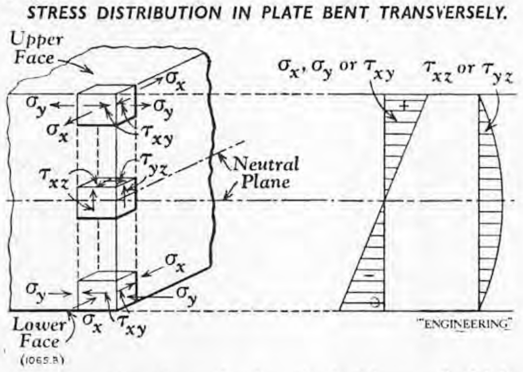
By PROFESSOR A. H. GIBSON, D.Sc., LL.D., M.I.C.E., M.I.Mech.E. Fifth edition. Constable and Company, Limited, 10, Orange-street, Leicester-square, London, W.C.2. [Price 35s. net.]

PROFESSOR GIBSON'S book occupies a special position among text-books on hydraulics. It is a work in which the author has drawn upon a wealth of experience on the experimental side, and in which he provides the mathematical framework of the analysis required in the drawing office and in the field. The range of the topics covered is vast, and some compression is inevitable. On this account the treatment is essentially one for the advanced student who wishes to see his existing knowledge of the subject in a more general setting, and to appreciate the application of the principles of mechanics to the design of hydraulic machinery.

The revision of the previous edition, which appeared in 1930, includes the substitution of new topics for some which have become obsolete, and the inclusion of a completely new chapter on the principles of the construction and operation of scale models. This chapter presents an instructive introduction to a subject on which Dr. Gibson writes with authority, especially in regard to the scope of models as instruments of research into complicated problems of hydraulics. Importance is attached to his remarks because much depends on how far it is feasible in a model to reproduce accurately all the relevant factors. In the model of an estuary, for instance, while it is usually possible to reproduce approximately, by fans, the effect of any prevailing wind, it is impossible to

PHOTO-ELASTIC STUDY OF PLATES BENT TRANSVERSELY.

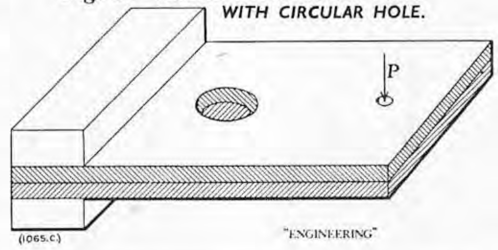
Fig. 2.
STRESS DISTRIBUTION IN PLATE BENT TRANSVERSELY.



reproduce the effect of gales, the incidence of which, as regards duration and direction, is casual, though the general effect of a specified gale may be examined by this means. While it is true that, in a tidal estuary, the combined scouring action of the ebb and flow currents constitutes the dominant factor in the maintenance of the deep-water channels, and that, for any period of time in which there is no prevailing gale-direction, the effects of these disturbing agencies may be expected to counteract each other, yet one violent gale in an exposed estuary may produce changes greater than would occur in months, or even years, under conditions of normal ebb and flow. For this reason, anything approaching close agreement in the matter of details between the actual estuary and its model over a period of years is highly improbable, except where the estuary is more or less sheltered and the physical features are such as will bring about well-defined and comparatively strong currents. Nevertheless, the present scope of models is remarkable, particularly in circumstances where the field of inquiry can be restricted to a comparison of the relative merits of different schemes. Thus, in a model for investigating the scour at the toe of a proposed spillway, even though the conditions are such that the actual depth and length of scour are not reproduced with any great accuracy, the relative merits of different designs in reducing scour are likely to be indicated accurately. The ramifications of this fascinating subject are numerous, as are also the references to other technical and scientific writings on the subject, and the new chapter suffices to show the noteworthy advances which have been made during recent years in an experimental field that offers great hopes for the future.

ALMANACS AND CALENDARS.—Monthly tear-off wall calendars have reached us from the Information Service of the Ministry of Economic Affairs, The Hague, Holland; Charing Cross Electrical Installation Co., Ltd., 61, Chandos-place, Strand, London, W.C.2; Charles Churchill & Co., Ltd., and associated companies, Coventry-road, South Yardley, Birmingham; James Howden & Co., Ltd., 195, Scotland-street, Glasgow, C.5; Mavor and Coulson, Ltd., Bridgeton, Glasgow, S.E.; and Mullard, Ltd., Century House, Shaftesbury-avenue, London, W.C.2. Wall calendars with tear-off sheets showing on each the current month in heavy type, and the preceding and following months in smaller type, have been received from Holman Brothers, Ltd., Camborne; the Hunslet Engine Co., Ltd., Jack-lane, Leeds, 10; B. Levy & Co. (Patterns), Ltd., 1-5, Osbert-street, Vincent-square, London, S.W.1; Priest Furnaces Ltd., Longlands, Middlesbrough; and Russell Newbery & Co., Ltd., Essex Works, Dagenham, Essex. Wall calendars showing three months on each sheet, and including daily tear-off pads in addition, have come to hand from the Butterley Co., Ltd., Butterley, Derby; and Frederick Parker Ltd., Viaduct Works, Leicester. Mono Pumps Ltd., Mono House, 67, Clerkenwell-road, London, E.C.1, have sent us a tear-off wall calendar showing two months on each sheet; while from Permali Ltd., Bristol-road, Gloucester, we have received a wall calendar giving particulars of the whole year on one sheet. The Bristol Aeroplane Co., Ltd., Filton House, Bristol, have sent us a 1953 replacement pad for their wall-map and calendar.

Fig. 3. LOADED RECTANGULAR PLATE WITH CIRCULAR HOLE.



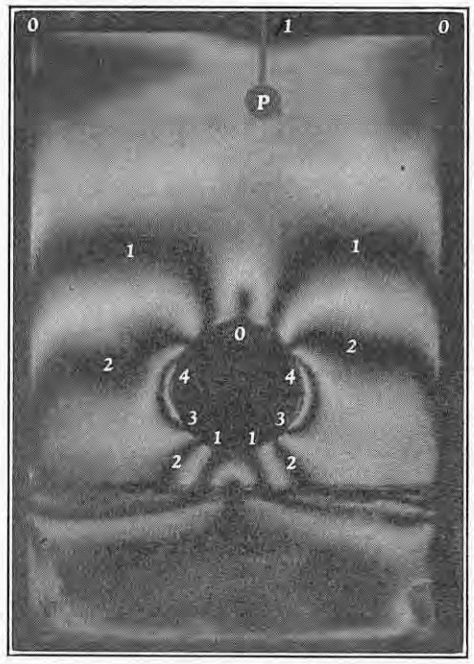


FIG. 4. ISOCHROMATIC PATTERN OF PLATE IN FIG. 3; CROSS POLARISATION FILTERS.

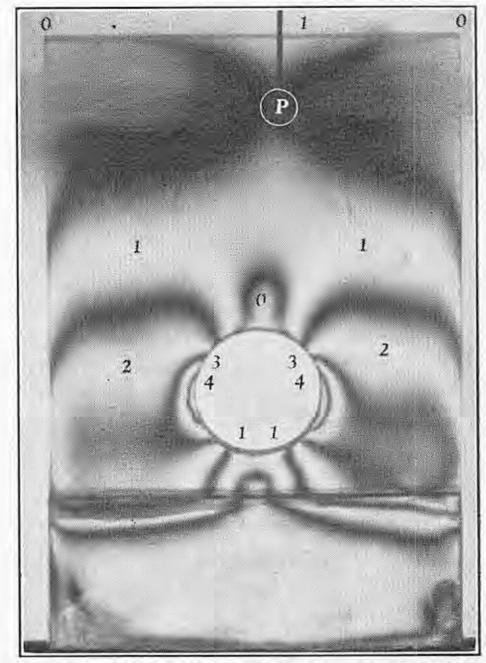


FIG. 5. ISOCHROMATIC PATTERN; PARALLEL POLARISATION FILTERS.

PHOTO-ELASTIC RESEARCH ON PLATES IN TRANSVERSE BENDING.

By DR.-ING. ALBRECHT KUSKE.

(*Concluded from page* 21.)

DIFFERENT methods were developed by Favre and the author to measure the magnitude of the stresses in the plate. Favre used the interferometer method which allows the two principal stresses to be determined independently at any point of the plate, but the author used the method of isochromatics, which gives the difference of the principal stresses only. In ordinary plates, the two principal stresses, or their components, can easily be computed from the isochromatics and isoclinics by means of the equations of equilibrium or the equation of compatibility. In plates in transverse bending, however, the determination of the values of the two principal stresses is somewhat more difficult. The distribution of the normal and shear stresses in an element of a plate in transverse bending is indicated in Fig. 2, herewith. The normal stresses are equal but of opposite sign at opposite points of the surfaces. The shear stresses acting in the direction of the normal stresses have the same distribution. The transverse shear stresses, however, are zero at the surfaces and have their maximum value in the plane of symmetry. Their distribution is a parabolic one. The normal stress in the direction normal to the plane of the plate can be considered to be zero.

As the maximum normal stresses occur at the surface of the plate, all calculations can be confined to this plane. The equations of equilibrium in this plane read:

$$\frac{\partial \sigma_x}{\partial x} + \frac{\partial \tau_{xy}}{\partial y} + \frac{\partial \tau_{xz}}{\partial z} = 0 \quad . \quad . \quad (2)$$

$$\frac{\partial \sigma_y}{\partial y} + \frac{\partial \tau_{xy}}{\partial x} + \frac{\partial \tau_{yz}}{\partial z} = 0 \quad . \quad . \quad (3)$$

$$\frac{\partial \tau_{xz}}{\partial x} + \frac{\partial \tau_{yz}}{\partial y} = 0 \quad . \quad . \quad . \quad (4)$$

where x and y are co-ordinates in the plane of the plate and z is the co-ordinate normal to that plane. As τ_{xz} and τ_{yz} are proportional to the total transverse forces T_{xz} and T_{yz}, respectively, (i.e., the integral of τ_{xz} or τ_{yz} between $+\frac{h}{2}$ and $-\frac{h}{2}$) the last of these equations can be rewritten

$$\frac{\partial T_{xz}}{\partial x} + \frac{\partial T_{yz}}{\partial y} = 0 \quad . \quad . \quad . \quad (5)$$

Along an edge free from load, the principal stress in the direction normal to the edge, within the plane of the plate, is zero. Thus, the other principal stress, namely, that in the direction of the edge, can easily be determined from the isochromatics. If the direction of the edge is that of the x-axis, σ_x and $\frac{\partial \sigma_x}{\partial_x}$ are known.

The shear stresses τ_{xy} can be calculated from the values given by the isochromatics and isoclinics within the whole plane of the plate from the well-known equation

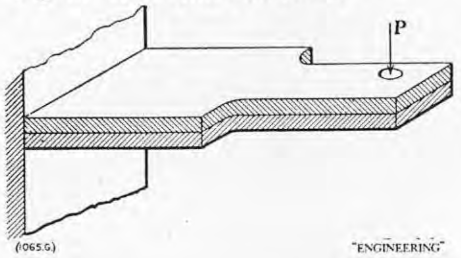
$$\tau_{xy} = \tfrac{1}{2}(\sigma_1 - \sigma_2) \sin 2\phi \quad . \quad . \quad . \quad (6)$$

Thus, τ_{xy} and, hence, $\frac{\partial \tau_{xy}}{\partial x}$ and $\frac{\partial \tau_{xy}}{\partial y}$, are known at every point of the plate.

The transverse shear stresses, or the forces T_{xz} and T_{yz} can be added vectorially and produce a resultant shear force T_z. This resultant indicates the magnitude and the direction of the maximum shear force for all the different possible directions of section at one point of the plate. The shear force in the direction normal to that of the resultant is zero. If the equations of equilibrium are applied to this direction, the terms containing τ_{xz} or τ_{yz} vanish. Along a load-free edge, the direction of T_z coincides with that of the edge, excepting those points where T_z is zero. Unfortunately, the value and direction of T_z within the plate, except at load-free edges, cannot be measured directly in this method. They can, however, be found by applying the equations of equilibrium step by step. Assuming the direction of T_z were known at every point of the

PHOTO-ELASTIC STUDY OF PLATES BENT TRANSVERSELY.

Fig. 6. PLATE WITH TWO FILLETS.



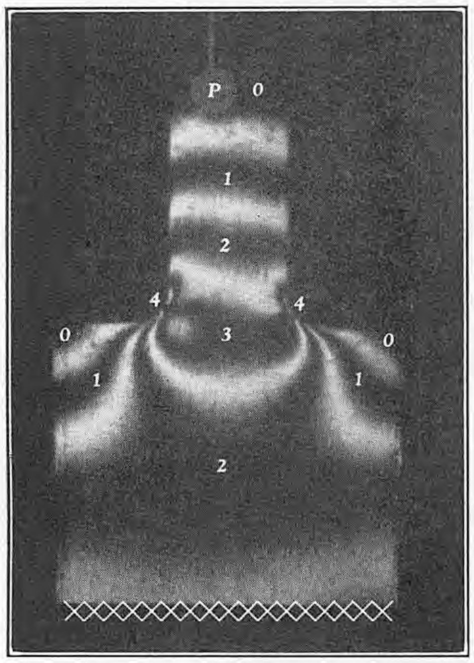
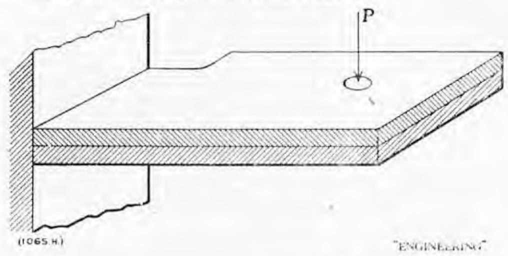


FIG. 7. ISOCHROMATIC PATTERN OF PLATE IN FIG. 6.

Fig. 8. PLATE WITH ONE FILLET.



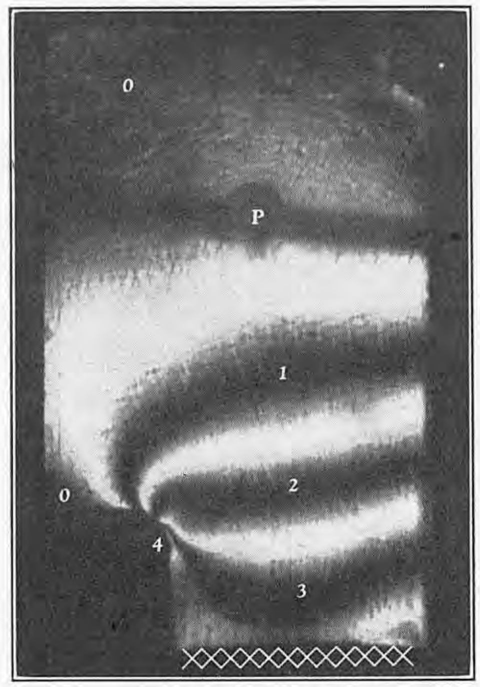
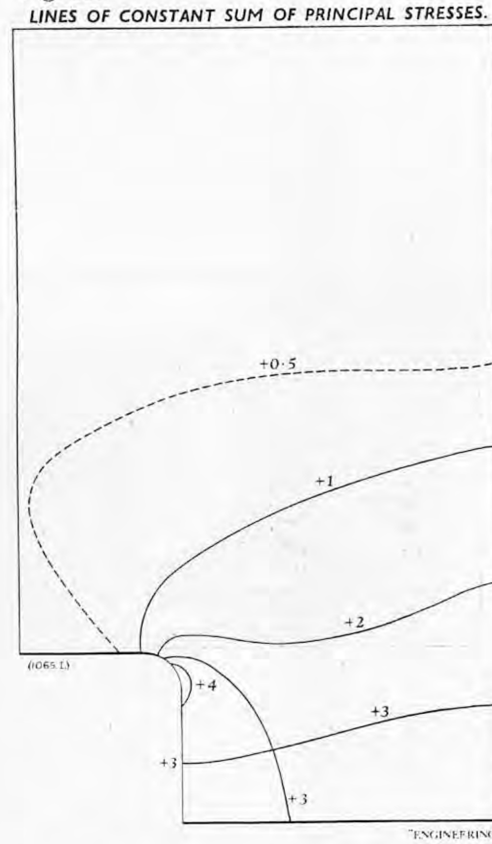


FIG. 9. ISOCHROMATIC PATTERN OF PLATE IN FIG. 8.

Fig. 10. LINES OF CONSTANT SUM OF PRINCIPAL STRESSES.



plate, a system of lines indicating the direction of T_z could be drawn. The amount of shear stress or shear force acting between two neighbouring lines would be constant. Thus the shear stress would be proportional to the distances of the two neighbouring lines. By applying the equations of equilibrium along a load-free edge, T_z can be calculated from the isochromatics and isoclinics only as already shown. As the edge is one of the T_z-lines, a neighbouring line can be found from the values of T_z along the edge. Its distance from the edge will be proportional to the inverse of the value of T_z at each point. Theoretically, a neighbouring line can be found by this method only if the distance is very small. In practice, the permissible length of each step depends on the kind of problem. The longer the step the less accurate the approximation. By applying this method, the direction of the T_z-line, and thus the normal to it, can be found at some distance from the edge. The equations of equilibrium can be applied to the direction normal to the T_z-line, neglecting the term containing τ_{xz} or τ_{yz}, whichever is appropriate. In this way, all stress components, excepting T_z, or τ_{xz} or τ_{yz}, can be found along the T_z-line. The direction of the T_z-line must then be taken as the x- or y-direction. This involves transforming the stress components, but the equations of equilibrium can then be applied anew and the values of T_z along the T_z-line can be found in the same way as along the edge. From these values, the distance of the next T_z-line can be determined. By repeating this cycle of operations a sufficient number of times, the whole plane of the plate can be covered by T_z-lines and all stress components can be found.

This method is quite convenient if the normal to the T_z-lines is straight or almost straight. Otherwise, the transformation of the stress components is somewhat tedious. There are several similar methods in which the equations of equilibrium can be applied, but none is as simple as those used in the two-dimensional photo-elasticity applied to ordinary plates. Another method for determining the stress components in a plate in transverse bending is based on the equations of compatibility. This requirement produces a very simple equation valid, for any load-free plane surface of a three-dimensional body provided $\frac{\partial^2 \sigma_z}{\partial z^2} = 0$. This equation

$$\nabla^2 (\sigma_1 + \sigma_2) \equiv \nabla^2 (\sigma_x + \sigma_y) = 0,$$

where

$$\nabla^2 \equiv \frac{\partial^2}{\partial x^2} + \frac{\partial^2}{\partial y^2} \quad . \quad . \quad (7)$$

is well known in two-dimensional photo-elasticity. Several methods of solving it have been developed. Mathematically, this equation is identical with that of a two-dimensional potential. Mathematical, graphical, and experimental methods of solving problems of this kind are well known. A solution, however, can only be given if the values of the potential—in this case the values of $(\sigma_1 + \sigma_2)$—are given at every point of the edge. In plates in transverse bending, the edge of the loaded area of the surface must also be considered as an edge. Along the load-free edge, $(\sigma_1 + \sigma_2)$ can be determined from the isochromatics since one of the principal stresses, σ_2, say, is zero, and $(\sigma_1 + \sigma_2) = (\sigma_1 - \sigma_2)$. In order to find the value of $(\sigma_1 + \sigma_2)$ along the edge of the loaded part of the plate, however, some other method has generally to be applied first. Only in some exceptional cases can this be avoided. The author found the graphical solution of these problems to be most convenient and accurate. With the well-known rules of the potential theory in mind, it requires only a few minutes to find a solution even in complicated cases.

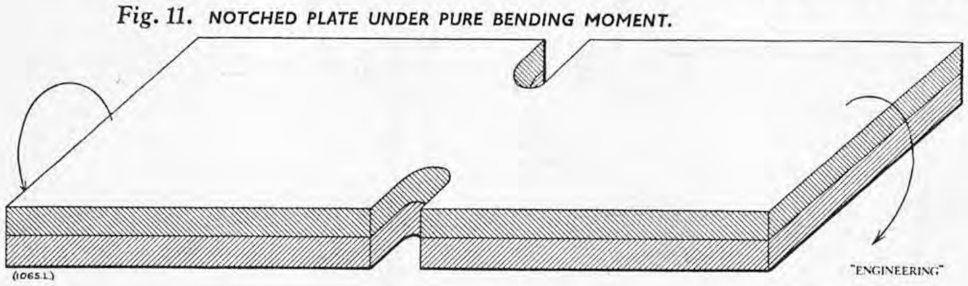
Greater speed and accuracy can be obtained with the aid of the equations of equilibrium when the system of the lines $(\sigma_1 + \sigma_2) = \text{const.}$ has to be drawn. Along the load-free edges, the direction of these lines can be computed. For example, along load-free straight edges, the direction of the lines along which $(\sigma_1 + \sigma_2)$ is constant coincides with that of the ischromatics. The approximate mathematical method of solving the equation $\nabla^2 (\sigma_1 + \sigma_2) = 0$, in spite of its somewhat tedious nature, seems to produce less accurate results than the graphical one. This was found by the author when checking graphically results obtained by the mathematical method in two-dimensional photo-elasticity. Experimental methods which make use of an electrical field, or the soap-film analogy, have not yet been applied to plates in transverse bending, as the graphical method seems most convenient.

Experimental methods for measuring the principal stresses within the plate have also been used by the author, including that employed in two-dimensional photo-elasticity which makes use of convergent or divergent light, or light at an oblique incidence. By means of a nomogram developed by the author, the principal stresses can be found with great accuracy even when the stress gradient is steep. Another method employed by him makes use of the factor of stress concentration around a hole. This method had also been used in two-dimensional photo-elasticity. The factor of stress concentration at the edge of a circular hole in a plate in transverse bending is 1·8 where the edge is parallel to the direction of the principal stress and 0·2 where it is at right angles to that direction. These values were confirmed experimentally by the two-sheet method.

According to the laws of scaling, the results obtained by the two-sheet method can be applied to plates of any material and size, or to any magnitude of load, if the shape of the plate and mode of application of the load are similar to those of the model. They are even applicable to plates of any thickness, between certain limits. A slight variation

PHOTO-ELASTIC STUDY OF PLATES BENT TRANSVERSELY.

Fig. 11. NOTCHED PLATE UNDER PURE BENDING MOMENT.



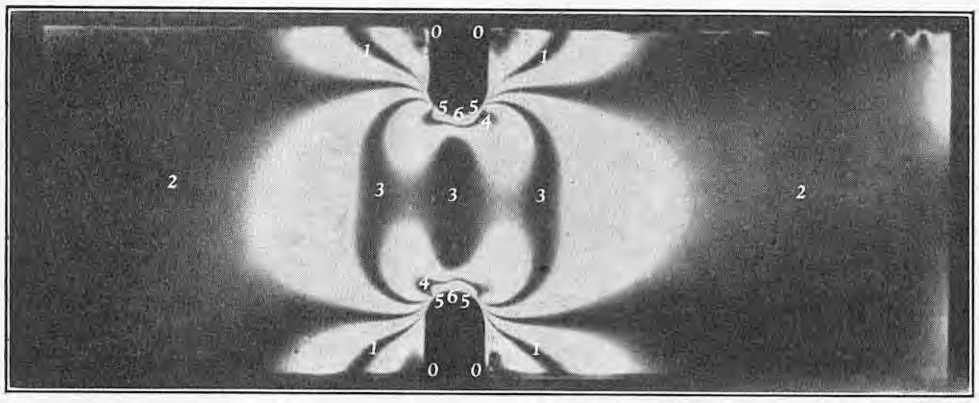
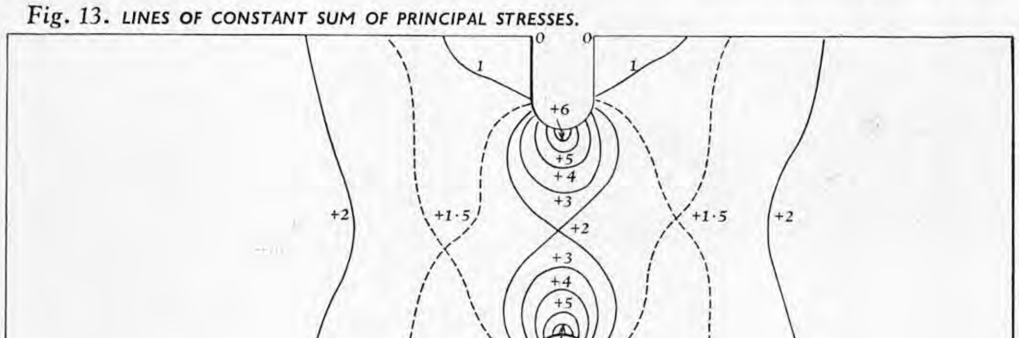


FIG. 12. NOTCHED PLATE LOADED BY PURE BENDING MOMENT (FIG. 11).

Fig. 13. LINES OF CONSTANT SUM OF PRINCIPAL STRESSES.



of the stress distribution can occur if the Poisson's ratios for the material of the model and that of the plate differ. In most cases it is negligibly small.

The real value of the stress along an isochromatic can easily be found by means of the formula (1), or a simple test. In most cases, however, knowledge of the stress distribution only is sufficient. This will be demonstrated by the examples which follow. In most publications on plates in transverse bending, instead of the surface stresses σ_x, σ_y, and τ_{xy}, the bending moment and torque are used. They are related by the moment of resistance.

Figs. 3, 4 and 5, on page 36, show the results of an investigation of a plate with a circular hole bent by a single load P. Fig. 3 indicates the shape of the model and position and direction of the load. This model was actually glued to two extra sheets of plastic, as shown in Fig. 3, to avoid concentrated reactions along the edge where the plate was fixed. Fig. 4 shows the pattern of isochromatics photographed in monochromatic light. The directions of polarisation of the filters were at right angles. Fig. 5 is a photograph of the same model viewed with the filters parallel. Hence, the dark lines indicate a path difference of $(n + \frac{1}{2})$ wavelengths. This procedure of taking two photographs is generally advisable when the phase difference is small. The number of fringes obtained on one photograph only would generally be insufficient to determine the stresses with good accuracy. Two photographs double the number of fringes.

The isochromatics (dark lines) in Fig. 4 indicate the lines of constant stress difference equal to an integral multiple of a certain basic value which can be found, for example, by a simple bending test with a sample prepared for this purpose. The numerals in Figs. 4 and 5 indicate the multiples of the basic value. In optical terms, these numerals represent "fringe order," i.e., the multiple of the wavelength. In Fig. 5, the numerals are inscribed in the same way as in Fig. 4, since the inclusion of fractions on the photograph would be inconvenient. Only the $(n + \frac{1}{2})$ isochromatics, however, should be read from this photograph.

Although the theoretical solution for a plate with a circular hole was based on the assumption of an infinite plate loaded by a pure bending moment, it seems to hold true for a wide range of sizes and types of loading. In the case investigated, although the plate was rather small compared with the diameter of the hole, and was loaded by a single force, the factor of stress concentration found was the same as that obtained from the theoretical solution. The fringe order of the maximum stress at the edge of the hole is 4·2, while in the region of the plate undisturbed by the hole, and at the same distance from the load as the hole, the corresponding value is 2·3. Hence the factor of stress concentration is 1·8. Along the outer edges, the isochromatics bend a little, owing to the fact that slight changes occur in the model with the passage of time. The hole, however, was freshly drilled when the photograph was taken. The stress along the edge of the hole, therefore, is free from inaccuracy.

Fig. 14. STRESS ALONG EDGE OF A NOTCH.

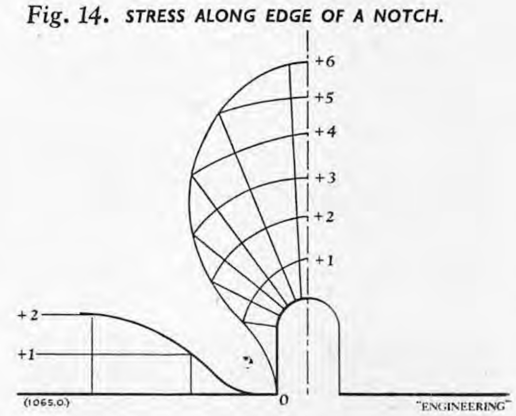
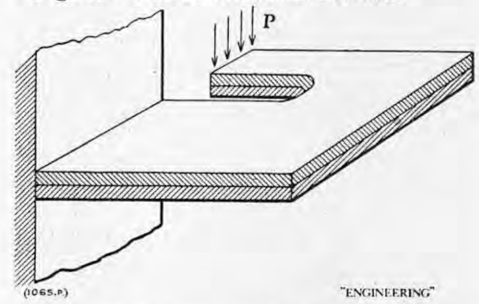


Fig. 15. LOADED STAIRCASE LANDING.



Figs. 6 and 7 show a model with circular fillets. In Fig. 6, the load and method of suspension are indicated in perspective. Fig. 7 shows the pattern of isochromatics obtained in this case. The factor of stress concentration can easily be read from the photograph. The maximum stress at the fillets has the fringe order 4·0, and the average stress in the corresponding cross-section can be found by extrapolation to be 3·0. Hence the factor of stress concentration in this case is 1·33.

The case of Figs. 8, 9 and 10 is similar to that of Figs. 6 and 7. The factor of stress concentration, however, appears to be slightly higher, namely, $\frac{4·0}{2·8} = 1·42$. Fig. 10 shows the pattern of the lines for which $(\sigma_1 + \sigma_2)$ is a constant. This was determined graphically. The stress along the loaded edges was estimated. The two principal stresses σ_1 and σ_2 at the surface of the plate can be found by using the two patterns of Figs. 9 and 10, since the two principal stresses are obviously half the sum or half the difference of the two values obtained from these patterns:

$$\sigma_1 = \frac{(\sigma_1 + \sigma_2) + (\sigma_1 - \sigma_2)}{2} \quad . \quad . \quad (8)$$

$$\sigma_2 = \frac{(\sigma_1 + \sigma_2) - (\sigma_1 - \sigma_2)}{2} \quad . \quad . \quad (9)$$

In Figs. 11 to 14, the case of a notched plate loaded by a pure bending moment is illustrated in a similar way. Fig. 14 gives the stress along the edge of the plate. The factor of stress concentration is $\frac{6·0}{2·0} = 3·0$ if the maximum stress in the notch is compared with the average stress in the undisturbed region of the plate. It is $\frac{6·0}{4·0} = 1·5$ if the maximum stress is compared with the average stress in the cross-section through the centres of curvature of the notches.

Figs. 15 to 24 show the results of an investigation of a more complex problem. It is a staircase landing which was loaded in several different ways to find out the most dangerous one. Only one of those cases is treated in these figures. Fig. 16 shows the normal pattern of isochromatics, and Figs. 17 to 22 show photographs taken in plane-polarised light. Hence, they contain the isoclinics also. As each of these photographs was taken at a different position

PHOTO-ELASTIC STUDY OF PLATES BENT TRANSVERSELY.

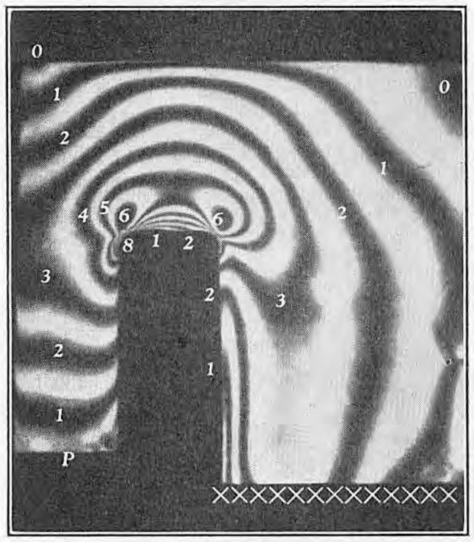


FIG. 16. STAIRCASE LANDING LOADED BY SINGLE FORCE (SEE FIG. 15).

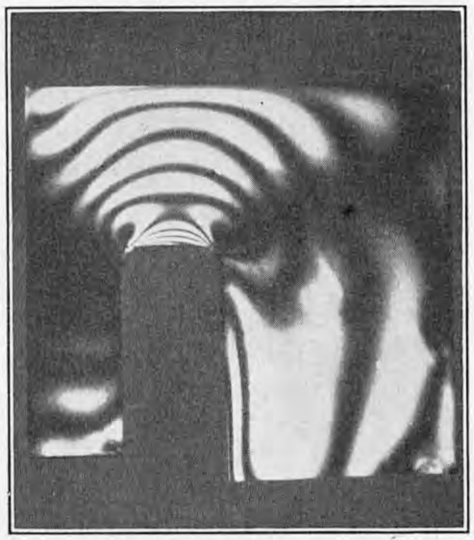


FIG. 17. MODEL IN PLANE POLARISED LIGHT, PARALLEL TO EDGES.

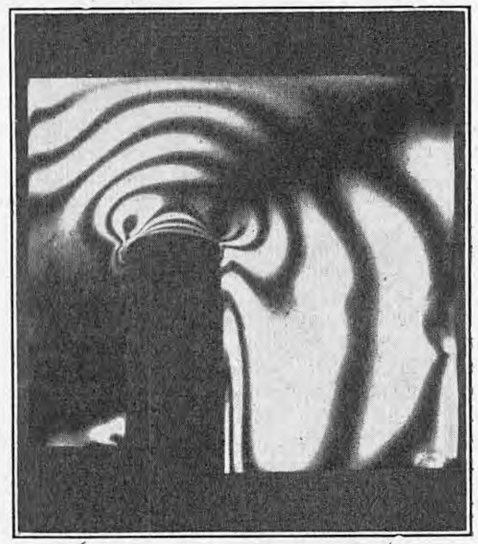


FIG. 18. MODEL WITH POLARISATION TURNED 15 DEG. COUNTER-CLOCKWISE.

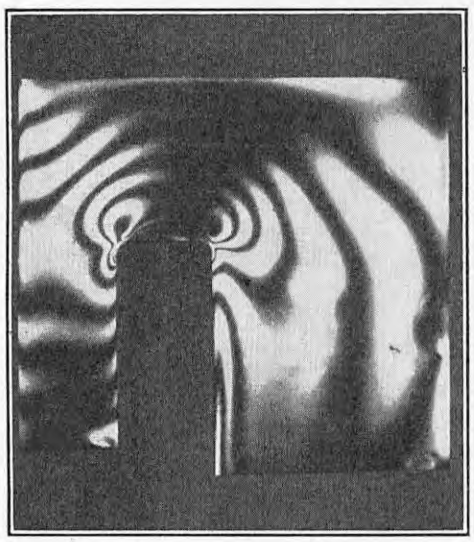


FIG. 19. POLARISATION TURNED 30 DEG. COUNTER-CLOCKWISE.

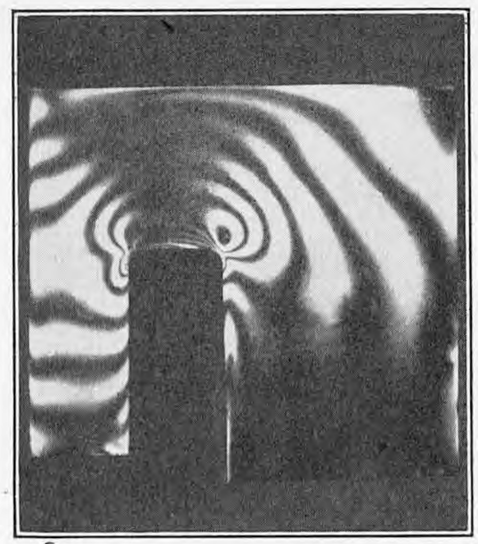


FIG. 20. POLARISATION 45 DEG. COUNTER-CLOCKWISE.

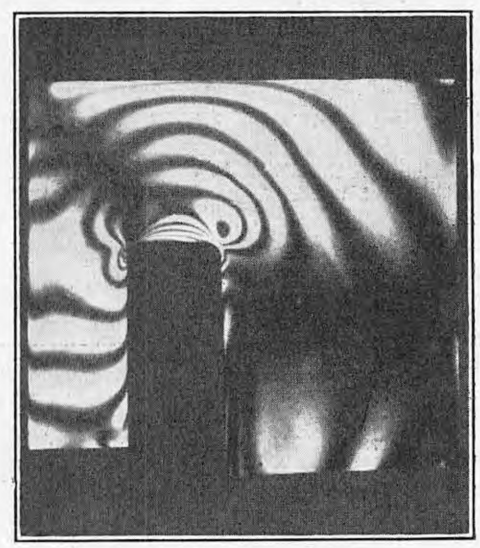


FIG. 21. POLARISATION 60 DEG. COUNTER-CLOCKWISE.

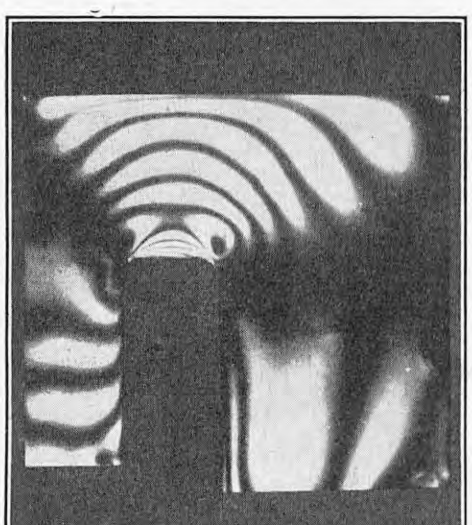


FIG. 22. POLARISATION 75 DEG. COUNTER-CLOCKWISE.

Fig. 23. SYSTEM OF ISOSTATICS AT SURFACE OF PLATE.

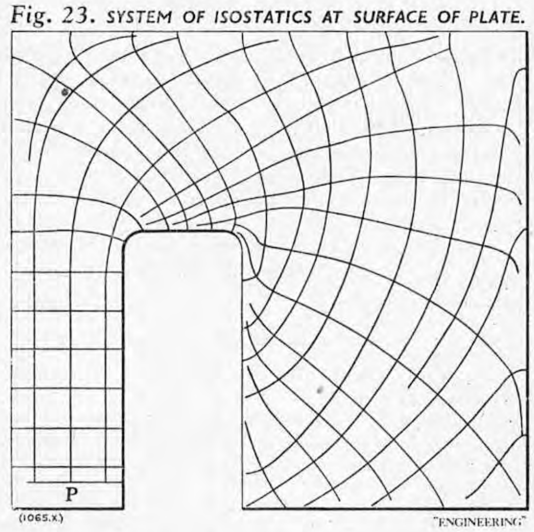
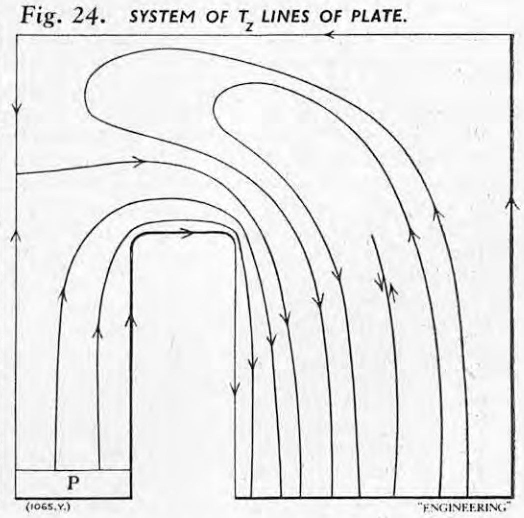


Fig. 24. SYSTEM OF T_z LINES OF PLATE.



of the polarisation filters they differ as to the isoclinics, although the pattern of ischromatics remains the same for all of them. Fig. 23 is the pattern of isostatics derived from the isoclinics. Fig. 24 shows the system of T_z-lines, which was obtained by applying the equations of equilibrium. It shows the general appearance of such systems.

Photo-elastic methods in general have proved to be not only of great value in solving special problems but also instructive. Patterns obtained by the classic method of two-dimensional photo-elasticity have given to many engineers a more realistic idea of stress distribution than mathematical formulæ could ever do. The classical method, however, is confined to ordinary plates, whereas a similar rapid method for the investigation of plates in transverse bending was unknown before the two-sheet method was developed. As problems of plates in transverse bending, especially those of complicated shape, are at least as difficult to solve by numerical methods as those of plates loaded in the direction of their plane only, it is likely that the two-sheet method will acquire the same significance as the classical method. By providing a quick solution of any problem and instructive patterns of stress distributions, it is likely to hasten progress and prove of educational value.

FLOW CONTROL BY ELECTRONIC WEIGHING MACHINE.

An interesting example of the use of electronic equipment for controlling the flow of materials is provided by two constant-weight feeder equipments which have been installed by Messrs. Richard Simon and Sons, Limited, Nottingham, in the Heysham works of Imperial Chemical Industries, Limited. These machines, which are illustrated in Fig. 1, are designed to regulate the flow of powdered limestone, about 10 tons per hour of which is used in a continuous chemical process. The method of operation is shown diagrammatically in Fig. 2, from which it will be seen that the powdered limestone is fed into the hopper and is then loaded on to a conveyor belt by an electrically-driven screw. The centre of the loaded belt passes over a roller which is linked mechanically with a weighing mechanism. This mechanism is provided with two sets of contacts that are connected to circuits through which signals are transmitted to the electronic control gear when the load on the belt is too heavy or too light. As a result, the speed of the motor driving the screw is adjusted through a controller and a pilot motor until balance is restored. This enables a constant flow of limestone to be obtained for a given speed of the belt.

These feeders deliver a constant flow of material at any desired rate, irrespective of any alterations in bulk density or changes in ability to flow. In fact, a reduction in the rate of feed caused by, say, a partial blockage in the inlet to the machine will result in the necessary correction being made to the pilot motor and speed-setter unit (shown in Fig. 2). Similarly, a change in the density or consistency of the product will cause the feeder controller to operate, so that the flow will be adjusted to the desired pre-set rate. The feeders are set for a given rate of flow by placing the required weights on the weighing beam and adjusting the conveyor speed controller until the required speed of the motor, or the rate of flow in tons per hour, is shown on the tachometer dial. The feeders are provided with a simple automatic two-rate correction control which ensures that, if a large change takes place in the bulk density of the material, a continuous correction is applied to the feed control unit until the feed rate is correct. To prevent hunting, corrections are then supplied in small increments only. Pilot lamps are provided to show the operator what correction is being applied to the feed rate and there is an alarm which sounds when there is no material above the feed inlet.

The control gear for these machines, with its associated electronic equipment, was manufactured by the General Electric Company, Limited, Kingsway, London, W.C.2, and is housed in a ventilated cubicle of sheet-steel construction. To prevent the ingress of dust the cubicles for both equipments are mounted side by side in a pressurised control room. The equipment, as shown in Fig. 3, consists of a 3-h.p. variable-speed separately-excited direct-current motor for driving the screw and a similar motor rated at $1\frac{1}{2}$ h.p. for operating the conveyor belt. The armatures of both these motors are supplied from the 440-volt three-phase mains through thyratron rectifiers and the separately-excited fields through metal rectifiers from the same source. A three-phase bank of thyratrons is used for supplying the screw motor and a two-phase bank for the conveyor motor. Otherwise, the two control circuits are similar.

The method of operation is as follows. An adjustable "speed setting" reference voltage is provided for the control of each motor. These voltages are compared with the voltage across the armature of the conveyor or screw motor with which they are associated, and the difference is then multiplied and supplied to the control grids of the thyratrons. The voltage applied to the motor armatures is next varied in turn to match the voltage selected manually in the case of the conveyor motor and by the pilot motor in the case of the screw motor, in accordance with the signals from the contacts on the weighing mechanism.

ELECTRONIC WEIGHING MACHINE.

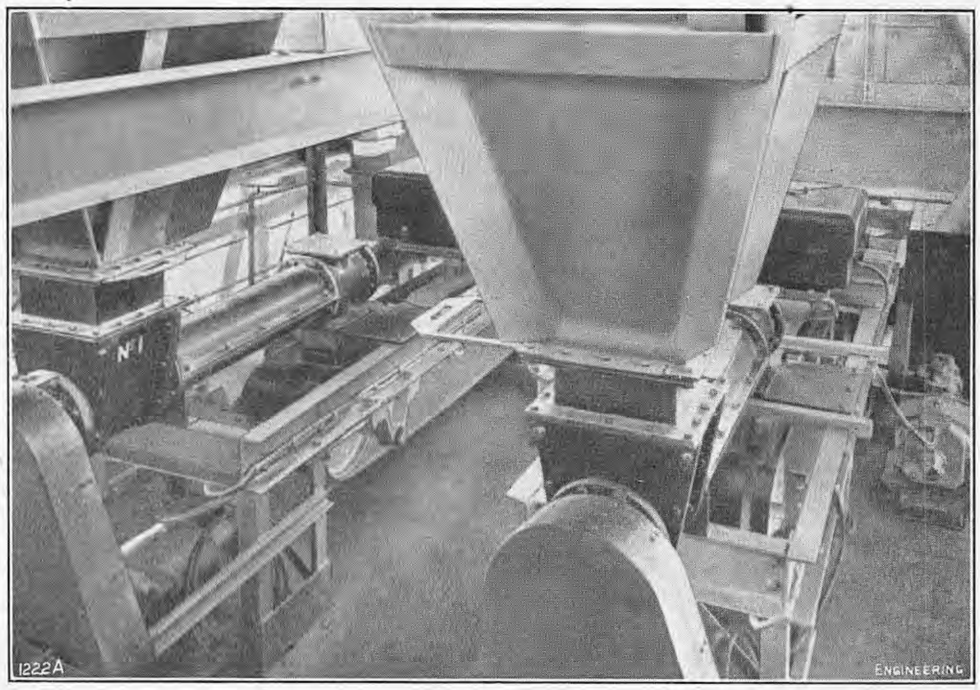


FIG. 1.

Fig. 2.

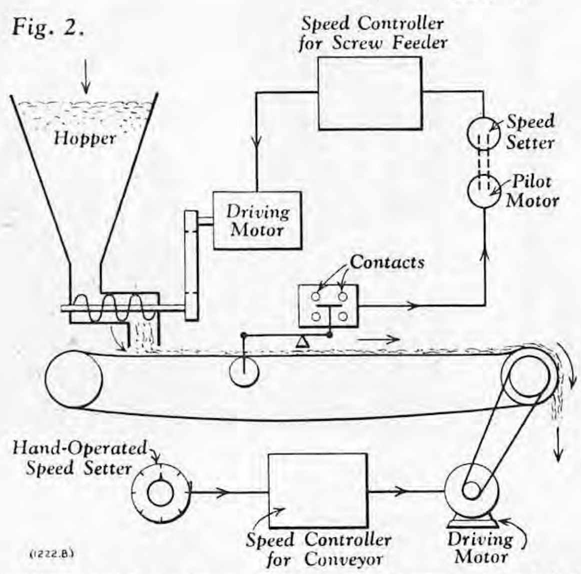
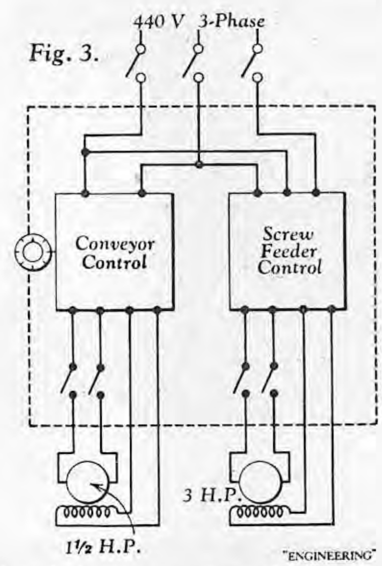


Fig. 3.



A limiting circuit is included in the system to prevent the armature current exceeding a predetermined value, thus protecting the thyratrons from overload. This maintains the current at the limiting value for 30 seconds after the motor has stalled, when a thermal overload trip opens the armature contactor. The fall in motor speed as the mechanical load rises is corrected by a compensating circuit which increases the voltage applied to the armature in proportion to the increase in the armature current.

Capital for Industry.—In a booklet entitled *The Problem of Capital for British Industry*, Mr. S. P. Chambers, C.B., deputy chairman of Imperial Chemical Industries, Ltd., explains, in straightforward language, the urgent need of capital to maintain and expand the equipment of industry if the standard of living in this country is not to deteriorate. The booklet might be used with good effect, in factories and elsewhere, to spread an appreciation of a problem which, though simple to express, is not understood nearly as widely as its implications to everyone demand. It is a reprint of an address given recently to the Industrial Co-partnership Association and is available from the Association, at 36, Victoria-street, London, S.W.1, price 2*s*. each, or at reduced rates for quantities.

Proposed Wind Tunnel for Aircraft Research Association Ltd.—Early in 1952, 14 aircraft firms formed the Aircraft Research Association Ltd. to provide and use a high-speed wind tunnel for development work. Plans for the tunnel are now advanced, and it is hoped that construction will commence in 1953. The tunnel will probably be sited near the National Aeronautical Establishment, Bedford. It will run at speeds up to 1,000 m.p.h., and will have a 10 ft. by 8 ft. working section, for testing models of 5 ft. to 6 ft. span. Power will be provided by a 35,000-h.p. electric motor supplied from the grid system. The tunnel will be water-cooled, and it is proposed to utilise the heat extracted from the tunnel for heating office blocks and workshops. Models to be tested will be mounted and adjusted on trolleys outside the tunnel, ready to wheel in as soon as tests on the previous model have been completed. Later, a smaller supersonic tunnel for tests at Mach numbers up to 3 will be provided.

Low-Pressure Reinforced Plastics.—The British Plastics Federation have been considering provision in their organisation for firms interested in low-pressure reinforced plastics, and have decided to form a technical committee consisting of representatives from the appropriate groups of the Federation. It will be known as the Glass and Asbestos Fibre Reinforced Plastics Technical Committee and will hold its first meeting at the Federation's offices, 47-48, Piccadilly, London, W.1, on Thursday, January 15. Membership of the committee is restricted to members of the Federation, which comprises the following groups: plastics material manufacturers' (including manufacturers of synthetic resins and moulding powders), moulders', fabricators', engineers', laminated and fibrous products, and raw-material suppliers'. Firms eligible for representation on the committee are those carrying out experiments on, or production of, reinforced plastics or materials for their manufacture, such as resins or fibres.

BRITISH ELECTRICITY AUTHORITY: GENERATING PLANT COMMISSIONED IN 1952.

Power Station.*	B.E.A. Division.	Turbo-Generator Plant.			Boiler Plant.			High-Pressure Pipework.
		Installed Capacity.		Maker.	Capacity.		Maker.	Maker.
		No.	Capacity, each, kW.		No.	Lb. per hr. Each.		
BANKSIDE	London	1	60,000	British Thomson-Houston Co. ..	2	375,000	Foster Wheeler ..	C. A. Parsons & Co.
BARKING "C"	London	1	75,000	British Thomson-Houston Co. ..	—	—	—	Aiton & Co.
Battersea "B"	London	—	—	—	2	425,000	Babock & Wilcox ..	Aiton & Co.
Blackburn	North Western	1	40,000	English Electric Co.	3	150,000	Simon-Carves	Babcock & Wilcox
Blackwall Point ..	London	1	30,000	English Electric Co.	1	365,000	Babcock & Wilcox ..	Babcock & Wilcox
Braehead	South West Scotland ..	1	50,000	C. A. Parsons & Co.	2	300,000	Babcock & Wilcox ..	Babcock & Wilcox
BRIGHTON "B" ..	South Eastern	1	52,500	Richardsons, Westgarth & Co. ..	2	320,000	Babcock & Wilcox ..	C. A. Parsons & Co.
Bromborough	Merseyside and North Wales	2	50,000	English Electric Co.	2	300,000	Babcock & Wilcox ..	Stewarts and Lloyds
BRUNSWICK WHARF ..	London	2	52,500	Metropolitan-Vickers Electrical Co.	4	320,000	Clarke Chapman ..	C. A. Parsons & Co.
Clarence Dock	Merseyside and North Wales	—	—	—	2	350,000	Babcock & Wilcox ..	Stewarts and Lloyds
Cliff Quay	Eastern	1	45,000	Metropolitan-Vickers Electrical Co.	—	—	—	Aiton & Co.
Croydon "B"	South Eastern	—	—	—	2	320,000	Simon-Carves	Aiton & Co.
Deptford East	London	—	—	—	1	250,000	Foster Wheeler ..	John Thompson
HUNCOAT	North Western	2	30,000	General Electric Co.	2	305,000	Simon-Carves	C. A. Parsons & Co.
Keadby	Yorkshire	2	60,000	C. A. Parsons & Co.	1	550,000	Stirling Boiler Co. ..	C. A. Parsons & Co.
LITTLEBROOK "C" ..	South Eastern	1	60,000	C. A. Parsons & Co.	2	360,000	International Combustion	C. A. Parsons & Co.
Nechells "B"	Midlands	1	52,500	C. A. Parsons & Co.	3	230,000	International Combustion	Stewarts and Lloyds
Northampton	East Midlands	1	30,000	C. A. Parsons & Co.	2	190,000	Simon-Carves	Stewarts and Lloyds
North Tees "C" ..	North Eastern	2	60,000	C. A. Parsons & Co.	2	360,000	Babcock & Wilcox ..	Babcock & Wilcox
Plymouth "B"	South Western	2	31,500	Metropolitan-Vickers Electrical Co.	2	320,000	Yarrow	Babcock & Wilcox
Poole	Southern	1	50,000	C. A. Parsons & Co.	2	300,000	International Combustion	Aiton & Co.
Portsmouth	Southern	1	30,000	British Thomson-Houston Co. ..	2	180,000	Mitchell	C. A. Parsons & Co.
Rotherham	Yorkshire	—	—	—	1	200,000	International Combustion	Stewarts and Lloyds
Rye House	Eastern	1	32,000	Richardsons, Westgarth and C. A. Parsons	1	350,000	Babcock & Wilcox ..	Stewarts and Lloyds
Skelton Grange	Yorkshire	1	60,000	C. A. Parsons & Co.	2	360,000	International Combustion	Aiton & Co.
Staythorpe	East Midlands	1	60,000	British Thomson-Houston Co. ..	3	240,000	Babcock & Wilcox ..	Aiton & Co.
Thornhill	Yorkshire	1	45,000	English Electric Co.	1	180,000	Mitchell	Stewarts and Lloyds
USKMOUTH	South Wales	1	60,000	General Electric Co.	2	360,000	Babcock & Wilcox ..	Aiton & Co.
Warrington	Merseyside and North Wales	1	30,000	Brush Electrical Eng'g. Co. ..	1	200,000	Simon-Carves	C. A. Parsons & Co.
West Ham "B"	London	2	30,000	English Electric Co.	3	180,000	John Thompson	Aiton & Co.
Westwood	North Western	1	30,000	British Thomson-Houston Co. ..	2	300,000	Babcock & Wilcox ..	Stewarts and Lloyds
Woolwich	London	1	30,000	General Electric Co.	2	180,000	John Thompson	C. A. Parsons & Co.
Totals: 32 stations ..		34	1,550,000 kW.		59	16,985,000 lb. per hour		

* The names in large type are those of new stations, in which plant has been commissioned for the first time in 1952. The others are existing stations to which extensions have been made.

GENERATING PLANT INSTALLED BY THE B.E.A. IN 1952.

THE accompanying Table, prepared by the Chief Engineer's Department of the British Electricity Authority, summarises the new plant installed by the Authority during 1952. It represents an additional output capacity of 1,539,000 kW, which is a considerable improvement over 1951, when 1,113,000 kW of plant were installed. The additional plant, comprising 34 turbo-alternators and 59 boilers, having an aggregate evaporative capacity of 16,985,000 lb. per hour, was installed in 32 of the Authority's power stations. Seven of these, shown in large type in the Table, are new stations in which plant has been installed for the first time. The Authority's maximum planned rate of commissioning for 1951 was 1,250,000 kW and, for 1952, 1,400,000 kW, making a total for the two years of 2,650,000 kW. The actual plant installed in the two years aggregates 2,652,000 kW. The maximum planned rate of commissioning for 1953 is 1,500,000 kW, but it is stated that, because of shortages of steel and other materials, there may be difficulty in achieving the target.

SCOTTISH MOTOR SHOW.—After a lapse of four years a Scottish motor show will be held again next autumn. It is to be held in the Kelvin Hall, Glasgow, from November 13 to 21. The occasion coincides with the jubilee of the Scottish Motor Trades Association. Sections for private cars and caravans, light and medium commercial vehicles, transport-service equipment, and accessories and components will be included.

UNDERGROUND STOWING AT A DURHAM COLLIERY.—Work is proceeding on an experiment on underground stowing at Crookhall Colliery, near Consett, County Durham. Pit waste is fed to a crushing and grinding machine at the pithead, which turns the material into a mixture of small stones and sand. This is blown, by means of compressed air, along 5-in. diameter steel pipes into underground workings from which the coal has been extracted. The worked-out spaces are packed tight with the material. Water is added if the material is too dusty, but the filled-in working soon becomes solid owing to pressure from the floor and the roof. The main stowing machine on the surface weighs 26 tons and is mobile, operating smoothly on six large rubber-tyred wheels. This method of stowing is stated to be relatively cheap.

EARLY DEVELOPMENT OF THE CENTRIFUGAL PUMP.*

By L. E. HARRIS, A.M.I.Mech.E.

THE development of the centrifugal pump to its present state of dominance in the pumping of water and other liquids has been comparatively slow and spasmodic, extending over more than 250 years. In or before the Sixteenth Century, the effects of centrifugal force were known, if not fully appreciated, but its conscious application to specific purposes, such as the raising of water, was little understood. Leonardo da Vinci (1452-1519) produced a tentative design for a means of raising water by centrifugal force, but it would be an exaggeration to call this a centrifugal pump. The examples of such pumps to be found in Agricola's *De Re Metallica* (1557) or in Ramelli† illustrated essentially rotary displacement machines, very different in principle from centrifugal machines. Ramelli shows a rotary displacement pump in which the entry is circumferential and the discharge also is circumferential and tangential to the direction of the rotation of the blades; but an essential for a centrifugal pump or fan is axial entry and circumferential discharge, in order that outward flow from the centre can be created. It is worthy of note however, that, even if Ramelli's machine was not a centrifugal pump in the true sense, it had the interesting feature of an eccentric casing with blades sliding in grooves in the drum, exactly in the style of modern rotary blowers. This shows that the designer understood the effect of centrifugal force in creating outward radial movement, even if he was not aware of the manner in which it could be applied to the raising of water.

In choosing 1689 for the beginning of this paper I have done so with the conviction that the true originator of the centrifugal pump was Denis Papin. In 1688, he was appointed professor of mathematics at Marburg, in Prussia. Shortly after his arrival there, he became connected with the work which his patron, the Landgrave of Hesse, was engaged in on his estate. This involved cutting a canal through water-logged land where the subsoil water rose so quickly that it was impossible to keep the works dry by means of the pumps then normally employed. It was then, and for this purpose, that Papin evolved his centrifugal pump, an idea which won such approval from the Landgrave that he ordered the publication of the invention in the *Acta Eruditorum* in 1689.* This pump was primarily an experimental model with two blades only, running in a circular casing. It had the practical defects of the absence of a stuffing box where the shaft passed through the casing, and a disproportionately small discharge branch; but it formed the basis for Papin's experimental work, resulting in a pump which was employed practically. From what he published subsequently in the *Philosophical Transactions* of the Royal Society in 1705, it is clear that, by then, Papin had expanded his ideas considerably, incorporating in his design a multi-bladed propeller and, of most import, a spiral casing.

Papin's communication to the Royal Society of June, 1705, was entitled "Part of a letter from Mr. D. Papin to Dr. Frederick Slare . . . concerning an Improvement of the Hessian Bellows &c."† In this letter, Papin begins: "I am busie at present for a Coal Mine, which hath been lett off because of impurity of the Air. I have therefore improved the Hessian Bellows: I don't question but you have seen that new Contrivance printed *Lipsiae in Actis Eruditorum anno* 1699 with this title *Rotatilis Suctor et Pressor Hassiacus.* And it may be applied for Wind as well as for Water." In fact, as stated above, the first description appeared in 1689 under the full title of *Rotatilis Suctor et Pressor Hassiacus, in Serenissima Aula Casselana demonstratus et detectus*; and later, in 1695, there was another paper, entitled *Description de la Pompe de Hesse enrichie des usages qui luy manquoient dans la premiere edition*, embodying the results obtained by a pump made for Hofrath Salomon Reisel of Wurtemburg. Papin had earlier carried out experiments on syphons for Reisel, the results being communicated by him to the Royal Society in January, 1684-85.‡ Reisel and Papin

* Paper read before the Newcomen Society, in London, on Wednesday, January 7, 1953. Abridged.

† *Le Diverse et Artificiose Machine del Capitano Agostino Ramelli*, Paris, 1588.

* *Leibnizens und Huygens' Briefwechsel mit Papin*, by E. Gerland, Berlin, 1881.

† *Phil. Trans.*, No. 300, pages 1990-1991 (1705).

‡ *Ibid.*, No. 167, pages 847 and 848 (1684-85).

were also associated in the design of the former's "Suctor et Pressor Würtembergicus," a complicated form of water-lifting apparatus embodying a design of rotary pump evolved by Johan Jordan, to whom, however, it would be rash to ascribe the invention of the centrifugal pump.* Papin may have obtained inspiration for his own "Suctor et Pressor Hassiacus" from Jordan's machine, but the latter's influence on the development of the centrifugal pump must be largely, if not entirely, vicarious.†

In June, 1704, Papin was writing to Leibniz from Cassel, telling him that he was quite prepared to wager that "un homme avec une de mes pompes feroit plus d'effet que deux ou trois hommes avec la vis d'archimède"; and he then referred to the working of the pump, "dans un grand bassin que Monseigneur [the Landgrave] a fait faire icy dans l'île proché du chateau." From this we can conclude that the pump had been employed practically. But Papin was fully alive to the drawbacks of the centrifugal pump because, in the same letter, he said: "The machine which operates by centrifugal force is excellent in Theory; but, Monsieur, I find in it a great inconvenience in practice, for where it is used to raise water to some considerable height, it is necessary to impart to it a high speed and one always uniform."

Papin had advanced ideas on the design of his pump, but, no doubt, was handicapped by constructional difficulties, and, certainly, by the lack of suitable prime movers. It is significant, perhaps, that in, or immediately after, 1705, Papin appears to have abandoned further experiments on the centrifugal pump. It was not until some 27 years later that the next step was taken. In 1732, 20 years after the presumed date of Papin's death, Kernelien Le Demour published in Paris his description of a "Machine pour élever de l'eau,"‡ a very crude appliance—it cannot with justice be called a pump—designed to raise water by centrifugal force. Le Demour's machine certainly worked, as is proved by the tests carried out by the Académie des Sciences, when it was reported that "it has made 34 revolutions in as many seconds and has raised about 220 pints of water to a height of six feet. The pipe was inclined at 50 degrees"; a performance equivalent to about 80 gallons per minute against the head of six feet, and somewhat surprising in view of the primitive construction.§ Clearly, this apparatus was designed to lift water through the agency of centrifugal force, but it is doubtful if it had any practical value. Furthermore, it owes nothing to Papin, of whose work Le Demour may have been quite ignorant, and it would be true to say that the idea does not represent a development, but rather a retrogressive step.

The knowledge of Le Demour's proposals possibly spread to Holland, because in August, 1736, Daniel Gabriel Fahrenheit, then residing in Amsterdam, was granted a patent for "An invention relating to a new water-machine," which has been described, perhaps somewhat inaccurately, as one of the first designs of a centrifugal pump.‖ It consisted of a vertical shaft carrying a number of bent or straight tubes in an oblique position. When this system was set in motion, the water ascended into these tubes and was discharged at the top into a circular gutter. The similarity to Le Demour's device is apparent, and, while it would be easy to conclude that Fahrenheit was plagiarising the ideas of his predecessor, there is an element of novelty in the employment of a number of tubes as compared to the single tube of Le Demour. If, subsequently, there is little evidence of further development of the invention, this may be because Fahrenheit was taken ill when travelling from Amsterdam to the Hague in connection with the patent application and died on September 16, 1736.

* *Pumping Machinery*, by G. F. Westcott, Science Museum Handbook, page 60 (1932).

† *Die Entwicklung des Kreiselpumpen- und Ventilatorenbaues bei der Firma Gebr. Sulzer, A.G.*, Winterthur, n.d.; and E. Gerland, *op cit.*, page 37.

‡ *Machines Approvées par L'Académie Royale des Sciences de Paris*, vol. VI, page 9, no. 363 (1732).

§ *Histoire de l'Académie Royale des Sciences, année* 1732, page 118, Paris, 1735.

‖ *Patents for Inventions in the Netherlands during the 16th, 17th and 18th Centuries*, by G. Doorman, page 192, The Hague, 1942.

Professor s'Gravesande, to whom Fahrenheit bequeathed half the patent rights and the title to the invention, made some improvements and the machine was tried out in practice, but the results were disappointing and the machine was dismantled.

In a paper read before the Institution of Civil Engineers in 1876* R. C. Parsons stated that the mathematician Euler brought out a primitive form of centrifugal pump in 1754, an account of which he published in the *Proceedings* of the Berlin Academy. That statement is not strictly correct, because, while Euler published five papers in the "Classe de Mathématique" of these *Proceedings*, the only one which concerns the present inquiry was that entitled "Théorie plus complette des Machines qui sont mises en mouvement par la réaction de l'eau," and it comprises, as Euler says at the outset, a fuller development of remarks which he had made in an earlier year on "the effect which the Machine projected by M. de Segner at Halle is capable of producing." Johan Andreas von Segner was professor of mathematics and physics at Göttingen from 1735-1755 and had published two pamphlets in 1750, describing his horizontal water-wheels. In the same year, Euler presented a paper to the Academy of Berlin, entitled "Recherche sur l'effet d'une Machine Hydraulique proposé par Mr. Segner, Professeur a Göttingue," relating to the comparatively primitive form of reaction water-turbine. This paper is important in that it embodies the first mathematical analysis of the operation of a reaction water-turbine; it formed the basis of Euler's subsequent mathematical analysis of the centrifugal pump.

In 1751, Euler again presented a paper on the subject of Segner's machine, and then, in the same year, came the paper entitled "Recherche sur une nouvelle maniere d'élever de l'eau proposée par M. de Mour,† which relates to Le Demour's proposals of 1732. In this paper, Euler discussed the mathematics of Le Demour's simple device, and then proposed a more advanced form of this machine which he described as follows (trans.): "The machine will have the form of a hollow funnel of which the interior surface is a parabolic cone formed by the revolution of a parabola around the axis. The exterior surface is a cone generally similar but greater, forming with the interior surface the cavity in which the water can rise. And to hold the two surfaces together, the cavity is divided from top to bottom by diaphragms . . . To operate the machine it is immersed into water . . . so that the cylindrical portion is below the water, the height of the cylinder being regulated accordingly."

From this description it would be safe to say that, practically, Euler advanced little beyond the proposals of Le Demour, except that he replaced the single pipe by the continuous parabolic space between the outer and inner walls. In this respect, he was following closely on the lines of Leonardo da Vinci. The one thing which Euler did do was to initiate a true mathematical inquiry into the employment of centrifugal force as a means of raising water—it would not be true to say, into the centrifugal pump; an inquiry based fundamentally, however, on a consideration of the operation of Segner's simple reaction water-turbine, without, apparently, any knowledge of, or certainly any relation to, the stage of development which Papin had reached half a century earlier. This is, perhaps, somewhat remarkable if Euler was aware of what Papin had published. The explanation probably is that Euler, being first and foremost a mathematician, was not interested in the practical application of the centrifugal pump, but merely in the mathematical analysis. This analysis, or theory, did not lead to any appreciable advance in the development of the centrifugal pump, although it was not replaced until the publication of Unwin's theory in 1877.‡ Indeed, some of Euler's theories still have a place in modern calculations of centrifugal

* "The Theory of the Centrifugal Pump as Supported by Experiment," by R. C. Parsons, *Proc. Inst. C.E.*, vol. xlvii (1876-77).

† *Histoire de l'Academie des Sciences . . . à Berlin*, 1751, page 303.

‡ "The Centrifugal Pump," by W. C. Unwin, *Proc. Inst.C.E.*, vol. liii (1877).

pumps, particularly in relation to the law of similitude.

Euler's theory appears to have remained a pure theory throughout the remainder of the Eighteenth Century, and it is doubtful whether it penetrated far beyond the philosophical confines of the Berlin Academy; there was no further advance towards the practical employment of the centrifugal pump until the next century. There was, however, an interesting machine patented in England in 1785 by John Skeys, which, while it made little impression on the mechanical world and, possibly, exercised no influence on the development of the centrifugal pump, contained features making it worthy of attention. The specification of John Skeys, described as a member of the British Factory in Lisbon, is stated to cover the "Discovery made, and communicated to me, by a certain Foreigner with whom I am connected, of *A Pump on a new Construction*."* The machine consisted of a number of "wheels," which Skeys terms "aqualators" and which he described as being "similar to a common ventilator," mounted one above the other and "continued to the height to which the water is to be raised." These "aqualators" clearly possessed a very small radial, or centrifugal, component, and the machine worked more on the principle of the Archimedean screw, thus foreshadowing a comparatively modern development in rotodynamic pumps, namely, the axial-flow or propeller pump occupying the upper ranges of the curve of specific speeds.

There is another point worthy of attention. Skeys stated that "under each aqualator may be placed what I call a strainer . . . which renders the water more steady, so that it must ascend in right lines . . . Under the strainer is what I call a breaker"; and he goes on to say that these breakers are intended to break "the circular motion of the water, and are highly essential to the power of the pump." Thus Skeys was appreciating an essential need in true vertical axial-flow pumps for some means of converting the rotary motion of the water into axial flow.

Barker's Mill, a crude form of reaction water-turbine, is said to have been invented in 1740, thus antedating Skeys' invention, which in its reversed form, had been tentatively employed as a means of pumping. This machine must be noted because the next development after the invention of John Skeys was that of John Victor Jorge, Lieutenant Captain in the Portuguese Service, which he presented to the Académie des Sciences of Paris in 1816.† There is little to be said either of or for this invention, except that fundamentally it embodied a reversed-flow Barker's mill.

(*To be continued.*)

SHORT-TIME WORKING AT ALUMINIUM WORKS.—A four-day working week is to be introduced in the near future at the Rogerstone, Newport, Monmouthshire, works of the Northern Aluminium Co., Ltd., owing to the falling-off of orders. Some 3,000 workpeople are likely to be affected by the decision, which has been taken with a view to avoiding any discharges of workpeople on redundancy grounds. An announcement on behalf of the company states that every effort will be made to maintain a high level of employment and that it is hoped that the short working will be of a temporary nature only.

PREVENTING COLLISIONS AT SEA: REVISED REGULATIONS.—The revised international regulations for preventing collisions at sea will come into force on January 1, 1954. These regulations were approved by the International Conference on the Safety of Life at Sea, held in London in 1948. The Conference invited the United Kingdom Government to forward the 1948 regulations to other governments which had accepted the existing regulations, and to fix the date of the application, with a year's notice, of the revised regulations, after they had been accepted by the countries concerned. These countries are as follows: Australia, Belgium, Brazil, Burma, Canada, Chile, Colombia, Denmark, Dominica, Ecuador, Egypt, Finland, France, Greece, Holland, Hungary, Iceland, India, Iraq, Republic of Ireland, Italy, Mexico, New Zealand, Nicaragua, Norway, Pakistan, Peru, Poland, Rumania, South Africa, Spain, Sweden, Turkey, United Kingdom, United States, U.S.S.R., and Yugoslavia.

* British Patent No. 1506, December 7, 1785.

† *Repertory of Arts*, vol. XXXIII, 2nd series, 1818.

1-IN. CAPSTAN LATHE.

MURAD DEVELOPMENTS, LIMITED, AYLESBURY.

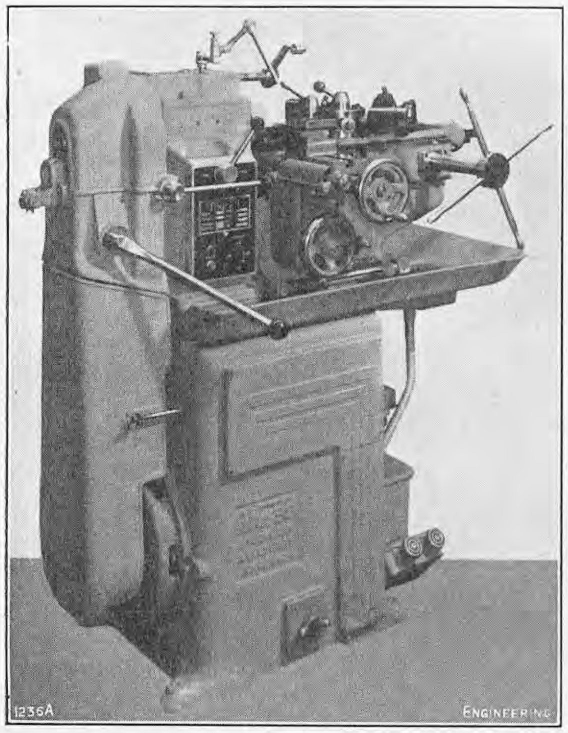


FIG. 1.

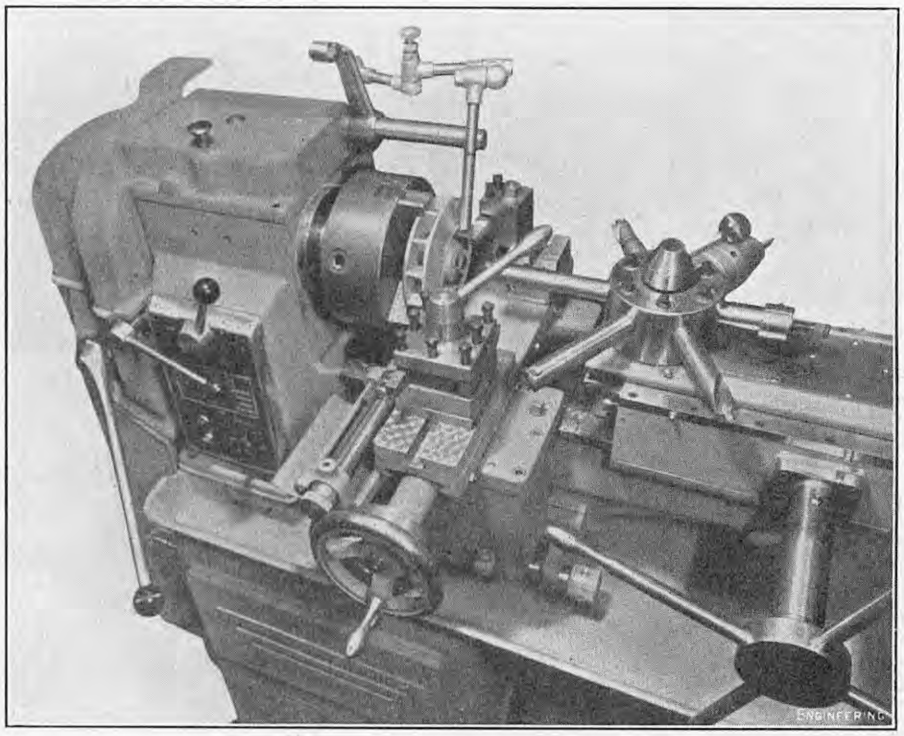


FIG. 2.

1-IN. CAPSTAN LATHE.

A USEFUL feature of the No. 1A capstan lathe introduced a few months ago by Murad Developments, Limited, Aylesbury, Buckinghamshire, is a rear tool-post which can be adjusted in a line parallel to the axis of the lathe spindle. It is supported on an auxiliary slide which is itself mounted on the main cross-slide, and the movement of $\frac{3}{8}$ in. allowed on this auxiliary slide enables the operator to set the position of the rear tool, relative to the front tool-post, quickly and accurately. Micrometer adjustment is provided. The lathe is also fitted with collets of the dead-length type, thus ensuring the maximum accuracy in machining, particularly on second-operation work. The spindle, bored $1\frac{7}{16}$ in. in diameter, has a flanged nose for carrying chucks—a design which is considered superior to a screwed nose as the chuck cannot unscrew when the spindle is stopped or run in reverse. The lathe is shown in Fig. 1 and the rear tool-post can be seen in Fig. 2.

The machine has a maximum round-bar capacity in the collet of 1 in.; square-section bars up to 0·70 in. and hexagon sections up to $\frac{7}{8}$ in. across the flats can also be machined. The swing over the bed is $11\frac{1}{2}$ in., and over the cross-slide 6 in. The drive from a three-phase motor, developing 1 h.p. at 720 r.p.m. and 4 h.p. at 2,800 r.p.m., is transmitted to the headstock through V-belts. The range of spindle speeds depends on the frequency of the electricity supply (50-cycle or 60-cycle) and on which of three possible ranges is chosen for one or other of the frequencies. Each range consists of six speeds, the fastest being from 270 to 3,110 r.p.m., on a 60-cycle supply, and the slowest being 85 to 860 r.p.m., on a 50-cycle supply.

The lathe is mounted on a pedestal, so that its alignments and accuracy are not affected by the condition of the floor. The height at which it is set has been considered carefully in the design to ensure that the operator can stand comfortably upright, without fatigue which might lower production. The bed is carried on the pedestal at three points. The saddle has a sliding movement of 7 in. and its apron gears are automatically oiled. The cross-slide has a maximum transverse movement of $4\frac{1}{2}$ in., with stops, and it supports a four-way tool-post the position of which, on the slide, is adjustable. Stop bars, of the slotted indexing type, are provided for both the sliding and surfacing motions. The tool-posts are designed to take $\frac{5}{8}$-in. square-section tools. The turret has a maximum useful stroke of $4\frac{1}{4}$ in. The maximum distance from the front of the collet cap to the turret is 16 in. and the height from the top of the turret slide to the centre of the 1-in. diameter tool holes is $1\frac{9}{16}$ in. All slides are hand scraped to an alignment of within 0·0005 in. and they are generously proportioned. The spindle runs in pre-loaded precision bearings. The lathe's standard equipment includes a centring-tool holder, a roller-steady turning-tool holder, a self-releasing tap holder, an adjustable drill holder, a single-V steady turning-tool holder, a double-V steady turning-tool holder, an adjustable stop, a self-releasing die holder, a drill and facing-tool holder, and a holder for knee turning tools.

GROUND TESTS ON HELICOPTERS.

THE application and principles of ground testing of helicopters were described in two papers presented respectively by Mr. M. J. Brennan, B.Sc., A.M.I.Mech.E., and Mr. Raoul Hafner, at a session of the Helicopter Association of Great Britain, on "Simulation of Helicopter Flight Loads by Ground Tests (with Special Reference to Fatigue and Wear)," held in London on Friday, December 5. Mr. Brennan, whose paper preceded that of Mr. Hafner, described the tests that had been carried out on the prototype Saunders-Roe Skeeter, whereas Mr. Hafner was more concerned with the fundamentals of ground testing.

Dealing firstly with Mr. Hafner's paper, for which he preferred to use the title "Simulation of Operating Conditions of Helicopters in Flight Tests," the lecturer said that a complete simulation of all operating conditions on a whole helicopter was neither economically practicable nor technically necessary. There were two aspects to be considered in carrying out a partial simulation: firstly, determining and assessing the magnitude of all the elements, best carried out by flight tests on a prototype machine with suitable instrumentation; secondly, reproducing these features on a test specimen in a ground rig. It could usually be arranged that conditions in the ground tests were more severe than in flight, so that the conclusions would be conservative.

Among various ground tests cited by Mr. Hafner, he dealt in some detail with endurance tests on the main-rotor controls, the power plant and transmission, and the main rotor. The rotor controls formed a complex dynamic system of rods, levers, pulleys, cables, dampers, irreversible linkages, etc. Since it was not generally possible to calculate their modes of oscillation, it was profitable to fit an exciter in the rotor head to study the dynamic behaviour of the system under various frequencies and amplitudes of excitation. The flight-test programme was then drawn up to contain the critical conditions revealed by the preliminary tests, strain gauges being located in the critical areas of the control system. From an analysis of the flight-test results, an assessment was made of the cumulative damage in fatigue and wear over a given number of flying hours. The control system was then loaded in a ground rig so that the cumulative damage in any part of the system was at least as great as that from the same period of typical flying. This was verified by comparing the ground and flight strain recordings. Endurance tests were then carried out, in stages, until it was possible to reach certain conclusions on the life of the components and the desirable periods between inspections and reconditioning.

POWER AND TRANSMISSION SYSTEM TESTS.

The power and transmission system, which could be regarded as consisting of a number of masses with interposed elasticities, was capable of torsional oscillation in a corresponding number of natural modes and frequencies. It was also exposed to cyclic forces from the engine and the rotors at various frequencies, which could give rise to resonance and consequent high stresses. A theoretical analysis of the linear and torsional characteristics of the system should therefore be carried out to establish critical rotor speeds and highly-stressed areas, to enable the locations of strain-gauges and other instruments to be judiciously selected for the prototype flight trials, which should consist of a number of short flights each representing a critical combination of forward speed, rotor speed, power, normal accelerations, etc. Again, the cumulative damage could be assessed from such flight records. In the ground rig, it was advisable to reproduce the major part of the structure, particularly all parts locating the transmission, engine and cooling-air ducts. The test specimen was suspended, by a cable attached to the rotor hub, from a gantry, to represent a low-frequency suspension under an acceleration of $1g$, corresponding to rectilinear flight. The helicopter rotor was generally replaced by a large fan, with adjustable drag plates connected by an adjustable spring coupling, to provide for a wide variation in rotor torque without interfering with the condition of suspension. A small number of suitable combinations of power and rotor speed were then chosen to give a cumulated damage at least as great as that established by the flight tests.

Similarly, the torsional and flapping modes of vibration of the rotor blade had to be calculated before flight tests on the rotor and hub assembly were carried out, to determine the critical regions under the forcing excitation of cyclic lift variation. The ground-running of the test specimen was conveniently carried out on a rotor testing tower of sufficient height to avoid aerodynamic ground effects. The tower should preferably be universally mounted at its base, and braced by slack and weighted steel cables giving a low-frequency suspension of the rotor in its plane of rotation. The collective pitch of the rotor blades could be varied as well as the rotor speed. The harmonic lift variation due to forward speed could be reproduced by two methods: either by a cyclic change of blade incidence, which had the disadvantage of introducing a high-frequency blade-pitch oscillation that, if it approached the blade fundamental torsional mode, could introduce torsional stresses not present in flight; or by placing an obstruction in the rotor slipstream. The location of the obstruction could be varied radially and in azimuth to give the desired cyclic variation. It had in fact been found difficult to produce good simulation of flight conditions on the rotor tower. With a single obstruction, the strain was too low at the middle of the blade. This could be corrected by using more than one obstruction. In conclusion, Mr. Hafner said that up to 600 tests of various kinds might be necessary to establish the airworthiness of a new helicopter type.

GROUND TESTS ON THE "SKEETER."

Turning to Mr. Brennan's paper, the lecturer said that, in 1951, a draft proposal for testing prototype helicopters suggested that strain-gauge measurements on the transmission, control and rotor systems should be made during ground runs, over a complete range of flight control movements. If the aircraft, on inspection after 50 hours' running, showed no signs of fatigue or wear, a second identical prototype helicopter should be flown, and the strain records obtained in flight compared with those obtained during ground running. A 360 hours' endurance run on the ground should then be carried out under simulated air loads and fluctuations. Such a programme had now been nearly completed on the Skeeter helicopter.

The strains on the rotor blades and articulating links, the hub, transmission and control rods, were measured by strain-gauge bridges feeding signals through slip-rings to a galvanometer indicating steady strains, and to a de Havilland 12-channel galvanometer recorder registering fluctuating strains. By thus measuring the steady-stress levels and the stress oscillations separately, it was found that, whereas the maximum steady loads in flight exceeded those on the ground, the fluctuating loads obtained during ground running were greater, in nearly all the components, than the fluctuating flight loads. It was concluded, therefore, that on the Skeeter, fatigue defects would be revealed by ordinary ground-running tests without the necessity for simulating flight loads by periodic control movements or by barriers erected beneath the rotors. Some 200 hours of endurance running had now been accumulated, with no serious defects. Owing to the limitations imposed by the slip-rings, only three strain-gauge bridges could be used at a time on the rotating system, and the complete series of flight and ground tests were repeated for five sets of connections. Saunders-Roe, Limited, were therefore developing recording equipment for mounting in the rotor head, thus rendering slip-rings unnecessary.

MECHANISED SHELL-MOULDING PROCESS.

POLYGRAM CASTING COMPANY, LIMITED, LONDON.

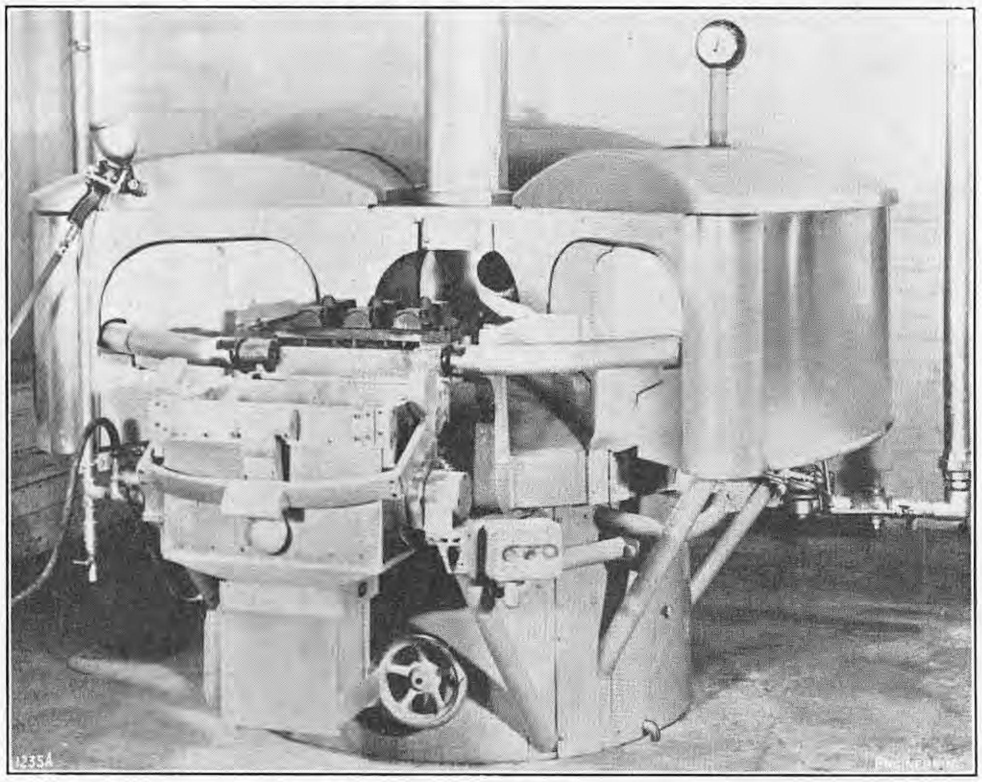


FIG. 1. "POLYGRAM" AUTOMATIC SHELL-MOULDING MACHINE.

DEVELOPMENTS IN SHELL MOULDING.

THE essentials of "shell moulding" are now well known among foundrymen. The process was first introduced commercially some six years ago, but it is only within the past twelve months that interest in shell moulding has become widespread. The process consists essentially of depositing evenly over the face of a heated metal half-mould pattern plate a finely-divided mixture composed principally of sand and a thermosetting phenolic resin. This is usually referred to as "investing" the plate with the sand-resin mixture. The heat from the plate causes the resin to melt and form a thin shell, about $\frac{1}{4}$ in. in thickness, over the entire surface of the pattern. After curing at a temperature of between 350 deg. and 450 deg. C., for a short period, the shell half-mould, or "biscuit" as it is rather aptly termed, is removed from the plate and either assembled at once for pouring the casting or stored until required. The two halves of the complete mould are held together by clips or other convenient method and the pouring of the metal can be conducted in either the horizontal or the vertical plane, the method of holding the mould being adapted to suit the circumstances, although the horizontal position is generally preferred. Soon after pouring, the hot metal ignites the resin binder, which is rapidly burnt out and the casting may be freed from the remaining sand by subsequent tapping or shaking. The process, we understand, is applicable to virtually all ferrous and non-ferrous metals, although special precautions are necessary when casting magnesium as this metal reacts chemically with the resin binder. The inner faces of the shell mould are smooth and the resultant castings have a highly satisfactory and even surface. It is claimed that limits can be held to $\pm 0 \cdot 002$ in. or $0 \cdot 003$ in. over each half of the casting.

The operations involved in the production of shell moulds, in the past, have been carried out by hand. They are, however, particularly amenable to mechanisation, which not only reduces the man-hours required to produce a given number of moulds, but also enables many of the variables to be standardised, so that products of consistent quality are turned out. A machine which has been specially designed for producing shell moulds is shown in Fig. 1. It is the Polygram automatic shell-moulding machine, Mark IV, which we recently saw in operation in an annexe to the foundry of the makers, the Polygram Casting Company, Limited, at Power-road, Gunnersbury, London, W.4. The machine is circular in plan, having an overall diameter of 6 ft. 6 in., and a height to the crown of the oven dome of 4 ft. 3 in. In front of the machine may be seen the investment bin containing the mixture of sand and resin. The bin is counter-balanced and is fitted with a manual roll-over mechanism enabling it to be inverted with relative ease. An electrically-driven rotary indexing mechanism takes the shell mould through three successive oven stages for curing. The oven is gas-heated and the temperature is maintained constant by a thermostat.

The hot pattern plate is first sprayed with a stripping solution to enable the finished shell mould to be easily detached at the end of the operation. The pattern plate, immediately after spraying, is shown on the machine in Fig. 2 opposite. The pattern plate is then rolled through 180 deg. and comes to rest face downwards over the open mouth of the investment bin, where it is clamped into position, as may be seen in Fig. 3. The bin is now inverted to allow the light-grey sand-resin mixture to fall on to the pattern plate. After the lapse of a suitable investment time, the bin is returned to the original position and the pattern plate, with its adhering sand-resin shell, is rolled back through 180 deg. to its initial position, as shown in Fig. 4. By means of a push-button switch, the motor driving the indexing mechanism is started up and the invested pattern plate enters the oven through automatically-opening and closing doors, and its place, in front of the operator, is taken by a fully-cured mould, which has just emerged from the oven (Fig. 5). An automatic ejection device raises the finished brown-coloured "biscuit" on ejector pins and the operator lifts the mould and places it on an adjoining table. The pattern plate is then re-sprayed with stripping fluid and the cycle of operations recommenced. The mean time for a complete cycle of the machine is 120 seconds, during which four half-moulds are produced. The investing operation takes a quarter of the total time, namely, 30 seconds, and the remaining $1\frac{1}{2}$ minutes are spent in the oven for the curing operation.

MECHANISED SHELL-MOULDING PROCESS.

POLYGRAM CASTING COMPANY, LIMITED, LONDON.

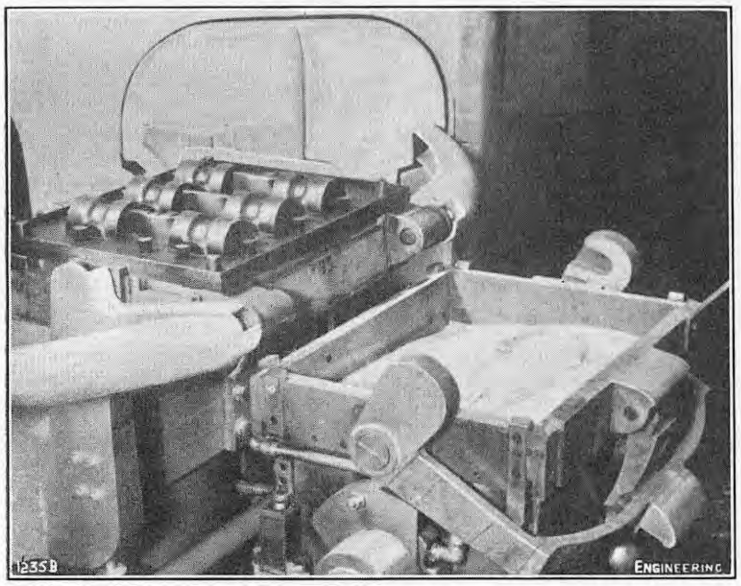


FIG. 2. PATTERN PLATE READY FOR INVESTMENT.

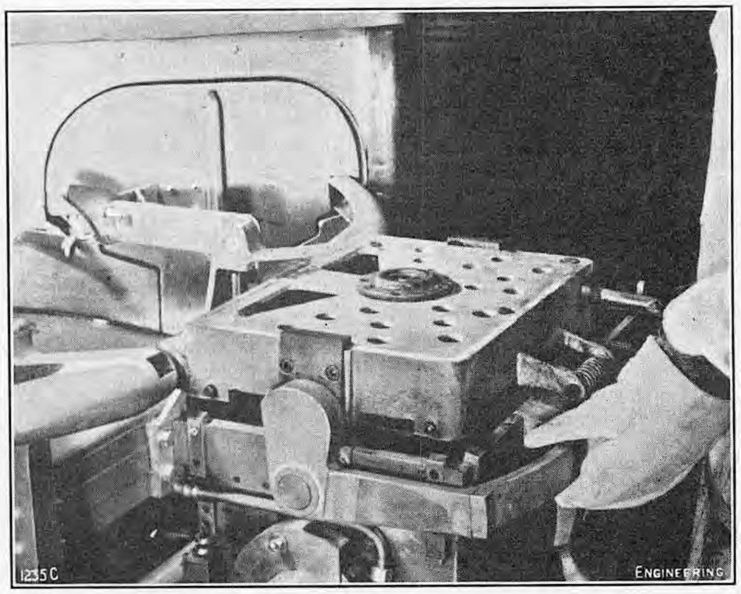


FIG. 3. PATTERN PLATE CLAMPED ON BIN.

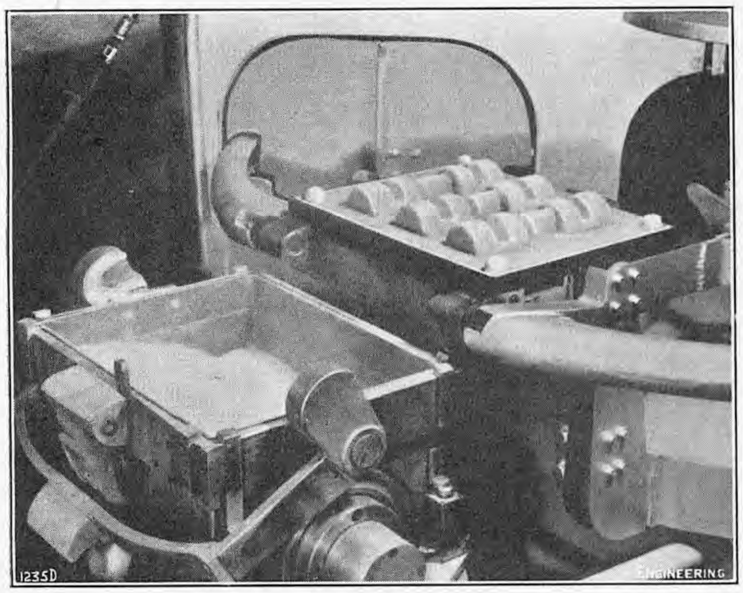


FIG. 4. SAND SHELL OVER PATTERN PLATE.

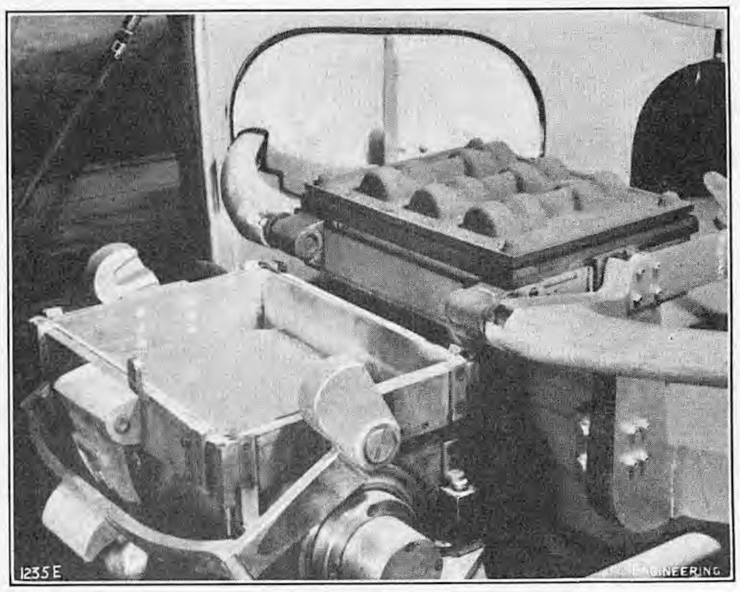


FIG. 5. CURED HALF-MOULD OR "BISCUIT."

A special feature of the machine is that all mains supplies are brought up under the base so as to give free floor space right round the machine. This facilitates sweeping and maintenance. The consumption of gas in the oven is kept to a minimum by the design of the burners and by lagging. The consumption, it is estimated, is at the rate of about 200 cub. ft. in the first 20 minutes after lighting up, while the oven is reaching the curing temperature. Thereafter, it is at the rate of less than 150 cub. ft. per hour for the remainder of the working day. A gas governor ensures that the temperature of the oven is rapidly returned to the pre-arranged point after the indexing mechanism brings in colder materials. The indexing mechanism of the machine is driven by a 1-h.p. screen-protected squirrel-cage induction motor which is protected from mechanical overload by a safety clutch on the main shaft drive. It is emphasised that the machine can be operated by unskilled labour and that the work involved is clean and not arduous.

Among the advantages claimed for shell moulding are that the "biscuits" may be stored for long periods and that, as they are light in weight, they can be made in one place and conveyed to another in a manner which would be impossible with normal moulding boxes. Shell moulds may be stored in piles taking up relatively little space and, even when assembled and ready for pouring, a shell mould does not take up much room. Moreover, where ordinary sand moulds require 10 tons of sand, it is stated that the equivalent shell moulds require only one ton, thus eliminating much conveying plant and lifting gear. It is also claimed that good feeding of the castings is made possible by the high permeability of the thin shell of the mould and that the reduction in surface friction, due to the smooth surface of the mould, means that smaller gates, runners and risers may be employed.

PRESENTATION OF TECHNICAL INFORMATION.

THE preparation of technical reports and memoranda within an industrial organisation formed the principal subject of a one-day conference of engineers and technical executives held at University College, London, on Monday, January 5. The conference, which was sponsored by the Communication Training Centre of the British Association for Commercial and Industrial Education, was opened by Professor R. O. Kapp, who said that the need for studying the presentation of technical information—a subject which had many aspects—had developed with the complexity and size of industrial organisations. Ability to write good English was insufficient for conveying technical information; it was necessary to understand the reader's reactions and limitations, and this required experience. He thought that training within industry was probably the best way to raise the standard of technical writing. Professor Kapp was followed by Mr. B. C. Brooke, who spoke on "Simplifying Vocabulary," and discussed examples of unsatisfactory wording, and Mr. A. C. Leyton, who presented some suggestions for revising drafts of technical reports so that they could be readily understood by managing executives not familiar with highly-specialised technicalities. The same three speakers then discussed the psychology of presenting technical information. In reading a technical paper, Professor Kapp said, the reader had, firstly, to discover what the report was about, secondly, to attempt to understand it, and thirdly to memorise its main points. The writer should set out the paper so as to simplify these three functions. Mr. Leyton spoke from the viewpoint of management, who had to base a course of action on the recommendations given in a report, and Mr. Brooke described some of the difficulties he had encountered, and how they had been overcome, in teaching the presentation of technical information to engineering students. After a luncheon break, the conference continued with an analysis of some technical papers by Mr. Brooke, and concluded with a talk by Mr. Leyton on methods of arranging technical reports. Short discussions followed each paper, but the time allowed was hardly adequate.

NOTES FROM THE INDUSTRIAL CENTRES.

SCOTLAND.

John G. Kincaid & Co.'s New Greenock Works.—Shortages of materials were given by Mr. Randal G. Kincaid, chairman of John G. Kincaid & Co., Ltd., Greenock, as one reason for a decline in the firm's output during 1952. Propelling machinery turned out totalled 37,530 h.p., as against 74,945 h.p. in 1951. Progress was made during the year with the construction of a new works, which will be fitted out as a blacksmith's shop at one end and a fabrication shop at the other. The latter section is being built to meet the increased demands for fabricated components such as bedplates and frames, and will be equipped with modern machines for the marking-off, cutting, and welding of heavy steel plates.

Stocks of Coal in Scotland.—Scottish coal stocks declined by 238,000 tons in eight weeks from the middle of October, as compared with an increase of 36,000 tons in the corresponding period of 1951. This reflected the colder weather and also a decline in the colliery output. The withdrawals from reserves reduced the total distributed stocks to 1,367,000 tons, against 1,387,000 tons 12 months before.

James Watt Dock, Greenock.—For about three months from March 12 the James Watt Dock, Greenock, will become tidal. During this period the western caisson will be removed for overhaul, and, until March 17, while the gate is being dismantled, the dock will be closed to traffic. The water in the dock, normally maintained at a level of 28 ft., will then fall to as low as 17 ft. at low water.

S.S. "Margareta" Salved from Ailsa Craig.—The Finnish steamer Margareta, 2,915 tons, which grounded on a submerged rock at the foot of the south wall of Ailsa Craig, in the River Clyde, was dragged clear on December 29. Examination of the hull, before the vessel was towed to Faslane in the Gareloch for a complete overhaul, showed the existence of small punctures in it, but no large holes.

Dock Improvements at Leith.—A falling-off in import and export figures occurred at Leith during 1952. The commissioners, however, have made no change in their considerable programme of dock improvements. These include an extension to one of the large sheds; the erection of 18 electric cranes, mostly of three- and six-tons capacity; the renewal of the concrete floor of the Newhaven fishmarket; the completion of a battery-charging station for the maintenance of fork-lift trucks and bogies; and the building of new offices.

Jute Manufacture in Dundee.—Jute Industries Ltd. have been allocated a factory on Craigie Industrial Estate, at Milton, Dundee, formerly occupied by Mingware Ltd. The factory will be used for the manufacture of products for the dollar market. Mr. W. G. N. Walker, chairman of Jute Industries Ltd., said that it was hoped that the new factory would be in production in a few weeks' time. Mingware Ltd., a subsidiary of Smith's Electric Clocks, vacated the factory on November 29 last.

CLEVELAND AND THE NORTHERN COUNTIES.

Staff Changes at Billingham Works.—Changes in the personnel at the Billingham Works of Imperial Chemical Industries Ltd. have been announced. Mr. W. K. Hall, work-study manager, has been appointed works general manager in succession to Mr. C. M. Wright, who has been appointed personnel director in place of Mr. P. M. Ray. Dr. H. E. North, works manager of the I.C.I. Works at Prudhoe, Northumberland, has succeeded Mr. Hall as work-study manager. Dr. R. J. Morley, manager of the ammonia gas and power section of the technical department, has been appointed director-general of carbonisation for the National Coal Board and has been succeeded at the I.C.I. by Mr. E. G. Brown, deputy works manager at the oil works, who in turn is succeeded by Dr. W. D. Huebner, deputy works manager of the ammonia works. Mr. A. W. Holmes, of the technical department, has been appointed Dr. Huebner's successor.

Long-Service Foundrymen at Middlesbrough.—Seventy employees of Cochrans (Middlesbro') Foundry, Ltd., have between them given a total of nearly 3,000 years of service to the firm. Seventy-seven-years-old Mr. G. Bellamy, power-house attendant, who has been with the company for 62 years, is the longest-serving workman.

Ship-Repairing Activity at Sunderland.—During 1952, the Sunderland ship-repairing firms of T. W. Greenwell & Co., Ltd., and S. P. Austin & Son, Ltd., between them repaired 657 ships. Messrs. Austin dealt with 500 vessels, mainly colliers, while Messrs. Greenwell worked on 68 ships in their dry docks and 89 vessels alongside their quays.

Colliery Development.—Further mining developments are planned in the No. 3 Area of the Northern (Northumberland and Cumberland) Division of the National Coal Board. These involve Linton, Ellington Lynemouth and Woodhorn collieries, the construction of a new drift at Longhirst and the building of a mineral railway from Lynemouth to Woodhorn. During 1952, pits in the No. 3 Area mined about 60,000 tons more coal than in 1951. At Shilbottle Colliery, Northumberland, where a development scheme has been in progress, the output is now about 300 tons a day more than previously. A new drift, to be opened at Ulgham, will produce about 1,200 tons a day.

Tyne Coal and Coke Shipments.—During 1952 coal and coke shipments from the Tyne amounted to 9,251,371 tons, an increase of 574,257 tons on 1951 but a decrease of 3,500,000 tons from the 1938 total.

Coal Shipments from River Wear.—Although no detailed figures have yet been issued, it is estimated that coal shipments from the River Wear, in 1952, reached 3,189,000 tons, the highest figure since 1939, or 44,000 tons more than was the case in 1951.

LANCASHIRE AND SOUTH YORKSHIRE.

Hacksaw-Blade Standardisation.—The standardisation of British hacksaw blades, in agreement with American and Canadian manufacturers, became operative on New Year's day. It involves the elimination of 41 different sizes of blades and the addition of a new standard list of nine new ones. Sheffield makers state that this marks the biggest change since the introduction of high-speed steel blades. It is contended that the changes will not only reduce costs, but increase the efficiency of sawing machines, raise production and improve export prospects, particularly in the Canadian and other markets in which American firms, at present, are strongly represented.

Coal Position in Sheffield.—It is authoritatively stated that, in Sheffield, stocks of fuel at gas and electricity undertakings are better than for some years past. The view is held that some industrial concerns are not stocking enough coal in the light of the ample supplies available. Off-the-ration domestic coal, described as "nutty slack," is in very strong request, and Sunday deliveries have had to be instituted in an endeavour to keep pace with the demand.

Aircraft Runway at Chesterfield.—Chesterfield Corporation have purchased an 83-acre site to the east of the town with the intention of providing a runway for light aircraft and helicopters in order to link Chesterfield to world air services at Ringway Airport, Manchester. The proposals are to be discussed by Chesterfield Civil Aviation Sub-committee.

THE MIDLANDS.

Factory Tour by Minister of Supply.—A three-day tour of engineering factories in the Midlands was commenced by Mr. Duncan Sandys, the Minister of Supply, on Monday last. In a speech to employees in Birmingham, Mr. Sandys referred to threats of a trade recession in the Midlands and said there was no doubt that competition had recently become much keener. Two fundamental problems had to be solved if it was to be overcome: the speeding up of deliveries and the reduction of prices. He later met trade-union leaders and others from all parts of the Midlands for a very full discussion on problems confronting the industry, but, by agreement between the unions and employers' representatives, no statement was issued.

Extensions at Rufford Colliery.—At Rufford Colliery, Nottinghamshire, a new shaft is being sunk which, it is officially stated, will more than double the output. It will be the third shaft at the colliery and will exploit the Low-Main, Hard, and Black-Shale seams. The present shafts will continue to exploit the higher seams. The yield from the new shaft, which will be 880 yd. deep, is expected to be a million tons a year.

Jubilee of H. M. Hobson, Ltd.—On January 15, H. M. Hobson, Ltd., of Fordhouses and Birmingham-road, Wolverhampton, will celebrate their 50th anniversary. The company started in London, but have had works in Wolverhampton for 41 years. After the recent war, the whole of their activities became centralised at Wolverhampton. They have been closely associated with the motor and aircraft industries since they were founded, and produced, in the early days, the well-known Claudel-Hobson carburettor.

The Effect of Time Study.—In 1949, a group of employees in the grey-iron foundry dressing shop at the works of John Harper & Co., Ltd., Willenhall, Staffordshire, asked the management to apply time study to their jobs. In two years, the output of the shop doubled, and 30 men were released for other work in the organisation. Experience has shown that the re-organised dressing shop could deal with more castings than the foundry could produce, so that methods of speeding up production in the foundry had to be adopted. The company are now preparing to close down their Meehanite dressing shop, and to transfer the work to the grey-iron shop.

Short-Time Working in the Wood-Screw Industry.—A four-day week has started in the wood-screw factories of Guest, Keen and Nettlefolds, Ltd., at Smethwick, King's Norton, Cannock, and Glasgow. It is believed that customers are now trying to reduce heavy stocks which were laid down when a shortage of metal appeared imminent. Only the wood-screw factories of the company are affected; the bolt and nut works have substantial orders.

Break in Gas Supplies.—There was an unusual incident on December 30, when the gas supplies for the towns of Wednesbury and Darlaston failed without warning. Some 13,000 consumers were without gas for about half an hour. The supply is obtained from the West Midlands Gas Board's works at Swan Village, West Bromwich. The Board subsequently stated that a valve was inadvertently closed, and are now investigating the cause.

Meeting to Discuss City Development Plan.—A meeting is being organised by the National Union of Manufacturers (Midland Area), at Digbeth Institute, Birmingham, on January 15, to discuss the City of Birmingham development plan. Numerous small manufacturers have been disturbed by the fact that their premises have been scheduled for demolition, before alternative accommodation has been found. These manufacturers, and other objectors to the plan, have been invited to state their views at the meeting.

SOUTH-WEST ENGLAND AND SOUTH WALES.

Anglo-Argentine Trade Agreement.—The signing of the new trade agreement with the Argentine will mean a resumption, from South Wales, of large-scale coal shipments, which have been suspended for several months. Under the new arrangements, Britain will supply about 800,000 tons of coal to the Argentine during the ensuing year, and, if previous experience is any guide, the bulk of this quantity will originate from South Wales. In addition, another of South Wales's basic trades should benefit as a result of the new agreement. Under this, the Argentine has contracted to take 27,000 tons of tin-plate during 1953.

Loss on Coal Mining.—Statistics published by the National Coal Board show that during the third quarter of 1952 the South-Western Divisional Board operated its collieries at a loss of 1,500,823*l*., equivalent to 5*s*. 4*d*. per ton, compared with a loss of only 178,438*l*., or just under 7*d*. per ton, in the previous quarter. In the South Wales and Monmouthshire coalfield, in which there was a profit of 80,235*l*. in the second quarter of the year, there was a loss of 1,204,399*l*., or 4*s*. 6*d*. per ton in the third quarter. In the Forest of Dean, the loss was equivalent to 15*s*. 6*d*. per ton and in Somerset to 1*l*. 5*s*. 10*d*. per ton. During 1952, the South-Western Division of the Coal Board produced 25,050,400 tons of saleable coal, compared with 24,668,800 tons in 1951.

Proposed Shipyard at Newport, Mon.—Early permission to proceed with the work of setting up a shipbuilding yard on the River Usk at Newport is expected. The sponsor of the scheme is Group-Captain George Bailey, head of the ship-repairing firm of C. H. Bailey, Ltd., who have large interests at Cardiff, Barry, and Newport. The Newport project has been estimated to cost about 1,500,000*l*., and the plans have been examined by the Admiralty. The proposed site of 50 acres was inspected last July by Sir Graham Cunningham, independent chairman, and five members of the Shipbuilding Advisory Committee.

NOTICES OF MEETINGS.

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

Institute of Fuel.—*North-Eastern Section*: Monday, January 12, 6.30 p.m., King's College, Newcastle-upon-Tyne. "Treatment of Water for Boiler-Feed Purposes," by Mr. C. J. Carter. *East Midland Section*: Wednesday, January 14, 7 p.m., Welbeck Hotel, Nottingham. "Peak Steam Demands and Thermal Storage," by Dr. E. G. Ritchie. Thursday, January 15, 6.15 p.m., Gas Showrooms, Nottingham. "An Investigation of Whole-House Heating," by Mr. F. C. Lant and Dr. J. C. Weston.

Illuminating Engineering Society.—*Sheffield Centre*: Monday, January 12, 6.30 p.m., The University, Western Bank, Sheffield. Presidential Address by Mr. W. J. Wellwood Ferguson. *London*: Tuesday, January 13, 6 p.m., Lighting Service Bureau, 2, Savoy-hill, W.C.2. "Some Aspects of Power Station Lighting," by Mr. P. D. Figgis.

Institution of Production Engineers.—*Sheffield Section*: Monday, January 12, 6.30 p.m., Royal Victoria Station Hotel, Sheffield. "Photo-Elasticity," by Colonel H. T. Jessop. *Yorkshire Section*: Monday, January 12, 7 p.m., Hotel Metropole, King-street, Leeds. "Modern Marking Methods," by Mr. A. Throp. *Halifax Section*: Monday, January 12, 7.15 p.m., The White Swan Hotel, Halifax. "Foremanship," by Mr. A. P. Young. *Western Section*: Wednesday, January 14, 7.30 p.m., Works of Westinghouse Brake and Signal Co., Ltd., Chippenham, Wiltshire. "Production Management's Responsibility for Productivity," by Mr. B. H. Dyson. *Edinburgh Section*: Wednesday, January 14, 7.30 p.m., North British Station Hotel, Edinburgh. "Simplification for Production," by Mr. A. B. Brown. *Southern Section*: Thursday, January 15, 7 p.m., Polygon Hotel, Southampton. "Costing as an Aid to Management," by Mr. H. H. Norcross. *Glasgow Section*: Thursday, January 15, 7.30 p.m., 39, Elmbank-crescent, Glasgow. "An Engineering Analysis of Organisation," by Mr. K. J. Shone.

Institution of the Rubber Industry.—*Midland Branch*: Monday, January 12, 6.45 p.m., James Watt Memorial Institute, Birmingham. "The Study of Ozone Cracking by Cinematography," by Miss D. Wyatt and Mr. V. E. Gough. *Institution*: Tuesday, January 13, Royal Society for Tropical Medicine and Hygiene, 26, Portland-place, W.1. 5.30 p.m., Discussion on "Calendering." 7 p.m., (i) "Latex Thread Coagulation," by Dr. R. G. James; and (ii) "Latex for Surface Coatings," by Dr. H. J. Stern. *Scottish Section*: Tuesday, January 13, 7.30 p.m., 25, Charlotte-square, Edinburgh. "Replanning Scottish Resources on a Self-Sufficient Basis," by Mr. D. A. Lamont. *Southern Section*: Wednesday, January 14, 7.15 p.m., Polygon Hotel, Southampton. "Costing," by Mr. J. B. W. Toole.

Junior Institution of Engineers.—*North-Western Section*: Monday, January 12, 7 p.m., 16, St. Mary's Parsonage, Manchester. Chairman's Address by Mr. F. E. Bancroft. *Sheffield Section*: Monday, January 12, 7.30 p.m., Livesey Clegg House, Union-street, Sheffield. "Science Looks at Works Corrosion," by Mr. H. G. Gow. *Institution*: Friday, January 16, 7 p.m., Townsend House, Greycoat-place, S.W.1. "Statistics for Practical Engineers," by Mr. S. J. Button.

Institution of Electrical Engineers.—*London Students' Section*: Monday, January 12, 7 p.m., Victoria-embankment, W.C.2. Film Evening. *Radio Section*: Wednesday, January 14, 5.30 p.m., Victoria-embankment, W.C.2. "Printed and Potted Electronic Circuits," by Mr. G. W. A. Dummer and Mr. D. L. Johnston. *Merseyside and North Wales Centre*: Wednesday, January 14, 6.45 p.m., Philharmonic Hall, Liverpool. Faraday Lecture on "Light from the Dark Ages, or the Evolution of Electricity Supply," by Mr. A. R. Cooper.

Incorporated Plant Engineers.—*Dundee Branch*: Monday, January 12, 7.30 p.m., Mather's Hotel, Dundee. "Electricity in the Textile Industry," by Mr. J. D. Campbell. *East Lancashire Branch*: Tuesday, January 13, 7.15 p.m., Engineers' Club, Manchester. Open Meeting. *Blackburn Branch*: Thursday, January 15, 7.30 p.m., Chamber of Commerce, Richmond-terrace, Blackburn. Discussion on "Induction Generation by Back-Pressure Equipment." *Birmingham Branch*: Friday, January 16, 7.30 p.m., Imperial Hotel, Birmingham. Contractors' Plant Discussion Group.

Institute of Road Transport Engineers.—*Scottish Centre*: Monday, January 12, 7.30 p.m., North British Hotel, Edinburgh. "The Application of Rubber Bonding to Commercial Vehicles," by Mr. A. J. Hirst. *Midlands Centre*: Tuesday, January 13, 7.30 p.m., Crown Inn, Broad-street, Birmingham. "The Application of Synthetic Resin Adhesives in the Road Transport Industry," by Mr. T. Maxwell Hudson. *Yorkshire Centre*: Thursday, January 15, 7.30 p.m., Hotel Metropole, Leeds. "The Development of a Flat Four-Passenger Car Engine," by Mr. C. G. Grangefield.

Association of Supervising Electrical Engineers.—*North-West London Branch*: Monday, January 12, 8 p.m., Prince of Wales Hotel, Kingsbury. "Industrial X-Ray Equipment," by Mr. F. L. Veale. *Bolton Branch*: Tuesday, January 13, 7.30 p.m., Balmoral Hotel, Bradshawgate, Bolton. "Industrial Switchgear," by Mr. A. T. Crawford. *Bradford Branch*: Wednesday, January 14, 7.30 p.m., Midland Hotel, Bradford. "Further Applications of X-Rays," by Mr. A. Hudson.

Institution of Chemical Engineers.—Tuesday, January 13, 3 p.m and 6 p.m., Geological Society's Apartments, Burlington House, Piccadilly, W.1. Symposium on "Bursting Discs."

Institution of Civil Engineers.—*Public Health Engineering Division*: Tuesday, January 13, 5.30 p.m., Great George-street, S.W.1. "The Storage, Collection and Disposal of Domestic Refuse," by Mr. J. C. Dawes.

Institute of Marine Engineers.—Tuesday, January 13, 5.30 p.m., 85, The Minories, E.C.3. "Burning of Boiler Oil in Two- and Four-Stroke Diesel Engines and Development of Fuel-Injection Equipment," by Mr. A. G. Arnold.

Institution of Sanitary Engineers.—Tuesday, January 13, 6 p.m., Caxton Hall, Westminster, S.W.1. "Waterproofing of Concrete Structures," by Mr. Isaac Hopkins.

Institution of Heating and Ventilating Engineers.—*South-Western Branch*: Tuesday, January 13, 6.30 p.m., R.W.A. School of Architecture, Bristol. "The Pump Packs Up," by Mr. T. H. F. Holman.

Institute of Metals.—*South Wales Section*: Tuesday, January 13, 6.30 p.m., University College, Swansea. "Metallurgical Problems Arising from Stratospheric Flight," by Major P. L. Teed.

Institution of Engineers and Shipbuilders in Scotland.—Tuesday, January 13, 6.30 p.m., 39, Elmbank-crescent, Glasgow. "Tunnel Type Vessels," by Mr. A. R. Mitchell.

Institution of Structural Engineers.—*Lancashire and Cheshire Branch*: Tuesday, January 13, 7 p.m., College of Technology, Liverpool. "Continuous Welded Structures at Abbey Works, Port Talbot," by Mr. W. R. Atkins. *Northern Counties Branch*: Wednesday, January 14, 6.30 p.m., Neville Hall, Newcastle-upon-Tyne. Open Meeting.

Royal Society of Arts.—Wednesday, January 14, 2.30 p.m., John Adam-street, W.C.2. "Use and Abuse of Fuels," by Mr. W. E. P. Johnson.

Royal Sanitary Institute.—Wednesday, January 14, 2.30 p.m., 90, Buckingham Palace-road, S.W.1. "Fluorides in Water Supplies," by Dr. R. C. Hoather.

Institute of Petroleum.—Wednesday, January 14, 5.30 p.m., 26, Portland-place, W.1. "Methods of Hydrocarbon Type Analysis," by Mr. H. C. Rampton.

Institution of Locomotive Engineers.—Wednesday, January 14, 5.30 p.m., Institution of Mechanical Engineers, Storey's-gate, St. James's Park, S.W.1. "Limitations of Acceleration and Braking with Electric Traction," by Mr. A. S. Robertson.

British Institution of Radio Engineers.—*North-Eastern Section*: Wednesday, January 14, 6 p.m., Neville Hall, Newcastle-upon-Tyne. "Hearing Aids," by Mr. R. A. Bull.

Institution of Engineers-in-Charge.—Wednesday, January 14, 6.30 p.m., St. Bride Institute, Fleet-street, E.C.4. "Atomic and Other Weapons," by Mr. A. W. Moore.

British Association of Chemists.—*London Section*: Wednesday, January 14, 7 p.m., Wellcome Research Institution, Euston-road, N.W.1. "Patents and the Chemical Manufacturer," by Mr. N. F. Baker.

Institution of Mechanical Engineers.—*East Midlands Branch*: Wednesday, January 14, 7.30 p.m., County Technical College, Newark-on-Trent. "Mechanism of Work-Hardening in Metals," by Professor N. F. Mott. *Midland Branch*: Thursday, January 15, 6 p.m., James Watt Memorial Institute, Birmingham. "Watch Production," by Mr. R. A. Fell and Mr. P. Indermuhle. *Institution*: Friday, January 16, 5.30 p.m., Storey's-gate, St. James's Park, S.W.1. "Control Valves for Direct-Hydraulic Presses," by Mr. F. H. Towler and Mr. J. M. Towler. Automobile Division.—*Derby Centre*: Monday, January 12, 7.15 p.m., Midland Hotel, Derby. Open Meeting. *Luton Centre*: Monday, January 12, 7.30 p.m., Town Hall, Luton. "Design and Development of an Economical Automobile Gearbox," by Mr. T. C. F. Stott. *London*: Tuesday, January 13, 5.30 p.m., Storey's-gate, St. James's Park, S.W.1. "Life Assessment Tests for Commercial Vehicles," by Mr. John Alden.

Institution of Mining and Metallurgy.—Thursday, January 15, 5 p.m., Geological Society's Apartments, Burlington House, Piccadilly, W.1. (i) "Removal of Sulphides from Tin-Wolfram Concentrates in Portugal," by Mr. J. C. Allan; and (ii) "Determination of Sulphur in Iron Pyrites," by Mr. E. A. Hontoir.

PERSONAL.

H.R.H. The Duke of Edinburgh has graciously accepted election to honorary membership of the Institution of Metallurgists, 4, Grosvenor-gardens, London, S.W.1.

Sir Geoffrey Burton has been elected chairman of the board of Blaw Knox Ltd., in succession to the late Mr. J. T. Goddard.

Mr. C. C. Walker, C.B.E., A.M.I.C.E., F.R.Ae.S., chief engineer and a founder director of the de Havilland Aircraft Co. Ltd., has been elected honorary foreign Fellow of the Institute of the Aeronautical Sciences of the United States for the year 1952.

Engineer Rear-Admiral C. W. Lambert, C.B., general works manager of the Appleby-Frodingham branch of the United Steel Companies Ltd., Sheffield, is retiring on June 30. He will be succeeded by Mr. Albert Jackson, works manager (steel) and deputy general works manager. As from January 1, Mr. T. P. Lloyd, B.Sc., A.I.M., T.D., has been appointed assistant works manager (steel) and as from July 1, he will succeed Mr. Jackson as works manager (steel). Mr. V. Watkins, at present maintenance manager of the Steel, Peech and Tozer branch of the Companies, has been made deputy chief engineer. Mr. C. Wilkinson, at present assistant cold rolling-mill manager, has been appointed cold rolling-mill manager in succession to Mr. J. Lees, who has left to become manager of the hot-rolling mill at Arthur Lee and Sons, Ltd., Meadow Hall Works, Sheffield.

Mr. A. G. E. Briggs, joint assistant managing director, Tube Investments Ltd. (Electrical Division), on whom the honour of Knight Bachelor was conferred in the New Year Honours List, and who was lent to the Ministry of Supply as deputy controller of supplies (munitions production) in March, 1951, relinquished this appointment on December 31, 1952, and has resumed his full-time duties with the company.

Mr. R. W. Cooper, M.C., chairman of the British Aluminium Co. Ltd., Norfolk House, St. James's-square, London, S.W.1, has relinquished his directorship and has been succeeded as chairman, as from January 1, by Viscount Portal of Hungerford, K.G., G.C.B., O.M., D.S.O., M.C. Mr. E. F. O. Gascoigne has been elected a director.

Mr. William Masterton and Dr. S. G. Hooker, O.B.E., D.I.C., F.R.Ae.S., have been appointed directors of the Bristol Aeroplane Co., Ltd., Filton House, Bristol.

Mr. T. Hall, Mr. E. Hepworth and Mr. A. H. Royle have been appointed directors of the Pioneer Oilsealing and Moulding Co. Ltd.

Mr. H. D. Challen, A.M.I.Mech.E., has been re-elected chairman of the Gauge and Tool Makers' Association, Standbrook House, Old Bond-street, London, W.1. Mr. A. E. Whyman has been re-elected vice-chairman.

Mr. J. A. Perham has been appointed managing director of the Atlas Diesel Co. Ltd., Beresford-avenue, Wembley, Middlesex, in succession to Mr. E. B. F. Johnsson, who has been appointed managing director of Swedish Atlas Compressed Air Ltd.

Mr. R. P. Brookes has been appointed a director of Guest, Keen and Nettlefolds Ltd.

Mr. E. A. Bromfield has been appointed general secretary of the Association of Supervising Electrical Engineers, 54, Station-road, New Barnet, Hertfordshire, in succession to the late Mr. A. Brammer.

Mr. Maurice Tattersfield, A.C.A., F.C.C.S., has been appointed group controller of accounts to the Brush ABOE Group of Companies.

Mr. F. Carleton Anderson, a founder director of the Harland Engineering Co. Ltd., retired on January 1. Mr. W. Scott and Mr. L. Spiro, both long-service members of the staff, have been elected to the board.

Mr. W. A. Green, B.Sc., M.I.Mech.E., consulting engineer specialising in Diesel-engine problems, has taken Mr. G. B. Fox, M.I.Mech.E., into partnership. The style of the firm will be Green and Fox, and the address: Rowans, Monks-road, Virginia Water, Surrey. (Telephone: Wentworth 3140.)

Mr. T. N. Sneddon, agent at Horden, Blackhall and Easington Collieries, for the past five years, has been appointed an assistant area production manager for the Northern (Northumberland and Cumberland) Division, National Coal Board. He begins his new duties on January 17. His successor as agent is Mr. J. T. Robson of the Durham Division.

The Society of Motor Manufacturers and Traders, 148, Piccadilly, London, W.1, have appointed Mr. R. W. Walker, A.M.I.Mech.E., to be their representative in South America, in place of Colonel K. R. Stirling-Wyllie, and Mr. A. E. Grant-Crofton, to be their representative on the Continent of Europe.

The name of Transformers and Welders Ltd., has been changed to Transformers (Watford) Ltd., Sandown-road, Watford, Hertfordshire.

AIRCRAFT-STRUCTURE TESTING EQUIPMENT.

(*For Description, see Page 55.*)

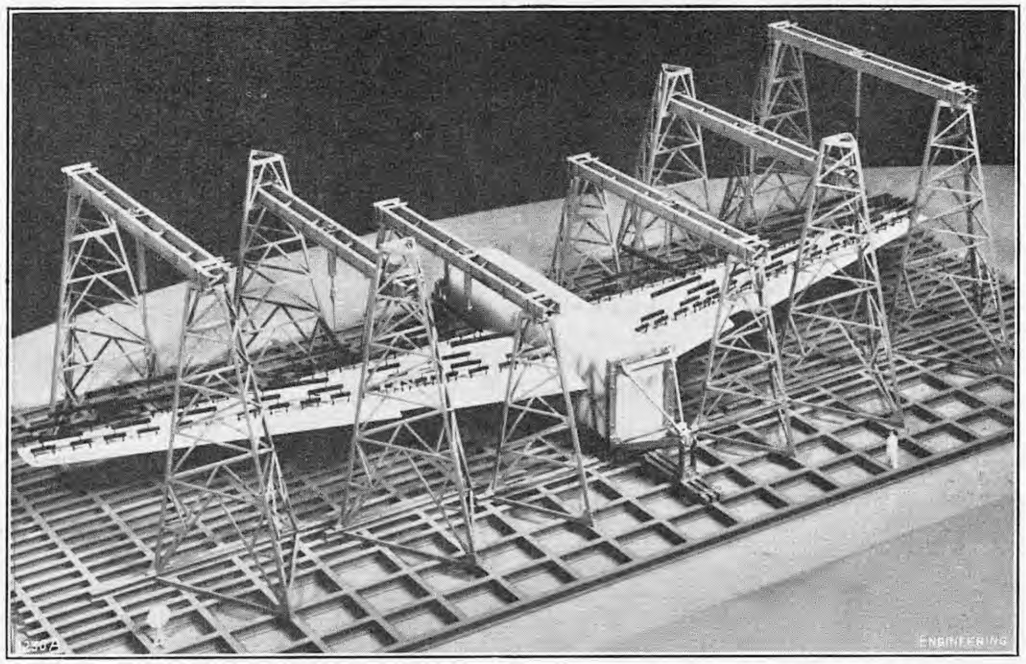


Fig. 1. Model of Test Frame Arranged for Wing Test.

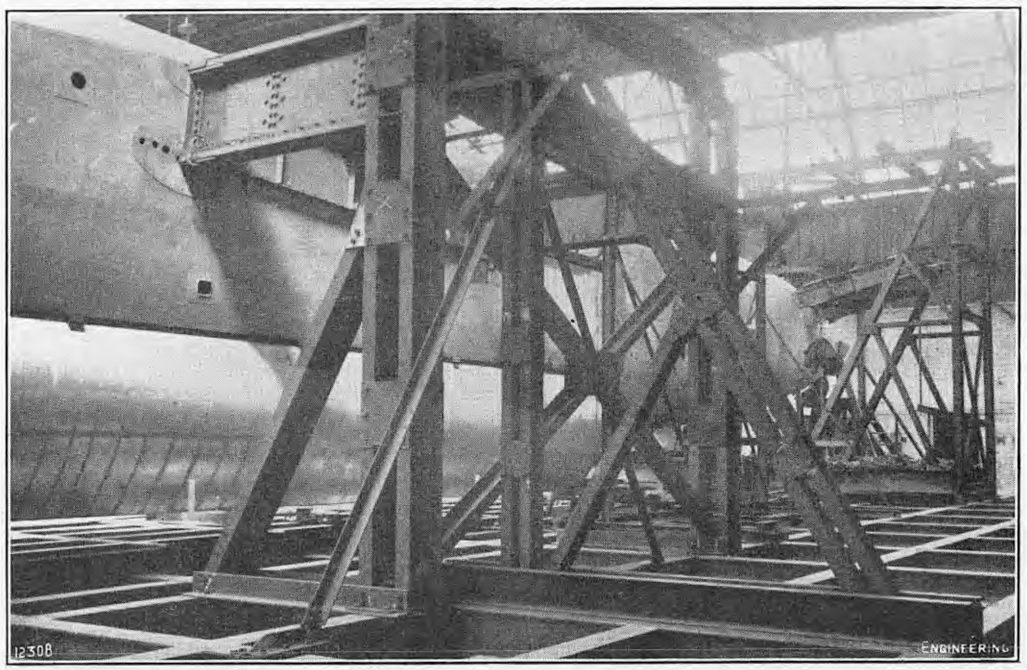


Fig. 2. Side Frame Supporting Fuselage on Test Rig.

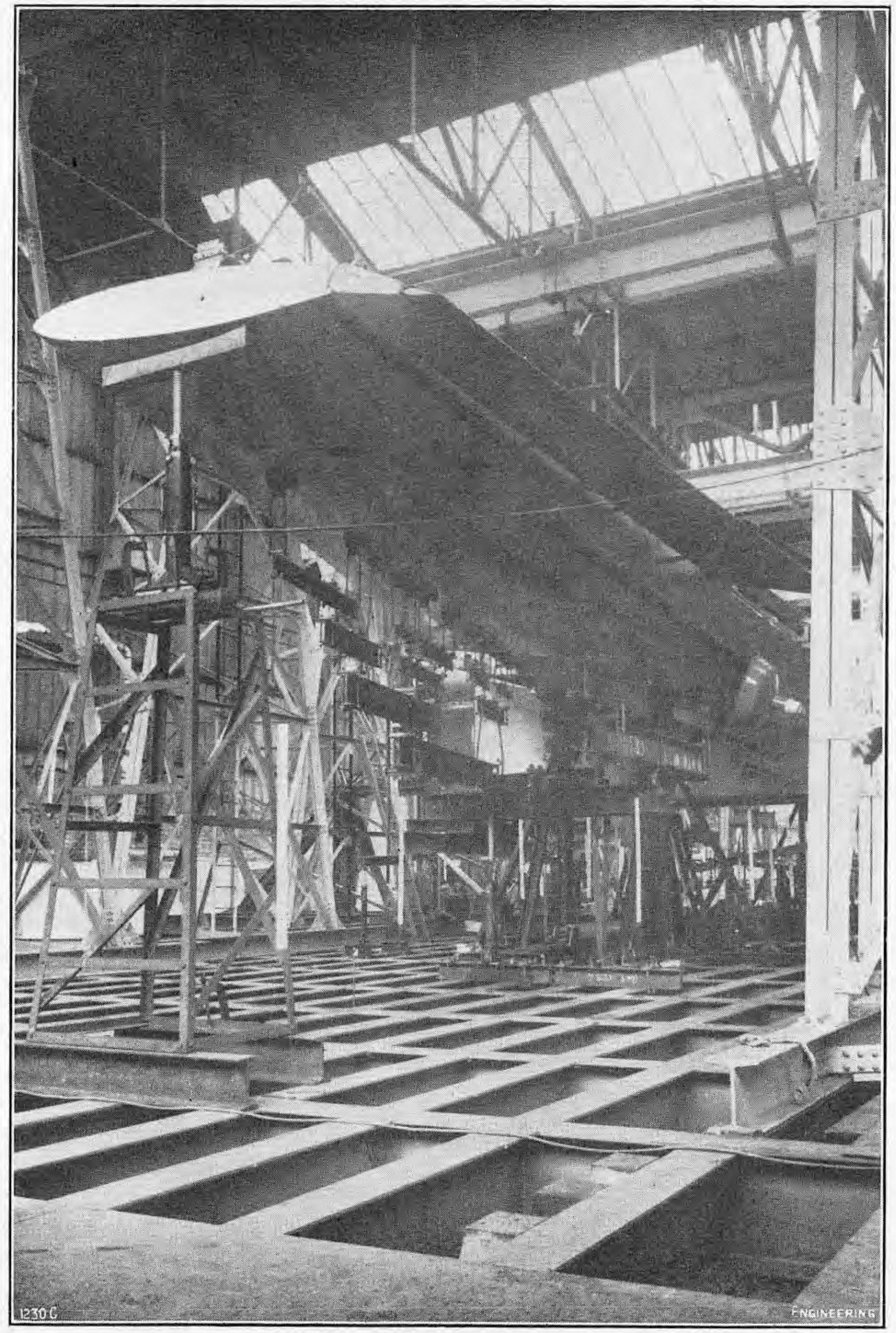


Fig. 3. Wing Under Test.

ENGINEERING

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TIME FOR RECEIPT OF ADVERTISEMENTS.

Classified advertisements intended for insertion in the current week's issue must be received not later than first post Wednesday.

"Copy" instructions and alterations to standing advertisements for display announcements must be received 14 days previous to the date of publication, otherwise it may be impossible to submit proofs for approval.

The Proprietors will not hold themselves responsible for advertisers' blocks left in their possession for more than two years.

INDEX TO VOL. 173.

The Index to Vol. 173 of ENGINEERING (January-June, 1952) is now ready and will be sent to any reader, without charge and postage paid, on application being made to the Publisher. In order to reduce the consumption of paper, copies of the Index are being distributed only in response to such applications.

CONTENTS.

ENGINEERING

FRIDAY, JANUARY 9, 1953.

VOL. 175. NO. 4537.

CREATION AND INVENTION.

ALL human invention and creation spring from the veiled activities of the human mind, and he would be an unimaginative engineer who did not sometimes wish that his own mind—and the minds of those senior and junior to him—would function at a more consistently high level. He sees about him, among the whole range of engineering products, occasional evidence of perfect invention and design, and in such cases he knows that the success was due to something more than conscientious effort. If he is fortunate enough to rejoice in such a work of his own doing, he can reflect, with humility, that however hard he may have worked, however much he may have exercised his will, it was a sudden illumination from the unconscious mind which provided the essential essence of the solution. Reasoning and calculation took him some way, but ultimately the perfect answer was unexpectedly thrown up into his conscious thinking.

Such experiences of the function of the unconscious mind in the creative process are common, though just how common it is difficult to say. Artists are familiar with them, and so too are mathematicians, scientists and engineers when they are working at the height of their powers. Conscious and routine effort deals with man's routine tasks, but the illumination which comes from the unconscious workings of the mind leads to those revolutionary changes which mark the history of science and engineering. It leads also to those changes—in design for example—which, though of lesser import, are yet significant advances in their own sphere. Would it be practicable and wise, then, for a man to take thought for the efficiency of his mind in creating, so that, in the future as in the past, it will solve the problems which loom large? Mr. Brewster Ghiselin, who has recently edited a book on the creative process,* evidently thinks it would. He remarks that "insight into the processes of invention can increase the efficiency of almost any developed and active intelligence. Not even the most vigorously creative minds always find their way quickly to efficiency. Yet many creative workers have little knowledge of the pertinent materials and would not know where to look for them."

He has therefore compiled an anthology of writings by men and women who have paused to consider the characteristics of their own creative processes. Anyone who has experienced the spontaneous illumination which transcends ordinary thinking and reasoning cannot fail to be encouraged by these records of Einstein, Poincaré, Mozart and many others. He will learn, for example, that "inspiration" is not so much a monopoly of geniuses, as an activity with which many are blessed but few develop. There is no golden rule or magic formula; indeed no two minds work alike. But the book makes it quite clear that "inspiration" without solid working and thinking is extremely rare, if not altogether unknown. Mozart alone, among the 38 whose writings are included in the anthology, appears to have enjoyed a spontaneous, unpremeditated flow of ideas, but even he acknowledges the need for conscious effort: "All this [i.e., the flow of musical ideas] fires my soul, and, provided I am not disturbed, my subject enlarges itself, becomes methodised and defined, and the whole, though it be long, stands almost complete and finished in my mind . . ." At the other extreme, even some of the poets recall the long and arduous work essential to the creation of a poem.

How composers and poets work may seem to have little bearing on the inventive efforts of those concerned with science and technology. In fact, however, as Mr. Ghiselin's book shows, there is a continuous thread running through all the recorded experiences gathered together in his anthology. Graham Wallas—whose *Art of Thought* is unfortunately not quoted—summed it up very well. He postulated four stages of invention or creation: examination of the problem; a period of relaxation (i.e., a period when the conscious mind is occupied with anything but the problem); the illumination, which more often than not is spontaneous and unpredictable; and the final verification, when the solution is worked out in its entirety. The first and the last stages demand conscious hard work: a willed effort animated by a passion for the subject. R. W. Gerard, part of whose article on "The Biological Basis of the Imagination" is quoted in the anthology, says that "The unconscious work goes on only over problems that are important to the waking mind, only when the mind's possessor worries about them, only when he cares, passionately." He recalls the advice Pavlov gave to young men on the requisites for the effective pursuit of science: "Third, passion. Remember that science demands from a man all his life. If you had two lives, that would not be enough for you. Be passionate in your work and your searchings." And Gerard himself adds courage: "It took great fortitude for Kepler to adhere to his new notion of infinity (as the second focus of a parabola), for, as he said, 'The idea seems absurd, but I can find no flaw in it,' just as it did for Galileo to murmur among his inquisitors, 'Yet the world does move'."

The struggle for invention, however, may begin

* *The Creative Process: A Symposium.* Compiled and edited, with an introduction, by Brewster Ghiselin, University of California Press, Berkeley, California, U.S.A.; and Cambridge University Press, 200, Euston-road, London, N.W.1. [Price 49s.]

simply as "an extreme dissatisfaction with established order"—to use Mr. Ghiselin's phrase. To most men, the inventor's originality may appear eccentric; his ideas are accepted slowly, as it is realised that he has invented something that is needed. Even to the inventor himself, his ideas may at first lack precise determination and fixity. The mind is agitated by innumerable forces, all pointing towards a new order, a new theory, or a new design—A. N. Whitehead's "state of imaginative muddled suspense which precedes successful inductive generalisation." At this stage, it seems, too much conscious control of thought may kill the new idea which the unconscious mind is developing.

Concerning this, Henri Poincaré's article on "Mathematical Creation," a translation of which is the first of Mr. Ghiselin's selections, is most apposite to the needs of the scientific mind. Poincaré described in great detail how he came to write his first "memoir" on Fuchsian functions. Mathematical creation, he said, "does not consist in making new combinations with mathematical entities already known. Anyone could do that, but the combinations so made would be infinite in number and most of them absolutely without interest. To create consists precisely in not making useless combinations and in making those which are useful and which are only a small minority. Invention is discernment, choice." He describes how for fifteen days he strove to prove that there could not be any functions of the type he subsequently called Fuchsian functions. "One evening, contrary to my custom, I drank black coffee and could not sleep. Ideas rose in crowds; I felt them collide until pairs interlocked, so to speak, making a stable combination. By the next morning I had established the existence of a class of Fuchsian functions, those which come from the hypergeometric series; I had only to write out the results, which took but a few hours." The nature of the unconscious activity which eventually caused the ideas to rise in crowds was, and is, a mystery, but he concluded that "The useful combinations are precisely the most beautiful, I mean those best able to charm this special sensibility that all mathematicians know, but of which the profane are so ignorant as often to be tempted to smile at it."

Reading the collected evidence of these distinguished creators and inventors, and perhaps aware of the unseen workings of his own mind, the scientist and the engineer will search for a means of managing his own creative processes. He can hardly read this anthology without reaching a better understanding. Mr. Ghiselin says it is necessary "to be able to look into the wings [of the mind] where the action is not yet organised, and to feel the importance of what is happening off-stage." To the engineering designer, it is possible that the experience of a sculptor—Henry Moore—may be of value, since the designer, like the sculptor, must "respond to form in three dimensions." He explains that a child learning to see first distinguishes only two-dimensional shape. Later, for its personal safety and practical needs, it develops the ability to judge roughly three-dimensional shapes, but having satisfied the requirements of practical necessity most people go no farther. "Though they may attain considerable accuracy in the perception of flat form, they do not make the further intellectual and emotional effort needed to comprehend form in its full spatial existence." An engineer at the drawing board, working by orthographic projection, can too easily avoid visualising his design in its three-dimensional form. That, perhaps, is a special case of a common failing among technical men: that they confine themselves too rigidly to the logical, reasoning progress of thought. Artists, in whatever medium, would not be artists if they did not allow the unconscious mind free rein; engineers would be greater engineers if they did.

ELECTRICITY IN ONTARIO.

THE increase of the British Electricity Authorities' generating capacity by 1,539,000 kW in 1952 raises hopes that power cuts will become less frequent in the future. The Hydro-Electric Power Commission of Ontario has also in the past been forced at times to restrict supplies but, as in 1951 it increased the generating capacity of its systems by 211,450 kW, it may be approaching the time when restriction may not be necessary. The Canadian figure is considerably smaller than the British, but as the population of Great Britain is some ten times greater than that of Ontario, the performance of the latter is the more notable. As electricity generation in Ontario is mainly dependent on water power, output may be affected by weather conditions in a way that does not apply in this country and although continually rising demand has been one reason for the restrictions which have had to be imposed in the past, temporary water shortage has been an important factor. As this is an uncontrollable state of affairs which may, and probably will, recur, greater security has been provided for by constructing two steam stations of an ultimate combined capacity of 664,000 kW.

The steam plants have clearly not been built as an economy measure, as in the chairman's introduction to the Report of the Commission for 1951,* it is stated "their contribution in the form of greater security must compensate for the substantially higher cost of electric power derived from steam." The first unit in the Richard L. Hearn generating station in Toronto was not set in operation until the official opening on October 26, 1951, and the starting up of the J. Clark Keith station in Windsor was even later, the date being November 16, 1951. These stations naturally embody the features of the best modern practice. Pulverised-coal firing is used and steam is produced at 875 lb. per sq. in. pressure and 900 deg. F. The Toronto station will ultimately contain four 100,000-kW generating sets and the Windsor station four 66,000 kW sets.

The Commission is faced with frequency-standardisation problems, some supplies gradually being changed over from 25 to 60 cycles. To meet present conditions, the first set started up at the Toronto station is fitted with a two-pole rotor which at 1,500 r.p.m. generates 88,000 kW at 25 cycles and 11,200 volts; ultimately it will be provided with a four-pole rotor and, running at 1,800 r.p.m., will deliver 100,000 kW at 60 cycles and 13,800 volts. The Windsor station will from the first generate at 60 cycles. The machines run at 3,600 r.p.m. with a terminal voltage of 13,800. In both stations, the alternators are hydrogen cooled. Unit lay-out is employed in both stations, each turbine being connected to its own boiler and the alternator being solidly connected to its step-up transformer bank. Special arrangements are made in the Windsor station which enable two of the alternators to be disconnected from their turbines and operated as synchronous condensers when required.

The Commission has, in all, 64 hydro-electric stations and eight fuel stations, but these latter, apart from the new Toronto and Windsor stations, are small and of relative unimportance in their contribution to the total energy distributed. Comparison between the cost of energy supplied by a small steam or Diesel station and that furnished by a 400,000-kW hydro-electric station would be of little value, but information about the relative costs per unit generated at the new steam stations and large water-power stations, which will presumably become available in the future, should furnish a guide to future policy. Running costs are, of course, the factor which swell the steam-station figure. In by far the majority of cases, it is the heavy construction costs for hydro-electric plant, owing to the civil-engineering work involved in their construction, which largely determine the cost of energy.

Some comparison between the capital cost of the two types of station can be drawn from figures given in the report. The Richard L. Hearn steam station in Toronto cost about 150 dols. per kilowatt, and the J. Clark Keith station in Windsor about 182 dols. per kilowatt. Hydro-electric station figures are much higher. The largest station of this type at present under construction is the Sir Adam Beck-Niagara No. 2 station on the Niagara River. There is already a No. 1 station in operation. No. 2 station, when completed, will have a capacity of 525,000 kW and on present estimates will cost about 353 dols. per kilowatt. There are two other new water-power developments, the Chenaux station and the Otto Holden station, both on the Ottawa. The former, of which the last sets went into service in September, 1951, has a total capacity of 120,000 kW and cost about 237 dols. per kilowatt. The Otto Holden station, placed in service in 1952, has a capacity of 204,000 kW and cost 267 dols. per kilowatt. Work in connection with the relatively-expensive Adam Beck No. 2 station has included the driving of a tunnel five miles long and the excavation of an open channel two miles long.

It is stated in the chairman's introduction that the sources of energy from which the Commission can supply power at low cost are to be found on the Niagara and St. Lawrence Rivers. The 525,000-kW Adam Beck No. 2 station is an example of the utilisation of a site on the Niagara River, and it may be assumed that the most favourable site will be first utilised, so that future projects will be more expensive. The Ottawa River, which forms part of the boundary between Ontario and Quebec, would seem to be the natural river on which to seek sites for development as it lies not far from the most highly-developed part of the Province. In 1945, when the Commission started its development programme, it had one station, at Chats Falls on that river; the station was owned jointly with the Ottawa Valley Power Company. Now it constitutes the main source of power, but it is stated in the body of the report that the construction of the Otto Holden station will virtually complete the Commission's development programme on the Ottawa, and it is added that the rapidity with which output from stations on the river has been used emphasises "the urgent necessity of developing power from the St. Lawrence."

At the end of December, 1951, the combined dependable peak capacity of all sources of power was 2,941,750 kW; this was 211,450 kW greater than in December, 1950, an increase of 7·7 per cent. The Commission's generating stations produced a total of 14,025,616,458 kWh, and 4,785,835,598 kWh were purchased, giving a total supply of 18,811,452,056 kWh. This figure exceeded that of 1950 by 18·5 per cent. The Commission supplies power in bulk to municipalities, which, in turn, supply industrial customers, but 203 industrial users are supplied directly by the Commission. The extent of this service is shown by the fact that the combined monthly average peak load of these industrial consumers was 939,263·5 kW. A list given of industries and their consumptions shows "Steel and Electro-Metallurgical" as the heaviest class of consumer, from the point of view of peak load, but "Pulp and Paper" took the largest number of kilowatt-hours, indicating that it provided a better load factor. Third place, both in peak load and consumption, is occupied by "Chemical, Electro-Chemical (including Cyanamid)." The list includes mining, abrasives, milling, general manufacturing and other activities, which covers all the major industries of the Province.

* *Forty-Fourth Annual Report of the Hydro-Electric Power Commission of Ontario* 1951. Head Office, 620, University Avenue, Toronto, Ontario, Canada.

NOTES.

THE INSTITUTION OF MECHANICAL ENGINEERS.

THE old problem of effective liaison between the drawing office and the shops was at the root of Captain G. C. Adams's paper to the Institution of Mechanical Engineers, on Friday, January 2. He considered with great thoroughness and from first principles the maze of factors governing interchangeability and the specification of manufacturing limits of size, as influenced by statistical considerations. Describing his philosophy of design, or attitude of mind, which would indicate what principles to adopt in given circumstances, he said that the starting point was for the designer to tell the truth to the best of his ability. He should tell it in the simplest and clearest way possible, so that the reader of his drawing might realise his aims and needs with the least effort and delay. If he did not know what he really wanted and could not find out, he should make an honest guess and not be afraid to change his mind with experience. If the designer was to play fair, he must not pretend to want more than he needed. It did not follow that the producer, or inspector, would wish to take advantage of all the relaxations which the design permitted. In the discussion which followed the paper, Mr. F. H. Rolt, O.B.E., dealt with some gauging problems, and remarked that sometimes at the National Physical Laboratory, when they were asked to give a certificate for a gauge, they passed it even if it was slightly outside the limits, provided that they found, on examination, that the uncertainty of their measuring tools covered the amount by which the measured size exceeded the certifiable limit. That was being fair to the manufacturer, but not to the user, since the real size of the gauge might equally well be beyond the size they had already noted. He thought they might have been too considerate to the manufacturers and unfair to the users. Dr. W. Abbott, C.M.G., commented on the application of the theory of probability and the effect of the shape of the distribution curve. Mr. H. G. Conway welcomed Captain Adams's invention of the factor R—the minimum clearance divided by the sum of the tolerances on the two mating parts—which was a useful idea. He also rebutted the author's criticisms of the International Standards Association's tolerance system—a British version of which, adapted to inch units, is to be published by the British Standards Institution. He hoped no one would take Captain Adams too seriously when he suggested that, in the I.S.A. system, a lot of extra allowances or fits would have to be introduced. Mr. J. Loxham said there was a need for a general tightening up of inspection standards in this and other countries, because too many firms made a practice of accepting components which were outside the limits specified on the drawing.

STRUCTURAL DESIGN CALCULATIONS IN PRACTICE.

The Council of the Institution of Civil Engineers, on the recommendation of the Board of the Structural and Building Division of the Institution, are proposing to hold a conference entitled "Correlation of Stresses and Displacements with Calculations and/or Laboratory Experiments." The object of the conference will be to discuss the degree of reliance that can be placed on the designer's approach to the calculation of critical stresses and displacements, so that improvements can be made in design methods, especially in respect of achieving more economic use of materials. In order to implement their decision the Council have appointed a steering committee consisting of Professor A. J. S. Pippard, chairman, Dr. Norman Davey, Dr. Guthlac Wilson and Professor J. F. Baker. At a preliminary meeting the committee decided that it would be unwise to hold such a conference before September, 1955, and that two or three days should be allotted to discussion, which would be confined to the consideration of civil engineering structures and their foundations. In announcing the conference in the January issue of the *Chartered Civil Engineer*, the Institution point out that the collection of data in respect of settlements and of earth pressures, etc., need not be restricted to official research organisations such as the Building Research Station, but that there is ample opportunity for individual research of the utmost value. It is important, however, that any scheme for site measurement should be well planned and that the main object of the conference—the correlation of measurements made on full-scale structures with design calculations or laboratory tests—should be borne in mind, and the committee are willing to advise on the suitability of any work that is proposed. The committee hope that members of the Institution who are willing to assist the objects of the conference will communicate with them, indicating the scope of their possible contribution.

SALARIES OF MEMBERS OF PUBLIC BOARDS.

An interesting feature of Britain's nationalised industries is that no salaries are drawn by some members of the Boards controlling them. Fourteen of these officials, most of whom, however, give only part-time service, are holders of unpaid posts, although other part-time members of the same Boards receive 500*l*. a year each. Two other part-time officials, members of the British European Airways Corporation, voluntarily decline to draw the salaries, 1,500*l*. and 500*l*., respectively, which their positions carry. Moreover, according to a Treasury report entitled *Public Boards* (Cmd. 8725, H.M. Stationery Office, price 9*d*. net), most of those referred to have given their services in this way for several years. The chairman of the North of Scotland Hydro-Electric Board, Mr. Thomas Johnston, LL.D., who is also a member of the British Electricity Authority, takes no renumeration from either appointment. On the other hand, the renumeration and allowances paid to members of nationalised Boards amount to considerable sums in many instances. The chairmen of twelve Area Boards under the B.E.A. receive 4,000*l*. a year each and the chairmen of two other Area Boards are paid even higher salaries, equivalent to those they earned as officials of the private undertakings which have been nationalised. The highest paid is Lord Citrine, K.B.E., chairman of the British Electricity Authority, and a former trade-union leader, who was for 20 years secretary of the Trades Union Congress. He receives 8,500*l*. a year. Lord Hurcomb, G.C.B., chairman of the British Transport Commission, is entitled to a like salary, but draws only 7,000*l*. Sir Miles Thomas, M.I.Mech.E., chairman of the British Overseas Airways Corporation, Sir Hubert Houldsworth, Q.C., chairman of the National Coal Board, and Sir John Green, chairman of the Iron and Steel Corporation, each receive 7,500*l*. a year. Mr. John Elliot, chairman of the Railway Executive is paid 7,000*l*. a year, and Colonel H. C. Smith, C.B.E., M.I.C.E., chairman of the Gas Council, 6,000*l*. a year. Several officials receive 5,000*l*. each. It is pointed out that only Sir John Stephenson, Sir John Green and Mr. A. R. McBain were members of more than one Board in 1952, compared with eight holders of duplicated posts of the same kind in 1951. Expense allowances mentioned in the report, which are additional to salaries, are exclusive of any arrangements made by the Boards to provide cars and chauffeurs for use on official business. "It is understood," the Treasury states, that 35 members are provided with a car and driver, eight with a car, and five with a driver.

OBITUARY.

PROFESSOR A. H. JAMESON.

WE regret to record the death of Professor A. H. Jameson, which occurred at Worthing on Tuesday, December 23, 1952, at the age of 78. In his early days he was engaged on a number of important civil engineering works and later was well known as an active participant on the educational side of the profession.

Alexander Hope Jameson was born in London on October 15, 1874, and, after being educated privately, at the age of seventeen entered Owens College, Manchester, as an engineering student. Here he took a three-years' course and was then appointed Bishop Berkeley Fellow and Demonstrator in the Whitworth Engineering Laboratory. This position he held for three years until he became a pupil with the Lancashire and Yorkshire Railway in 1897. In 1900, after a short period in the service of Messrs. Blake Smith and Company, hydraulic engineers, Manchester, he returned to the Lancashire and Yorkshire Railway as assistant to Mr. W. C. Hall, who was then resident engineer at Halifax. Later, he held a similar position under Mr. R. H. Clay, resident engineer at Wakefield, being engaged on a number of widening works and station improvements.

In 1901, Jameson joined the staff of the Derwent Valley Water Board as assistant to Mr. Edward Sandeman and for the next four years was engaged in surveying and setting out 30 miles of main aqueduct and on work both in the office and in the field in connection with the Derwent dam, Bamford filters and Ambergate service reservoir. In 1905 he became resident engineer to the Board for the construction of part of the main aqueduct between Grindleford and Rowsley, and from 1909 to 1912 held a similar position in connection with the construction of the Thirlmere aqueduct at a time when the third pipe-line was being installed.

In 1912 he was appointed Professor of Civil Engineering in the University of London, and occupied the chair in this subject at King's College, Strand. For the rest of his active life he was engaged in this position, during which period he published a number of papers on problems connected with the design and construction of weirs, aqueducts and reservoirs. He was also the author of a number of textbooks: *Contour Geometry*, *Advanced Surveying*, *Fluid Mechanics* and *Mathematical Geography*. In 1932, he became Dean of the Engineering Faculty of London University and retired with the title of Emeritus Professor in 1935.

Professor Jameson was elected an associate member of the Institution of Civil Engineers in 1901 and was transferred to the class of members in 1912.

MR. S. H. BUSCH.

WE also regret to record the death of Mr. S. H. Busch, which occurred at the age of 69, on Friday, January 2, 1953.

Sune Hjalmar Busch was born in Sweden on June 18, 1883, and was educated at the Hogra Reallaroverket in Stockholm and at the Chalmers Engineering University, Gothenburg, where he studied electrical engineering. In 1904, he obtained a position as engineer in the Power Department of Allmänna Svenska Elektriska A.B., at their headquarters in Västerås, where he was engaged on estimating work. Two years later he became manager of the Jonkopning branch of the firm, where he was responsible for carrying out contracts in connection with the erection of a power house, the construction of tramways and the establishment of a supply of electricity in the district. In 1909, he returned to Västerås, where he was engaged in the export department on the preparation of estimates; and this led, in 1910, to his appointment as manager of Asea Electric, Limited, in London. He remained with this concern until his retirement in 1947, having held the positions of managing director and chairman.

During his long association with Asea Electric, Limited, Mr. Busch had travelled extensively, especially in connection with the preparation and negotiation of large contracts for the supply of electric power in different parts of the world. Among the schemes for which his firm were wholly or in part responsible, mention may be made of the electrification of sections of the Southern Railway (now Southern Region, British Railways), and of the factories of the South African Iron and Steel Corporation and the Bengal Steel Corporation. He had also been engaged on the construction of the Ganges and Perak hydro-electric scheme, and on the Arapuni hydro-electric scheme in New Zealand, as well as on the erection of a 100-MW station for the Vaal Power Company in South Africa.

Mr. Busch was elected an associate member of the Institution of Electrical Engineers in 1910 and was transferred to the class of members in 1943.

LETTERS TO THE EDITOR.

LABORATORY REPRODUCTION OF THE FIELD DENSITY OF SAND.

TO THE EDITOR OF ENGINEERING.

SIR,—Dr. J. Kolbuszewski, in his letter in ENGINEERING of November 28, 1952, on page 700, criticised a statement concerning the limitations in the laboratory reproduction of the field density of sand which I made on page 58 of my book, *Soil Mechanics, Foundations and Earth Structures*, which you reviewed in that same issue, on page 684.

May I reply that the above letter discussed a sentence from my book out of context and therefore did not convey its point to your readers? The sentence quoted, and objected to, was: "The determination of both $e_{max.}$ and $e_{min.}$ can be made in a laboratory, but the reproduction of *e*, that is, of the actual natural state of a deposit, is not possible in the laboratory." Dr. Kolbuszewski thereupon described the results of his laboratory research on the factors controlling the deposition of sands, which permits the laboratory reproduction of any field density, once the actual porosity *n* of the field deposit is known. However, he offered no explanation of how this field value of *n* (and, therefore, of *e*) could be reliably established. This question, however, was the main point of the sentence to which he objected, which was immediately followed, in the same paragraph on page 58 of my book, by statements to that effect: "The determination of *e* in the field is difficult because of the difficulty of extraction of really undisturbed samples of sand. It requires great care and is possible only for the upper layers which are accessible by open excavation. No fully reliable methods have been devised so far for the really undisturbed extraction of sand samples from below the water level or from boreholes (Art. 12-6)." Some uncertainties involved in sampling sands, especially loose ones, from boreholes even by the most up-to-date methods—such as that of A. W. Bishop—were further emphasised in Art. 12-7 on page 348 of my book. On the other hand, the possibility of obtaining in the laboratory various desired densities of sands was also indicated; for instance, by Fig. 18-8 on page 579. These page numbers were all given in the subject index.

I do not question the importance for laboratory techniques of Dr. Kolbuszewski's very interesting recent research. It should receive careful and sympathetic consideration by any organisation attempting the standardisation of relative density determinations in the laboratory. Field methods for the fully accurate and reliable estimations of actual relative densities of all sand deposits will also undoubtedly be developed with time; but it is my belief that the further healthy development of soil mechanics and of its practical applications is predicted on a clear realisation by everyone concerned of the present—even if temporary and only partial—limitations in our knowledge and techniques.

Yours faithfully,
GREGORY P. TSCHEBOTARIOFF,
Dr. Ing., Professor of Civil Engineering.
Princeton University,
Princeton, New Jersey, U.S.A.
December 29, 1952.

DU PONT: THE AUTOBIOGRAPHY OF AN AMERICAN ENTERPRISE.

TO THE EDITOR OF ENGINEERING.

SIR,—We thank you for the review of the Du Pont book, on page 808 in your issue of December 19, 1952, but note that you state "[No price indicated]." We should like to inform your readers, however, that copies are available in this country, either directly from this house or through booksellers, at 36s. per copy.

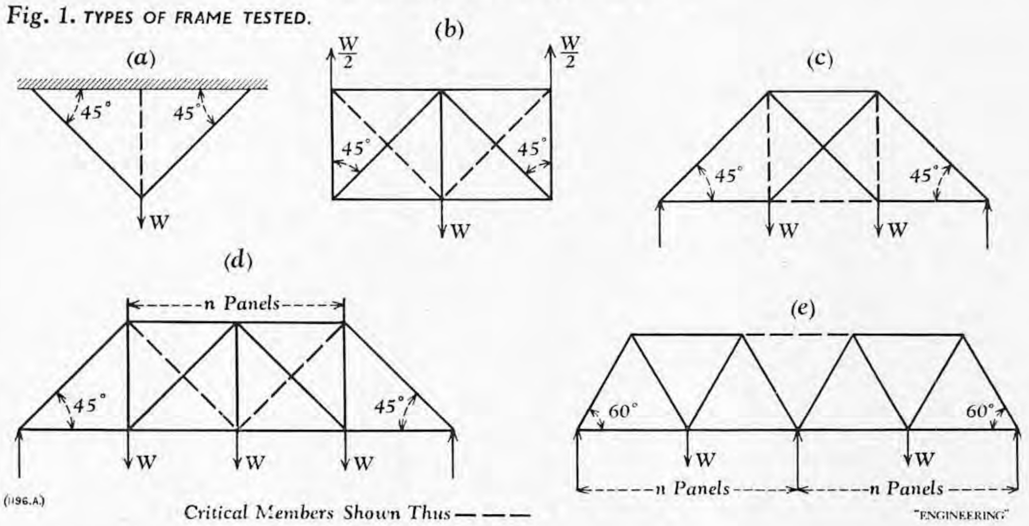
Yours truly,
SCRIBNERS.

23, Bedford-square,
London, W.C.1.
December 24, 1952.

TESTS ON SMALL TRIANGULATED STEEL FRAMES.

(For Description, see Opposite Page.)

Fig. 1. TYPES OF FRAME TESTED.



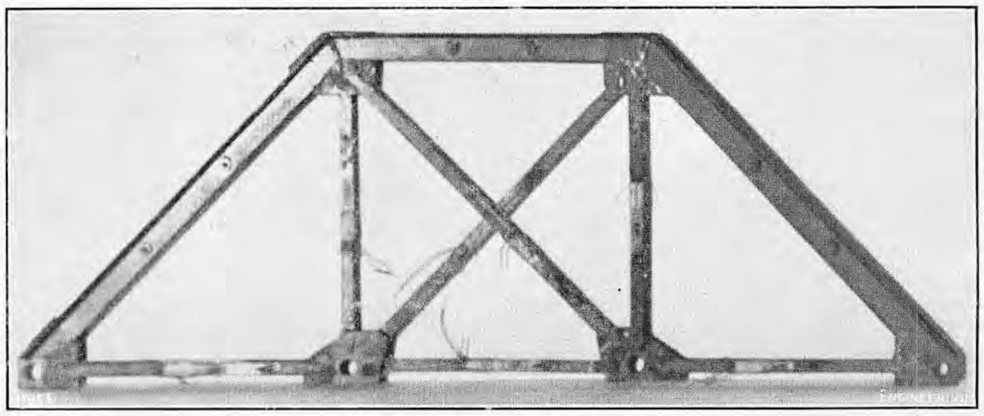


FIG. 2. WELDED FRAME No. 6 TYPE (*c*).

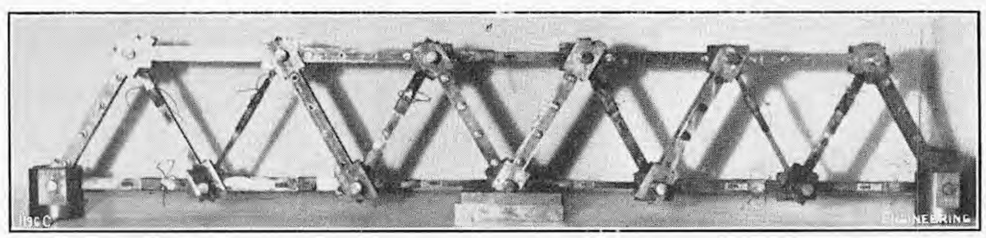


FIG. 3. PIN-JOINTED FRAME No. 13 TYPE (*e*).

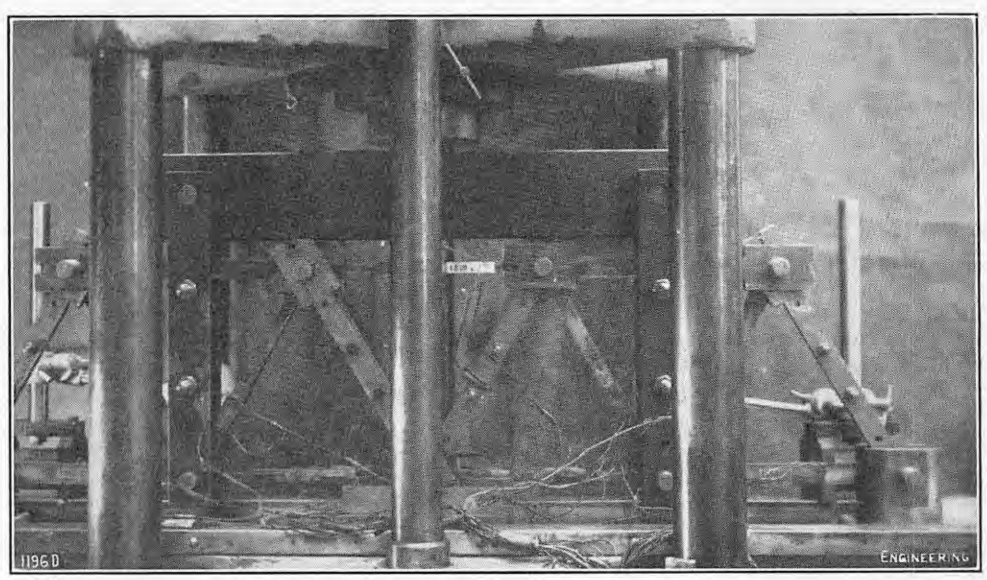


FIG. 4. PIN-JOINTED FRAME No. 11 TYPE (*e*) IN TESTING MACHINE.

BRITISH ELECTRICITY AUTHORITY AND PRIVATE GENERATING PLANT.—As a result of a recommendation of the Ridley Committee that restrictions on the use and installation of private generating plant should be abandoned, it is announced by the British Electricity Authority that Area Boards will be prepared to enter into new contracts in cases where a consumer desires to use such plant and such use would contravene the provisions of his existing agreement. While the new contract will reflect the costs of connecting and supplying the consumer, it will leave him free to use his private plant.

TESTS ON SMALL TRIANGULATED STEEL FRAMES.

Fig. 5. DEFLECTION CURVES FOR FRAME No. 9.

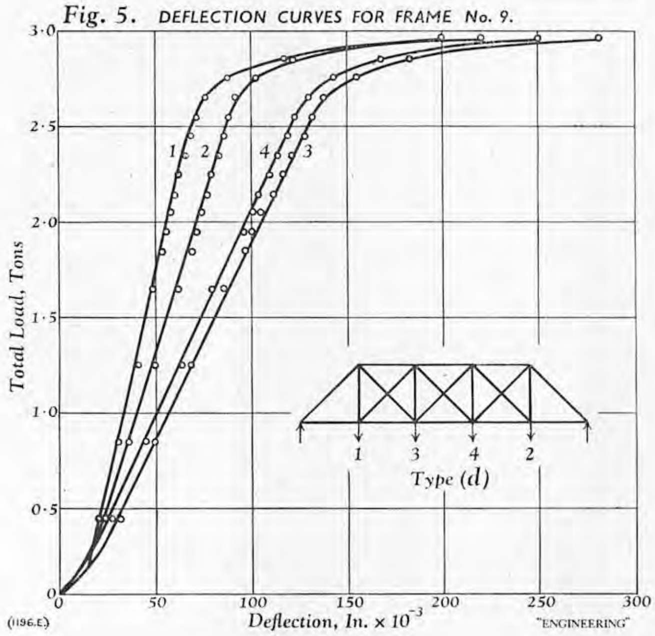
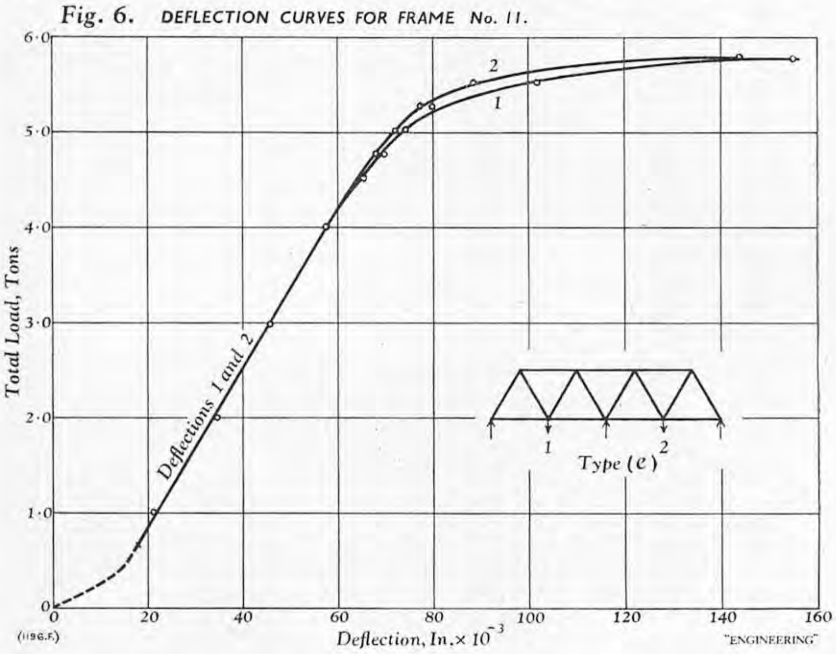


Fig. 6. DEFLECTION CURVES FOR FRAME No. 11.



TESTS ON SMALL TRIANGULATED STEEL FRAMES.

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

MUCH of the research that has been carried out on the plastic theory for steel structures has been on rigid-jointed building frames of the portal type, and for this type of structure many published results of experimental tests are already available. The writer, however, has been unable to discover any published results of experimental work on triangulated frames and it was decided, therefore, to carry out a series of tests on models of such frames under static loading. The results of these tests are presented here.

The types of frame considered are shown in Fig. 1, opposite. All the models were constructed of mild steel having a yield stress of 15 tons per square inch, and all, except one which was of welded construction, were pin-jointed in order to avoid secondary moments that would otherwise make comparison between theoretical and experimental results difficult. In order to ensure that there was no significant initial lack of fit in the models, jigs were made so that the fabrication of the individual members could be controlled within close limits. Each individual member was symmetrical about its longitudinal axis. Pins of $\frac{5}{8}$ in. diameter were used to join the members together, the theoretical lengths of the members between the points of intersection being either 8 in. or $\sqrt{2} \times 8$ in. The frames were symmetrical about a longitudinal vertical plane and this required a majority of the members to be double members. Frames Nos. 6 and 13—the former a welded frame—are illustrated in Figs. 2 and 3, respectively.

The structures tested were designed so that under the collapse loads all tension members had reached their capacity loads. It can be shown that, for such designs, the critical members for each type of structure considered, i.e., those members which yield before the collapse loads are attained with the given load systems, are those shown by the " broken " bars in Fig. 1. For type (c), the vertical tension members were made slightly above their theoretical cross-sectional areas so that only the horizontal tension member yielded before the collapse loads were attained.

In all the frames tested, care was taken to see that there was no fear of compression members buckling (due to unavoidable slight eccentricities), from either elastic or elasto-plastic failure, before the collapse loads for the structure were reached. Little is known of the relation between the decrease of overall length and the load carried by a compression member which has buckled, but the writer is at the present time conducting some research into this relationship for compression members and also into the behaviour of buckled members in triangulated structures under load.

Electrical resistance strain gauges were used in conjunction with Wheatstone bridge to measure the strains in the members of the frames, which were loaded in an Avery testing machine. Frame No. 11, in the testing machine and ready for loading, is shown in Fig. 4, opposite. For each frame the loads were applied incrementally and simultaneously at each loading point up to the collapse load. A table of results is given below. The " collapse load," in column No. 5, is that load at which excessive deformations of the structure were observed; the final column, No. 7, represents the value of the following relationship :—

$$100 \times \frac{\text{(theoretical collapse load)} - \text{(theoretical yield load)}}{\text{theoretical yield load}}.$$

The close agreement between the theoretical and experimental results will be noted. The load-deflection graphs for the frames were all of the same general shape and typical graphs for frames Nos. 9 and 11 are shown in Figs. 5 and 6, above.

The conventional assumption made for a statically indeterminate structure is that such a structure reaches its limit of usefulness when plastic yield occurs in any fibre at any point in the structure. It is clear, however, from a consideration of the results given above and from the typical load-deflection graphs shown that a triangulated indeterminate structure reaches its true limit of usefulness when excessive deformations of the structure develop. The large discrepancy between the conventionally assumed limit and the true limit of usefulness for any frame is shown by reference to column No. 7.

In the plastic theory of structures, maximum permissible working loads are based on the collapse loads and are obtained by using a suitable load factor. In the elastic theory of structures, working loads are obtained by using a maximum allowable stress based on the yield stress of the steel used. It would appear from these tests that for triangulated structures loaded as shown, higher maximum permissible working loads will be obtained by using the plastic rather than the elastic theory.

The above results were obtained as part of a general investigation into triangulated steel structures, carried out at King's College, London, aided by a grant from the Research Fund of the University of London.

Frame No.	Type of Frame (see Fig. 1).	Load at which first Yield of a Member Occurred. Load at Each Loading Point. Tons.		Collapse Load. Load at Each Loading Point. Tons.		Available Capacity Above Theoretical Yield, Per cent.
		Experimental.	Theoretical.	Experimental.	Theoretical.	
(1)	(2)	(3)	(4)	(5)	(6)	(7)
1	a	1·60	1·62	2·00	1·90	17·3
2	a	0·80	0·82	1·20	1·18	43·9
3	b	2·16	2·12	2·64	2·62	23·6
4	b	0·86	0·88	1·12	1·14	29·6
5	c	1·50	1·56	2·00	1·84	17·9
6*	c	2·90	2·84	3·20	3·24	14·1
7	d (n = 2)	2·30	2·34	3·20	3·06	30·7
8	d (n = 3)	1·70	1·76	2·40	2·48	40·9
9	d (n = 3)	1·90	1·98	2·90	2·80	41·4
10	e (n = 2)	1·90	1·96	3·20	3·12	59·2
11	e (n = 2)	4·00	4·24	5·75	5·52	30·3
12	e (n = 3)	3·66	3·84	5·50	5·76	48·6
13	e (n = 3)	5·20	4·88	7·40	7·36	50·9

* Frame 6 was of welded construction.

BRITISH ASSOCIATION.—This year's meeting of the British Association for the Advancement of Science will be held in Liverpool from Wednesday, September 2, to Wednesday, September 9, inclusive. Invitations to attend will be sent to about a thousand sixth-form students in schools in the Liverpool area and the Association's President, Sir Edward Appleton, F.R.S., has announced his intention of delivering a special presidential address to this juvenile audience.

THE HONOURS LIST.

The New Year Honours List, which was published on January 1, includes the names of engineers and others connected with technical and scientific work and with industry. A first list of names appeared on page 18, *ante*.

Order of the Bath.

C.B.—Mr. J. Buckingham, Royal Naval Scientific Service; Dr. W. H. Glanville, C.B.E., M.I.C.E., director, Road Research Laboratory; Rear-Admiral (E) F. T. Mason, shortly to be Engineer-in-Chief of the Fleet; Mr. R. Spence, chief chemist, Atomic Energy Research Establishment, Harwell; and Major-General H. Williams, C.B.E., R.E., Engineer-in-Chief, Indian Army.

Order of Saint Michael and Saint George.

C.M.G.—Mr. R. W. Foxlee, C.B.E., M.I.C.E., engineer-in-chief, Crown Agents for the Colonies.

Order of the British Empire.

C.B.E.—Mr. O. N. Arup, architectural engineer; Brigadier R. E. Bagnall-Wild, O.B.E., late R.E.; Mr. E. E. H. Bate, M.B.E., M.C., chief works engineer, Ministry of Works; Rear Admiral (E) F. S. Billings; Mr. F. J. Bywater, M.C., chairman, Council for Codes of Practice for Buildings, Construction and Engineering Services; Mr. H. F. Carpenter, secretary, British Electricity Authority; Mr. W. Cawood, deputy director, Royal Aircraft Establishment; Mr. H. A. Cruse, director and general works manager, Westinghouse Brake and Signal Co. Ltd.; Mr. B. W. A. Dickson, lately director and general manager, Vickers-Armstrongs Ltd. (Aircraft Section); Mr. F. P. Egerton, M.I.E.E., Central Electricity Board, Malaya; Mr. L. V. Keitley-Duff, lately general manager, Antofagasta-Bolivia Railway; Mr. H. J. Poole, chief superintendent, Armament Research Establishment; Mr. J. A. Smale, A.F.C., B.Sc., M.I.E.E., engineer-in-chief, Cable and Wireless Ltd.; Mr. C. A. P. Southwell, M.C., managing director, Kuwait Oil Co. Ltd.; Mr. F. V. Spark, director, Harland and Wolff Ltd.; Mr. A. H. Topham, joint managing director, Mawdsley's Ltd.; Mr. A. Turnbull, M.B.E., vice-chairman of Governors, Royal Technical College; Mr. C. J. Turner, M.Sc., A.M.I. Mech.E., chief engineer, Division of Atomic Energy (Production), Risley; Mr. L. C. Tyte, deputy chief scientific officer, Fort Halstead; Mr. S. A. H. Whetmore, Imperial Chemical Industries Ltd., Billingham; Captain (L) R. C. Wield, R.N.; Mr. J. Williamson, M.I.C.E., James Williamson and Partners, Glasgow; and Brigadier J. C. T. Willis, O.B.E., late R.E.

O.B.E.—Mr. W. D. Arnot, Public Works Department, Kenya; Mr. R. L. Batley, Merseyside and North Wales Division British Electricity Authority; Mr. J. H. Brookes, J.P., Principal, College of Technology, Oxford; Mr. J. S. Carter, deputy chief alkali inspector; Mr. B. Curran, director, Edward Curran Engineering Co., Ltd.; Mr. J. A. Cuthbertson, managing director, J. A. Cuthbertson Ltd.; Mr. H. G. Davis, B.Sc. (Eng.), M.I.E.E., chief regional engineer, General Post Office; Dr. J. W. Drinkwater, Wh.Sc., A.M.I.Mech.E., assistant director of engine research, Ministry of Supply; Mr. N. F. Duke, D.S.O., D.F.C., A.F.C., chief test pilot, Hawker Aircraft Ltd.; Mr. L. J. Dunn, director of irrigation, Sudan Government; Mr. J. O. M. Fisher, general manager, Humber Graving Dock and Engineering Co. Ltd.; Comdr. (E) P. K. L. Fry, R.N.; Mr. O. W. Godwin, principal, Atomic Energy Division, Ministry of Supply; Mr. A. Griffiths, production director, F. Perkins Ltd.; Mr. C. W. Grindell, director, Burt, Boulton and Haywood Ltd.; Mr. W. K. Hall, works general manager, Imperial Chemical Industries Ltd., Billingham; Mr. G. L. Hopkin, senior principal scientific officer, Ministry of Supply; Mr. H. Johnston, A.M.I.Mech.E., chief engineer, North Eastern Gas Board; Mr. J. E. Jones, T.D., B.Sc., A.M.I.C.E., senior engineer, Ministry of Transport; Mr. J. L. King, M.I.E.E., resident engineer, London, Electricity Corporation of Nigeria; Mr. N. R. McCurdy, director, Royal Afred Observatory, Mauritius; Mr. A. D. MacKellar, divisional organiser, Association of Engineering and Shipbuilding Draughtsmen; Mr. J. Maddock, principal scientific officer, Ministry of Supply; Mr. E. H. Mott, senior principal scientific officer, Ministry of Supply; Mr. A. C. Nicholson, for services to the development of agricultural machinery; Professor S. J. Palmer, professor of naval architecture, Royal Naval College, Greenwich; and Mr. R. V. W. Stock, M.C., B.Sc. (Eng.), M.I.C.E., chief engineer, Thames Conservancy.

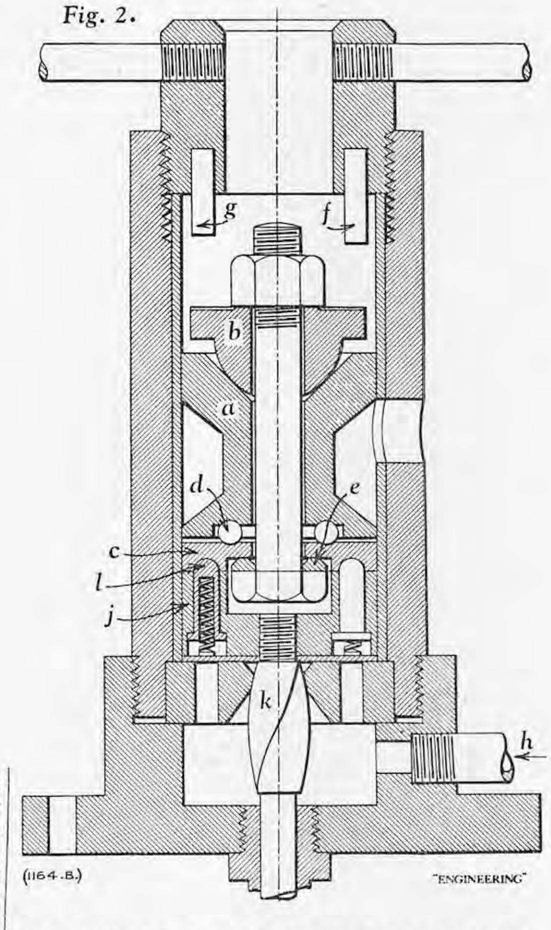
M.B.E.—Mr. A. G. Booth, M.I.Mech.E., chief technical engineer, Humber Ltd.; Mr. J. F. Booth, managing director, Hepworth Iron Co. Ltd.; Mr. I. F. Fisher, works manager, British Timken Ltd.; Mr. F. Fletcher, manager, special technical productions, General Electric Co. Ltd.; Mr. G. V. Griffiths, Borough Engineer and Surveyor, Port Talbot; Mr. T. Guthrie, technical manager, Swan, Hunter, and Wigham Richardson Ltd.; Mr. A. S. Helms, lately generation engineer, British Electricity Authority; Mr. F. Herdman, engineer manager, Gun-Mounting Department, Vickers-Armstrongs Ltd.; Mr. H. S. Jones, chief engineer, Round Oak Steel Works, Ltd.; Mr. L. A. Jouning, works manager, Aron Electricity Meter Ltd.; Lieut. (E) T. E. Meopham, R.N. (ret.); Lieut. (L) H. A. Minns, R.N.; Mr. B. L. Newbould, manager, steel-melting department, Thos. Firth and John Brown Ltd.; Mr. J. H. Polson, moulding-shop superintendent, David Brown Foundries Co.; Mr. E. Salthouse, chief draughtsman, Harland and Wolff, Ltd.; Mr. E. Saunders, lately works manager, Imperial Chemical Industries, Ltd., Silvertown; Lieut.-Cmdr. (E) R. S. H. Silburn, R.N. (ret.); Mr. C. J. Watts, chief draughtsman, Camper and Nicholsons Ltd.; Mr. F. J. Whittaker, overseer, Warship Production Department, Northern Ireland; Mr. D. R. Williams, J.P., senior partner, William Brothers, Swansea; and Mr. T. S. Wood, A.M.I.E.E., chief draughtsman, electricity department, John Brown & Co. Ltd., Clydebank.

Shipbuilding Progress at Walker-on-Tyne.—At the launch of the 20,000-tons deadweight oil tanker Saxonglen from the Walker-on-Tyne shipyard of Vickers-Armstrongs Ltd., it was stated that the firm's 1952 output of 76,000 gross tons was a record. It was hoped, by 1955, to reach an output of 100,000 tons annually. Mr. G. H. Houlden, general manager, stated that this output would depend upon adequate supplies of steel. If Vickers-Armstrongs attain their output of 100,000 tons annually it will represent an increase of almost 100 per cent. on their average output for the past few years. In 1951, the yard launched 67,000 tons; in 1950, 55,000 tons; in 1949, 57,000 tons; and in 1948, 36,000 tons.

TESTING NUTS AND BOLTS.

Fig. 1. Machine for Vibration Testing of Nuts and Bolts.

Fig. 2.



TESTING NUTS AND BOLTS FOR RESISTANCE TO VIBRATION.

A machine for determining the comparative lives of different types of nuts and bolts when tightened up and subjected to vibration has been developed by the Lester Lock Nut and Washer Company, Limited, Camp Hill Works, Wordsley, Staffordshire. It applies repeated shock loads to the underside of the nut, the point of application of the load moving round the nut with each application. A conventional nut and bolt fixed in the machine and tightened in the normal way gradually work loose under test; they are then retightened and tested again. This gradual loosening, followed by retightening, may occur several times before ultimate failure takes place, though, of course, complete loosening of the nut on its seat would be regarded, in many uses of nuts and bolts, as tantamount to ultimate failure. In other uses—on railway track fishplates, for example—periodical retightening by maintenance staff is acceptable; in these cases, ultimate failure may be due to fracture of the bolt, stripping of the threads, fracture of a cotter, etc. With the Lester vibrator machine the life of a nut and bolt—up to, say, the first complete loosening—is measured in terms of the number of applied shocks. It can also be measured directly in time (minutes and seconds), provided the machine is run at the standard rate of 712 shocks per minute. Typical results from the machine will be given in an article on the new Lester anti-vibration nut, to be published shortly in Engineering. The following description of the design and use of the machine is based on information supplied by the firm.

The vibrator machine, together with the piston unit which forms an inner reciprocating member, is shown in Fig. 1, and a section through the complete machine is given in Fig. 2. The piston unit, through which the bolt is passed, consists of the piston itself, *a*, a rocker head *b*, a ring *c*, a ball thrust bearing *d*, and a hardened washer *e*. The unit is free to slide vertically in the cylinder, at the top of which is a head, screwed in and provided with a striking pin *f* and a check pin *g* (slightly shorter than *f*). Thus,

AIRCRAFT-STRUCTURE TESTING EQUIPMENT.

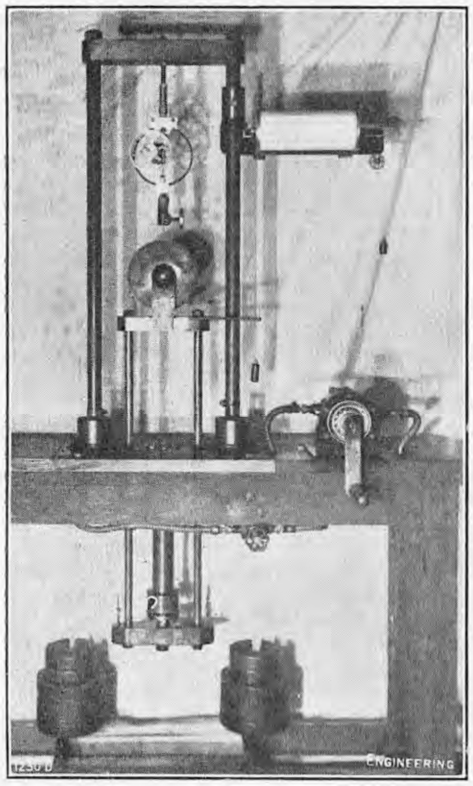


FIG. 4. APPARATUS FOR MEASURING "PEELING" STRENGTH.

when the piston unit reciprocates, the rocker head is tilted by the striking pin repeatedly. At each blow the thrust between the underside of the nut and the top of the rocker head is reduced near the point of application and increased at a point diametrically opposite. The check pin g controls the tilt of the rocker head when the nut becomes loose. An air compressor from which the outlet valve has been removed is connected to the cylinder at h. Thus when the compressor is running, there is no substantial flow of air (since the outlet valve has been removed), but there are pulsations of pressure which act on the piston, alternately forcing it up under pressure and drawing it down by suction.

Between the piston unit and the air connection there is a secondary piston j, which has a twisted square shank k and four spring-loaded pins l, the latter engaging in recesses in the ring c. When the main piston returns to the bottom of its stroke, the secondary piston gives it a small rotational movement, the movement amounting to 20 r.p.m., i.e., at 712 shocks per minute there are about 35 shocks during each revolution of the main piston. The hardened washer e has a prescribed friction area, so as to eliminate variations in torque (as shown on a torque-measuring spanner) due to fortuitous variations in the bolt-head contact surface. Similarly, the rocker head b is machined with an inner ring face on which the nut is seated, and the ball thrust bearing also provides a connection of constant torsional friction.

The construction of the vibrator machine facilitates measurements, etc., in connection with tests of nuts and bolts. Thus, with the piston unit removed from the cylinder, the overall length of the bolt is readily measured by a micrometer; and this can be done before and after the bolt is stressed due to tightening of the nut, as well as at any stage during and after the test. If the head of the bolt to be tested is held in a vice and the ring c locked to the piston a, the nut can then be tightened in the normal way. With a conventional nut the friction to be overcome in tightening it arises on the mating faces of the nut and the rocker head, and on the loaded side of the thread, but with the Lester lock nut to be described in the other article both sides of the thread are loaded and therefore both cause friction. If the ring c is not locked to the piston a, there

Fig. 5.

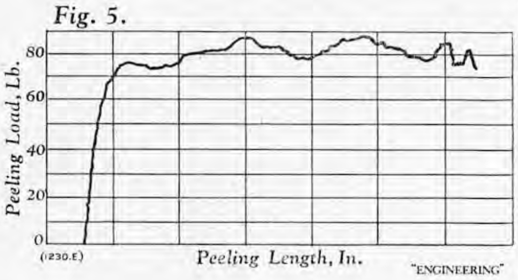


FIG. 6. AUTOMATIC RECORDER FOR STRAIN GAUGES.

is no relative movement between the nut and the rocker head when the nut is tightened, since the ball thrust bearing comes into use. This procedure for measuring tightening torque is adopted in all tests, and it provides, in conjunction with a torque-measuring spanner, a more accurate indication of the locking torque due to the friction of the threads.

Any relative movement between the nut and the bolt during a test is readily observed by suitably marking them before the test. After a test, when there is no tension in the bolt, the friction between the nut and the bolt, which would resist unscrewing, is determined by means of a torque wrench. With a Lester lock nut there would always be friction of this kind, but with a conventional nut there would not be any.

AIRCRAFT-STRUCTURE TESTING EQUIPMENT.

AN unusual type of aircraft-structure testing frame, which can be readily adapted to accommodate different full-scale wings, fuselages, and other air-frame components, has been designed and installed in the research and testing department of Short Brothers and Harland, Limited, Queen's Island, Belfast. A model of the frame set up for a full-span wing test is illustrated in Fig. 1, on page 48. The frame consists of a 300-ton grillage of welded 16-in. by 8in. rolled-steel joists, 200 ft. long by 90 ft. wide, resting on the reinforced-concrete floor of the test house. On the grillage can be clamped rigidly, at any desired station, portable loading frames and anchorages for the test specimen. The grillage can withstand a bending moment of 24,000 ton-inches. For tests on wings and similar components, six pairs of portable braced triangular pylons are employed, supporting gantries on which are mounted hydraulic loading jacks. Each pylon is provided with a ladder, a hydraulic pipe-line for supplying the loading jacks, and two floodlights which can be directed on to the upper and lower surfaces of the specimen during a test.

In order to keep the area around the test specimen as free as possible from electrical leads, a conduit system is contained in the grillage, with socket positions at several points distributed over the grillage area. Two hydraulic pipe-lines are also provided along the length of the grillage, with tapping points at intervals.

The pylons, each of which can carry a compression load of 20 tons, are constructed in sections, giving a choice of three pylon heights of approximately 10 ft., 19 ft. and 28 ft. The loading gantries, which consist of built-up cross-beams, 32 ft. long, can either span across the top of a pair of pylons, or between frames 4 ft. 6 in. below the top of the pylons. This gives the gantry a clear span of up to 28 ft. Each gantry can withstand a 30-ton load at any position along its length. To allow for the considerable deflection of a wing under load, long-travel tension jacks are employed. Six 25-ton jacks are available, two of which have travels of 6 ft. and 4 ft. There are, in addition, a number of smaller jacks. The loading linkages are arranged so that the pressure is the same in all the jacks, and is controlled from a portable panel connected to the end of one of the hydraulic pressure-supply lines in the grillage. Vertical deflections are recorded during the tests with surveyor's levels, using a piled structure as a backsight.

TESTS ON THE SA/4 BOMBER AEROPLANE.

The main structural tests on the SA/4 jet-propelled bomber aircraft, which flew for the first time in the late summer of 1951, were carried out on this test frame. For the full-span wing test, after the loading pylons and cross-beams had been set up, the two wings were placed in position on shop trolleys running in channel-section rails laid on the grillage. Each wing was then lifted by hoists from the overhead cross-beams. A portion of the centre-section fuselage, attached to steel end-frames, was then manœuvred between the wings and was clamped in position on the grillage. The entire specimen was then lifted by jacking under the end-frame. The method of attachment of the fuselage end-frames to the grillage was as follows: each vertical end-frame formed the base of a pyramid structure, the apex of which carried a universal trunnion fitting attached to a vertical pin-ended strut secured to the grillage. To resist drag loads, the front trunnion was also restrained in a fore-and-aft direction. After anchoring the wing specimen, dummy engine and undercarriage loading structures were secured in position. The overhead loading linkages, of the standard type commonly used in such tests, as illustrated in Fig. 1, were then assembled, and the tests were carried out—two "proof" tests under take-off and landing loads, and a test to destruction under flight loads. Fig. 3, on page 48, shows the underside of the wing.

In setting up the fuselage for test on the frame, it was first lifted by two mobile cranes on to a sledge resting on the grillage. The sledge was then traversed to the testing site, and dummy stub-"wings," which provided restraint, were jacked into position and secured to the fuselage root attachments. The specimen was then lifted from the sledge by jacks placed under the stub wings. Side frames, for supporting the specimen, were brought into position, as shown in Fig. 2, page 48, and were connected to the stub wings by pin-ended links, so that the fuselage centre section was constrained as it would be by the actual wings in flight.

The jacks were then removed, and the bomb doors, dummy nose-wheel undercarriage leg, tailplane and fin were attached to the fuselage. To support the tailplane and fin loads, which were applied by a single concentrated load at the tip of each, a large load-reaction rig was erected around the tail-unit supporting jacks on which the tailplane rested. The rig also carried pulleys over which balance weights were suspended to counterbalance the weight of the rear fuselage, dummy fin and tailplane. The first test carried out on the fuselage was a "proof" loading simulating landing loads, followed by a test to destruction under torsional loads arising from yawed flight.

Tests on the undercarriage bogie beam and the bomb doors were also carried out on the grillage; in the former case, part of the test apparatus was accommodated below floor level, and the grillage itself provided direct reaction. For testing the bomb doors, a single loading unit was constructed and secured to the grillage. The loading linkage was attached to the bomb-door specimen by sponge-rubber pads on the surface; with thin skin panels, this method of loading offers the minimum constraint to wrinkling.

OTHER TESTING MACHINES.

In addition to the structural test frame, Short Brothers and Harland, Limited, have assembled a comprehensive collection of structural and materials testing equipment. The 150-ton structure-testing machine constructed for the company by Messrs. W. and T. Avery, Limited, Birmingham, has already been described in ENGINEERING, on page 79 of the 165th volume (1948). It may be recalled that it comprises two separate hydraulically-operated vertical units controlled from a common panel—one for tensile tests on specimens up to 9 ft. 9 in. long, and the other for compression tests on structures up to 15 ft. long, or for applying a bending moment over a maximum span of 7 ft. This machine is used for determining the strength of reinforced skin panels and many types of load-carrying components and assemblies.

The machine illustrated in Fig. 4, on page 55, is for determining the "peeling" strength of metal-to-metal joints bonded with Redux synthetic resin. The test specimen, two metal strips 1 in. wide bonded together, is wrapped around a drum. One strip is attached to the drum, and one end of the other strip is anchored, through a steel ring, to the top of the machine. During the test, the carriage on which the drum is mounted is lowered by a hydraulic jack operated by a rotary hand pump, so that the drum centre is moved away from the anchorage, causing the drum to rotate and the specimen to peel. In transmitting the peeling load to the anchorage, the steel ring deforms slightly, and through a mechanism which magnifies the change of vertical diameter, it operates a pen recorder, the drum of which is rotated by the movement of the jack. Fig. 5, on page 55, shows the type of record obtained in this way.

STRAIN-GAUGE MEASUREMENTS.

In tests where only a small number of strain gauges are employed, strain measurements are carried out near the site of the test using standard Tinsley strain-measuring apparatus. For the large structural tests, however, all strains are recorded remotely in a laboratory some 50 yards away from the test rig. In a major test this may require some 30 miles of wire. It is broken down into 40-ft. lengths carrying enough wiring to deal with 30 or 50 gauges. The strain-gauge leads are attached to strip connectors which permit rapid assembly and dismantling. Communication between the two sites is by light signals and telephone.

Fig. 6, on page 55, shows the remote strain-gauge recording desk developed by the company, which records automatically at a rate of three gauges a second. A "deflection" system is used, working into a high-impedance load. The out-of-balance voltages generated are compared with known out-of-balance voltages from a calibrated network. The small signals, ranging from a few microvolts to a millivolt, developed in each of the direct-current Wheatstone bridges when one resistance arm (the strain gauge) is changed in value, are fed to standard Post Office selector switches, from which they are fed in sequence through a contact modulator to a highly-selective band-pass amplifier tuned to the contact-modulator frequency. Sense is given to the signals by a direct-current bias, eliminating the necessity for a phase-sensitive rectifier. The output is then recorded at the instant of a pulse generated in the chart-driving mechanism, which simultaneously advances the selector switch one segment. It is also possible to select any gauge and record it separately if desired.

With this arrangement, four test observers can make duplicate recordings of some 120 gauge sites, and can produce individual stress readings with a delay of little more than one increment behind the loading rate of the specimen. To ensure accuracy, calibration curves are inserted before each recording. Two known signals are also inserted between each ten gauges, which provide a ready means for identifying each recorded value, as well as a datum from which to measure strain. Permanent records, which cannot be erased, are produced on standard chart paper by a spark puncture.

LABOUR NOTES.

REDUNDANCY notices are to be given during the next few weeks to about one thousand employees at the Courthouse Green factory, Coventry, of the British Motor Corporation, according to an announcement made last Friday. The men concerned have been engaged on the production of 8-h.p. engines for the Morris Minor four-door export model motor cars. These cars are now being powered by the 800-c.c. engines used in the Austin seven models, and are constructed at the corporation's works at Longbridge, Birmingham. Resolutions favouring short-time work, in lieu of the discharge of employees on redundancy grounds, were passed at a mass meeting of employees at the Courthouse Green works, after the announcement. Shop stewards representing the three thousand persons employed there declared that strike action would be taken if men were discharged owing to redundancy.

Employees at Courthouse Green likely to be declared redundant under the corporation's proposals are members of the Amalgamated Engineering Union, the Transport and General Workers' Union, and the National Society of Metal Mechanics. Shop stewards at the factory are understood to have informed officials of these unions that the management there had promised that other work would be found for the men when their employment on the Morris motor-car engines came to an end. They suggest that work is being transferred from Coventry to Birmingham because rates of pay are somewhat lower there. On the other hand, a representative of the corporation stated that the building of engines at Longbridge works instead of at Coventry was due solely to the rationalisation of production, following the amalgamation of the Austin and Morris companies. It was unfortunate, he said, that the Morris engine factory at Coventry had had to take the first knock, but work would return there. As to rates of pay, there might be a question of a fraction of a penny "here and there," but there was no substance in the allegations that wages were lower in Birmingham than at Coventry.

Mr. L. P. Lord, chairman of the corporation, referred to the redundacny proposals as being part of the firm's re-organisation scheme and said that the management had intensely disliked making the decision to discharge workpeople in Coventry. However, it had been decided to put the Austin engine into Morris motor cars and this had raised the question of where these engines should be constructed. It was not possible to run two engine factories; therefore, after due consideration, the Longbridge factory at Birmingham had been chosen. The corporation had to do its utmost to meet foreign competition. It was surely preferable to have engines made by British people in Birmingham rather than by the corporation's competitors in France and Germany.

Arrangements were made earlier this week for the situation to be considered in detail by union representatives and an executive official of the corporation, at a joint meeting yesterday morning. It has been reported that, towards the end of the summer, the manufacture of six-cylinder engines for commercial vehicles will be undertaken at the Courthouse Green works. The unions concerned appear to take the view that the corporation should allow the construction of Morris motor-car engines to continue during some of the coming months and then adopt a period of short-time working until the factory is ready to commence the production of commercial engines.

Major difficulties confronting the chemical industry during the present year are referred to by Mr. R. Edwards, the general secretary of the Chemical Workers' Union, in the January issue of the *Chemical Worker*, the union's official journal. He considers that, after 50 years of expansion and development, the industry will face its most difficult period in the coming months. During 1952, he states, an average of 13·4 per cent. of the industry's labour force was discharged owing to redundancy. In the plastics industry, during the same period, discharges for that reason amounted to 20·9 per cent., on the average; in the heavy-chemicals industry, the average was 12·8 per cent.; and, in the fertiliser industry, it amounted to 8·9 per cent. Chemical exports fell in value from 13,500,000*l.* a month during the first three months of 1952, to 10,500,000*l.* in September last.

Expensive modern chemical equipment, Mr. Edwards affirms, is at present lying idle "because of a serious recession in trade." The production of sulphuric acid fell by over 50 per cent. during 1952, owing to a decline in demand. Competition from the United States and from the revitalised industries of Germany, Italy and Japan has been intensified and if full employment is to be maintained for employees in Britain's chemical industry during 1953, new methods of production, new sales organisation, and "new blood with new ideas" are urgently needed.

To release the flow of world trade, he continues, and establish functional trade organisations, would bring the peoples of the world into close contact for economic purposes and be the most certain way of maintaining peace. With this intention in mind, the Chemical Workers' Union is engaged upon a detailed plan designed to enable the industry to fight against the danger of a slump. Outlets in world markets for Britain's surplus chemicals have to be found, and, as a first step, some central organisation is necessary, to collate information regarding the production of chemicals, the quantities that would not be marketable under existing conditions, and the best means of disposing of that surplus. Trading methods would have to be revolutionary and unorthodox.

The prospects of the coal-mining industry during 1953 and a summary of the progress made during the past year were referred to by Sir Hubert Houldsworth, the chairman of the National Coal Board, at a luncheon in London on Tuesday last. He anticipated that more coal would be mined in Britain and more coal sent overseas during 1953, than in the year gone by, in spite of the increase of miners' annual holidays from one week to two. Compared with 1951, production had risen by 800,000 tons in 1952, mainly owing to the extra working day provided by the leap year.

Some redundancy among tin-plate operatives in West Wales, probably of a temporary nature only, is expected to follow the closure of six out-of-date hand mills in the Llanelly area. The probable obsolescence of these mills as a result of increasing production at the Trostre works of the Steel Company of Wales Limited, has been expected for some time. Although no official statement has been issued by the managements of the mills in question, it is understood that a week's notice on redundancy grounds will shortly be issued to employees at some of these works, and that they will then continue in work on a week-to-week basis. It is considered likely that mills at other places in the vicinity of Llanelly, which have been idle owing to shortages of man-power, may now be re-opened, in order to absorb some of the redundant workpeople. The possible introduction of a six-hour shift in place of the existing eight-hour shift is also understood to be under consideration.

Meetings to consider the employment situation have been held recently by a number of organisations in the West Wales district, as well as by some of the employees concerned. The West Wales district committee of the Welsh Board for Industry decided last Friday to ask for official information respecting the plans of the Iron and Steel Board for dealing with redundancies in the local tin-plate industry. Some 4,000 operatives are involved in the contemplated mill closures and, among them, are most of the six hundred Italians at work in the industry. These men originally came to Britain for training as miners, on a two-year basis. Later, they transferred to the tin-plate industry and it appears to be generally understood that in the absorption of redundant employees at other mills, preference will be given to Welsh operatives.

WEAR-RESISTING PHOSPHATE COATINGS ON STEEL.

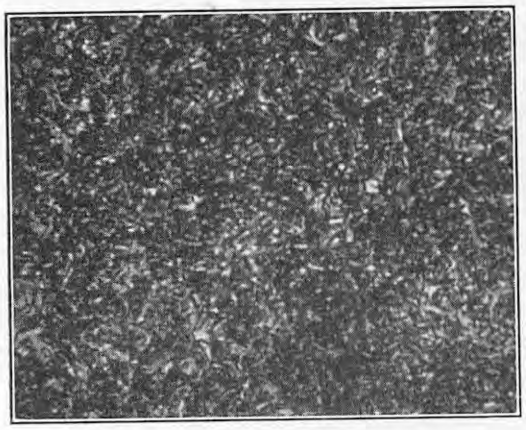


FIG. 1. FINE COATING. × 284.

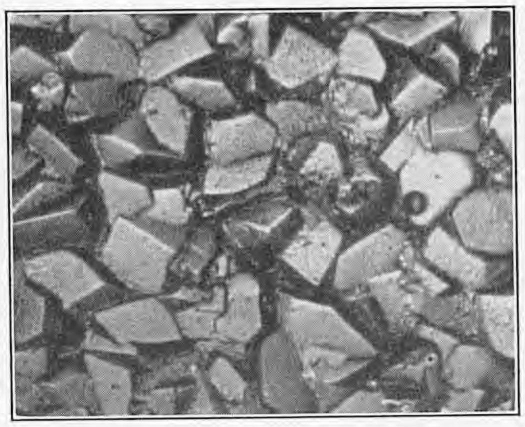


FIG. 2. MEDIUM COATING. × 284.

FIG. 3. COARSE COATING. × 284.

WEAR-RESISTING PHOSPHATE COATINGS ON STEEL.

AMONG the many protective coatings and films now available for application to ferrous and other metals and alloys, processes involving the formation of metallic phosphates have become firmly established in industry during the past 20 odd years. This is because they are relatively easy to apply, and, although thin enough to entail little change in the dimensions of the components treated, they are tenaciously adherent. The phosphate films by themselves, however, are not intended to afford the maximum resistance to corrosive influences; they must be given a coating of paint or lacquer, and the phosphated surfaces provide an excellent bond for these materials, which may be applied by brushing or spraying. Alternatively, the phosphated surfaces may be impregnated with oil which is retained by the absorbent nature of the coating. Two phosphating processes which have been in use for many years, "Parkerizing" and "Bonderizing," are owned and administered by the Pyrene Company, Limited, Metal Finishing Division, Great West-road, Brentford, Middlesex. The two processes are similar and both involve the simple dipping of iron or steel articles, after preliminary degreasing, in a bath containing hot solutions of manganese di-hydrogen phosphate, zinc di-hydrogen phosphate, or similar salt, together with an accelerator or accelerators. The temperature at which the bath is maintained, its composition, and the time of immersion vary with the nature, structure and thickness of the coating desired, but the temperature is usually between 130 and 200 deg. F., and the time of immersion may range from a few seconds to 30 minutes.

In recent years the absorptive and oil-retaining characteristics of phosphate coatings have been shown to possess distinct advantages for the treatment of cylinder liners, pistons and piston rings, gears of all types, camshafts, valves, and other internal-combustion engine components subject to wear in service. As a result of research into this particular field of application of phosphate coatings on steels, the "Parco-Lubrite" process has been introduced by the Pyrene Company and has now been adopted by several leading manufacturers of motor cars.

The evolution of hydrogen which occurs when an article is first dipped in the bath in the Parco-Lubrite process indicates that the steel surface is etched, but after a few minutes this is followed by the precipitation of the double phosphates of iron and of manganese contained in the bath. The final deposit varies from about 0·0002 in. to 0·0003 in. in thickness; it is crystalline and the degree of fineness of the structure can be controlled. Microphotographs of this type of coating are shown in Figs. 1 to 3, on this page. Fig. 1 depicts a fine coating, Fig. 2 a medium coating, and Fig. 3 a coarse coating. The very coarse coating shown in Fig. 4 is not normally used for industrial purposes, but it is indicative of what can be accomplished by the control of the various factors involved in the process.

FIG. 4. VERY COARSE COATING. × 284.

As in the "parent" process of Parkerizing, the Parco-Lubrite coating is integral with the base metal. In consequence, although the coating is gradually worn away in the running-in period, even when the level of the base metal is reached, a crystalline film remains as an oil-retaining medium for a considerable period. The Parco-Lubrite coating is stated to fulfil four main functions. In the first place, it prevents the welding of two metal surfaces under load, and, secondly, it increases the efficiency of the lubrication. In the third place, it assures the rapid and safe running-in of working parts and, fourthly, any steel burrs or other irregularities resulting from the machining operations are removed chemically by preferential attack during the treatment of the component. Investigations conducted by the Motor Industry Research Association and the Mechanical Engineering Research Organisation have shown the effectiveness of the process in preventing seizure and scuffing between two steel surfaces. Reports of several of these investigations have been published in our columns, among them being a paper by Dr. F. T. Barwell, read before the Institution of Engineers and Shipbuilders in Scotland and reprinted on pages 649 and 697 of vol. 172 (1950).

Another relatively new development of the phosphate process is the application of coatings to facilitate the cold-working of metals in wire, tube and deep-drawing operations. For this purpose, the Pyrene Company's Bonderizing process is employed and the appropriately cleaned wire rods, hot-worked "hollows" which are the starting material for the production of cold-drawn seamless tubes, and stock for deep-drawing, are immersed for some 5 to 10 minutes in a phosphating solution maintained at a temperature of between 140 deg. and 160 deg. F. The coating is grey in colour and consists predominantly of zinc tertiary phosphate. Its absorbent property ensures that a uniform film of drawing lubricant is distributed over the entire surface of metal. The Bonderite coating, as it is termed, is tightly adherent and persists throughout the drawing operations and, if desired, may be finally removed with dilute caustic-soda solution. A satisfactory surface to which any metal coating may be applied is thereby produced. Alternatively, in the case of some deep-drawing applications, the phosphate coating may be left on as a basis for painting or lacquering. Among the benefits claimed for the phosphate technique, when applied to cold-working processes, are increased die or tool life, faster drawing speeds, increased reductions per pass, the elimination of intermediate annealings and improved surface condition of the finished products.

RUNWAYS FOR JET AIRCRAFT.

AT a symposium held recently in Montreal by the International Civil Aviation Organisation, aerodrome requirements for jet-propelled aircraft were discussed. Aerodrome pavements, it was stated, could be injured by blast, heat or fuel spillage. Experience with the Comet air-liner, in which the engines were mounted in the wings with their thrust axes parallel to the ground, had revealed no adverse effect on pavements. It was suggested, therefore, that aircraft designers should aim at keeping the height and inclination of jet engines "at reasonable dimensions." Experience in the United States with "pod"-mounted jet engines had resulted in ground-surface temperatures as high as 400 deg. to 500 deg. F. The use of rockets or afterburning for assisted take-off would lead to still more severe conditions. Fuel spilled from jet engines during starting, stopping and accelerating had a softening effect on certain non-rigid pavements, and rendered them more sensitive to erosion by heat and blast. Concrete itself was not affected, but the bituminous joints between concrete slabs were, and if they became eroded by heat and blast, damage to the concrete might follow. Research on jet-resistant joint materials was in progress.

Discussing runway lengths, it was stated that the Comet air-liner required a longer landing run than that of the larger piston-engine aircraft; the take-off run was similar in both types. Work was in progress on methods for increasing the landing drag of jet-propelled air-liners, but nevertheless runways should have a reasonable coefficient of friction for braking efficiency. The layout of taxiways, "holding areas" where piston-engined aircraft could carry out their pre-flight checks, and loading aprons was also discussed in relation to the need for minimising jet-engine fuel consumption during taxi-ing.

CREEP PROPERTIES OF STEELS FOR POWER PLANTS—I.*

By A. E. Johnson, D.Sc., M.Sc.Tech., M.I.Mech.E., and N. E. Frost, B.Sc., A.M.I.Mech.E.

(*Concluded from page* 28.)

0·5 *Per Cent. Molybdenum,* 0·23 *Per Cent. Vanadium Steel: Bar Material.*—The results of the initial tests at 4 tons per square inch and 1,103 deg., 1,121 deg., and 1,139 deg. F. for this material indicate that, over this range of temperature, the creep strains at 300 hours rise in the ratio 2 : 1, and the corresponding creep rates in much the same ratio. This range of rates and stresses provided sufficient data to cover the increases due to overstress and temperature applied in the cycling tests. The test at 1,103 deg. F., giving 0·00087 creep strain at 300 hours, was chosen as the criterion test. Two stress-fluctuating tests giving, respectively, increases of 10 per cent. for 50 per cent. and 20 per cent. for 25 per cent. of cycles of 24 hours and 2 hours, respectively, were made in this case. On the basis of creep strain, the results indicate a slight frequency effect which may be due to recovery phenomena, being such as would be caused by these. With the exception of the test of 24-hour period and 10 per cent. overstress, no appreciable equivalent temperature increment is indicated by the creep-rate criterion, but this test shows an increment of 8 deg. F. which may, of course, correspond with some small frequency effect. However, in view of the indication that frequency effect was not marked, no attempt to trace such an effect was made in the case of the temperature cycles.

Two further purely stress-fluctuation tests, involving 30 per cent. and 50 per cent. increments for 5 per cent. of the cyclic time, were made as in the case of the plain carbon and molybdenum steels. Here, the 30 per cent. increase gave results very similar to those of the basic criterion test, while the 50 per cent. increase appeared to correspond to a design temperature increment of about 12 deg. F. Thus, for this material at 1,103 deg. F., the influence of the peak stress tests of higher percentages is much less marked than for the carbon and molybdenum steels.

Turning to the question of temperature fluctuations, two tests were made in which temperature fluctuations of 5·4 deg. F. for 50 per cent. of 24 hours, and of 8 deg. F. for 25 per cent. of 24 hours, were imposed. These temperature increments were expected to provide results of somewhat similar order to those given by the stress increases of 10 per cent. for 50 per cent. of 24 hours, and 20 per cent. for 25 per cent. of 24 hours. The first expectation was reasonably correct, while the second was somewhat of an overestimate in the case of the strain, though not as regards creep rate. It appears, however, that some scatter of results due to dissimilarity of test pieces is appearing in this group of tests.

In virtue of the fact that this material had proved relatively insensitive to the higher peaks of stress, it was felt that its reaction to relatively high peak temperatures should be examined to see whether a similar lack of sensitivity was apparent. Accordingly, two tests were made in which temperature fluctuations of 36 deg. and 54 deg. F. occurred for 50 per cent. and 25 per cent. of operating time. It was found that the average equivalent design temperature increment corresponding to these two tests were, respectively, 24 deg. and 26 deg. F., i.e., more or less similar, but of the order of twice the increment due to any other cycle imposed upon the material. Evidently, therefore, temperature fluctuations of this order are relatively serious in their effects. For this material, the two criteria of rate and strain corresponded fairly well upon a number of occasions, but differed very appreciably on others.

Finally, for this bar material, two tests under combined stress and temperature fluctuations were made; these involved, respectively, an overstress of 10 per cent. combined with a temperature rise of 5·4 deg. F. for 50 per cent. of the cyclic time, and overstress of 20 per cent. combined with a temperature rise of 5·4 deg. F. for 50 per cent. of the cyclic time. As it happened, these gave almost identical results, of an order somewhat similar to that given by the 50 per cent. overstress, and higher than any other cycle concerned except the two pure temperature cycles of 36 deg. and 54 deg. F., respectively.

0·5 *Per Cent. Molybdenum,* 0·23 *Per Cent. Vanadium Steel: Pipe Material.*—Results of the initial tests at 4 tons per square inch and at temperatures of 1,139 deg., 1,193 deg., 1,211 deg., and 1,238 deg. F. on this material indicated that the creep strain increased over this range in the ratio 4 : 1 or 5 : 1, and creep rates in the ratio 13 : 1, which provided ample data to cover the increases due to overstress and excess temperature applied in the cycling tests. The test at 1,193 deg. F., which gave a creep strain of 0·00089, was adopted as the criterion test. Two pairs of tests were made, having stress fluctuations of 10 per cent. for 50 per cent. of 24 hours and 2 hours, and of 20 per cent. for 25 per cent. of the same periods. The results of the tests taken in pairs were virtually similar, indicating no appreciable frequency effect for this material. Actually, the results of all four tests were quite similar, and indicated an average equivalent design temperature increment of about 7 deg. to 8 deg. F.

Two stress peaks, of 30 per cent. and 50 per cent., for 5 per cent. of periods of 24 hours, were applied in two further tests, and were equivalent to design temperature increments of 10 deg. and 27 deg. F., respectively. Evidently, therefore, in this steel the severity of the effect of fluctuating tests rises sharply at stress peak values greater than 30 per cent.

Three cycles with purely temperature fluctuations were made for this material, these fluctuations being, respectively, 8 deg. F. and 54 deg. F. for 25 per cent. of 24 hours, and 36 deg. F. for 50 per cent. of 24 hours. The first of these was expected to be somewhat similar in its effects to a cycle of 20 per cent. overstress for 25 per cent. of 24 hours. Actually, it appeared to be appreciably less severe, and almost analogous to the basic cycle, but it is possible that the results of this test are influenced by the initial dissimilarities of specimen material. The other two tests were equivalent in effect to design temperature increments of 25 deg. and 33 deg. F., respectively, and were, therefore, of appreciable severity as in the case of the bar material.

At this stage, it is useful, perhaps, before proceeding to examine the applicability of the suggested analytical treatment, to trace any generalities in the experimental behaviour of the four materials which appear to arise from the more detailed commentary outlined above. First, for all steels, cycles of overstress and excess temperature which have been imposed did not result in a greater increase of creep strain than is represented by a ratio of 2 : 1, or of rates than is represented by a ratio of 3 : 1, except in the case of the 50 per cent. overstress for 5 per cent. of 24 hours for the carbon steel, when the strain rose in the ratio 3 : 1 or 4 : 1, and creep rate in the ratio 9 : 1, and also the case of the test with a temperature fluctuation of 54 deg. F. for the molybdenum-vanadium steel pipe material where a 3 : 1 to 4 : 1 rise in creep rate only was observed. Secondly, no frequency effect of either stress or temperature was more severe than to cause a strain or rate increase of more than 1·5 : 1.

From the designers' point of view, the above generalities need to be considered against the background of the creep characteristics of the material, particularly the onset of tertiary creep at the temperatures in question. It certainly appears that, from a practical point of view, no serious worry should be caused by the effect of frequency, but, on the other hand, it may be manifest from a consideration of the characteristics of the material that a doubling of

CREEP PROPERTIES OF STEELS.

Fig. 5. DEVIATION (EXPERIMENTAL OVER ANALYTICAL) OF DESIGN TEMPERATURE INCREMENT FOR 0·17%C. STEEL AT 959 DEG. F.

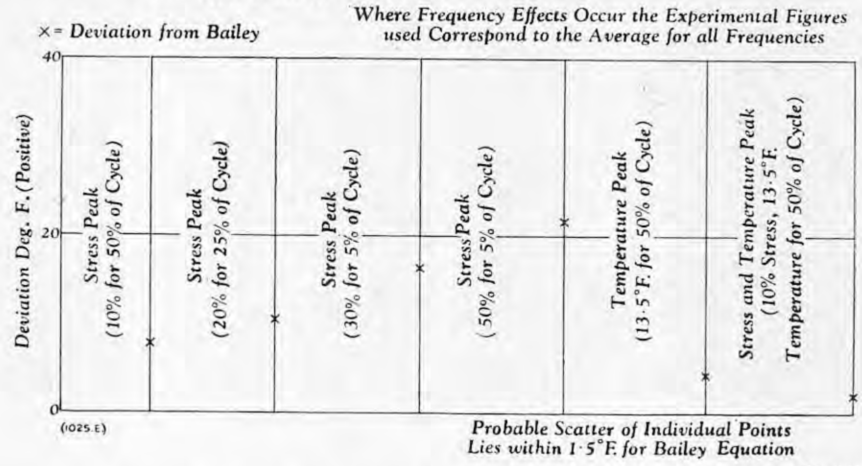
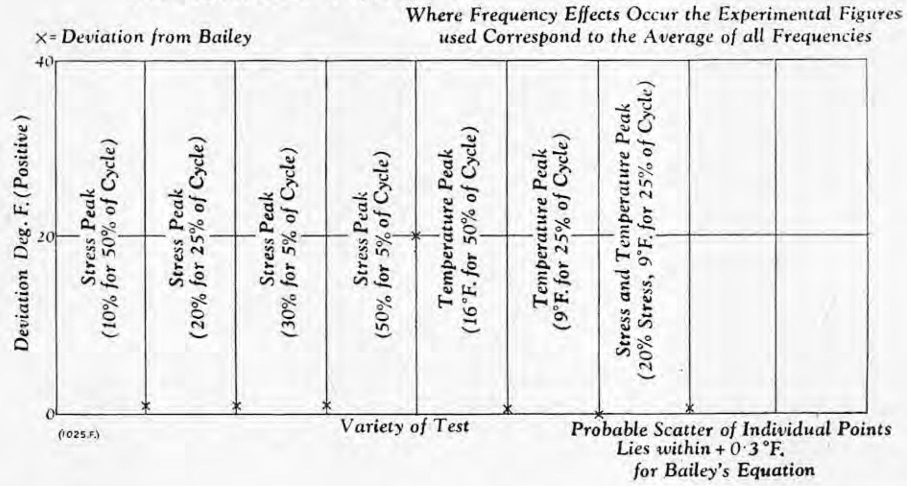


Fig. 6. DEVIATION (EXPERIMENTAL OVER ANALYTICAL) OF DESIGN TEMPERATURE INCREMENT FOR 0·5% Mo STEEL AT 1,085 DEG. F.



* Communication from the National Physical Laboratory. Abridged

CREEP PROPERTIES OF STEELS.

Fig. 7. DEVIATION (EXPERIMENTAL OVER ANALYTICAL) OF DESIGN TEMPERATURE INCREMENT FOR 0·5% Mo, 0·23% Va STEEL PIPE MATERIAL AT 1,193 DEG. F.

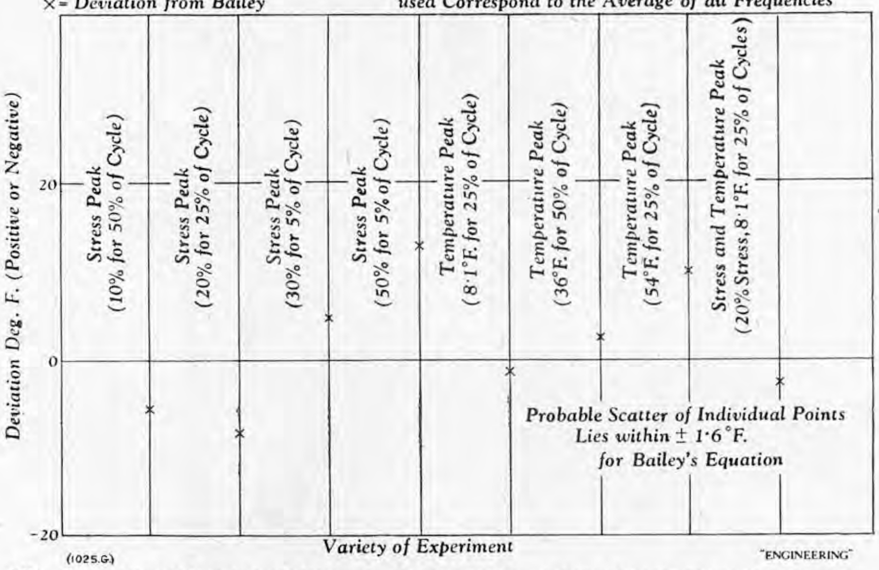
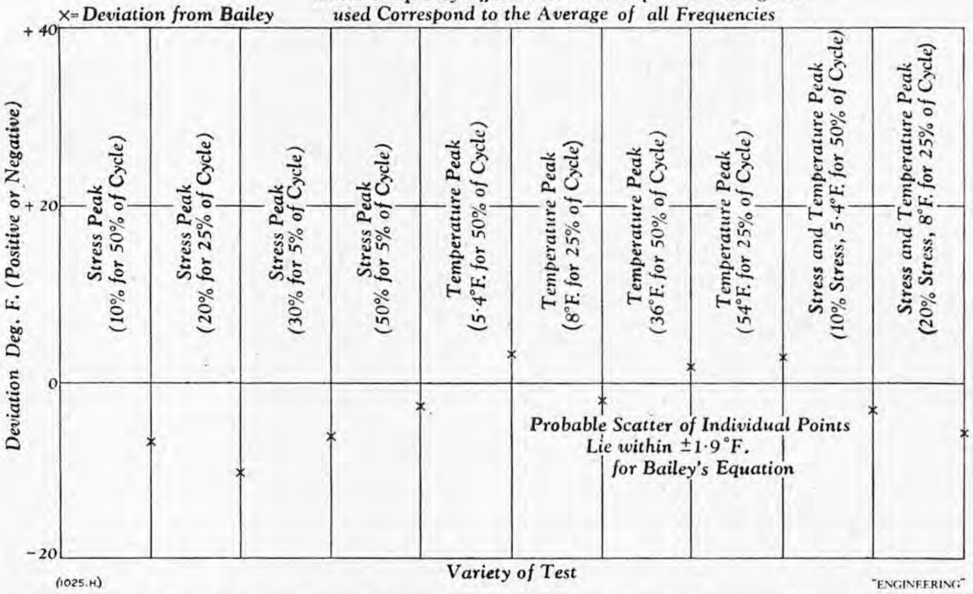


Fig. 8. DEVIATION (EXPERIMENTAL OVER ANALYTICAL) OF DESIGN TEMPERATURE INCREMENT FOR 0·5% Mo, 0·23% Va BAR MATERIAL AT 1,103 DEG. F.



the magnitude of the total creep strain within the life of a plant component might lead to serious difficulty. Those fluctuations, which cause increases of three times or more in the strain or rate, are obviously more than likely to cause trouble within the life of the component.

RELATION BETWEEN EXPERIMENTAL RESULTS AND ANALYTICAL ESTIMATES OF PERFORMANCES.

A means of estimating the effects of cycles of fluctuating stress and temperature, using the characteristics arising from normal constant stress and temperature creep tests, has been suggested by Dr. R. W. Bailey in two papers recently published by the Institution of Mechanical Engineers.* Dr. Bailey suggests that the behaviour of many materials undergoing creep may be represented approximately by the relation

$$\frac{dx}{dt} = \mathrm{B} f^n e^{a\theta} x^{-p}$$

where $\frac{dx}{dt}$ is the creep rate measured at values of specific creep strain, and where B, n, a, and p are treated as constants over restricted ranges of variation, f is stress, t is temperature, and x is creep strain.

* "Steam Piping for High Pressures and High Temperatures," *Proc. I. Mech. E.*, vol. 164, page 329 (1951); and "Creep Relationships and their Application to Parts Under Pressure," *Proc. I. Mech. E.*, vol. 164, page 429 (1951).

Within restricted ranges of variation, Dr. Bailey states that the above equation may be integrated to give the equation

$$x = [\mathrm{B}(p+1)]^{\frac{1}{p+1}} f^{\frac{n}{p+1}} e^{\frac{a}{p+1}\theta} t^{\frac{1}{p+1}},$$

and that values of n may be obtained by means of a plot of log f and log t for specific creep strains, values of p by means of a plot of log x against log t for specific creep strains, and a by means of a plot of θ against log t.

Obviously, if the restricted ranges of variation envisaged by Dr. Bailey be exceeded in peak-load or temperature tests, the approximation would be expected to break down, quite apart from all considerations of whether approximations of this sort based upon constant stress and temperature data can rationally be applied to variable loading and temperature conditions of the type occurring in the tests considered.

Since the power-plant parts mostly concerned are loaded by internal pressure P, stress may closely be taken as proportional to pressure, and in what follows the use of f may be taken as equally representing P.

If θ be the rated or steady operating temperature; $\bar{\theta}$ the design temperature providing for peaks and operating conditions; f', f'', etc., peak stresses; θ', θ'', etc., peak temperatures; α', α'' fractions of the total life occupied by the peaks f', θ', f'', θ'', etc.; x the creep strain at time t, and $\bar{x}$ the creep strain at life period $\bar{t}$; and if it be assumed that peak periods are distributing uniformly over the life, consideration of a single characteristic period of duration Δt, small in relation to t and $\bar{t}$, which contains the peak features and the associated running period under steady conditions, the following relationship would hold between the increment of creep strain Δx and its components.

$$\begin{aligned}\Delta x = \mathrm{A} f^n e^{a\bar{\theta}} x^{-p} \Delta t &= \mathrm{A} f'^n e^{a\theta'} x^{-p} \alpha' \Delta t \\ &+ \mathrm{A} f''^n e^{a\theta''} x^{-p} \alpha'' \Delta t + \ldots \\ &+ \mathrm{A} f^n e^{a\theta} x^{-p} \{1 - [\alpha' + \alpha'' + \ldots] \Delta t\}\end{aligned}$$

giving

$$f^n e^{a\bar{\theta}} = \Sigma f'^n e^{a\theta'} \alpha' + f^n e^{a\theta} (1 - \Sigma \alpha')$$

Dr. Bailey makes the assumption that a stress peak may be replaced by its equivalent temperature; e.g., applied to the peak f' θ', let $\delta\,\theta'$ be the increase in θ' necessary to compensate for changing the pressure from f' to f.

For this,

$$f'^n e^{a\theta'} = f^n e^{a(\theta' + \delta\theta')}$$

giving

$$\delta\,\theta' = \frac{n}{a} \log e \frac{f'}{f}$$

Then, in the above equation,

$$f^n e^{a\bar{\theta}} = \Sigma \alpha' f^n e^{a(\theta' + \delta\theta')} + (1 - \Sigma\alpha') f^n e^{a\theta}$$

$$a^{a\theta} = \alpha' e^{a(\theta + \delta\theta')} + (1 - \Sigma\alpha') e^{a\theta}$$

$$\bar{\theta} = \frac{1}{a} \log e [\Sigma \alpha' e^{a(\theta' + \delta\theta')} + (1 - \Sigma\alpha') e^{a\theta}]$$

This gives the design temperature $\bar{\theta}$, allowing for peaks to be taken with the rated pressure P.

In the present set of experiments, three special cases arise. These are as follow:

(*a*) The case where only one type of peak involving an increase in temperature only for a fraction α of total time.

Here

$$e^{a\bar{\theta}} = \alpha e^{a\theta'} + (1 - \alpha) e^{a\theta} = \alpha (e^{a\theta'} - e^{a\theta}) + e^{a\theta}$$

$$\alpha = \frac{e^{a\bar{\theta}} - e^{a\theta}}{e^{a\theta'} - e^{a\theta}} = \frac{e^{a(\bar{\theta} - \theta)} - 1}{e^{a(\theta' - \theta)} - 1}$$

Solving for $(\bar{\theta} - \theta)$, we have finally

$$\overline{\bar{\theta} - \theta} = \frac{1}{a} \log e [\alpha e^{a(\theta' - \theta)} + (1 - \alpha)]$$

(*b*) The case where the peak involves an increase of stress as well as temperature, the two being of equal periodicity.

The temperature θ' is then increased by

$$\delta\,\theta' = \frac{n}{a} \log e \frac{f'}{f} \text{ giving eventually}$$

$$\overline{\bar{\theta} - \theta} = \frac{1}{a} \log e [\alpha e^{a(\theta' + \delta\theta' - \theta)} + (1 - \alpha)]$$

(*c*) Finally, the case where only one type of peak involving an increase in stress occurs. Here the equation for $(\bar{\theta} - \theta)$ reduces to

$$\overline{\bar{\theta} - \theta} = \frac{1}{a} \log e [\alpha e^{a\,\delta\theta'} + (1 - \alpha)]$$

For the three steels concerned in the experimental work, values of n, a, and p have been suggested by Bailey. In some cases, however, suitable data was available at the National Physical Laboratory for the determination of these "constants" after the manner suggested by Bailey, and both sets of values are given in Table VII, on page 60, and both are made use of subsequently in computation.

In Tables II to V, values of $\bar{\theta} - \theta$ for the various experiments and materials concerned, obtained by the analytical means discussed above, and using the values of the "constants" as indicated in the appropriate columns, are compared with the experimentally determined values previously discussed; and in Figs. 5 to 8 the average deviation of the individual experimental values* from the analytically derived values given by the Bailey

* Where several tests are performed to investigate frequency effects, the average value of the set is given.

equations is shown in relation to the appropriate test. In each of Figs. 5 to 8 the probable scatter corresponding to the analytically derived values is given.* The features of these Tables and figures are probably best discussed initially in relation to individual materials.

Comparing, first, the analytical figures given for the carbon steel with the experimental values, it is seen that a considerable disparity occurs in all tests except the one which shows a pure temperature fluctuation only, and one test of combined temperature and stress fluctuations. Apart from these tests, the experimental figures give anything from a 2 : 1 to a 3 : 1 ratio to the analytical figures, and the disparity is most marked at the relatively high values of pure stress peaks. Obviously, therefore, the analytical treatment is seriously in error for this material; in particular, it seems as though the convention of replacing stress peaks by temperature peaks is open to doubt.

In the case of the molybdenum steel, the figures given by the Bailey equations are particularly close for all tests, and, if the average experimental figures for several tests of a frequency range are taken, the deviation of the analytical from experimental values is only of order of a degree or two ; with the exception only of the test, at 50 per cent. overstress for

TABLE VII.—*Value of Constants in Equation*

$$\frac{dx}{dt} = \mathrm{B} f^{n} e^{a\theta} x^{-p}$$

for Rates Measured at Specific Strains.

Material.	Values Suggested by Dr. Bailey.		Values Obtained from N.P.L. data.	
	n.	*a.*	*n.*	*a.*
0·17 per cent. Carbon steel	6	0·049	7·3	0·064
0·5 per cent. Molybdenum steel	3	0·0385	—	—
0·5 per cent. Molybdenum, 0·23 per cent. vanadium steel	6	0·031	— (bar) 5·6 (pipe)	0·028 (bar) 0·027 (pipe)

5 per cent. of 24 hours, where the disparity is very great, being in a 10 : 1 ratio. Thus this set of tests, though they do not cast quite the same doubt upon the general applicability of the analytical equations as do the tests on the carbon steel, nevertheless indicate the same considerable shortening in the matter of the test at a particularly high stress peak.

In the case of the molybdenum-vanadium steel bar material, the Bailey analytical figures in general gave values which, in the cases involving the pressure peaks, are above the experimental values by increments approaching 10 deg. F. in some cases ; this is also true of one combined stress and temperature peak test. In other tests, the Bailey figures are within 3 deg. F. of experiment. Where the analytical figures are in excess of the experimental the difference may, in fact, be due to creep recovery.

This set of tests, therefore, while not emphasising in the same degree a disparity between the analytical and experimental figures in any particular mode of test, shows in many tests deviations both positive and negative of an order approaching 10 deg. F., and gives the same indication of doubt concerning the application of the analytical expressions as was given by the carbon and molybdenum steels. It is notable that the experimental and analytical figures are quite reasonably of the same order in the case of the high temperature peaks of 36 deg. and 54 deg. F.

Finally, considering the figures given in Table V for the molybdenum-vanadium pipe steel, comparison of analytical and experimental figures shows that, in tests comprising pure stress peaks, the deviation of experimental values changed from a negative value of as much as 7 deg. F. to a positive value approaching 20 deg. F. at the highest 50 per cent. peak stress. The two lower pure temperature peaks give quite good correspondence between experimental values, and the Bailey analytical values. However, the highest temperature peak experimental values exceed those of the Bailey analysis by 10 deg. F., or a 3 : 2 ratio. The one combined stress and temperature peak test made shows fair agreement between experimental and analytical values. Surveying the results for this material, therefore, we find a considerable disagreement between analytical and experimental values, emphasised particularly, as in two of the other materials, by the tests at the particularly high peaks of stress and temperature.

Summarising the indications given by all four of the above groups of tests, the conclusion is unavoidable that the proposed analytical treatment is not adequate in all cases. The convention of representing the stress peaks by equivalent temperature peaks particularly seems open to doubt in the region of high stress peaks, and marked disagreement between analytical and experimental values occurs at some high temperature peaks. It is obvious that, in many cases of moderate stress or temperature fluctuation, the analytical expressions may give an indication of a moderately correct or safe nature ; but, in the case of the more extreme fluctuations, the analysis appears likely to give seriously misleading results.

The following general conclusions appear to be merited.

(1) The majority of the cyclical fluctuations of stress and temperature dealt with cause increases of creep strain which are within a ratio of 2 : 1 of those given by the basic creep tests. Large fluctuations, of order 50 per cent. overstress or 50 deg. F. excess temperature, may, however, modify creep rate and strain to a degree completely outside these limits. Whether the 2 : 1 ratio quoted can be regarded as safe in the case of a particular material will be determined, of course, by the designer in the light of the known creep characteristics of the material.

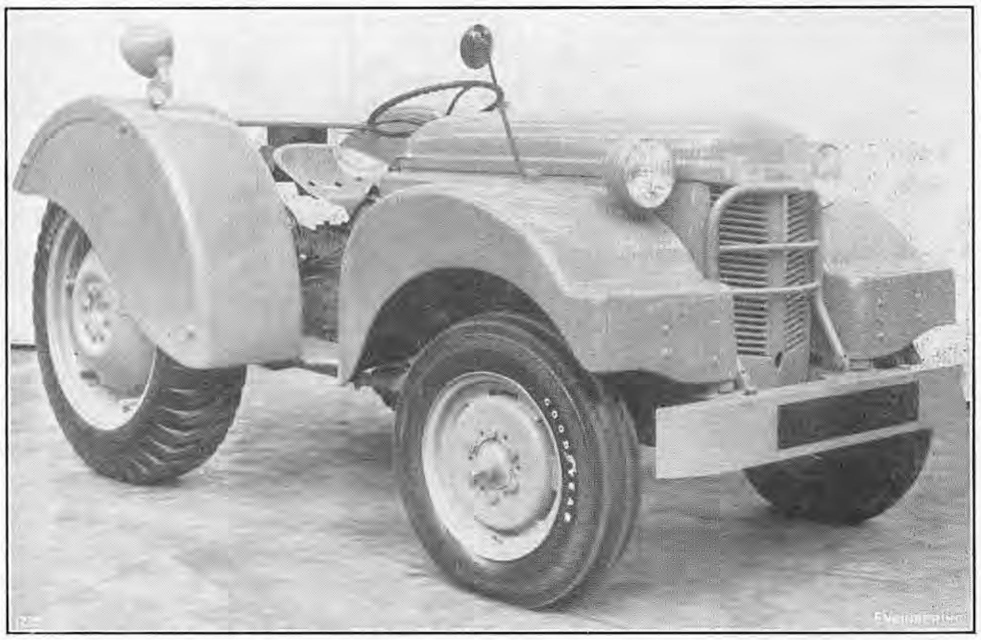
(2) The effect of frequency of stress or temperature fluctuations is never greater than expressed by a 1·5 : 1 ratio to a mean value, and it is suggested that no serious worry should be caused to the designer by such effects.

(3) The analytical treatment so far put forward cannot be said to represent the present set of experimental results completely adequately ; particularly does the representation of stress peaks by equivalent temperature peaks appear to be erroneous at the higher peak values.

* Based upon consideration of the range of variation of arithmetical constants as between individual tests.

SMALL INDUSTRIAL TRACTOR.

HARRY FERGUSON, LTD. COVENTRY.



A SMALL INDUSTRIAL TRACTOR.

THE small industrial tractor illustrated above, which is now being mass-produced by Harry Ferguson, Limited, Coventry, has been developed as a modification of the well-known Ferguson agricultural tractor, driven by a 25-h.p. to 28-h.p. four-cylinder engine having a bore and stroke of $3\frac{3}{16}$ in. and 4 in., respectively, and running at a maximum speed of 2,000 r.p.m. The engine is built by the Standard Motor Company, Limited, and is available in three forms, suitable for vaporising oil, petrol or lamp oil, the last-mentioned type being intended for export. In the Diesel type of engine, the Freeman-Sanders patented form of combustion chamber is used. C.A.V. fuel-injection equipment is fitted, the rate of injection being controlled by a pneumatic governor. To assist starting in cold weather, a Kigas heater is provided; this comprises a small fuel tank fitted with a hand-operated pump, and an atomising nozzle in the manifold for spraying the fuel on to an electrically-heated glow-plug. Other equipment supplied with this type of engine includes an oil cleaner, twin fuel-filters and decompression gear.

The gearbox is a constant-mesh type with four forward gears and one reverse gear. The steering is hydraulically assisted. The electrical equipment comprises a 12-volt battery, with an auxiliary dynamo of the non-ventilated type and a starter motor. The starter motor is operated from the sixth position of the gear lever and a special interlocking device ensures that the starter cannot be engaged accidentally while the tractor is running.

To make the tractor suitable for work in coal yards, docks, construction sites and in factory premises, it has been redesigned to meet the statutory requirements for vehicles to run on public roads. Two independent brake systems, one hydraulically-assisted, have been fitted, as well as a horn, driving mirror and headlights, and the front is protected by a robust spring-mounted bumper. The mudguards can be easily detached to leave the tractor suitable for all-round agricultural purposes. The overall dimensions of the tractor, with mudguards, are : length, 10 ft. 4 in. ; width, 5 ft. $7\frac{1}{4}$ in. ; and height, 4 ft. $6\frac{1}{2}$ in.

INSTITUTION OF MECHANICAL ENGINEERS.—The Council of the Institution of Mechanical Engineers, Storey's-gate, St. James's Park, London, S.W.1, announce that the summer meeting of the Institution this year will be held in Sheffield on Wednesday, Thursday and Friday, July 1, 2 and 3. A provisional programme and other information will be published later.

THE OLD CENTRALIANS.—The next monthly luncheon of the "Old Centralians"—the association of former Students of the City and Guilds College and Finsbury College—will be held on Wednesday, January 14, at the restaurant Chez Auguste, 47, Frith-street, London, W.1. Dr. T. E. Allibone, F.R.S., will speak on "Atomic Energy." The luncheon secretary is Mr. A. C. Vivian, Beaufort House, Gravel-lane, London, E.1.

RHEOSTATIC BRAKE FOR TROLLEY 'BUSES.

Fig. 1.

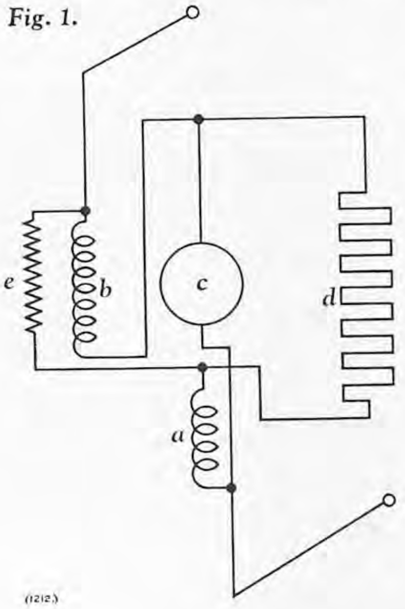
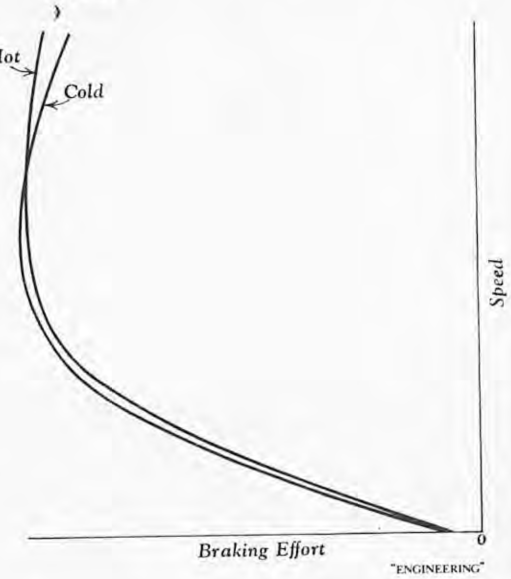


Fig. 2.



RHEOSTATIC BRAKE FOR TROLLEY 'BUSES.

To overcome excessive wear on their brake blocks, trolley 'buses were formerly fitted with rheostatic braking which operated in conjunction with compound-wound motors regenerating to the line. The use of regeneration, however, often required the installation of special equipment to absorb the surplus current, with the result that the employment of simple rheostatic braking has been usual for some time. The majority of these rheostatic systems consist of compound-wound motors, both fields of which are used when motoring, a separately-excited shunt field being employed for braking. In some cases, this field is used by itself, but in others it is associated with the starting resistors, so that an inverse-compounding characteristic is obtained. Whatever system is used, however, the braking effort depends on the temperature of the field windings and is not, therefore, as powerful as it might be when the windings are hot under normal hot-running conditions. Moreover, the braking effort is not maintained at the lower speeds and, when a separately-excited field opposed by some turns of series winding is used, it is necessary to incorporate more copper in the motor to produce the necessary magnetic flux.

The rheostatic braking system introduced by the General Electric Company, Limited, Kingsway, London, W.C.2, some two years ago at Reading, was designed to overcome these disadvantages. It incorporates a series winding for motoring, thus necessitating the employment of a small separately-excited field winding in order to reduce the amount of copper used to a minimum. As shown in the diagram, Fig. 1, a section of the series winding *a* is used to excite the braking system and control is effected by a separately-excited field winding *b*. This winding is associated with the motor braking voltage and, as it functions in both the positive and negative senses, only a few series turns are required for braking.

The power circuits of the system are arranged so that during braking only a portion of the series field winding remains in circuit and the current flows through it in the opposite direction to that in the armature *c*. A braking circuit through the armature, the braking resistor *d*, and the series field winding *a*, is therefore set up, the regulating shunt field winding *b* being in series with the armature across the line. When braking at high speed occurs the armature voltage exceeds the line voltage and produces inverse excitation. On the other hand, at low speeds the line voltage exceeds the armature voltage and the excitation will be increased. Should the trolley arm leave the line, the resistor *e* will energise the separately-excited field winding *b* sufficiently at high speeds to maintain the desired braking effect. There will, however, be some falling off at lower speeds.

It is claimed that the control of the excitation in the manner described gives a more constant braking curve under both hot and cold conditions, as shown in Fig. 2, and has the further great advantage that the torque varies little whether the motor is hot or cold. Consequently, the normal braking and safe running torques can be made equal and need not be limited by considerations of the safety of the transmission in the cold state.

TRADE PUBLICATIONS.

Safety Equipment.—An illustrated booklet giving details of safety equipment, including wirework guards for machinery, matting, gloves, goggles, respirators and footwear, has been received from Industrial Guarding Equipment, Ltd., Mill Works, Alvechurch, Birmingham.

Pig-Casting Machine.—A brochure issued by Ashmore, Benson, Pease & Co., Stockton-on-Tees, contains an illustrated description of their stationary-wheel pig-casting machine. Particulars of the Davit-type hot-metal ladle-tilting mechanism are also included.

Aluminium, Magnesium and Zinc Casting Alloys.—The Birmingham Aluminium Casting (1903) Co. Ltd., Birmid Works, Dartmouth-road, Smethwick, Birmingham, 40, have issued a new edition of their "Birmal Data Book," containing information regarding the properties of the alloys in general use for light-alloy casting and zinc-alloy pressure die casting processes.

Nylon Belting.—Gandy Ltd., Wheatland Works, Wallasey, Cheshire, have sent us a folder describing their nylon drop-stamp belting.

Drying Equipment.—Typical installations of tunnel-type, oven-type, multi-compartment, kiln-type and other forms of industrial drying plants are shown in publication No. 4706, issued by the Sturtevant Engineering Co. Ltd., Southern House, Cannon-street, London, E.C.4.

Earth-Continuity System.—Details of the Portaway earth-continuity system designed by them are given in a leaflet received from Porter Electrical Products Ltd., Bramhope, Leeds.

Molybdenised Lubricants.—The Ragosine Oil Co. Ltd., Ibex House, Minories, London, E.C.3, have issued a brochure giving details of their molybdenised lubricants, containing molybdenum disulphide, for use where conditions do not allow conventional lubricants to be applied.

Corrosion-Resistant Materials in Marine Engineering.—A publication, issued by the Mond Nickel Co. Ltd., Sunderland House, Curzon-street, London, W.1, and dealing with "Corrosion-Resistant Materials in Marine Engineering" is based on a paper presented to the Institute of Marine Engineers by Mr. L. W. Johnson and Mr. E. J. Bradbury. It is concerned with the theoretical aspects of corrosion, corrosive media encountered in marine engineering, and the corrosion behaviour and properties of various metallic materials.

Oil Products.—Edgar Vaughan & Co., Ltd., Legge-street, Birmingham, 4, have sent us particulars of their metal-cutting oils, drawing compounds, hydraulic oils, rust preventives, alkalyne-type industrial cleaning compounds, lubricants, and leather packings.

THE APPLICATION OF RESEARCH TO THE GAS TURBINE.*

By HAYNE CONSTANT, C.B.E., M.A., F.R.S.

(*Concluded from page* 31.)

HAVING completed the rather negative process of deciding what not to do, we had to take one further step before we could crystallise our programme of work. This step—and it is one which we repeatedly take—is the process of trying to visualise the layout and the thermodynamic cycles that are likely to be used for different applications, to assist us in anticipating the problems that the gas turbine is likely to throw up. It has become necessary for us, therefore, to spend a certain amount of time making comparisons of the various possible forms of engine for different applications. This is a most interesting occupation, but also a most dangerous one. Quite a small error in the assumptions made can be magnified in the ensuing argument and lead finally to totally wrong conclusions. An even more potent source of error can be due to the effect of faulty judgment in deciding what to take into account and what to neglect.

A good example of this is to be found in the vicissitudes of the ducted-fan engine. In the early days several engines were built with ducted fans having their blades mounted on separate low-pressure turbines. These proved unsatisfactory because it was extremely difficult to get the air into an intake near the rear end of a nacelle and also because the mechanical layout invited bearing and sealing problems. We made a new assessment of the problem in 1946 and decided that a better arrangement would be to place the ducted fan in front of the engine, so that it feeds air into the main compressor. This opinion was probably right, but where we went astray was to conclude that the load of the fan on the main turbo-compressor would be so great that acceleration would be prohibitively slow. Looking back, we now see that, had our judgment been better, we should not have passed over this most promising type of engine simply because we could not at that time see the answer to the acceleration problem—an answer which, incidentally, we had already been advocating for other types of engine. Nevertheless, in spite of the difficulty and dangers of making comparative assessments of different forms of engine, such assessments are absolutely necessary.

The comparative assessment of aero-engines is a very complicated business. The airframe and the engine interact on each other to such an extent that it is not sufficient to compare the bare engines on the basis of their weight and fuel consumption. Different engines may have different frontal areas and drags, and react differently to changes in altitude and forward speed. They may also have different reserves of power for take-off and short periods of boost. The only satisfactory method of comparison is that of comparing the performance of hypothetical aircraft, each powered by the different engines which are to be compared. Such a process is involved and takes a long time. Even so, it is only an approximation to the truth. It does not take into account, for example, the advantages that one form of power plant may offer in simplicity, reliability, ease of installation, long life, freedom from vibration and cheapness. So, when the assessments said that jet propulsion was only suitable for short-endurance aircraft such as fighters, and that piston engines were best for very long ranges, we simply refused to believe them. We have consistently held that, in spite of what all the figures and calculations say, jet propulsion is better than propeller propulsion. This again is almost accepted by the aircraft world to-day, but ten, or even five, years ago we were regarded as being rather unrealistic.

The examination that we made of the application of the gas turbine to railway traction led us to the

* The 21st Andrew Laing Lecture, delivered to the North-East Coast Institution of Engineers and Shipbuilders at Newcastle-upon-Tyne on December 12, 1952. Abridged.

conclusion that what was required was a simple form of engine running on liquid fuel and driving from a separate power turbine through a mechanical, rather than an electrical, transmission. Tests that we made to determine the torque characteristics of multi-stage turbines showed that no change-speed gearbox would be required. We thought it likely that such locomotives would prove more suitable abroad than on the railways of this country, where high traffic densities are forcing us towards electrification. It is too early to say whether these views were correct.

We foresaw the use of gas turbines for stand-by and peak load uses in works power stations, using simple cycles with efficiencies of up to 25 per cent. We thought it unlikely that there would be much scope for large base-load power stations unless some simple means of coal burning could be devised. We have always been very optimistic about the likelihood of the widespread application of the gas turbine to marine propulsion, but rather vague about the form that the engine should take. This, I think, springs from a consciousness of the extent of our ignorance of marine affairs. When, for example, we note that naval architects often design their engine-rooms much larger than is necessary because of a rule laid down before any of them were born, we realise that our mental planes do not intersect.

The concept that we first arrived at for the large marine engine was that of obtaining the maximum possible efficiency and flexibility by dispersion. We envisaged a power plant of the double-compound type, with heat exchangers and intercoolers, the various components of which were connected together by trunking. Examples of such power plants have since been produced by various manufacturers. To-day we are not so sure. We believe that weight and bulk should mean more to the marine engineer than, in fact, they do. We have a growing feeling that the integral power plant, consisting of a single piece of machinery like a Diesel engine, may be the right solution. Such an engine might be a little less efficient than its dispersed competitor, but it would be vastly lighter, cheaper, and more compact.

There are so many possible arrangements and cycles that can be used in the gas turbine that a great amount of exploratory work, extending over several years, was needed before we could be sure that we had found the best answer for each duty. In the course of this work we explored over 100 cycles and variations of them, and had to work for as much as six weeks on some in order to determine the engine performance under part-load conditions. This process is a continuing one; new cycles, new modifications to old cycles, detailed changes in aerodynamics, such as boundary-layer bleeding; in mechanical design, such as adjustable turbine nozzles; and in thermodynamics, such as by-pass reheat, are continually making necessary the revision and re-working of performance calculations. As a result of all this work we have, we believe, obtained some idea of where the gas turbine is likely to be used and what form it will take.

The Establishment's Programme.

We have always believed that the gas turbine is essentially an aerodynamic machine, and our programme of work has faithfully reflected this belief. At the front of our aerodynamic programme has been our work on the deflection of air by a cascade of blades, since it is on this deflection that the performance of compressors and turbines depends. In 1945, our attitude towards the general problem of flow through blade cascades was one of great optimism. Such optimism is usually due to a failure to appreciate the true difficulties of the problem. In this instance, though we had, for example, considerable success in correlating the overall performance of the F.2 axial compressor with cascade data, we had not realised that, owing to its high hub ratio, this compressor represented a particularly easy subject.

Our general philosophy for the design of axial compressors and turbines was based on the use of two-dimensional cascade test data, corrected for three-dimensional effects. We believed that it should become possible, in time, to produce a family of curves giving the two-dimensional performance of a blade profile when arranged in cascade with any desired pitch-chord ratio, stagger or incidence. From these pictures, one for each profile, it should be possible to pick the desired design conditions, correct for three-dimensional effects, and thus obtain the performance of a single-stage compressor. We retain this belief to this day with one great modification. We have already produced the integral picture for the performance of the aerofoil which we know as C.1 under any conditions of operation and we have proved that its use accurately predicts the single-stage compressor performance. Where we have failed and have had to modify our outlook is in the application of our cascade data to compressors of small hub-ratio, having, that is to say, blades which are long in relation to the compressor diameter. In compressors such as these, the radial flows which take place make it impossible, with present knowledge, always to predict the position of the surge line.

Once the single-stage performance is known, the overall multi-stage performance is predicted by the addition of the appropriate number of stages. We used to do this by simple addition, in the belief that one stage would act independently of the presence of the adjacent stages. We now know that the tests on which this belief was based were misleading and that we have to apply a correction, known as a variable work-done factor, to take account of the fact that there is a progressive change through the compressor of the variation of axial velocity with radius; in other words, a thickening of the boundary layer takes place.

In some respects, we have, during the last five years, made great progress in a circle, returning approximately to our starting point. For example, all our early work on compressor blading was done on blades with a circular-arc backbone. Simple theory, confirmed by misleading wind-tunnel tests, then made it clear to us that a change to a parabolic-arc camber line would give better performance at high Mach numbers. We therefore started new programmes of cascade testing to give the necessary basic data on parabolic-arc blades. It was only after a more rigorous theoretical approach had been made, confirmed later by high-speed testing, that we realised that the parabolic blading, while giving higher choking flows, had appreciably lower critical Mach numbers; so we returned to circular-arc blades. Unless some new base profile is introduced, the basic data now available are probably adequate and little further routine wind-tunnel testing will be necessary. Our wind tunnels are therefore being diverted to other uses and attention is being concentrated to an increasing extent on the performance of rotating machinery.

Perhaps the biggest unknowns in axial-compressor design to-day are, first, the effects of Reynolds number on performance, effects now known to be dependent on the blade design and arrangement; and second, the conditions which determine the position of the surge line. This last problem is a most mysterious one. The great bulk of compressors develop their design capacity and surge at predicted mass flow; but occasionally, and for no apparent reason, someone designs a compressor with a surge capacity as much as 10 per cent. above or below the predicted value.

In spite of the false starts, the changes in direction, the failures of judgment and of understanding, which are inevitable in work designed to extend the frontiers of knowledge, great progress has been made. The overall result of the increase in knowledge which has been attained is that the polytropic compressor efficiency has risen from about 88 per cent. to about 91 per cent. and the maximum pressure ratio attainable from an axial compressor, which was about $4\frac{1}{2}:1$ in 1945, is now over $7:1$, being greater than is required for most gas-turbine applications. We now have the essential data on which the aerodynamic design of compressors and turbines is based.

The other essential component of the gas turbine, the combustion chamber, also has its problems. Combustion is a particularly difficult subject to study, in that it involves aerodynamic, chemical and physical problems. It was a pre-occupation of many organisations and interests long before the first gas turbine ever ran. The only excuse for the turbine engineer entering this field is that he has introduced all the old problems in a more acute form and, at the same time, offered a new philosophy or outlook to assist in dealing with them. He could, of course, have taken a Primus stove or the blow lamp as they stand, or he could have burnt heavy oil in the same way as it has been burnt under marine boilers for several decades; but the gas-turbine engineer wanted less space and a higher temperature and so again decided to make a fresh start. He has, therefore, become very interested in combustion, and, to understand it properly, he has turned to a study of its fundamentals.

An understanding of the processes of combustion involves a knowledge of a variety of processes, for many of which the basic data are not in existence. One of our tasks over the last few years, therefore, has been that of filling in these gaps in our knowledge. We have developed an experimental technique for measuring the spontaneous ignition temperatures of fuels. From this work, we have established the ignition delays for a variety of fuels under turbine operating conditions and measured their variation with pressure. A fairly complete picture of the mechanism of evaporation of a liquid fuel droplet has been built up. It has been found that, at high temperatures, the effect of fuel volatility is negligible, while at low temperatures its effect dominates the whole process. Again, it has been shown that the drag of a droplet increases upon burning at low Reynolds number and decreases when the Reynolds number during combustion is high. The formation of cenospheres and coke-like particules as the result of the combustion of heavy fuel has been demonstrated and explained. The effects of air vitiation upon the processes of combustion have been determined and their influence on the design of a chamber with exhaust-gas recirculation have been demonstrated.

Apart from our work in providing basic data, we have worked on a variety of more practical problems, selected in accordance with the general philosophy outlined above. An important problem, and one which is in every respect suitable for being worked on at the Establishment, is the cooled turbine. Although considerable thought had for some years been given to the problem of turbine cooling, it was not until late 1945 that we were in a position to make a serious start. At that date, we were aware of the work done in Germany during the war. We were not attracted by it, partly for obvious psychological reasons and partly on technical grounds which I believe to be valid.

We started the work with a clear preference for the use of water cooling. Within a year, we had come to believe that liquid cooling—using a substance other than water—was the most desirable method, but that air cooling was very much easier. When the moment came for a decision to be made, we decided that the first blades to be tested should be air-cooled, with the air passing radially through them, and that these should be followed up by blades internally cooled by water in Perkins tubes.

Looking back on the discussions we had during the early days of this work, I am struck by the way the human mind refuses to accept the correct solution to a problem until it has laboriously examined in turn all the alternatives which in retrospect look merely silly. I can well remember how, for months, I was firmly convinced that the cooled blade was going to be a solid metal blade with a ceramic sheathing to give a temperature drop and protection from oxidation, the heat being removed by cooling in the rotor. This and many other schemes had to be considered and rejected before we reached the methods at present in use.

During the last five years much ground has been covered and much information has been gained. We have tested various forms of blade in wind tunnels up to 1,200 deg. C. in order to determine the heat transfer coefficients, both gas to metal and metal to air. We have carried farther our experiments with Perkins tubes, we have tested a turbine with blades internally cooled with water, another with blades externally cooled by water sprays, and yet another with blades internally cooled by air. We have developed combustion chambers operating at temperatures up to 1,200 deg. C.; we have experimented with ducting and chambers having cooled

ELECTRICALLY-OPERATED TRAFFIC BARRIER.

WESTINGHOUSE BRAKE AND SIGNAL CO., LTD., LONDON.

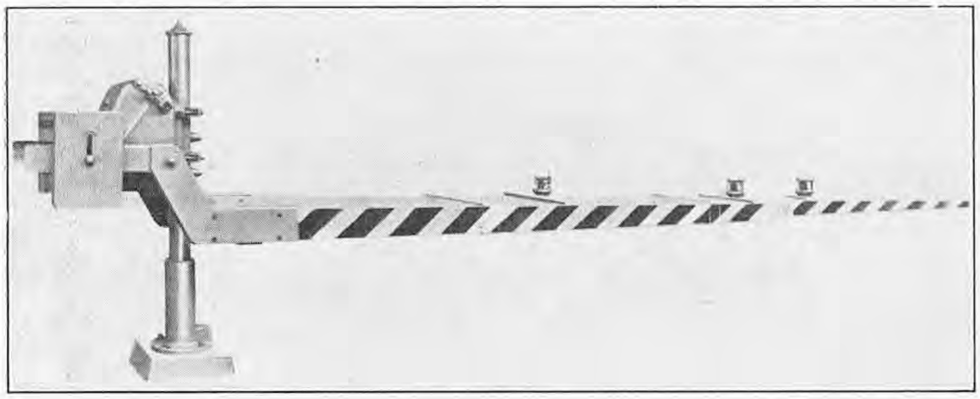


FIG. 1. COMPLETE BARRIER.

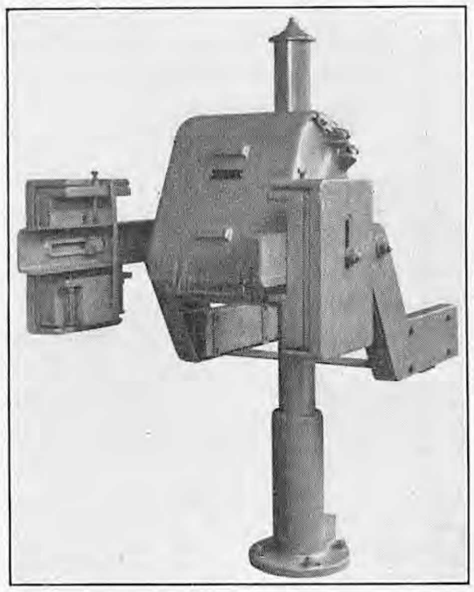


FIG. 2. OPERATING PILLAR AND COUNTER-WEIGHTS.

liners made from porous and other materials. After all this experience our original view, that liquid cooling is better than air, but more difficult, still holds good.

The work has been remarkable for the consistency with which our views have been held, the principal inconsistency being the way in which our judgment as to the most important problem has shifted, back and forth, between the problem of manufacture of a cooled blade, on the one hand, and the problem of cooling large areas of stationary ducting without excessive heat loss, on the other. Our current view is that the problem of cooling ducting has now been solved, but we have yet to see a design for an inexpensive, but efficient, cooled blade.

The work that we have done on heat exchangers, on the other hand, may be cited as an example in which our attitude of mind has changed considerably. When we commenced work on heat exchangers in 1946, we felt that the conventional recuperator of shell and tube or plate construction did not offer problems for which research might provide solutions. We therefore decided to start work on the rotary regenerative heat exchanger. A preliminary theoretical study of the possibilities of this kind of heat exchanger had made it clear that there was certainly a sealing problem; but the problem was one that we felt straightforward development could deal with. We were more concerned with the chance of there being some other unguessed-at difficulties, which, when revealed, might make it clear that this type of machine was impracticable; so, having decided that we could not foresee the problems and deal with them separately we decided to make a heat exchanger and see what happened. What emerged from the practical test was that there were no unexpected difficulties. Fouling, even when running on heavy fuel, could be controlled by soot-blowing; the heat transfer data were readily obtained and could be reconciled with theory, and mechanical reliability was satisfactory. Only the problem of sealing remained.

In conformity with our principles, we had been reluctant to embark on the problem of sealing, which we had considered to be a development problem more appropriate to industry. Our early progress reports did not, however, arouse the interest that we had hoped, and it seemed clear that industry, sceptical as ever, was awaiting a more practical demonstration. We decided, therefore, that we would ourselves either have to solve the sealing problem or to demonstrate very clearly that it could be solved. We have now carried this work as far as our resources will allow and have convinced ourselves that this problem has been solved. The immediate future will show whether we have succeeded in convincing other people.

Now that we have had some years' experience of heat exchangers, a change in our attitude towards them may be detected. To explain this, I must go off at a tangent. The minimum weight and bulk of any vehicle is very dependent on the weight and bulk of its power plant. This is well recognised in the aircraft world and the fact is exploited to the full. Road transport has already begun to appreciate the point and to realise that, by saving engine weight and bulk, you indirectly save fuel by reducing the weight of the vehicle. But in the railway and marine worlds, I do not think that it is realised how much smaller the vehicle could be made if more attention were paid to the design of the power unit. The most ravenous consumer of bulk and weight is the heat exchanger. Until recently we had to accept it as the only method of giving good fuel consumption. Now, however, the cooled high-pressure engine is on the point of emerging as a competitor and one which, we believe, is likely in the long run to win the day. We have therefore brought our work on heat exchangers to an end.

CONCLUSION.

Before I come to my conclusion, I should like to draw a moral. It is very easy to make experiments, but very difficult to deduce worth-while knowledge from them. In a field in which the problems to be solved greatly outnumber the facilities available for their solution, there is, paradoxically, a positive virtue in inaction—provided, of course, that inaction leads to more thought. It is only by the greatest possible use of really high-level thought that we can pick out the very few things that are worth doing and refrain from the great bulk of possible actions which are nothing more than beating the air. By such restraint we can ensure that our limited resources are used so that, when we do take action and make an experiment, there is an increased likelihood of a positive answer emerging. My moral is, therefore, "When in doubt, don't."

It is always very difficult to know what to put in and what to leave out when one is giving an account of the activities of an organisation. I have avoided this difficulty by concentrating on the philosophy that has guided us, selecting items of research primarily as illustrations of our outlook. I have, therefore, made no mention of many pieces of work, which, important though they may be in their end results, do not appear relevant to the theme. It is, of course, well known that good judgment, intuition or whatever you like to call it—essential for the successful research worker and not at all a bad thing for other people as well—must be based on the correct interpretation of experience. This experience, so far as we have been able to gain it at all, has been built up on a mass of theoretical and experimental work, much of it of a rather humdrum character. It is based on the tests of many engines, of dozens of compressors, turbines and heat exchangers, scores of combustion systems and hundreds of minor accessories. All this background of experience, when boiled down and crystallised out, affects one's outlook and forms one's philosophy. If my own philosophy—my attitude towards machinery—had to be expressed in two sentences I would borrow one from Henry Ford—

"Simplify and add lightness";

and one from James Watt—

"In all things, but proverbially in mechanism, the supreme excellence is simplicity."

ELECTRICALLY-OPERATED TRAFFIC BARRIER.

THE Westinghouse Brake and Signal Company, Limited, York Way, King's Cross, London, N.1, are now manufacturing an electrically-operated barrier for the protection of highway crossings or for controlling traffic in factories and other places. The barrier, which is illustrated in Fig. 1, consists of a $5\frac{1}{2}$-in. diameter tubular post to which the electrically-driven operating mechanism is attached. This mechanism raises the barrier arm from the horizontal to the vertical position, where it is held by an electric brake so that it is clear of the traffic. As shown in Fig. 2, counterweights are provided and can be adjusted so that barriers up to 38 ft. long can be made to descend to the horizontal position at a speed which is governed by a rheostatic brake. The direction of movement of the barrier can be reversed at any time during its descent and it can then be raised to the vertical position, should this be necessary. Spring buffers are fitted inside the case containing the driving mechanism to bring it to rest in the event of the barrier being broken when it is in the horizontal position or if the counterweights are put out of action while it is vertical. The position of the barrier in both the raised and lowered positions can be altered by adjusting stops on the buffers, thus correcting any tendency to droop.

As regards operation, the main shaft of the mechanism is driven by a 12-volt or 24-volt direct-current series motor through gearing and a friction clutch, the supply of electricity for this purpose being preferably obtained from a secondary battery. Alternatively, a hand generator can be used, the necessary hold-off current then being drawn from primary cells. The control circuit consists of a single wire and earth return and, when closed, excites the brake magnet so that the brake itself is released. The reactance is then disconnected, the motor connected to the line and the brake again applied through a change-over contact. As the brake acts through a free-wheel, the motor can raise the barrier but cannot lower it. When the barrier has moved through about 85 deg., the circuit is broken by a quick-acting switch, so that the motor comes to rest and is then prevented from rotating in the opposite direction by the brake. The barrier is therefore secured in the vertical position. The current required for this purpose is reduced to a minimum by opening a contact across the high-resistance portion of the brake-magnet winding.

To lower the barrier the control circuit is de-energised. This releases the brake and allows the barrier to descend under its own weight. During this operation rheostatic braking is provided by short-circuiting the motor, which is then running in the reverse direction, through a resistance, the value of which can be adjusted to vary the time of descent. Hand operation is possible if the power supply fails.

ANNUALS AND REFERENCE BOOKS.

Handbook of Tide Tables, Particulars of Docks, etc., 1953.

Port of London Authority, Tower Hill, London, E.C.3. [Price 3s.]

THE title of this pocketbook indicates the main sections of the contents, but there is also a considerable amount of varied information embraced in the "etc." It includes a table of distances above and below London Bridge within the limits of the Authority's jurisdiction, which extends upstream to Teddington lock (18·62 miles along the river) and downstream to a line drawn between Warden Point, Kent, and Havengore Creek, Essex (50·05 miles). Particulars are also given of the lengths of quays and the individual depths of water alongside them down to and including the Tilbury docks; and the dimensions of the graving docks (again including those at Tilbury) with any structural peculiarities, such as vertical side walls, which affect the docking of ships. It is noted that the total area of the P.L.A. estate is 4,140¾ acres (more than 6 square miles) and that the total length of the quays, excluding the Surrey Canal, is nearly 36 miles.

Whitaker's Almanack, 1953.

J. Whitaker and Sons, Limited, 13, Bedford-square, London, W.C.1. [Price, in cloth boards, 15s.; shorter edition, in paper covers, 7s. 6d.; library edition, bound in leather and with coloured maps, 30s.]

THE 1953—"Coronation Year"—edition of *Whitaker* is stated to be the largest yet published, containing 1,174 pages. It is adorned (the word is justified in full) by a coloured frontispiece of Her Majesty the Queen; "as is customary," the publishers' letter observed with the dignity of 85 years, "with the first edition of a new reign." In the years immediately following the war, many of the annual summaries tended to fall behind, but this shortcoming has now been remedied and the "Diary of the Year's Events" and the obituary notices are now up to date to the end of September 1952. The usual features—astronomical, administrative, statistical, political, etc.—are in their usual places, several being amplified by comparison with last year's issue; and the new features include a section on broadcasting, in the "Annual Summaries," with references to many of the more important stations, and, in the directory section, there is now a list of all the trades unions affiliated to the Trades Union Congress, with the addresses and the names of the secretaries. There is still, however, some more restoration of former features that might be done; for example, the index lists a full column of entries under "Royal Navy," but none of them mentions warships, even as "global tonnage."

The African Press and Advertising Annual, 1952-53.

CHAS. R. PASK, managing editor; BARON V. M. FREDERICKSZ, associate editor. Published at 616, Boston House, Strand-street, Cape Town, South Africa (P.O. Box 334). [Price 25s., including postage.]

THIS is the fourth edition of an annual which incorporates the former *South African Advertising Annual and Press Guide*. It covers all publications, including annuals, quarterlies, directories, native-language papers, etc., as well as newspapers and trade, technical, industrial and professional periodicals produced in the 36 countries or territories indicated on the key map facing the title-page, giving particulars of their type area, screens used, advertisement charges, and closing dates for the receipt of advertising copy. Summarised statistical and other data for the various countries are provided, and the directory sections contain all the necessary information to enable an intending advertiser to select publicity agents, etc., covering the field in which he is interested, including broadcasting. The last 50 pages or so are devoted to a "Who's Who in Advertising and the Press."

ELECTRICITY SUPPLY STATISTICS—During November, 1952, 5,982 million kilowatt-hours were generated in stations under the control of the British Electricity Authority, the North of Scotland Hydro-Electric Board and the Lochaber Power Company, compared with 5,489 million kilowatt-hours during the corresponding period of the previous year. Of this total 5,788 million kilowatt-hours were generated in steam stations. At the end of November, 1952, the installed capacity was 16,607 MW, an increase of 172 MW during the month. During the preceding twelve months the increase was 1,473 MW.

FLOOR PLANER.

THE accompanying illustration shows what is claimed to be the first mass-produced machine for planing wooden floors. A light-alloy casting houses the undercarriage and the cutter block, and also forms a platform on which the power unit is mounted. The cutter block, made of cast iron, is carried in a double row of self-aligning ball bearings and is fitted with two knives, each 8 in. long, secured to the block by set screws. A gauge is used to check the setting of the knives, which are of high-speed steel. Double V-belts transmit the drive to the cutter block from the power unit, any slack in the belt being taken up by adjusting the position of the motor along the top of the body. The machine can be fitted with an electric motor or a petrol engine, giving 4,200 cuts per minute. When working, the machine is drawn backwards, its weight being

shared between two ball-bearing wheels under the column and a front track roller which always runs on the newly-planed floor. In order to bring the knives into a working position, the cutter block is lowered on to the floor by retracting the undercarriage, which is controlled through a flexible cable by the hand lever located at the head of the steering column. The depth of cut made by the knives can be varied from zero to ¼ in. by a screw and lock-nut located on top of the cutter housing just behind the column. A metal deflector behind the cutter block throws the wooden chips out of the machine and clear of the work.

The illustration shows the planer equipped with a 1½-h.p. electric motor which can be either a direct-current or a single-phase alternating-current machine; it can be wired for any normal voltage. The motor, protected by two 30-ampere fuses, is controlled by a two-pole switch and is supplied with 50 ft. of industrial-weight trailing cable. The alternative power unit, interchangeable with the electric motor, is a 2·4-h.p. J.A.P. petrol engine, air-cooled and fitted with a special air-filter to protect it from wood dust.

The planer is made by Nufloor, Limited, 34, Lauriston-road, London, E.9. The body and column are spray-finished and rubber buffers are fitted along the front of the body. Although designed specifically for planing floors, its wider application was demonstrated recently during the maintenance work that has been carried out on the deck of the Hammersmith Bridge over the River Thames. The deck of the bridge was carried on timber baulks which required re-levelling; instead of having to lift the baulks out of their beds, transport them to timber mills for machining and then re-lay them, floor planers did the work *in situ*.

BOOKS RECEIVED.

Report of the Road Research Board, with the Report of the Director of Road Research for the Year 1951. H.M. Stationery Office, Kingsway, London, W.C.2. [Price 3s. 6d. net.]

United States Productivity Team Report. The British Cotton Industry. Report of a Productivity Team from the United States of America which Visited the United Kingdom in 1951. Office of Technical Services, Department of Commerce, Washington, D.C., U.S.A. [Price on application]; and British Productivity Council, 21, Tothill-street, London, S.W.1. [Price 3s.]

Overseas Economic Surveys. Libya. By H. J. LEGG. H.M. Stationery Office, Kingsway, London, W.C.2. [Price 1s. 9d. net.]

Calculus of Variations, with Applications to Physics and Engineering. By PROFESSOR ROBERT WEINSTOCK. McGraw-Hill Book Company Incorporated, 330, West 42nd-street, New York 36, U.S.A. [Price 6.50 dols.]; and McGraw-Hill Publishing Company Limited, 95, Farringdon-street, London, E.C.4. [Price 55s. 6d.]

Handbook of Tide Tables, Particulars of Docks, etc. 1953. Port of London Authority, Tower Hill, London, E.C.3. [Price 3s.]

Railway Commercial Practice. By H. F. SANDERSON. Vol. II. *Freight.* Chapman and Hall, Limited, 37, Essex-street, London, W.C.2. [Price 30s. net.]

Ministry of Transport. Railway Accidents. Report on the Derailment which Occurred on 18th April, 1952, at Blea Moor Between Dent and Ribblehead in the London Midland Region, British Railways. H.M. Stationery Office, Kingsway, London, W.C.2. [Price 6d. net.]

Practical Mathematics, being the Essentials of Arithmetic, Geometry, Algebra and Trigonometry. By the late PROFESSOR CLAUDE IRWIN PALMER and SAMUEL FLETCHER BIBB. Fourth edition. McGraw-Hill Book Company, Incorporated, 330, West 42nd-street, New York 36, U.S.A. [Price 6 dols.]; and McGraw-Hill Publishing Company, Limited, 95, Farringdon-street, London, E.C.4. [Price 48s.]

Fundamentals of Engineering Electronics. By PROFESSOR WILLIAM G. DOW. Second edition. John Wiley and Sons, Incorporated, 440, Fourth-avenue, New York 16, U.S.A. [Price 8.50 dols.]; and Chapman and Hall, Limited, 37, Essex-street, London, W.C.2. [Price 68s. net.]

Fatigue and Fracture of Metals. A Symposium held at the Massachusetts Institute of Technology, June 19-22, 1950. Edited by PROFESSOR WILLIAM M. MURRAY. Published jointly by the Technology Press of the Massachusetts Institute of Technology and John Wiley and Sons, Incorporated, 440, Fourth-avenue, New York 16, U.S.A. [Price 6 dols.]; and Chapman and Hall, Limited, 37, Essex-street, London, W.C.2. [Price 48s. net.]

Thermodynamique. By PROFESSOR Y. ROCARD. Masson et Compagnie, 120, Boulevard Saint-Germain, Paris (6e). [Price 3,650 francs in paper covers; 4,150 francs bound.]

The World's Oilfields. The Eastern Hemisphere. The Science of Petroleum Vol. VI, Part I. Edited by PROFESSOR V. C. ILLING. Oxford University Press (Geoffrey Cumberlege), Amen House, Warwick-square, London, E.C.4. [Price 52s. 6d. net.]

State Electricity Commission of Queensland. Fifteenth Report. 1952. Offices of the Commission, Scottish Union House, Eagle-street, Brisbane, Australia.

Introduction to Statistical Calculations. By J. MOUNSEY. English Universities Press, Limited, St. Paul's House, Warwick-square, London, E.C.4. [Price 15s. net.]

ASTM-IP Petroleum Measurement Tables. British edition. British (Imperial) Units of Measurement. Prepared jointly by the American Society for Testing Materials and the Institute of Petroleum. The Institute of Petroleum, 26, Portland-place, London, W.1. [Price 50s., post free.]

Post-War Building Studies. No. 29. *Fire Grading of Buildings. Part II. Fire Fighting Equipment. Part III. Personal Safety. Part IV. Chimneys and Flues.* By a Joint Committee of the Building Research Board and of the Fire Offices' Committee. H.M. Stationery Office, Kingsway, London, W.C.2. [Price 4s. 6d. net.]

Design and Use of Cutting Tools. By LEO J. ST. CLAIR. McGraw-Hill Book Company, Incorporated, 330, West 42nd-street, New York 36, U.S.A. [Price 7 dols.] and McGraw-Hill Publishing Company, Limited, 95, Farringdon-street, London, E.C.4. [Price 59s. 6d.]

Practical Calculus. By CLAUDE IRWIN PALMER and PROFESSOR CLAUDE E. STOUT. Second edition. McGraw-Hill Book Company, Incorporated, 330, West 42nd-street, New York 36, U.S.A. [Price 6.50 dols.]; and McGraw-Hill Publishing Company, Limited, 95, Farringdon-street, London, E.C.4. [Price 51s.]

Writing the Technical Report. By PROFESSOR J. RALEIGH NELSON. Third edition. McGraw-Hill Book Company Incorporated, 330, West 42nd-street, New York 36, U.S.A. [Price 4.50 dols.]; and McGraw-Hill Publishing Company, Limited, 95, Farringdon-street, London, E.C.4. [Price 38s. 6d.]