

THE LATERAL STABILITY OF UNRESTRAINED BEAMS.

By A. R. FLINT, B.Sc., Ph.D.

If a structural beam is of slender proportions, and is not provided with adequate support against buckling, it may become laterally unstable and collapse under a critical loading condition. Recently revised Codes of Practice present design rules for the estimation of permissible flange stresses, based on the critical bending moment for a beam under end couples applied in its plane of greatest stiffness. The majority of beams incorporated in engineering structures, however, are subjected to bending loads which give rise to a non-uniform distribution of bending moment across the span. The safe stresses in such members are higher than those predicted from design formulæ, and economy in materials may be effected if the designer is permitted to increase his working stress by an amount governed by the conditions of loading.

through a point on the cross-section in the plane of maximum bending stiffness, its line of action passing through the shear centre. The load is assumed to be free to move sideways with the beam, and its line of action to remain vertical. Under these conditions, the member will become unstable at a certain critical load, the magnitude of which depends upon the span and upon the constants of the beam and its material.

A test rig was constructed which was capable of simulating these conditions of loading and support, and was used to test a number of xylonite model beams. The models were supported by means of wire stays in rigid frames and were loaded by dead weight as shown in Fig. 1, herewith. A load hanger was suspended from a pulley hung on a rope loop which, in turn, passed over a light disc clamped to the beam section. This system ensured that the idealised conditions were attained, the effective point of application of the load being at the centre of the disc. A large test rig was subsequently developed, capable of testing steel and light-alloy beams of up to 15 ft. span and with a maximum section of

When the critical load is reached, the beam will remain in a state of neutral equilibrium in any slightly displaced position, such as that shown in Fig. 1. The critical load is then given* by

$$P_{crit.} = \frac{16.92}{L^2} \sqrt{\frac{EI_1 GJ}{\gamma}} \quad (1)$$

The critical stress is defined as the maximum stress on the span immediately prior to buckling, i.e.,

$$F_c = \frac{P_{crit.} L}{4Z_2} = \frac{4.23}{Z_2 L} \sqrt{\frac{EI_1 GJ}{\gamma}} \quad (2)$$

where I_1, I_2 are the second moments of area of the section in the planes of minimum and maximum stiffness, respectively; E, G , are the moduli of elasticity and rigidity, respectively; J is the torsion constant; L is the span; Z_2 is the maximum modulus of section, and $\gamma = \frac{I_2 - I_1}{I_2}$.

These formulæ are only satisfactory for slender members, and the influence of warping of the section during torsion must be included in estimates of buckling stresses for "stocky" beams. It has been shown† that the above expression may be modified to allow for warping effects to give an accurate value for the critical stress, as

$$F'_c = F_c \sqrt{1 + \frac{\alpha \pi^2 C}{GJL^2}} \quad (3)$$

in which F'_c is the true critical stress; F_c is given by equation (2); α is a numerical constant dependent on end conditions ($= 1$ for free ends); C is the warping constant $= \frac{EI_F h^2}{2}$ for I beams; and

$C = \frac{EI_F h^2}{2} \left(1 + \frac{t_w h^3}{4I_2} \right)$ for channels, where I_F is the maximum second moment of area of one flange, t_w is the web thickness, and h is the distance between flange centroids.

The numerical factor, α , is unity for the idealised end conditions assumed above. The increase in the buckling stress afforded by the warping resistance of the section may be conveniently plotted as shown in Fig. 2, page 66, in which the warping "stiffness," $\frac{GJL^2}{C}$, is related to the ratio, n , of the true critical load to that estimated from equation (2) for members with unrestrained ends.

If, however, the ends of a joist are welded to a relatively rigid stanchion or are set in concrete, there will be an additional warping restraint. This again increases the effective torsional stiffness of the member and, in consequence, raises its buckling load. The upper curve in Fig. 2 shows the influence of this restraint on the stability of the beam and is derived from mathematical analysis of the problem.‡ The increased critical stress may be conveniently estimated by introducing an empirical factor, α , into equation (3), and for practical purposes it will prove safe to assume that $\alpha = 2$ where ends are rigidly restrained against warping.

This type of restraint may be achieved in members in which the ends are not "built in." Stiffeners may be welded between the web and flanges at several positions adjacent to the supports, or thick stiffeners may be welded between the edges of the flanges in the direction of the beam axis, to form a short length of box section near the ends.

A further factor to be considered in investigating the stability of a beam is the height of the point of application of a point load above or below the shear centre. When the load is applied at the top flange of an I beam, for instance, its critical value falls below that given by the above formulæ, and, conversely, exceeds the estimated value when attached below the shear centre. This is due to the additional couple which is exerted by the load about the shear centre when buckling occurs, as a result of the vertical eccentricity of application. Mathematical solutions to the behaviour of beams under point load at mid-span with vertical eccentricity of load have been obtained by both analytical and strain-energy methods, and the results are

* "Elastic Stability of Long Beams under Transverse Forces," by A. G. M. Mitchell. *Phil. Mag.*, vol. 48 (1899).

† *Theory of Elastic Stability*, by S. Timoshenko. McGraw-Hill Publishing Co., Ltd.

‡ "On the Lateral Stability of Beams," by A. R. Flint. Ph.D. dissertation, Bristol University, 1948 (unpublished).

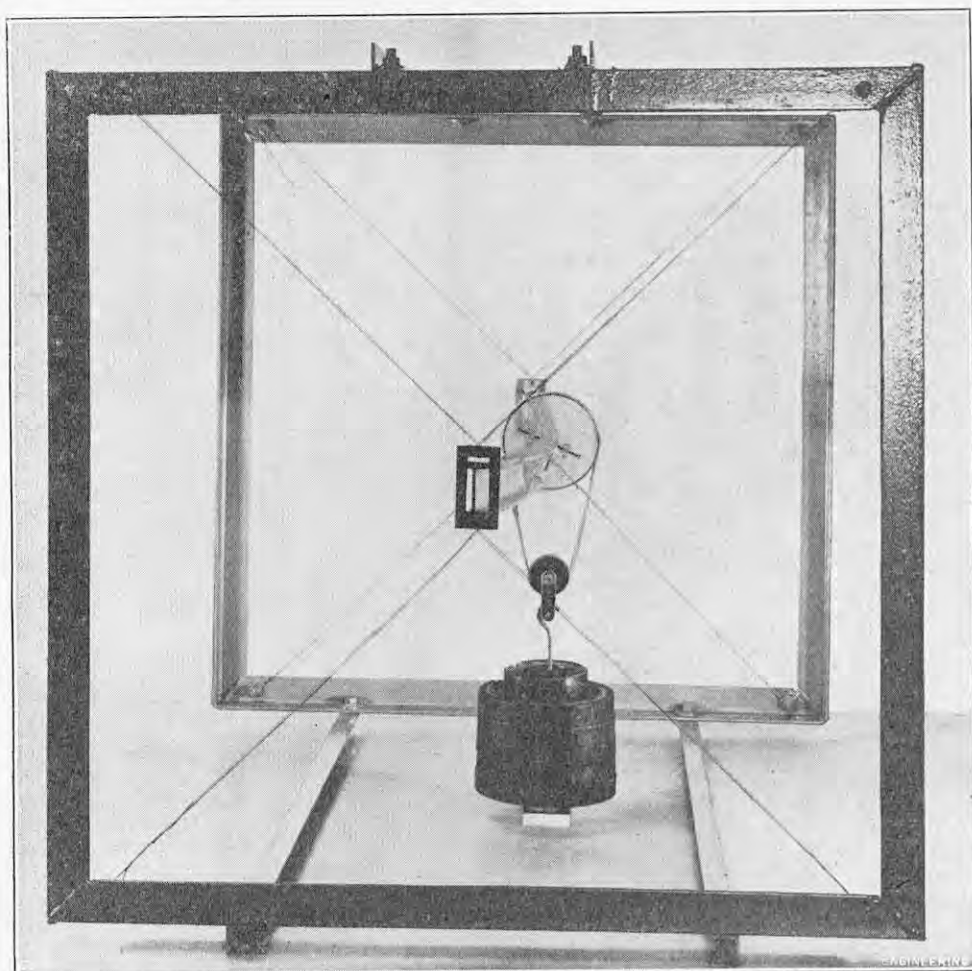


FIG. 1. METHOD OF SUPPORTING AND LOADING MODEL BEAM.

Though a number of mathematical solutions have been obtained to the problems of the buckling of beams under point loads, there has been little experimental verification of this work. Tests have usually been carried out in testing machines affording restraint to lateral and torsional movement along the span, and providing impractical conditions of support. In order to check existing and extended theory, series of tests on model and small standard beams have been carried out in the Engineering Laboratories of the University of Bristol, in which lateral stability has been studied under controlled conditions. It is apparent from the results of these tests that existing theory may be readily used to estimate the critical values of point loads. Design formulæ may be modified to allow for the influence of load positions and to include the effects of warping of cross-sections of the beam under torsion.

It is generally assumed, as a basis for theoretical solutions, that a beam is supported at its ends in such a way that free bending actions and axial movement may occur, but that no torsional movement is allowed at the supports. Load is applied

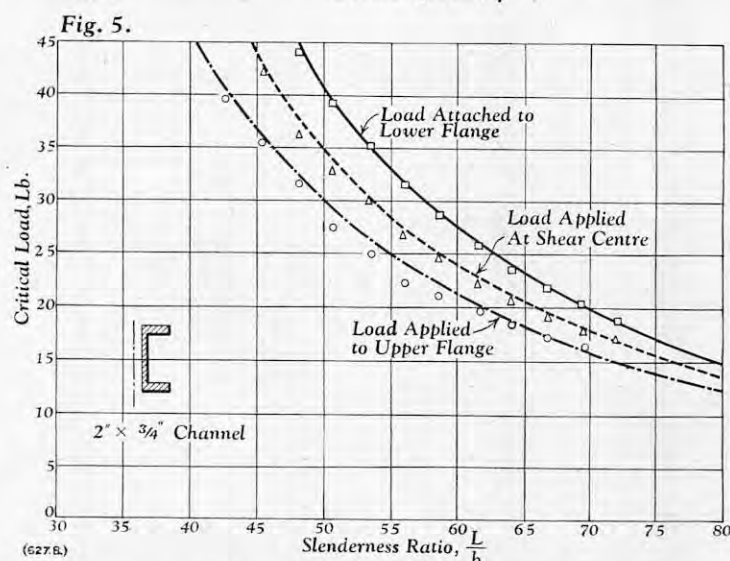
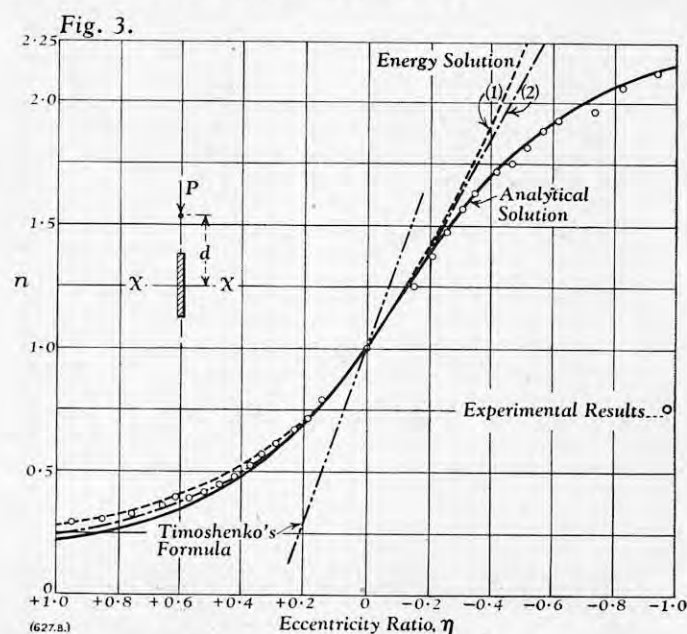
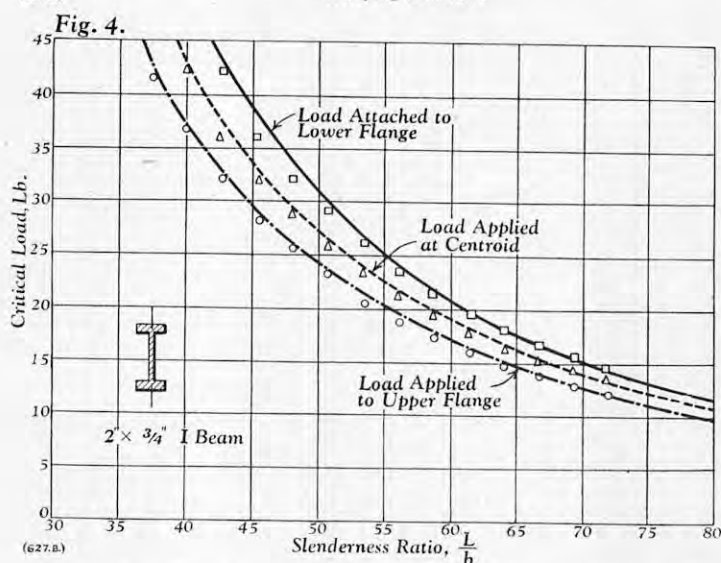
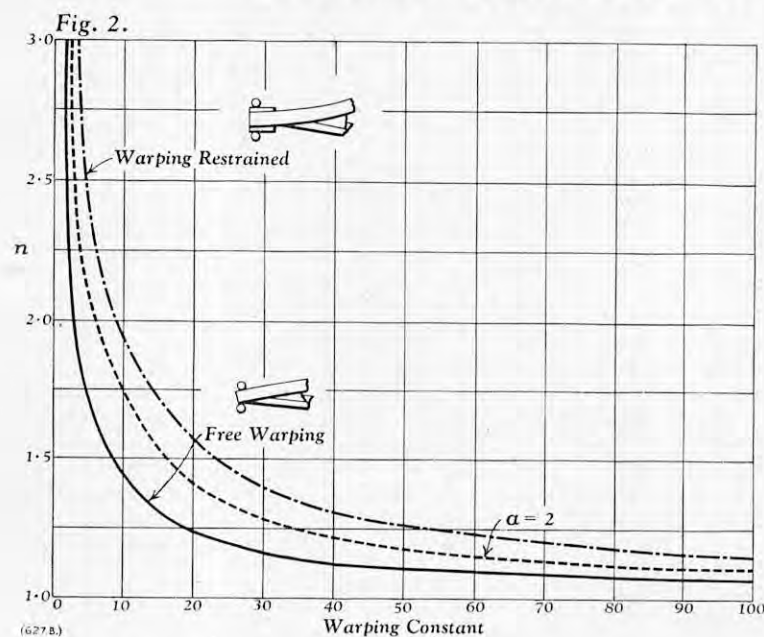
4 in. by 2 in. A load of 1 ton could be applied by means of water tanks attached to steel loading discs.* By use of these two rigs, a number of beams of different cross-section were tested, and their critical loads were observed with various positions of load application.

Beams under Point Load at Mid-Span.—Though the stability of beams under point load at mid-span has been analysed by several authors, there has been little experimental evidence to justify their conclusions. The influence of warping restraint, and of application of load above or below the shear centre, have not been fully appreciated or allowed for in design formulæ.

Consider a slender beam, loaded by a point load P applied at the shear centre at mid-span. The member is assumed to contain no initial distortion along its length, and the stress prior to buckling to be less than the limit of proportionality of the material.

* See "The Stability and Strength of Slender Beams," by A. R. Flint. Paper presented to British Association Meeting, 1950. *ENGINEERING*, vol. 170, page 545 (1950).

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shown graphically in Fig. 3, herewith. The ratio, n , between the true buckling load and the buckling load for zero eccentricity is related to a non-dimensional eccentricity ratio, $\eta = \frac{d}{L} \sqrt{\frac{EI_1}{GJ\gamma}}$, where d is the

height of the point of load application above the shear centre. (η is negative when the eccentricity is downwards.) The line of action of the load is assumed to pass through the shear centre prior to buckling.

The curves numbered (1) and (2) in Fig. 3, represent the strain-energy solutions obtained by assuming one and two terms, respectively, in the trigonometrical series for the buckled form. These are seen to be in error for large downwards eccentricities. When the load is applied at a considerable distance below the beam, it is found that the critical load tends towards that for failure in the second mode, at a value of 2.7 times the fundamental critical load. In this mode there is no rotation at mid-span, and an anti-symmetric buckled form. The practical range, however, assuming loads to be either applied to the top flange or attached to the lower flange, lies between $\eta = -0.2$ and $+0.2$, and the $n - \eta$ relationship is found to be nearly linear over this range. The first energy solution yields

$$F_c'' = F_c' \left\{ \sqrt{1 + 3.02 \eta^2} - 1.733 \eta \right\}, \quad (4)$$

where F_c'' is the true critical stress and F_c' is given by equation (3).

Thus, over the useful range of values, where η is small, we may write:

$$n = \frac{F_c''}{F_c'} = 1 - 1.733 \eta, \quad (5)$$

from which the true critical stress and load may be

easily evaluated. The approximation suggested by Timoshenko, namely, $n = 1 - 3.48 \eta$, is seen to be considerably in error.

It is seen that the variables in the expressions for critical load and stress for a given beam are the span and the distance of the point of application above or below the shear centre. Buckling loads, estimated by substitution of the measured beam constants into equation (4), have been compared with observed values for a number of beams of both model and small standard dimensions. The members were tested with three positions of load application on the section over a range of spans, the maximum stresses being limited to the elastic limit of the materials. The beams were allowed no overhang at the supports, thereby eliminating any end restraint of warping, which would increase the buckling loads.

The critical load was determined by observing the least load necessary to maintain a member in a slightly displaced position. Initial imperfections being slight, there was little lateral deflection of the beams prior to collapse, and the critical condition was sharply defined, with only about a 2 per cent. possible error in observing the buckling load. The variation of buckling load with flange slenderness is shown for several of the model sections in Figs. 4, 5 and 6, on this and the opposite pages, in which the experimental results are compared with the theoretical curves. The 2-in. by $\frac{3}{4}$ -in. I and channel sections had webs $\frac{1}{8}$ in. thick and flanges $\frac{1}{4}$ in. thick, the other sections having a uniform thickness of $\frac{1}{4}$ in. All these models were fabricated in xylonite.

Three positions of load application were used in tests on the first two beams, whereas the three remaining members were loaded at their shear

centres only. The T section was tested both with the flange in compression and in tension; and, as predicted, there was no observable difference between the buckling loads. This particular case emphasises the inefficiency of the old design data, based solely on the stiffness of the compression flange, which would indicate a marked difference in critical loads for the two positions of the section. The angle beam was supported with its plane of greatest flexural rigidity vertical, and was loaded through the shear centre; this avoided the lateral displacement which otherwise would occur owing to loading in other than a principal plane.

Agreement between estimated and observed values was found to be satisfactory in all cases, the errors nowhere exceeding 5 per cent. The difficulties encountered in the testing of struts, in which it proves extremely difficult to attain the critical load owing to imperfections in loading and shape, were far less important in these preliminary beam tests. The necessity for inclusion of the warping term in the above formulae was evident for members having slenderness ratios less than 50, and the influence of vertical eccentricity of loading was well illustrated in the first series of tests. For example, the buckling load for a 2-in. by $\frac{3}{4}$ -in. channel is reduced by 15 per cent. when the load is applied at the level of the top flange, with a slenderness ratio of 50. Corresponding increases in critical load occur when loads are applied below the shear centre.

Further verification of the effects of vertical eccentricity of load application has been obtained from a series of tests carried out on narrow rectangular beams, 1 in. by $\frac{1}{16}$ in. in section, loaded at mid-span in the rig shown in Fig. 7, opposite. The

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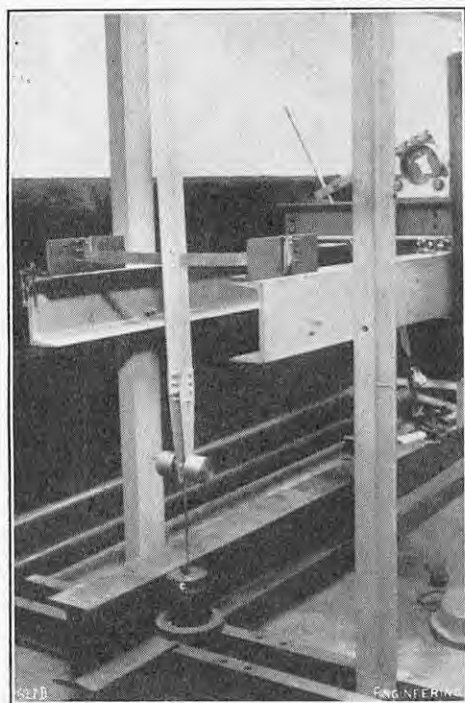
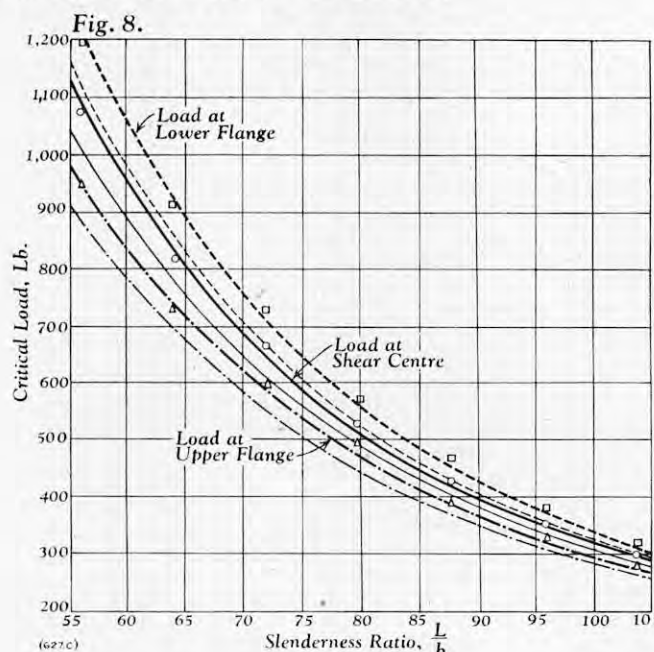
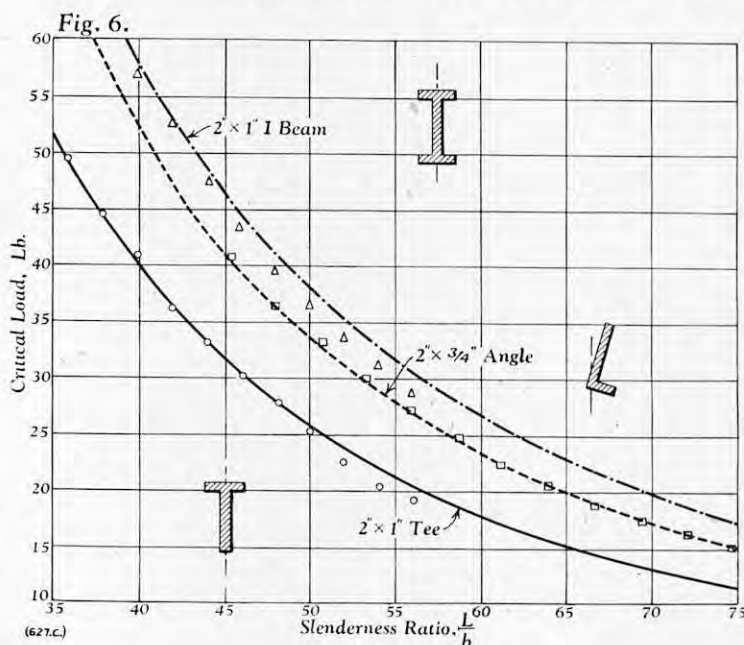


FIG. 7. TEST RIG FOR NARROW RECTANGULAR BEAM.

beams had idealised support conditions, and load was applied to a stiff loading arm clamped to the beam. This arm was mass-balanced about the point of attachment of the load hanger. By adjustment of the clamped position of the arm, the equivalent effect of loading the beam with any desired eccentricity could be obtained. When loaded above the beam, a light yoke was used from which the load was suspended by wires to permit freedom of lateral movement.

The limiting stresses necessitated the use of a light-alloy beam with downwards eccentricity of loading, a steel member being used for eccentricities above the beam to obtain a larger range of values (due to its higher elastic modulus). As in the previous tests, the critical load was taken as that necessary to maintain the system in neutral equilibrium. Results show fair agreement with the analytical solution over a large range of eccentricities as shown in Fig. 3. The test results were reduced to the same non-dimensional basis, and the curves with which they are compared may be applied to a beam of any section or span.

A 3-in. by 1½-in. light-alloy I beam was tested over a range of spans, with rigid restraint of warping

at the supports. Restraint was provided by clamping a length of the section at each end between heavy steel plates, and the effect of the small end couples due to the weight of these clamps was included in the estimation of buckling loads. Load was applied at mid-span at three positions on the section, and the critical values were observed in the usual way. The test results are shown in Fig. 8, herewith, in which the thick lines represent estimated buckling loads and the fine lines represent the critical loads for the same beam when warping is unrestrained at the ends. The range of warping constants covered in these tests included values of $\frac{GJL^2}{C}$ from 200 to 800, giving a maximum increase in buckling load of 10 per cent. above the free-end values. The accuracy of measurement of loads should be about 1 per cent. and, consequently, it may be concluded from comparison of test results that the theoretical solution plotted in Fig. 2 is satisfactory over the above range. Tests carried out on a similar beam with unrestrained ends have been described in the author's British Association paper previously referred to.

(To be continued.)

MINIATURE MAGNETIC EARPHONE.—The development of efficient miniature components has contributed greatly to the widespread use of electronic equipment for office dictating machines, very high-frequency communications equipment of the "walkie-talkie" type, and pocket-size radio receivers. A recent example of a miniature component is an earphone developed by Amplivox, Ltd., Amplivox House, 2, Bentinck-street, London, W.1. This earphone, which is highly sensitive and responds to a comparatively wide range of frequencies, has, roughly, the diameter of a sixpence and is light and comfortable to wear. It is held in position by a light wire which is hooked round the ear like spectacle attachments, thus obviating the use of a headband, and is robustly constructed to withstand rough usage. A strong connecting cord of oval section is employed to ensure flexibility, and the two-pin plug which connects it to the earphone is designed so that stress caused by lateral movement of the cord is balanced by pressure between the body of the plug and the earphone and not by forces on the pins. A stethoscope head set is available for use with the earphone, or alternatively, a flexible attachment to the ear may be employed. The wire attachment of the earphone holds the latter in position before the ear canal and does not intrude into it. When the earphone has to be used in particularly noisy surroundings, however, or when the output from the equipment is low, a plastic ear-cap can be fitted which excludes noise. Both high-resistance and low-resistance earphones can be supplied, with a frequency range of 100 to 4,000 cycles per second. The principal dimensions of the appliance are: diameter 0.835 in., depth 0.420 in. The weight is one third of an ounce. The sensitivity, power-handling capacity and frequency response of the earphone can be varied within limits, to suit individual requirements.

LITERATURE.

Transients in Electric Circuits using the Heaviside Operational Calculus.

By W. B. COULTHARD. Sir Isaac Pitman and Sons, Limited, 39, Parker-street, London, W.C.2. [Price 32s. 6d.]

THE first edition of this book was published ten years ago and for this second edition the opportunity has been taken to revise the whole text and to incorporate additional material on the use of electric circuits to simulate conditions obtaining in other branches of engineering, and on electro-mechanical devices, spot welders, linear control systems and the operation of synchronous machines. The section on eddy currents has been rewritten and expanded, and an operational method of analysing periodic wave forms has been developed. The treatment throughout is based on operational methods introduced by Heaviside which afford a direct and powerful line of attack on transient problems. The key concept is his unit function, the physical significance of which is that it automatically applies the whole frequency spectrum to the problem. The technique of handling operators is compactly presented, stress being laid on the development of operator equivalencies, including the expansion of operators by means of the binomial theorem, Taylor's theorem on partial fractions, the derivation of one operator from another with the aid of the shifting theorem and Borel's theorem and the use of the integral equation. Formal justification of all these procedures is not attempted as they are to be found in mathematical texts and as the main aim of the author is to illustrate their application to current problems in electrical engineering.

The first half of the book deals with lumped circuits, starting with the simplest case of the quiescent circuit and subsequently introducing subsidiary equations to take into account a variety of initial and boundary conditions. Prominence is given to the expansion method for dealing with sinusoidal voltages, while the Heaviside shifting method and the superposition theorem or Duhamel integral are employed for more complicated voltage expressions. To render transient effects in machines amenable, the analysis is simplified by neglecting the complex behaviour of iron. The second half of the book is devoted to smooth circuits, including repeated lumped circuits, wherein expansion yields practical positive powers of the operator p . A useful account of eddy currents in plates is followed by an important chapter on Fourier series and integrals, and the book concludes with two chapters on circuits with variable parameters. The latter may lead to Bessel equations or to functional

integral equations, but generally, graphical methods have to be resorted to and each particular problem treated individually. Typical examples serve to illustrate these alternative procedures. Though the treatment is concise and the exposition is clear; and the wide range and representative character of the problems dealt with should commend the book to all electrical engineers.

Practical Mathematics. Vol. 1.

By LOUIS TOFT and A. D. D. MCKAY. Third edition. Sir Isaac Pitman and Sons, Limited, Pitman House, Parker-street, Kingsway, London, W.C.2. [Price 20s. net.]

THE task of any writer of a text-book on elementary mathematics is no enviable one, nor is it an easy one, for he begins with the certain knowledge that all the basic theory at his disposal is already well-known and available elsewhere. The task, therefore, resolves itself into one of presenting the material in a novel and better manner, of illuminating fundamental theorems by judiciously selected examples which will ease the student's task of understanding, assimilating and ultimately applying the principles for himself. If the author fails in this, his work can scarcely be justified. Some authors, Mr. Toft and Mr. McKay, for example, have an ulterior motive, namely, to collect within one cover all the material requisite for a particular examination syllabus. This is itself a worthy aim, especially in these days when text-books have become relatively expensive; furthermore, it gives an author an opportunity to select examples from the student's main subject of study. An omnibus volume of this kind is only really objectionable when it is inconveniently large.

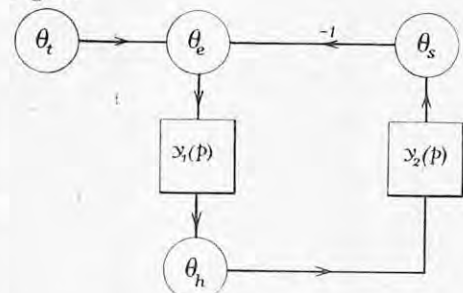
The fact that *Practical Mathematics* has been in existence for twenty years, has been frequently reprinted, and is now in its third edition, testifies to its popularity among teachers and students. In its latest form, however, it differs from the earlier editions in that the subject-matter has been rearranged and expanded to occupy two volumes. The authors state that the rearrangement has been made on the advice of many teachers in order that the book may meet the requirements of students preparing for an engineering degree at London University. Volume 1 deals with matter included in Part I of the syllabus and, to cover the latter completely, a chapter has been added on the more elementary parts of Statistics. Instead of beginning, as was formerly the case, with an introduction to that most useful branch of mathematics, the theory of determinants, the authors proceed at once to a discussion of limits, the convergence and divergence of infinite series, and kindred topics fundamental to the development of the infinitesimal calculus. The succeeding chapters follow the plan of the earlier editions, but the chapters on algebraic solid geometry, double and triple integrals, Fourier series, and spherical trigonometry have been omitted.

Generally speaking, the exposition is good, particularly in the development of the infinitesimal calculus. It might be argued that, occasionally, and without much loss to the student, parts of the theory could have been relegated to the exercises; for example, formulæ for subtangents and subnormals, radii of curvature in polar co-ordinates, and certain properties of conics might have been so treated on the grounds that they are seldom required and are not difficult to deduce. The chapter on statistics is an excellent introduction.

Errors and misprints appear to be rare. On page 147, the minimum-energy theorem for systems in equilibrium—in this case an over-rigid frame—is referred to as the "Principle of Least Action," a title which is usually applied to a fundamental result in dynamics discovered by Maupertuis and associated with the names of Lagrange and Jacobi. An error also occurs on page 459, where a certain curve is stated to be "an equidistant spiral, successive turns of which divide any radius through o (the origin) into an equal number of parts"—whatever that may mean. If, as may be suspected, the authors imply that the spiral cuts off equal intercepts on any radius, the result is incorrect for the conditions stated. Such slips, however, are minor blemishes on a book which will undoubtedly continue to find favour.

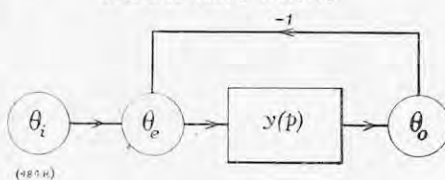
MECHANICAL HARMONIC ANALYSER.

Fig. 8.



θ_t = Target Motion
 θ_s = Sight Motion
 θ_e = Deviation of Sight from Target
 θ_h = Handle Displacement
 $Y_1(p)$ = Eye to hand Response of Human Operator
 $Y_2(p)$ = Response of Sight Controller to Handle Displacement
 (484.5.)

Fig. 9. DEPENDENCE DIAGRAM OF A SIMPLE SERVO SYSTEM.



MECHANICAL HARMONIC ANALYSER AND SOME APPLICATIONS TO SERVO SYSTEMS.

By J. G. HENDERSON, B.Sc.

(Concluded from page 53.)

THE analyser has been used in two novel ways, in addition to its conventional use for the analysis of periodic curves. First, it was used to determine the nearest linear law which best related two sets of quasi-periodic data and, secondly, it was used for the direct and inverse transformation of the frequency response of a stable, linear system to its transient response, which is of current interest to servo-system designers. The technique applied in the analysis of quasi-periodic curves was first adopted by Professor Tustin in an investigation of the responses of a human operator,* when the operator was a link in a closed-sequence control system that simulated a manually-controlled, servo-operated sight. The scheme of dependence is shown in the diagram reproduced as Fig. 8, herewith, where the transfer function, that is, the eye-to-hand response of the operator is represented by a linear relation $y_1(p)$, the validity of which has to be examined, and the response of the sight-controller to the hand control is $y_2(p)$, where p is a differential operator.

In a recent investigation, a periodic target-signal was generated by a photo-electric cam-follower and recorded by one pen on the chart of a three-pen recorder. In the absence of any response from the operator, the closed loop of the diagram is actually broken, that is, $y_1(p) = 0$, and the target motion θ_t appears as a deviation which is recorded by the second pen, to which is attached an index visible to the operator. As soon as the operator attempts to keep this index on zero, that is, to maintain the deviation θ_e at zero by moving the controller handle an amount θ_h , he produces a sight motion θ_s which is subtracted from the target motion θ_t to give a new error θ_e . If the human operator can be regarded as a linear circuit element, the system will settle down after an initial transient period and then θ_e , θ_h and θ_s will become periodic functions with (and this is the crux of the matter) precisely the same frequencies present in them as are present in the target signal. Hence, if θ_t , θ_e and θ_h are

Fig. 10.

OPEN-LOOP RESPONSE FOR $y(p) = \frac{30}{p(p+4.5)}$; $p = j\omega$

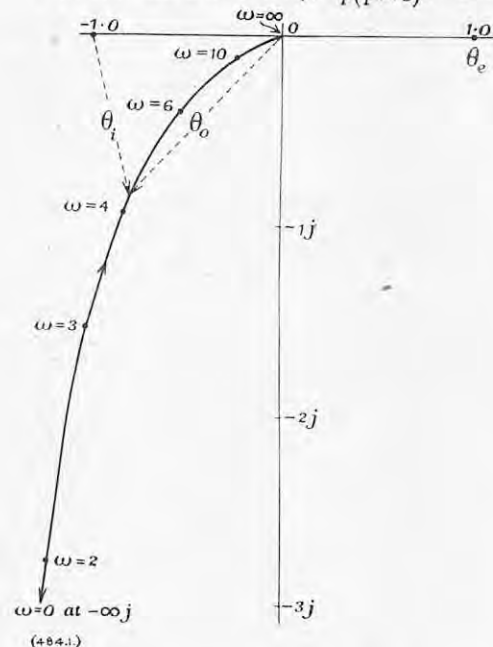
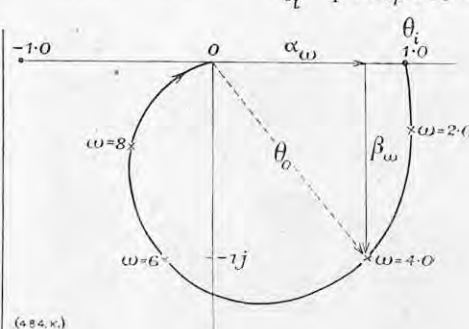


Fig. 11.

CLOSED-LOOP RESPONSE. $\frac{\theta_h}{\theta_t} = \frac{30}{p^2 + 4.5p + 30}$; $p = j\omega$



recorded and harmonic analyses made of the θ_e and θ_h curves, by looking for the same frequencies as were present in the θ_t curve, it is possible to determine the vector ratio $\frac{\theta_h}{\theta_e}$ for each harmonic component and, in this way, to deduce the frequency-response vector locus for the operator.

The actual records of θ_e and θ_h are obviously not periodic, since random disturbances are superimposed on them. However, on analysing them over many periods, it becomes apparent from the loci traced by this analyser that, although the amplitude and phase of harmonic present in θ_e and θ_h do vary from period to period, it is possible to represent the response of the operator to each frequency by a mean value of the ratio $\frac{\theta_h}{\theta_e}$. In this way, an approximate

response vector locus can be constructed and from this locus the nearest linear law that represents the operator's response can be deduced.* Such data can be used to improve the performance of manually-operated servo-systems. It will be apparent that this technique can be used to estimate the nearest linear law connecting two related sets of quasi-periodic data, by first determining the response-vector locus relating similar frequencies in the two sets of data, and then deducing the type of linear differential equation that would give such a sinusoidal response. This is not difficult for servo engineers, since they have become accustomed to associating the elementary types of response vector loci with their corresponding equations.*

The performance of any linear system is completely characterised by its differential equation; hence, once that equation is specified, the response

* See, for example, *Principles of Servo-Mechanisms* by G. S. Brown and D. P. Campbell. John Wiley and Sons, New York, page 157 (1948).

* *Journal I.E.E.*, 11A, page 190 (1947).

MECHANICAL HARMONIC ANALYSER.

Fig. 12. FREQUENCY SPECTRUM OF UNIT FUNCTION.

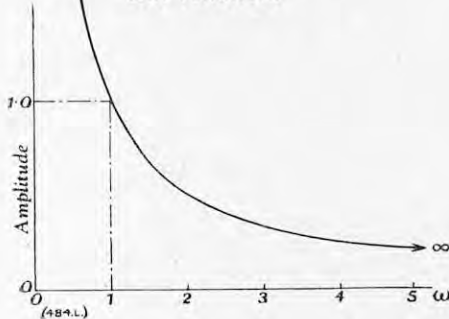


Fig. 13. FREQUENCY SPECTRUM OF UNIT IMPULSE.

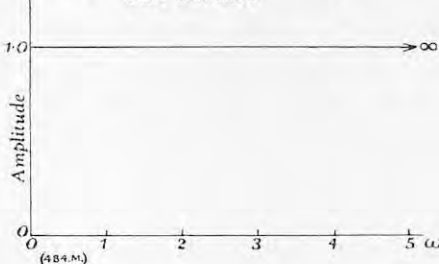


Fig. 14. ANALYSIS OF FREQUENCY-RESPONSE CURVE.

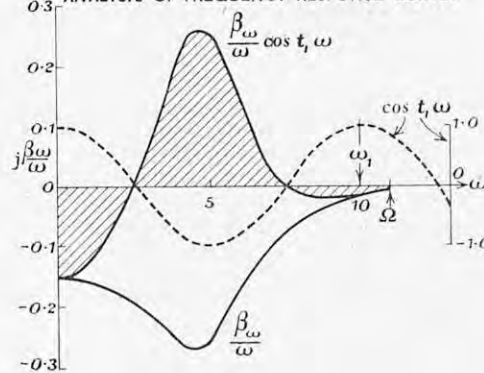


Fig. 15. RESPONSE TO UNIT FUNCTION.

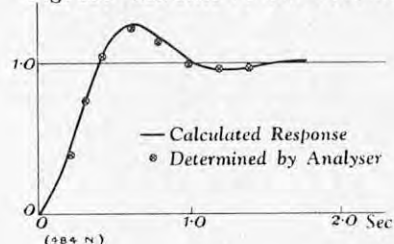


Fig. 16. EXACT TIME-RESPONSES.

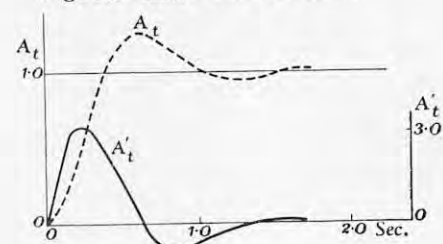
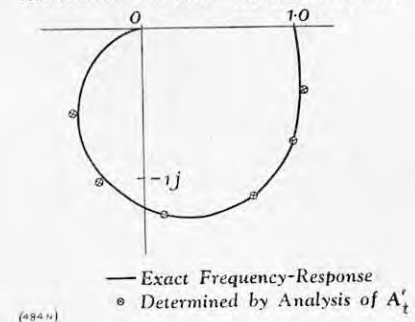


Fig. 17. TIME-RESPONSE TO FREQUENCY-RESPONSE TRANSFORMATION.



of the system can be computed for any input. Take as an example, the servo system represented by the dependence diagram shown in Fig. 9, opposite. The input, output and error quantities, θ_i , θ_0 and θ_e , are related by the equations

$$\begin{aligned}\theta_e &= \theta_i - \theta_0 \\ \frac{\theta_0}{\theta_e} &= y(p) = \frac{f(p)}{g(p)} \\ \frac{\theta_i}{\theta_0} &= \frac{y(p)}{1 + y(p)} = \frac{f(p)}{f(p) + g(p)}\end{aligned}$$

where $f(p)$ and $g(p)$ are polynomials in p .

The response to sinusoidal inputs can be readily calculated by substituting $p = j\omega$ in these equations, and thereafter the calculation is of a type with which engineers who have computed alternating-current electrical circuits are familiar. On the other hand, the calculation of the response to transients, such as unit function or unit impulse, by any of the methods of solving differential equations, classical or operational, requires the evaluation of the roots of the polynomial $f(p) + g(p) = 0$, which is a laborious task when the polynomial is of high order in p . Furthermore, this process has to be repeated whenever the polynomial coefficients are changed by some slight modification of the system as the design is developed. In consequence, in the past, much of servo design and synthesis has been based on the responses of systems to sinusoidal inputs. When this approach is adopted, it is most convenient to plot the vector locus of $\frac{\theta_0}{\theta_e} = y(j\omega)$, the open-loop response (shown in Fig. 10, opposite, for the case $y(j\omega) = \frac{30}{j\omega(j\omega + 4.5)}$), because then one can apply the Nyquist criterion of stability, which in its simplest form states that the system will be stable if the locus of $y(j\omega)$ cuts the vector $-1 + j0$. It will be apparent that if this locus passed through the point $(-1, j0)$, the equation $\theta_0 = -\theta_e$ would hold for some particular frequency and, on closing the feedback-loop, oscillations of this frequency could be sustained without any input. The stability of simple systems—those with a single mode of oscillation—can be deduced from the proximity of the open-loop response to the point $(-1, j0)$, but this technique is less easily applied to systems with several modes of oscillation. In the case of such systems, numerical methods have been developed for determining their transient response from their closed-loop frequency-response $\frac{\theta_0}{\theta_i}$. It will now be shown that this result can be obtained by using practically any type of harmonic analyser.

The closed-loop response-vector locus can be

readily obtained from the open-loop response locus, since $\frac{\theta_0}{\theta_i} = \frac{\theta_0}{\theta_e} + \frac{\theta_e}{\theta_i}$ is represented by the vector joining the point $(-1, j0)$ to the tip of the θ_0 vector; hence the response $\frac{\theta_0}{\theta_i}$ is as shown in Fig. 11, opposite. It is clear that if a multi-periodic signal, containing, say, components of three different frequencies, were applied to such a system, the output would be the sum of the system's responses to each frequency component of the input signal. This idea of the superposition of the responses is the basis of Fourier integral analysis. It can be shown that a unit-function transient, U_t , can be represented by a constant term plus an infinite number of sinusoidal terms specified by the equation

$$U_t = \frac{1}{2} + \frac{1}{\pi} \int_0^\infty \frac{\sin t\omega}{\omega} d\omega,$$

and unit impulse δ_t , which is the derivative of unit function, is specified by the equation

$$\delta_t = \frac{1}{\pi} \int_0^\infty \cos t\omega d\omega.$$

That is, the value of U_t or δ_t is given for any value of t by the summation of an infinite number of sinusoidal functions of time, with amplitude distributions which are shown respectively in Figs. 12 and 13, herewith. Hence, the response of any system to U_t or δ_t is given by the sum of the responses to each frequency component of these inputs. If the in-phase and quadrature components in the closed-loop response are represented by the expression $\frac{\theta_0}{\theta_i} = \alpha_\omega + j\beta_\omega$, the system response to unit function is

$$A = \frac{\alpha_0}{2} + \frac{1}{\pi} \int_0^\infty (\alpha_\omega + j\beta_\omega) \frac{\sin t\omega}{\omega} d\omega, \quad (7)$$

and the response to unit impulse

$$A'_t = \frac{1}{\pi} \int_0^\infty (\alpha_\omega + j\beta_\omega) \cos t\omega d\omega. \quad (8)$$

These responses, however, can be expressed in terms of either α_ω or β_ω since these two quantities are not independent. Both A_t and A'_t are zero for negative values of t , since the input signals are not applied until $t = 0$; hence, by expanding equations (7) and (8) and substituting negative values of t ,

$$\begin{aligned}A(-t) = 0 &= \frac{\alpha_0}{2} + \frac{1}{\pi} \int_0^\infty \alpha_\omega \frac{\sin(-t\omega)}{\omega} d\omega \\ &+ \frac{1}{\pi} \int_0^\infty \beta_\omega \frac{\cos(-t\omega)}{\omega} d\omega,\end{aligned}$$

whence,

$$\frac{\alpha_0}{2} + \frac{1}{\pi} \int_0^\infty \beta_\omega \frac{\cos t\omega}{\omega} d\omega = \frac{1}{\pi} \int_0^\infty \alpha_\omega \frac{\sin t\omega}{\omega} d\omega,$$

so that, substituting this relationship in equation (7),

$$A_t = \alpha_0 + \frac{2}{\pi} \int_0^\infty \frac{\beta_\omega \cos t\omega}{\omega} d\omega, \quad (9)$$

or

$$A_t = \frac{2}{\pi} \int_0^\infty \frac{\alpha_\omega \sin t\omega}{\omega} d\omega. \quad (10)$$

By a similar process it can be shown that

$$A'_t = \frac{2}{\pi} \int_0^\infty \alpha_\omega \cos t\omega d\omega, \quad (11)$$

or

$$A'_t = -\frac{2}{\pi} \int_0^\infty \beta_\omega \sin t\omega d\omega. \quad (12)$$

The integrals of equations (9)-(12) are similar in form to those met in normal harmonic analysis, except that the integration is continued for an infinite time. However, if the curves of $\frac{\alpha_\omega}{\omega}$, $\frac{\beta_\omega}{\omega}$, α_ω and β_ω plotted against ω are finite, and converge for high values of ω , an approximate solution of these integrals can be obtained after a finite range of integration with the aid of a harmonic analyser. Suppose that it is desired to find the unit-function response of the system represented by the closed loop response in Fig. 11. First, a curve of $\frac{\beta_\omega}{\omega}$ against ω is plotted for a range of say, $0 \leq \omega \leq \Omega$, as in Fig. 14, herewith. The curve of $\frac{\alpha_\omega}{\omega}$ against ω is no use in this case, since it is infinite at the origin. The harmonic analyser is then set to determine cosinusoidal components of this curve, and with the analyser set to execute one period of integration in a frequency range of 0 to ω_1 , the curve is tracked from 0 to its limit Ω . By this means, the integral,

$$\int_0^\Omega \frac{\beta_\omega}{\omega} \cos t_1 \omega d\omega,$$

represented by the shaded area in Fig. 14, is obtained, where $t_1 = \left(\frac{2\pi}{\omega_1}\right)$ is determined by the period setting of the analyser. On including the response to zero frequency (α_0) the result

$$A_{t1} \approx \alpha_0 + \frac{2}{\pi} \int_0^\Omega \frac{\beta_\omega}{\omega} \cos t_1 \omega d\omega,$$

is obtained.

By beginning with ω_1 very large and then repeatedly reducing the period to $\frac{\omega_1}{2}, \frac{\omega_1}{3}, \frac{\omega_1}{4}, \dots$, a series of uniformly spaced ordinates will be obtained for times $t_1, 2t_1, 3t_1, \dots$, which approximate to the response to unit function, as shown in Fig. 15, on page 69. The response at $t = 0$ corresponds to the zero-frequency response plus $\frac{2}{\pi}$ times the area of the

curve of $\frac{\beta_\omega}{\omega}$ against ω , between $\omega = 0$ and ∞ .

With a curve of finite range,

$$\Delta t_0 \approx \alpha_0 + \frac{2}{\pi} \int_0^\infty \frac{\beta_\omega}{\omega} d\omega;$$

hence, the error involved is

$$\Delta \Delta t_0 = -\frac{2}{\pi} \int_0^\infty \frac{\beta_\omega}{\omega} d\omega.$$

If we can assume that the response curve of $\frac{\beta_\omega}{\omega}$ against ω is asymptotic to the form $\frac{k}{\omega^n}$ for values of $\omega > \Omega$, the error is easily calculable, and is

$$\Delta \Delta t_0 = -\frac{2}{\pi} \frac{1}{n-1} \frac{k}{\Omega^{n-1}}.$$

This is, in fact, the largest error that will occur, the errors for larger values of t being smaller, though less easily calculated. Hence the range of ω for which the curve of $\frac{\beta_\omega}{\omega}$ is plotted should be determined with the magnitude of the above error in mind. The inverse process, namely, the determination of the locus of the frequency-response vector of a system from its transient response, is also practicable, although, in this case, analysis is confined to the response to unit impulse A'_t , since this curve (see Fig. 16, on page 69) is a convergent one, whereas the response to unit function A_t is not convergent. It can be shown that

$$\alpha_\omega + j\beta_\omega = \int_0^\infty A'_t (\cos \omega t + j \sin \omega t) dt.$$

A harmonic analyser may be used, also, to determine α_ω and β_ω provided that the value of A'_t , plotted against t , tends to zero in a finite time. For this purpose, the analyser is set to execute one period in a time ranging from 0 to t_1 ; then, assuming that A'_t is defined from 0 to T , tracking the curve gives

$$\alpha_{\omega_1} \approx \int_0^T A'_t \cos \omega_1 t dt$$

and

$$\beta_{\omega_1} \approx \int_0^T A'_t \sin \omega_1 t dt,$$

where $\omega_1 = \left(\frac{2\pi}{t_1}\right)$ is determined by the period setting.

On beginning with a large value of t_1 and then reducing the period to $\frac{t_1}{2}, \frac{t_1}{3}, \frac{t_1}{4}, \dots$, values of α_ω and β_ω will be obtained for frequencies $\omega_1, 2\omega_1, 3\omega_1, \dots$, from which the locus of the frequency-response vector can be constructed, as in Fig. 17.

The harmonic analyser described above has two properties which make it suitable for this latter transformation. First, the fact that it evaluates derivatives allows it to accept a curve of the unit-function response A_t which is simpler to obtain in practice than is the A'_t curve; secondly, it gives a vectorial representation of the components α_ω and β_ω , so that the locus of the tips of the vectors traced by the resolver plate is in fact the closed-loop response-vector locus. However, for the first transformation, namely, frequency response to transient response, the derivative feature is a minor handicap, since the curves for analysis must be the integrals of those specified in the equations given; for example, to obtain A_t we must analyse a curve of $\int_0^\infty \frac{\beta_\omega}{\omega} d\omega$ against ω . Finally, there is one feature of this analyser which is advantageous in both transformations, namely, the use of a disc and roller integrator as a variable-speed gear. This allows the period settings to be varied continuously from infinity to some fixed lower value, which permits one to determine ordinates and vectors wherever they seem most needed to delineate a satisfactory resultant curve.

THE ENGINEERING OUTLOOK.

III.—THE MACHINE-TOOL INDUSTRY.

WHILE in most branches of the engineering industry the full impact of the re-armament programme had not yet been felt in 1951, the machine-tool industry was already striving hard to keep abreast of the mounting orders. It is essential, indeed, that the bulk of the deliveries against defence orders for machine tools shall be made by the middle of 1952 if the re-armament programme is not to fall seriously behind schedule. Between January and August, 1951, 34,335 machine tools* (see Table I, herewith, taken from the *Monthly Digest of Statistics*) were produced, compared with 28,851 in the corresponding period of 1950. Defence deliveries, moreover, were maintained without any reduction in exports, which, in the period January to November, 1951, were valued at 16.6l. millions, compared with 15.3l. millions in the corresponding period of 1950. This does not mean, of course, that there has been no interference with the normal commercial production of machine tools; deliveries to civilian industry at home were severely restricted or delayed, and even export deliveries were interfered with to give defence first priority on some types of special-purpose machinery.

TABLE I.—DELIVERIES EX-WORKS OF BRITISH-BUILT MACHINE TOOLS.
(Monthly Averages or Calendar Months: Values in 1,000l.)

	Metal-working Machine Tools.			Wood-working Machine Tools.		
	Total.		For Export, Value.	Total.		For Export, Value.
	Number.	Value.		Number.	Value.	
1935	—	509	—	53	—	—
1948	3,737	2,591	940	1,462	347	125
1949	3,675	2,968	1,168	1,435	398	137
1950	3,742	3,223	1,178	1,374	381	135
1950—July	3,912	3,283	1,221	1,137	355	137
August	3,339	3,039	1,092	1,093	313	113
September	4,149	3,441	1,199	1,509	393	149
October	3,876	3,445	1,063	1,615	432	136
November	3,902	3,467	1,244	1,302	391	152
December	4,326	3,590	1,484	1,682	439	167
1951—January	4,200	3,583	1,238	1,737	413	130
February	4,110	3,570	1,437	1,287	331	90
March	4,272	3,854	1,309	1,413	422	181
April	4,176	3,897	1,242	1,527	475	159
May	4,820	3,734	1,306	1,346	357	134
June	4,538	4,044	1,433	1,278	421	139
July	4,039	3,810	1,236	1,498	459	151
August	4,180	3,661	1,319	1,214	378	136

On the whole, the machine-tool industry is responding well to the demand for increased production, despite the fact that there is little assurance that increased capacity can be kept employed after the emergency. In 1950, when 44,900 machine tools were produced, the numerical output was little higher than in 1938. The value of the 1950 output, 42.9l. millions, was somewhat above the 1938 level of 14l. millions, even after allowing for the fact that prices in 1950 were, perhaps, two and a half times as high as in 1938. The difference is accounted for by changes in the proportion of the various types of tools produced; the proportion of complex highly-specialised tools and the proportion of individual electric motors fitted was higher in 1950. War demand doubled the output of machine tools, which, in 1942, reached 96,000, valued at 33.5l. millions. In 1946, however, output had been cut by half and deliveries fell back from 45,075 in that year to 41,104 in 1949. Since exports, which were only 24,100 tons in 1938, had increased to 42,000 tons in 1949, it is evident that the falling output was due to failing demand at home, and yet at no time, in the interests of increasing output and efficiency, was there a greater need for up-to-date machine tools in the British engineering industry. On the most elementary calculation, the replacement demand on the 800,000 to 900,000 machine tools in use should have been 40,000 to 50,000 a year. In fact, the home market has

taken only about 30,000 a year since the war. The fault lies to some extent with Government fiscal policy, which taxed the sums that industry put to reserve as well as taxing profits, and made very inadequate allowance for depreciation. The economic necessity for restricting capital investment only partly justified this policy, since it penalised essential as well as less essential re-equipment schemes. It certainly took no account of the strategic considerations which demanded the existence of adequate capacity for the manufacture of capital equipment vital in war. It is true that the expansion in output of machine tools between 1938 and 1942 took place with surprisingly little expansion of capacity on the part of the machine-tool builders, being achieved very largely by extensive subcontracting, by calling on the Royal Ordnance Factories, and by working extra shifts.

The best way of meeting an emergency is not necessarily to keep extra capacity available. The Machine Tool Trades Association decided at the close of hostilities that the best way to meet the "probable necessity for re-armament"—a factor which they held to be of supreme importance in deciding what should be the appropriate level of the industry—was to maintain a state of readiness for rapid expansion. Even this, however, requires a certain minimum of peace-time operation and an adequate force of skilled labour. The number

employed in the machine-tool industry, however, was slowly falling up to the middle of 1950, because of competition from less skilled but more remunerative industries. In the year to September, 1951, its personnel increased by 7,100 to 81,600, but, even so, the difficulty of obtaining suitable labour has been a serious inconvenience to manufacturers.

The requirement of machine tools for re-armament was originally estimated by Mr. Hugh Gaitskell, M.P., at 50l. millions for retooling and 65l. millions for new capacity in the first two years of the three-year programme. Altogether, 35,000 machine tools were needed, of which 19,000 to 20,000 were to come from abroad, leaving a balance of 15,000 to 16,000 to be obtained from home sources. Relatively few, less than a thousand, in the strategic reserve of machine tools held over by the Ministry of Supply from the last war were suitable for use in the present programme. Most of the new tools required are special-purpose types—many, indeed, of a single-purpose type which could not be supplied in the United Kingdom. At the rate of production achieved in the first eight months, production in 1951 is likely to exceed that in 1950 by about 8,500 machines. Assuming that all this excess represents defence orders, and assuming the same level of production in 1952 as in 1951, it would only be possible to supply about 13,000 machine tools by the end of the year. It was decided, therefore, to reduce supplies to home civilian users, and in May it was announced that there would be a cut of 35 per cent. This, however, is equivalent to 11,000 tools and from current output figures it would appear that it was not necessary to be quite so drastic.

* As a matter of interest, the output of wood-working machine tools is included in Table I; but this article is concerned primarily with metal-working machine tools, and the term "machine tools" must be understood to mean metal-working machines.

Nevertheless, the engineering industry at home has been seriously inconvenienced by inability to obtain the machine tools required. A memorandum submitted to the Select Committee on Estimates by the Society of Motor Manufacturers and Traders, and mentioned in the Committee's tenth report, complained that it was becoming more difficult to obtain both British and foreign machine tools, that their prices were rising, and that the prospects of equipping any new plant were most unfavourable. There was, of course, no difficulty when it was the Ministry of Supply's duty to supply the tools under the defence programme; manufacturers had been told well in advance when to expect delivery. To make the most effective use of home production, manufacturers of machine tools were requested to provide the Ministry of Supply with detailed schedules of their deliveries. It was also decided, with the support of the Engineering Advisory Council and the Machine Tool Advisory Council, to set up Regional Panels, covering the same areas as the existing Regional Production Efficiency Panels of the Machine Tool Trades Association. Members of the panels were empowered to visit the works of users and to make suggestions about the use of, and the need for, machine tools; but the functions of the Panels remained purely advisory, final decisions resting with the Ministry of Supply.

In the United States, the business of finding machine tools for defence has gone less smoothly than in Britain. The output of the machine-tool industry in that country contracted severely after the war, to 250 million dollars in 1950. It is expected, however, that orders on hand in June, 1952, will reach 2,900 million dollars, which, at present delivery rates, would take seven years to clear. The task confronting manufacturers of machine tools is no less arduous than in the early years of the war, when, between 1939 and 1942, production was increased from 200 million to 1,500 million dollars. At that time, however, manufacturers received substantial aid and encouragement from the Government. They began the present emergency with serious disadvantages: materials and labour were scarce and costs were rising, but the General Ceiling Price Regulation froze prices at the level of those obtained for tools delivered in January, 1951. Since many of the machines delivered at that time were ordered before the outbreak of war in Korea, at prices far below the level of current contracts, machine-tool manufacturers had little incentive to increase production. After a long period of stagnation, marked by conflicting Government directives, a new price ceiling was fixed at 12 per cent. above the level ruling before the outbreak of war in Korea, and allowances were made to meet rising material and labour costs. The industry, which formerly had no prior claim on supplies of scarce materials, was granted first priority and at the end of 1951 had reached an annual rate of production more than double that of 1950. By June, 1952, it is hoped to achieve an annual output rate of 1,500 million dollars. The machine-tool industry in the United States in normal times is highly competitive, but it is now pooling ideas. It consists very largely of small concerns turning out one type of lathe, grinder, etc. The main centre is Cincinnati, which has 30 plants, accounting for half the output of machine tools in the United States: one firm, the Cincinnati Milling Machine Company, is the largest of its kind in the world.

In spite of the increase in production of machine tools in the United States, it has been found necessary to reserve the entire output for military and "defence-supporting industries." Under a Government Order which becomes effective on February 1, 1952, retooling by civilian manufacturers of motor cars, washing machines, refrigerators and other household appliances is forbidden; model-changes in the coming year are therefore likely to be few. The British Government were forced to place substantial orders for machine tools, of types not obtainable in Britain, with United States manufacturers. Fortunately, it was possible to make a quick assessment of requirements and to place the orders early; altogether, over 7,000 machine tools were ordered, to which the United States Government accorded a priority equal to that for their

own military equipment. The bulk should be ready for installation by the middle of 1952. Many have already been received. Table II, herewith, taken from the *Trade and Navigation Accounts*, shows that British imports from the United States in the period January to November, 1951, were 5.851 millions, which is 1.391 million higher than in the corresponding period of 1950. Military aid funds to the value of 112 million dollars have been made available to the British Government under the Mutual Defence Assistance Programme for the purchase of American machine tools.

TABLE II.—United Kingdom: Imports of Metal-Working Machine Tools. (January to November.)

	Quantity (1,000 Cwt.)			Value (1,000 £)		
	1949.	1950.	1951.	1949.	1950.	1951.
Commonwealth countries and the Irish Republic ..	1	4	1	38	98	61
Germany ..	120	170	89	675	505	1,681
Belgium ..	7	10	27	156	226	594
Switzerland ..	9	10	29	625	639	1,836
United States of America ..	97	70	107	3,078	3,460	5,850
Other Foreign countries ..	8	16	74	222	445	2,203
Total ..	242	280	327	4,794	5,373	12,225

The remainder of the machine tools required from abroad are to come from Europe; 3,200, valued at 8071. millions, from Germany; 1,900, valued at 71. millions, from France; 1,100, valued at 5.51. millions from Italy; 1,800 (5.31. millions) from Switzerland; and 1,000 (2.71. millions) from Belgium. Thanks to a large expansion in machine-tool output in Western Europe, little difficulty was experienced in placing orders in these countries through normal trade channels. The only output figures available are those given in the *General Survey of the European Engineering Industry*, published in April by the United Nations Economic Commission for Europe. These are quoted in Table III, herewith, from which it will be seen that

TABLE III.—Europe: Production of Metal-Working Machine Tools. (Value in million U.S. dollars at 1948 prices.)

Year.	All European Countries.	Eastern Countries.	Western Countries.
1938 ..	517.7	27.7	490.0
1948 ..	480.7	65.5	415.2
1949 ..	552.3	82.6	469.7
1952-53 (planned) ..	778.8	146.2	632.6

the planned output level of machine tools in 1952-53 is 50 per cent. higher than in 1948. These plans were formulated in 1949, and, as the writers of the *Survey* point out, it now seems likely that they will be over-fulfilled, due to the large demand of machine tools for defence. Western Germany is the largest producer of machine tools in Europe, though it now accounts for only perhaps about a quarter of European output, compared with 45 per cent. in 1938.

According to the original plans submitted to the Organisation for European Economic Co-operation, Germany was expected to account for only 22.9 per cent. of Western European output, but production has been increasing faster than originally expected. In 1950, the industry employed 40,000 persons in 500 establishments; the value of the output was 331. millions and of exports, 121. millions. The United Kingdom accounts for about one-fifth of the output of machine tools in Western Europe—about the same as before the war. Other Western European countries have increased their relative share of total output—some, considerably so. Italy, which produced 11 per cent. of the total output in 1938, was planning to produce 13.4 per cent. in 1952/53. According to the latest information available, there are 280 machine-tool manufacturers in Italy, with a capacity of 35,000 tons of machine tools per annum. The range of products covers some very highly specialised machines. Exports in 1950 were valued at 61. millions. France expected to increase its share of the European output from 9.0 in 1938 to 11.0 per cent. in 1952-53, and Switzerland planned an increase from 9.0 to 10.4

per cent. The most startling expansion in the output, however, was planned (and is taking place) in many of the smaller countries, whose share of European output was relatively insignificant before the war. Sweden, which contributed 3.5 per cent. of the Western European output in 1938, expected to provide 7.0 per cent. in 1952-53; Belgium (2.1 per cent.) expected to supply 8.0 per cent., and Austria, Denmark, Greece, Netherlands and Norway, together accounting for only 1.8 per cent. in 1938, planned to increase this to 7.3 per cent. in 1952-53.

Behind the Iron Curtain, the output of machine tools is also expanding rapidly. In Russia, it was planned to have 1.3 million metal-cutting machine tools in use by the end of 1950 and an annual production capacity of 95,000, and it is claimed that this has been carried out. Even in Hungary, which can hardly be considered an industrial country, the production of machine tools is scheduled to reach 18.51. millions a year by 1954 and some have already been exported, though the output is destined mainly for the home market. Whether this great expansion in the output of machine tools in both Eastern and Western Europe can be justified on other than strategic reasons is very doubtful. The *General Survey of the European Engineering Industry* points out that the increase in output planned for 1952-53 is by no means striking when compared with the general increase in output taking place in the engineering industry as a whole, and thinks that the increasing difficulty of placing orders in the United States will tend to stimulate production further. It is, however, only during the present emergency that there has been any difficulty in obtaining machine tools in the United States. The machine-tool industry in that country was working far below capacity in 1948 and 1949; according to some figures published by *The Iron Age* in February, 1951, the index of deliveries of machine tools in the United States fell from 100 in 1945 to 86.6 in 1948 and 81.0 in 1949, and foreign orders had dropped from 100 in 1945 to 44.2 in 1949. The fall in foreign orders was, of course, partly due to the dollar shortage. Moreover, while the output of engineering products in the world has been rising, it cannot be assumed that there will be a proportionate increase in the demand for machine tools; replacement demand is more important than new demand and, before the present emergency, the replacement demand was falling in the highly industrialised countries of the world. This could be only partly compensated by increased new demand in the under-developed countries.

Europe can hardly expect to build up a healthy machine-tool industry on the basis of the present inflated demand. Much of the output is still in the form of general-purpose tools and this is the type mainly in demand in the most promising markets—those countries, hitherto undeveloped, which are now developing their industrial potential. Unfortunately, much of the expansion which is taking place is in highly specialised tools, many of which are in direct competition with types manufactured in the United States. The American magazine *Business Week* reported in September that some Continental makes of machine tools were actually selling in Cleveland at prices 20 per cent. below those of the corresponding domestic machines.

It would not be wise, however, to assume that European machines would be competitive in less exceptional times. The expansion of the output of specialised machine tools in Europe is hardly likely to be beneficial unless the plans of individual countries are better co-ordinated than at present. It would certainly be very difficult to make out a case on purely economic grounds for the expansion of the machine-tool industry in, say, Greece. On the other hand, there is much to be said for the further concentration of the production of certain types of machines in those countries already specialising in them; Germany and Switzerland, for example, have achieved the most in the last decade in the production of thread-rolling, thread-grinding and gear-grinding machines, and might well, with profit, increase their production of these and similar machines. Six types of machine tool account for about one-third of the total output of machine tools in Europe. Table IV, on page 72, taken from the *General Survey*, previously men-

tioned, compares the output of these types in 1938 with plans for 1952-53.

Anxiety has been expressed already by some British machine-tool manufacturers about the threat to British exports implied in the expansion of European output. This is all the more serious since these European countries are at present gaining an entry in British markets when British manufacturers are unable to give delivery because of prior defence commitments. From Table V, herewith, taken from the *Trade and Navigation Accounts*, it will be seen, however, that the value of British exports of machine tools has been increasing since 1949. Though the volume has been falling slightly, this is accounted for by the smaller quantity of second-hand machine tools sent overseas. There is, therefore, little sign as yet that British exports are suffering from foreign competition. Lathes, mainly general-purpose, remain the largest single category of British exports of machine tools, the number exported in the first eleven months of 1951

TABLE IV.—Actual and Planned Production of Certain Metal-Working Machine Tools in Twelve European Countries in 1938 and 1952-53 (thousand U.S. dollars at 1948 prices).

Category.	Production.	
	1938.	Planned 1952-53.
Automatic lathes	22,800	29,475
Gear-cutting machines ..	10,675	16,335
Grinding machines	36,645	45,333
Boring and milling machines	24,740	40,500
Centre lathes	67,250	88,530
Planing machines	12,820	12,985
Total	174,930	233,158

TABLE V.—United Kingdom: Exports of Metal-Working Machine Tools by Types (January to November).

	(1,000 Cwt.)			(1,000L.)		
	1949.	1950.	1951.	1949.	1950.	1951.
New complete tools—						
Boring	48	52	29	867	938	653
Drilling	83	85	80	1,355	1,356	1,275
Grinding	65	67	60	1,383	1,492	1,474
Lathes:—						
Automatic	31	28	39	900	822	1,382
Capstan and turret	71	59	60	1,828	1,500	1,628
Other	109	110	100	2,027	2,098	2,105
Screwing and threading ..	12	12	13	530	481	495
Milling and gear-cutting ..	46	54	48	1,163	1,320	1,302
Planing, shaping and slotting ..	52	54	54	764	835	873
Presses	67	90	151	778	1,097	1,806
Punching and shearing	55	55	61	628	713	814
Sawing	15	12	10	214	179	171
Others	59	77	61	1,022	1,174	1,131
Used, complete tools	108	57	38	696	477	426
Parts	28	31	36	771	800	1,086
Total	849	843	840	14,926	15,291	16,621

being 4,835, compared with 4,776 in the corresponding period of 1950; the number of automatic lathes exported has also been increasing steadily, from 845 in the first eleven months of 1949 to 1,453 in the corresponding period of 1951. Presses showed the largest increase in exports, increasing by over 700,000L. to 1.8M. millions in the first eleven months of 1951. Exports of drilling machines, milling machines and sawing machines all showed a slight decrease in 1951; the only category showing a significant drop in value was boring machines, and even here the number of machines exported increased from 656 in the first eleven months of 1950 to 1,015 in the first eleven months of 1951.

The Commonwealth and Colonies continue to provide the best markets for British machine tools, accounting for nearly half of the British exports (see Table VI, herewith, taken from the *Trade and Navigation Accounts*). In the first eleven months of 1951, the total exports to these countries were slightly higher than in the corresponding period of 1950, aggregating 7.7L. millions, compared with 7.4L. millions. The increase, however, disguises a serious drop in exports to India and Pakistan, from 2.9L. millions to 1.7L. millions. It is to underdeveloped countries like these that British manufacturers must look increasingly; but export sales

tend to be erratic, since industrial expansion schemes are often more ambitious than resources will allow, and orders have to be cancelled because of recurring financial crises. The progress of exports to such rapidly developing countries as Australia and South Africa is much more stable. Australia in 1951 displaced India as the largest single market for British machine tools, and, in the first eleven months of the year, took British exports to the value of 2.2L. millions, 400,000L. more than in the corresponding period of 1950. The demand for British machine tools in Western Europe has not been affected so far by expanding production; no country, however nationalistically minded, can hope to be self-sufficient in machine tools, and some, in order to meet their defence requirements, have had to increase their purchases from Britain.

A hopeful sign for the future prosperity of British machine-tool exports is the large increase in exports to countries where purchases are too small

TABLE VI.—United Kingdom: Exports of Metal-Working Machine Tools by Countries (January to November).

	(1,000 Cwt.)			(1,000L.)		
	1949.	1950.	1951.	1949.	1950.	1951.
British West Africa	10	9	4	163	154	90
Union of S. Africa	62	67	76	1,009	1,044	1,364
British East Africa	15	9	7	245	152	130
India	131	143	79	2,276	2,299	1,340
Pakistan	9	32	17	196	629	332
Malaya	7	3	3	126	61	61
Australia	80	100	110	1,463	1,831	2,234
New Zealand	15	16	14	312	341	332
Canada	14	43	85	225	863	1,777
Other British countries	34	25	23	564	422	475
Irish Republic	8	7	5	113	111	101
Soviet Union	14	51	83	181	595	856
Finland	6	5	3	114	81	75
Sweden	36	29	27	606	603	713
Norway	23	20	10	412	340	178
Denmark	11	7	7	226	169	166
Poland	78	37	14	1,072	601	194
Netherlands	40	38	22	691	671	492
Belgium	18	19	18	273	318	408
France	44	29	27	793	646	659
Switzerland	9	9	8	175	211	209
Spain	11	9	8	201	160	155
Hungary	18	8	1	489	262	13
Czechoslovakia	23	6	5	316	118	76
Greece	4	0	5	75	129	89
Israel	3	6	7	61	111	145
Egypt	15	15	14	276	258	282
Brazil	9	21	33	175	500	794
Argentine Republic	39	6	6	874	137	155
Other Foreign countries	63	68	119	1,224	1,474	2,726
Total	849	843	840	14,926	15,291	16,621

to list separately in the *Trade and Navigation Accounts*. Exports to these countries—2.8L. millions in the first eleven months of 1951—were almost twice as large as in the corresponding period of 1950. Exports to countries within the Russian orbit, the continuance of which in 1950 caused a Parliamentary fracas, were considerably reduced in 1951. Exports to Poland and Hungary, which had totalled 1.05L. millions in the first eleven months of 1950, fell to 283,000L. in the corresponding period of 1951. Surprisingly, exports to Russia increased from 595,000L. to 856,000L.; it is to be presumed that fewer of the machine tools sent to Russia in 1951 could be considered as war potential, and that most were delivered against contracts signed before the Korean war. The Iron Curtain countries, however, have been one of the chief markets for British machine tools since the war; when, in the not too distant future, the re-armament demand has been met and the machine-tool industry is faced with the problem of keeping its expanded capacity employed, their loss may be particularly serious.

The fact that the peak re-armament demand for machine tools will be over before production for re-armament in other sections of industry is fully under way may in itself create a problem for the machine-tool industry. There will be, of course, a considerable volume of civilian orders on hand which have had to be deferred or postponed, but these are likely to be fairly quickly exhausted, perhaps before the remainder of the engineering industry has completed its defence deliveries.

Some Government economists in the United States foresee in 1952 a slackening of industrial activity and a general lowering of prices. This is, perhaps, unduly pessimistic; inflationary pressures are likely to continue at least until 1953. Thereafter,

there may well be cause for alarm unless the nations of the western world act as effectively and in as close co-operation as they have done in the matter of re-armament. The makers of machine tools will be particularly vulnerable, for, as argued above, their order books may be empty even before the onset of the slump. Much will depend upon the Government; but more will be required than ordinary anti-slump measures to stimulate consumer demand. It will be necessary to remove the obstacles to re-equipment imposed by the present tax system, and perhaps even to institute some subsidy scheme for the engineering industry which, after the manner of the cotton industry re-equipment scheme, may encourage measures for increasing productivity. Without some such policy, there will probably be little attempt to increase the rate of replacement of worn-out machine tools in use in industry, and without a substantially higher rate of replacement than in the period 1945 to 1950, British engineering will not hold its own in world markets. The machine-tool industry can be expected, as in the present emergency, to do everything required of it.

THE HYDRO-ELECTRIC POTENTIALITIES OF AUSTRIA.

By DR. E. KÖNIGSHOFER.

BEFORE the second World War, the development of power-generating installations in Europe kept pace with the demand of energy, though this demand was slowly increasing. Since the war, the demand for power has increased rapidly and the problem of increasing power production could not be satisfactorily solved. The increase in demand is attributable to the tendency of producers of all kinds of goods to be independent of manual labour. In the countries which accepted Marshall Aid, generating capacity, from 1938 to 1946, could be increased only by about 8 per cent.; and in the adjacent countries, it actually decreased by about 5 per cent.

The efforts made to improve the situation in Europe are well known. The P.U.P. (Public Utilities Panel) carried out an introductory survey; the E.C.E. (Economic Commission for Europe) was appointed by the United Nations as their economic organisation; and the O.E.E.C. (Organisation for European Economic Co-operation), with its Energy Committee, was also established. This committee reviewed the several projects drawn up by the European States to improve their energy production, and it was found that, even if all projects were realised, the future demand of energy could not be satisfied. The Energy Committee's budget of the energy surplus and deficiencies in the European countries revealed deficiencies for 1951-52, in millions of kilowatt-hours per annum, as follows: the Benelux countries, 390; Denmark, 90; France, 2,000; Italy, 6,000; Germany, 8,000; Trieste, 190; and Norway, 1,500. Only in three countries was there an available surplus, these being Austria, 980; Sweden, 90; and Switzerland, 500. The total deficiency, therefore, amounted to 16,600 million kWh.

Europe's unsatisfactory position in regard to energy is not occasioned by any lack of natural resources, as the continent possesses large reserves of hard and soft coal, substantial amounts of water power, natural gas, peat, and oil. As, however, it is divided into many countries, there is a shortage in some parts and a surplus in others. There is, however, one way to meet the ever-increasing demand for energy, and that is to regard the whole of Europe as one energy-providing territory, making the most of the rich resources and distributing the resultant energy to the various countries according to their needs. For this purpose, co-operation would be essential, so that countries experiencing a shortage of power might take advantage of the wealth of energy in those more fortunately situated. In particular, the water power available for hydro-electric development would have to be used. There is no doubt that Austria can meet the deficiency of energy resources in some European countries, and to export substantial quantities of electric energy when the water

2-8-2 LOCOMOTIVE FOR EAST AFRICAN RAILWAYS.

NORTH BRITISH LOCOMOTIVE COMPANY, LIMITED, GLASGOW.



power available there has been developed. As is shown above, Austria's potential water power exceeds the country's requirements.

It may be of interest, therefore, to consider what electrical energy can be produced by the Austrian power resources. To ascertain the amount of some of the water available, four research companies were formed. Their surveys do not exhaust all the resources, but they prepared some detailed plans, with estimates of the possible output, costs, and forecasts of the time required for the construction of hydro-electric plants. For example, the Studiengesellschaft Westtirol studied the possibilities of developing the water-power in the Oetz valley in the Tyrol. The Oetzaler Ache is a tributary of the Inn, its mouth being 45 km. (28 miles) west of Innsbruck. The plans deal with the utilisation of the Oetzaler Ache, its tributaries and neighbouring creeks. If developed, they render possible the exploitation of a difference of level between 2,340 m. (7,700 ft.) and 600 m. (1,970 ft.) and a catchment area of 893 square km. (230 square miles). The area is suitable for the siting of reservoirs; within an area 40 km. (25 miles) long and somewhat less in width, eight reservoirs could be constructed, including five reservoirs of great capacity, as shown in the accompanying table. The generating capa-

city for hydro-electric development is the river Bregenzer Ache, which runs into Lake Constance. The Studienkonsortium Bregenzer Ache was deputed to work out plans for this development. Their report states that the Bregenzer Ache could provide 533,000 kW on nine sites (four being storage sites) and 1,200 million kWh per annum, of which 61.5 per cent. would be available in winter.

The Eastern Tyrol has similarly favourable conditions for hydro-electric development. The Studiengesellschaft Osttirol was established to study its possibilities, and reported that, in five stages, a capacity of 430,000 kW could be installed and 1,205 million kWh per annum generated, 68 per cent. in the winter months.

By developing all these hydro-electric resources, the European balance of energy could be influenced decisively, and, it is generally admitted, the problem of meeting the total demand for electrical energy in Europe might be solved. As the four research companies reported, the most productive sources are in Austria, which thus feels able to contribute to the solution of the Continent's energy problem.

2-8-2 LOCOMOTIVES FOR EAST AFRICAN RAILWAYS.

THE photograph reproduced above shows one of a number of 2-8-2 locomotives which are being built for the East African Railways by North British Locomotive Company, Limited, 110, Flemington-street, Springburn, Glasgow, N. The locomotives are arranged for oil-burning, though they can readily be converted for solid fuel. The design is based on the River-class 2-8-2 locomotives already in service on the Nigerian Railway, where the gauge is 3 ft. 6 in.; the gauge of the East African Railways is at present 3 ft. 3½ in., but it is to be increased to 3 ft. 6 in. sometime in the future, when the new engines, designed with this in view, will be modified accordingly. The locomotives are being built to the requirements of Mr. G. Gibson, M.I.Mech.E., M.I.Loco.E., chief mechanical engineer, East African Railways, and are designed and built under the supervision of the Crown Agents for the Colonies.

The principal dimensions are: cylinders (two) 18 in. by 26 in.; coupled wheels, 4 ft. in diameter; boiler pressure, 200 lb. per square inch; tractive effort at 85 per cent. boiler pressure, 29,835 lb.; and adhesive weight, 51.92 tons. The boiler barrel consists of two rings, with the external diameter at the firebox end 5 ft. 5 in. The length between tubeplates is 16 ft. 4½ in., and there are 28 superheater flue tubes of 5½ in. external diameter, and 125 small tubes of 2 in. external diameter. The firebox is of the Belpaire type, with a steel inner box of all-welded construction. The firebox, roof and waterspace stays are of Dunic steel and flexible stays are provided in the breaking zones. The fire-pan is as deep as the design permits, with two burners fitted at the front of the box. The Melesco superheater header incorporates a multiple-valve regulator, and a Melesco steam lagged is fitted in the dome. The boiler and firebox are lagged with asbestos mattresses. The grate area (for solid fuel) is 38 sq. ft., and the heating surfaces are as follows: tubes, 1,732 sq. ft.; firebox, 146 sq. ft.; superheater, 446 sq. ft.; combined total, 2,324 sq. ft. General steam fittings include three Gresham and Craven No. 9 non-lifting injectors, two 1½-in. "Everlasting" blow-off cocks, two 3-in. diameter Ross pop safety-valves and two sets of Klinger reflex water-gauges.

The main frames are machined from rolled steel slabs, finished to a thickness of 4 in. and braced by transverse stays. Timken roller-bearing axleboxes are fitted to all axles of the locomotive and tender. The coupled axleboxes are of the cannon type, and all tender and carrying wheels and axles, complete with roller-bearing axleboxes, are identical and interchangeable as a unit between leading truck, trailing truck and tender bogies; these wheels are 2 ft. 9 in. in diameter. Laminated bearing springs are fitted to all coupled wheels and to the front and hind tracks. Compensation is arranged in two groups, from the front truck to the intermediate coupled wheels, and from the driving wheels to the hind-truck wheels. Automatic couplers of MCA-PH type are fitted at the front of the engine and the back of the tender. The frames at the front of the engine and at the back of the tender, together with the buffer beams, are arranged to accommodate the American knuckle-type coupler in addition to the MCA coupler. Walschaerts valve gear actuates 10-in. diameter piston-valves. The cylinders are lubricated by a Silvertown eight-feed mechanical lubricator, and Wota by-pass valves are fitted to the steam chests. The cylinder barrels are fitted with renewable cast-iron liners.

Lambert sanding equipment is fitted to the engine. Steam-brake equipment is provided for the engine, and an air brake for the tender and train. The steam brake includes an air-operated graduable steam-brake valve, and the Westinghouse fittings include two 10-in. by 10½-in. compressors, a 10-in. by 10-in. equalising reservoir and a No. 4 driver's brake valve. The compressors are lubricated by means of a Wakefield two-feed hydrostatic lubricator. As the automatic vacuum brake may be the future standard on the East African Railways, the air-brake equipment is arranged so that when the change-over occurs the least possible amount of work will be involved in the installation of the vacuum-brake equipment. The Stone's electric lighting equipment includes a turbo-generator, a headlamp at the front of the engine, a special 10-in. trailing "headlamp" at the back of the tender, gauge and lubricator lights, a motion light, injector-overflow lights and a fuel-tank light.

The tender is of the four-wheel double-bogie type, and the capacities of the water and oil-fuel tanks are 4,000 gallons and 2,375 gallons, respectively. The water and fuel tanks are of welded construction, but the internal stays and wash plates of the water tank are riveted to T-bars welded to the sides of the tank. The frame is built up of longitudinal and cross channels of riveted and welded construction, with cast-steel drag-boxes at the front and back. The bogies are of the plate-frame spring-beam type and are fitted with Timken roller-bearing axleboxes which, as already stated, are interchangeable with those of the front and hind trucks of the engine. In addition to the air brake a hand brake is also fitted.

The other principal dimensions and weights are: coupled wheelbase, 13 ft. 3 in.; engine wheelbase, 30 ft. 5 in.; total wheelbase, engine and tender, 57 ft. 2 in.; height to top of chimney, 12 ft. 6 in.; weight of engine in working order, 73.81 tons; and weight of tender in working order, 52.11 tons.

city to be installed in these stations would be 1,041,000 kW, giving a total annual production of energy of 2,190 million kWh, of which 61 per cent. would be produced in winter and 39 per cent. in summer.

The scheme suggested would have to be accomplished in stages. The first could be completed within 3½ years, with a production of 717 million kWh yearly. The total costs can be evaluated to 2,000 million Austrian schillings, making the cost per kilowatt-hour 15 Austrian groschen. Remembering that the total production of energy in Switzerland in 1950 was 11,500 million kWh, the plans prepared by the Studiengesellschaft Westtirol would represent a fifth of that production.

The Inn river rises in Switzerland, crosses the Engadine valley and thence enters Austria. The water power of the Inn and of its tributary the Kaunerbach lend themselves to hydro-electric development. The research company, the Studiengesellschaft Oberer Inn, was entrusted with a study of the possibilities of development in that area. The plans prepared stated that the water power of the upper Inn could be developed in two stages, likewise those of its tributary. By the installation of a generating capacity of 392,000 kW in four stations, some 1,409 million kWh per annum could be obtained, 43 per cent. of which could be produced in the winter months. Also suitable

Reservoir.	Useful Storage Capacity, Millions of cubic metres.	Energy Millions of kWh per Annum.	Maximum Water Level, m.	Difference in Level Between Reservoir and the Inn, m.
Zwieselstein ..	122	233	1,575	829
Fischbach ..	70	237	2,234	1,417
Riftsee ..	30	102	2,280	1,483
Vent ..	120	333	1,980	1,205
Finstertalersee ..	60	217	2,330	1,570

SUMMER MEETING OF THE INSTITUTION OF ELECTRICAL ENGINEERS.—It is announced that it has been necessary to change the date of the 1952 Summer Meeting of the Institution of Electrical Engineers. This will now take place in Ireland from Wednesday, June 25, to Saturday, June 28, instead of from Monday, June 30, to Friday, July 4. There will also be an informal reunion on Tuesday evening, June 24.

PROGRESS WITH THE RUSTON AND HORNSBY GAS TURBINE.

THE development of their 750-kW prototype gas turbine by Messrs. Ruston and Hornsby Limited, Lincoln, continues to make good progress and the design has shown sufficient promise to warrant a start being made on production. As a consequence, the firm are at present installing the necessary plant and equipment for batch production and it is understood that work has started on the first batch. If work proceeds according to plan, it is hoped to have the first production machine running by next March and the remainder at three-monthly intervals. Meanwhile, progress with the original prototype machine has now reached the point where it is used every day to supply part of the works electrical load, thereby reducing the demand on the public supply. In this duty, it has shown complete reliability, the only trouble having been experienced at the beginning of the tests, when the high-pressure fuel filter became choked with a lacquer-like deposit, arising from earlier tests during which heavy fuels were used. One factor which has been particularly noticeable during these runs has been the consistency of performance, the unit, despite its relatively small size, having proved to be quite as reliable as steam and oil-engine plant.

In general, the design of the prototype turbine remains much as before, the only mechanical change of significance incorporated during the past 12 months being the replacement of the original reduction-gearing by an Allen-Stoeckicht unit which was fitted to the existing casing. This has resulted in a marked reduction in the noise level and considerably smoother running. Similarly, the design of the production machines follows closely that of the prototype unit although some improvements have been incorporated as a result of running experience with the prototype. The methods employed for lining up the different components, for example, have been simplified and the location of the rotor with respect to stator made more direct, this now being accomplished with fewer joints. Possibly the most significant alteration is the use of a single combustion chamber in place of the two fitted on the prototype machine. This change has been adopted so as to overcome the inherent instability that exists with two chambers, since it is almost impossible exactly to match the burners. The trouble could have been overcome, of course, by fitting more chambers, but the single chamber was chosen as, apart from being more economical from the production viewpoint, a single chamber renders it easier to convert the machine from a non-recuperative unit to a recuperative one, and vice versa. Furthermore, the single chamber has been designed so that once the troubles experienced with the burning of residual fuels in gas turbines have been overcome, it will only be necessary to make minor changes to enable such fuels to be used. It may be mentioned, in this connection, that a flame tube suitable for burning residual fuels has already been developed.

Other modifications which may be mentioned are the incorporation of redesigned exhaust trunking to give better accessibility to the gearbox and improved arrangements for air-cooling the stators, less air now being bled from the compressor to give the same degree of cooling. Work, however, has by no means been confined to improving the gas turbine itself. A new plate-type heat exchanger, for example, is in course of development and present indications are that it will be considerably smaller than the existing tubular type, occupying approximately one-eighth the volume. Research on problems concerned with combustion and aerodynamics has continued throughout the past year. In the combustion field, attention has been concentrated on the burning of heavy liquid fuels, including coal-tar derivatives; promising results were obtained in each case, so much so that full-scale tests using one of the Admiralty's special-reference heavy fuels were carried out during the summer on the prototype turbine. Results obtained were encouraging in that there was negligible deposition of ash on the turbine blades and very complete combustion of the fuel was obtained. Useful data regarding the conditions necessary for complete combustion of gaseous fuels in gas turbines also has been collected and an advanced stage has been reached in the preparations for further tests which are to be carried out on sites where such fuels are obtainable.

Considerable progress has also been made in the technique of handling and burning peat, this work having been carried out under contract from the Ministry of Fuel and Power. The first design of a refractory combustion chamber has now been developed to the point where its combustion efficiency exceeds 90 per cent., regarded as satisfactory for initial tests of the complete peat-burning turbine. Construction of the latter is now in an advanced stage and preliminary runs using oil fuel have been made. Problems concerned with the dewatering of peat by pressing and thermal drying have also been investigated and the

HIGH-PRESSURE PORTABLE AIR COMPRESSOR.

CONSOLIDATED PNEUMATIC TOOL COMPANY, LIMITED, LONDON.

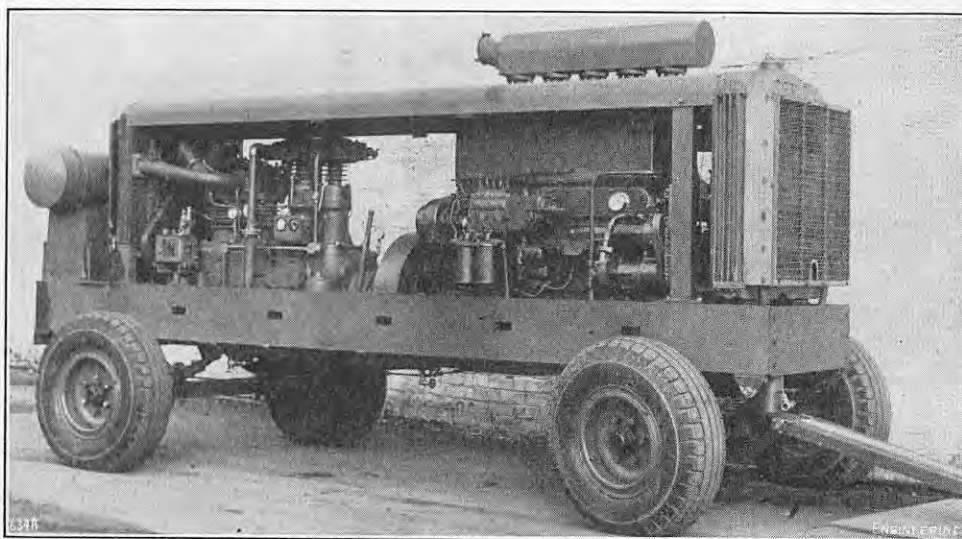


FIG. 1. COMPLETE UNIT WITH SIDE PANELS REMOVED.

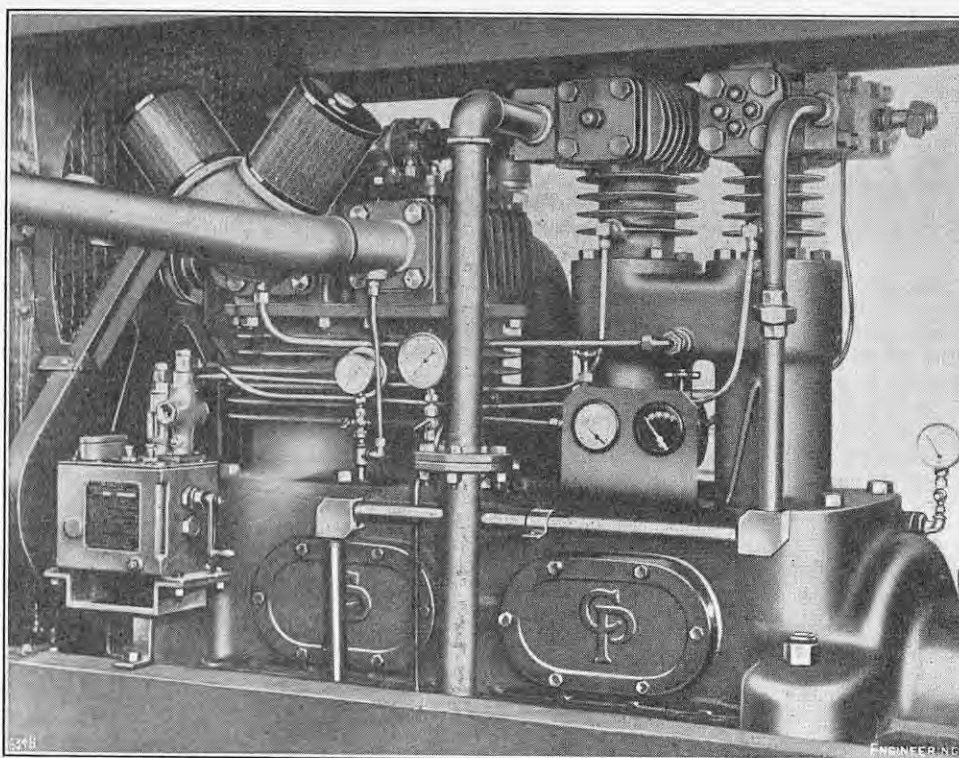


FIG. 2. FOUR-STAGE AIR COMPRESSOR.

equipment required for the first full-scale experiments has been ordered. So far as the development of turbines burning solid fuel is concerned, investigations have been made into the most effective means of separating ash from the products of combustion; a two-stage separator is now in course of construction.

ALMANACS AND CALENDARS.—We have received monthly tear-off wall calendars from Charles Churchill & Co., Ltd., Coventry-road, South Yardley, Birmingham; B. Levy & Co. (Patterns), Ltd., 1-5, Osbert-street, Vincent-square, London, S.W.1; and Nordac Ltd., Trading Estate, Cowley Mill-road, Uxbridge, Middlesex. A wall calendar showing the twelve months of 1952 on one sheet has reached us from Permali Ltd., Bristol-road, Gloucester; and a desk calendar with movable monthly cards has come to hand from Stewarts and Lloyds, Ltd., Brook House, Upper Brook-street, London, W.1. General Electrical Construction and Maintenance, Ltd., 14, Bow-lane, London, E.C.4, have sent us a perpetual calendar for desk use. A copy of the *South African Pictorial Calendar* for 1952, issued by the publicity and travel department of South African Railways, Johannesburg, has been received from their commercial representative in London, whose address is South Africa House, Trafalgar-square, London, W.C.2. This wall calendar is printed in English and Afrikaans, and contains 50 photographic illustrations of South African scenes.

HIGH-PRESSURE PORTABLE AIR COMPRESSOR.

THE portable air compressor illustrated on this and the opposite pages, has been developed by the Consolidated Pneumatic Tool Company, Limited, 232, Dawes-road, London, S.W.6, for use in oilfields. Known as the model PO-44, it is a vertical single-acting multi-stage air-cooled unit capable of producing pressures up to 1,500 lb. per square inch or 2,000 lb. per square inch intermittently, and although designed with oilfield duties in view, can obviously be used for many other purposes. There are four stages, the cylinders being arranged in line so that a four-throw crankshaft with one connecting rod to each crankpin can be used. This arrangement will be clear from the photograph of the compressor unit reproduced in Fig. 2 herewith, and from the drawings reproduced in Fig. 3, opposite, which shows a cross-section through the low-pressure and first intermediate-pressure cylinders and associated running gear and a section through the high-pressure cylinder. Another section of the high-pressure cylinder showing the valves is given in the top right-hand corner of Fig. 3. It will be noted that the first and second stages are fitted with trunk pistons whereas the high-pressure cylinders are provided with piston-type crossheads. Airtight rings are fitted to the crossheads so that each compression chamber is completely isolated from the crankcase,

HIGH-PRESSURE PORTABLE AIR COMPRESSOR.

CONSOLIDATED PNEUMATIC TOOL COMPANY, LIMITED, LONDON.

Fig. 3.

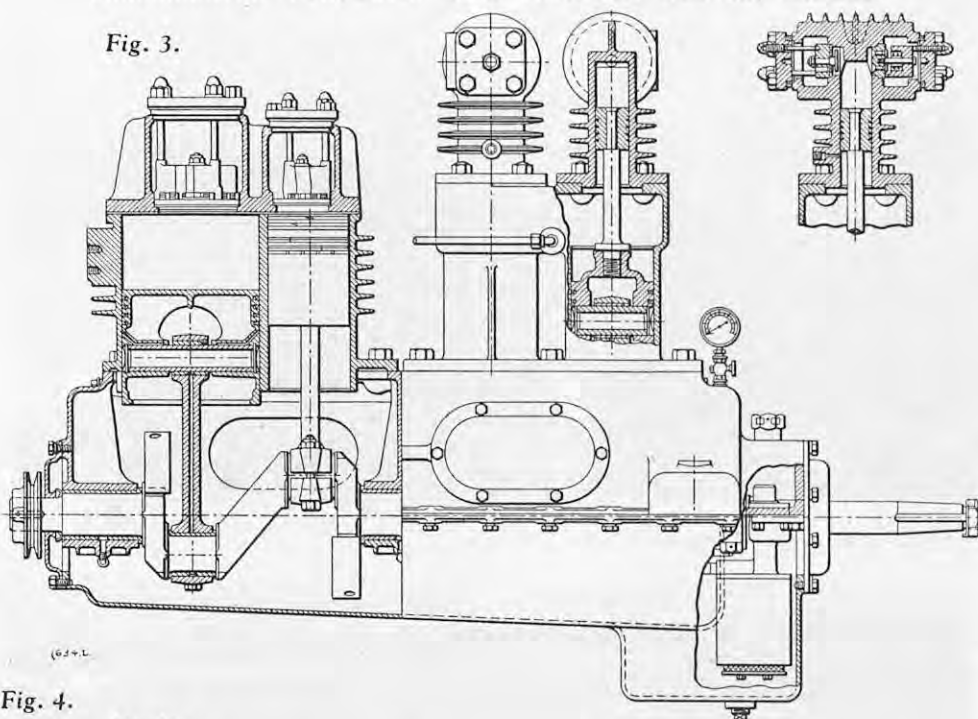
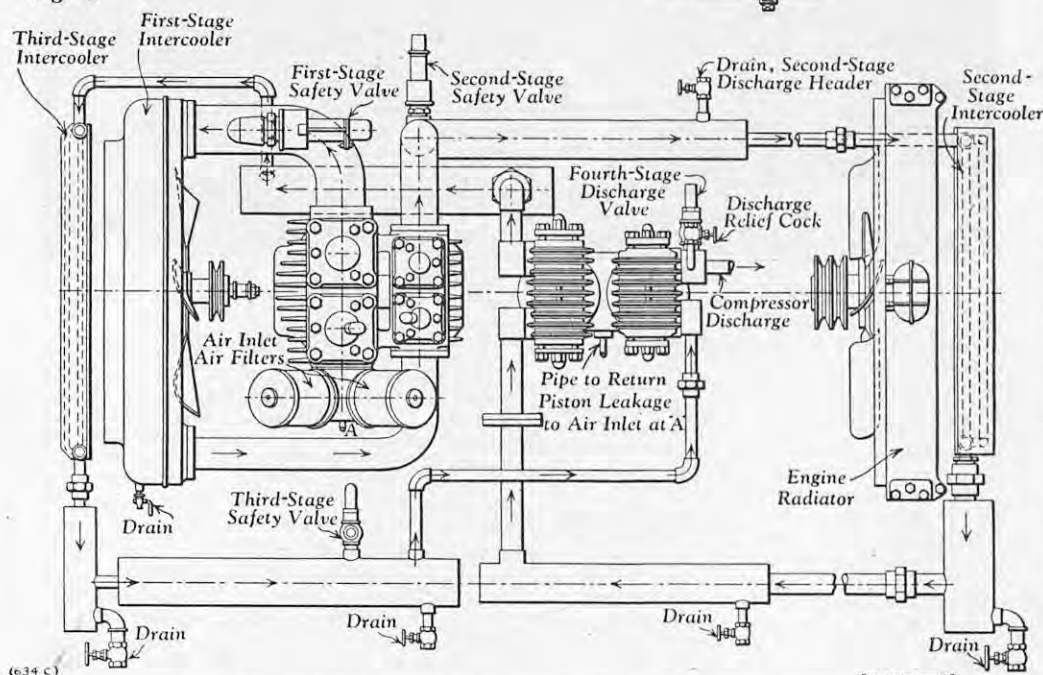


Fig. 4.



the enclosed spaces so formed being vented to the compressor intake.

The compressor is lubricated throughout by a forced-feed system, a gear-type pump delivering the oil to the main bearings from which it passes through holes drilled in the crankshaft to the big ends and then through the centres of the connecting rods to the gudgeon pins. The first-stage and second-stage pistons and the third-stage and fourth-stage crossheads are lubricated by the oil mist created in the crankcase but the third-stage and fourth-stage pistons are lubricated by a plunger-type belt-driven sight-feed lubricator. This unit can be seen in Fig. 2, immediately below the intake air filters. To enable full economy of multi-stage compression to be obtained, fan-cooled intercoolers of the finned-tube type are provided between each stage; these cool the air to within 20 deg. F. of ambient temperature. A diagram showing the flow of air through the compressor and associated coolers is reproduced in Fig. 4, above.

The compressor is driven by a Ruston and Hornsby 5VPH five-cylinder Diesel engine fitted with electrical starting gear, the engine being coupled to the compressor through a multi-plate spring-loaded clutch. The engine is cooled by means of a sectional-type radiator, cooling being assisted by a fan belt-driven from the engine crankshaft. The compressor and engine are mounted on an exceptionally rigid chassis of welded construction and, although not shown in Fig. 1, the complete plant is enclosed by removable side panels. Leaf springs are used for connecting the axles to the chassis and the leading wheels are steered

through an Ackerman linkage actuated by the draw-bar. The length of the complete unit is 15 ft. 4 in., the width, 6 ft. 9½ in., and the height, with exhaust muffler, 7 ft. 10 in.

The compressor can be supplied for various working pressures and the dimensions of the cylinders, therefore, vary according to the duty. For a unit designed for a working pressure of 1,000 lb. per square inch, for example, the diameters of the first-stage, second-stage, third-stage and fourth-stage cylinder bores are 9½ in., 5½ in., 3½ in., and 2½ in., respectively, whereas for a unit having a working pressure of 1,500 lb. per square inch, the first-stage cylinder bore remains the same but the second-stage, third-stage and fourth-stage cylinder bores are reduced to 5 in., 2½ in. and 1½ in., respectively. The stroke remains constant at 5½ in. for both units and the designed operating speed in each case is 900 r.p.m.

PEDESTAL-TYPE SAW BENCH.—The Startrite Engineering Co. Ltd., Waterside Works, Gads Hill, Gillingham, Kent, have added a 10-in. motor-driven rising-top pedestal-type saw bench to their range of woodworking machinery. The new machine is equipped with a rising and falling table and, in accordance with modern practice, the driving motor is placed in the pedestal. The table is provided with a canting fence for bevel cutting, a protractor and the usual guards. By using profile cutters the machine can be employed for moulding special shapes and, if fitted with an abrasive wheel, is suitable for cutting metal tubes and rods to length.

ELECTRICITY SUPPLY IN CANADA.

ACCORDING to a report for 1951, of Mr. R. H. Winters, Minister of Resources and Development, 881,250 h.p. of hydro-electric plant was brought into use in Canada, making a total of 13,340,774 h.p. when the dismantling of certain old units is taken into account. This represents about 24 per cent. of the known resources of the Dominion. Of the additions, 461,700 h.p. was in Quebec, but a striking feature of the new developments was the number of stations that were located in sparsely-settled regions, thus showing that the potential value of such sites is being increasingly recognised. Plant under construction, which will be brought into operation during 1952-53, amounted to 1,700,000 h.p., while approximately the same amount should be commissioned in 1954-55. The output was about 13 per cent. above that in 1950. Construction was also active in the field of power distribution. New main transmission lines were completed or were under construction in many parts of the country and secondary systems were being extended. Good progress was made in rural electrification.

As regards developments in the individual provinces, the construction of hydro-electric plants has been accelerated in Quebec, owing to the expansion in industrial activity. During the year under review, four units, with an aggregate capacity of 223,000 h.p., were installed in the Beauharnois No. 2 power house of the Quebec Hydro-Electric Commission on the St. Lawrence River, bringing the total up to 333,000 h.p. This station will, however, be extended to 666,000 h.p. probably by 1953, when 12 units operating under a 80-ft. head will be at work. A smaller station is being built on the Upper Ottawa River near Cadillac to meet the demands of the mines in the Temiscamingue-Abitibi district and will eventually have a capacity of 64,000 h.p. The Shawinigan Water and Power Company also made an important addition to their generating capacity by installing three 65,000-h.p. units in the La Tranche station, bringing the total up to 325,000 h.p., which may ultimately be increased to 390,000 h.p. The Aluminium Company of Canada were building two stations on the Peribonka River. One of these, at Chute-du-Diable, will have an installed capacity of 275,000 h.p. with an operating head of 110 ft., while the other, at Chute-à-la-Savanne, 13 miles downstream, will be of the same capacity and operate under the same conditions. Both stations will be connected by a double-circuit 154-kV line with the Saguenay system. The Manicouagan Power Company began the construction of a station near the mouth of the Manicouagan River. This will eventually contain six 50,000-h.p. units, operating under a 125-ft. head, of which two should be in commission early in 1953. Details of the construction of and extensions to a number of smaller stations are also mentioned, while the dismantling of the 58,500-h.p. station at Shawinigan Falls and other plants is noted.

In Manitoba, the extension of the station at Pine Falls on the Lower Winnipeg River continued and will, it is expected, be completed in 1952, when a total of 114,000 h.p. will be operating under a head of 37 ft. The Seven Sisters station on the Winnipeg River with a capacity of 225,000 h.p. and an operating head of 66 ft. should also be completed, and to allow of its efficient operation the Pinawa channel is to be closed by a rock and gravel fill and the 37,800-h.p. station which was started up in 1906 is being dismantled. The City of Winnipeg has an auxiliary steam station under construction, of which the first 15 MW unit is expected to be in operation early this year. A second unit of 25-MW capacity should be ready for load in 1953.

The position in Ontario may be summarised by saying that the heavy demand for power in the southern part of the province rendered it necessary to expedite the construction programme of the Hydro-Electric Power Commission. As a result, the Des Joachims station, with a capacity of 496,000 h.p., was practically completed, as was the 168,000-h.p. station at Chenaux. It is also hoped that the construction of the Otto Holden (formerly La Cave) station, which is to have a total capacity of 272,000 h.p., will be finished before the end of the present year. In addition, plans are well advanced for a second generating station at Queenston, which will contain seven units with a total capacity of 735,000 h.p. The intake for this station comprises a tunnel 45 ft. in diameter and 28,600 ft. long, followed by an open canal 200 ft. wide and 11,800 ft. long. It is hoped that four units will be in operation by the end of 1954 and the remainder during the following year. As regards steam stations in the province, the first stage of the construction of the new J. Clark Keith plant at Windsor was nearing completion in November, and the second should follow next month. Eventually, the station will contain four 66-MW sets. The Richard L. Hearn station at Toronto is being constructed in two sections, each containing one 88-MW 25-cycle and one 100-MW 60-cycle unit. Both the first 25-cycle and the first 60-cycle units are now in operation and the second stage should be completed early in 1953.

ELECTRICAL EQUIPMENT FOR MULTIPLE-UNIT TRAINS.

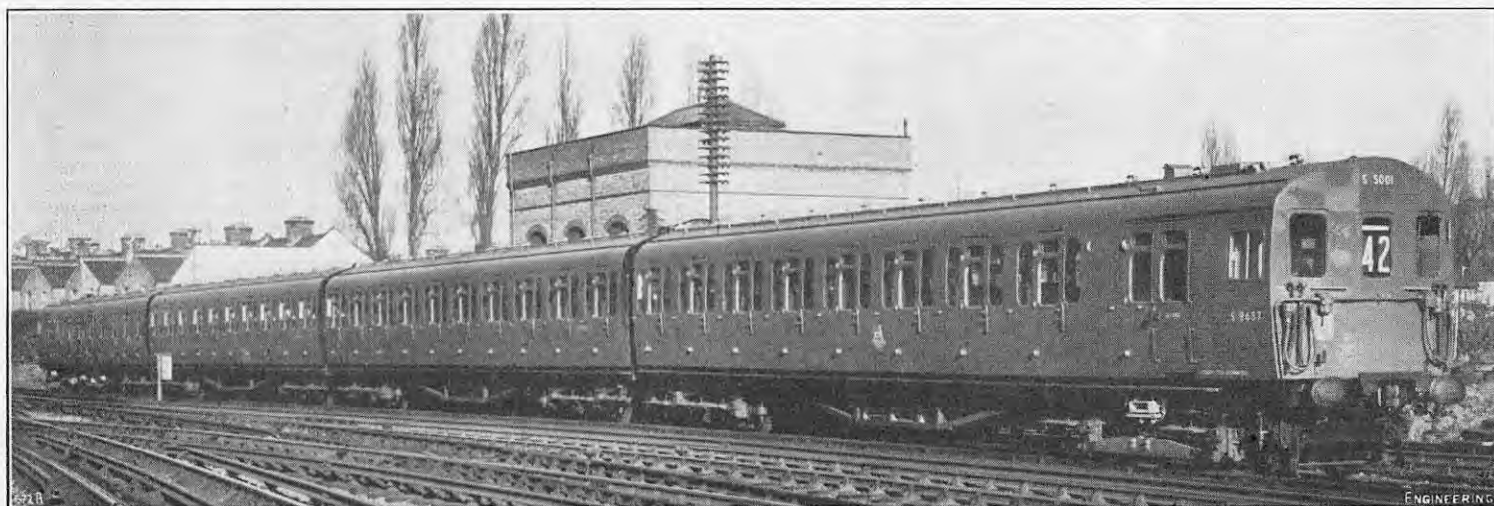


FIG. 1. FOUR-CAR ELECTRIC TRAIN.

ELECTRICAL EQUIPMENT FOR SOUTHERN REGION MULTIPLE-UNIT TRAINS.

THE four-car train illustrated in Fig. 1 is the first of the multiple-unit stock which is being rebuilt at the Eastleigh carriage works of the Southern Region, British Railways, to the design of Mr. R. A. Riddles, Railway Executive member for mechanical and electrical engineering, so that they can be used on either the suburban or express services. Its total length is 257 ft. 5 in. and its tare weight 136 tons, and it has seating accommodation for 386 passengers. Generally speaking, it is mechanically similar to the all-steel units which have been completed within recent years, but some changes have been made with a view to improving the operating efficiency. For instance, Buckeye automatic couplers are fitted at the outer ends, and the brake hose connections have been arranged above the solebar level, so that uncoupling and coupling can be effected without going between the coaches at track level. The driving cabs have no side doors, access to them being gained through a sliding door from the guard's compartments. All the auxiliary switches, fuses and contactors, as well as the voltage regulator and compressor governor, are housed in a cupboard at the rear offside.

The train includes two motor coaches, the leading bogies of which carry two axle-hung motors; the total capacity of these is 980 h.p. at the one-hour rating. The initial acceleration to 27 m.p.h. is 1 m.p.h. per second, which is the maximum possible within the limits of adhesion, when 25 per cent. of the axles are motored; and the balancing speed has been raised as far as possible by the use of field-weakening. It was not, however, considered worth-while increasing the proportion of motor axles for suburban traffic conditions where the average run between stops exceeds 1½ miles. The equipment for the series-parallel control of the motors, which includes bridge transition and field-weakening in two stages when parallel connections are in use, is carried on the under-frame of the coach. It consists of electro-pneumatic unit switches of a light-weight type with cam-operated silver butt contacts and starting resistances of expanded metal, which are only about one-third the weight of the cast-iron resistances previously used. These starting resistances can be seen in Fig. 2.

The master control system is operated at 73 volts, a supply being normally obtained from a motor-generator, which is also visible in Fig. 2, and a battery which is slung under the leading motor coach. In emergency, however, an alternative supply can be obtained from the motor coach next in rear in the train. This system of control has, of course, been used for many years on all Southern electric express stock, but with the exception of the experimental double-deck train this is the first time it has been employed on suburban stock. The master controller has four power notches: shunting; full series, full field; full parallel, full field; and full parallel, weak field. The acceleration is automatically regulated by a single current-limit relay on each motor coach, the characteristics of which are varied to suit series and parallel regulation. As the control circuits are supplied from a battery a no-current relay is included in the circuit, so that the equipment is returned to the shunting position if the power from the conductor rail fails. It also allows the system to be "notched up"

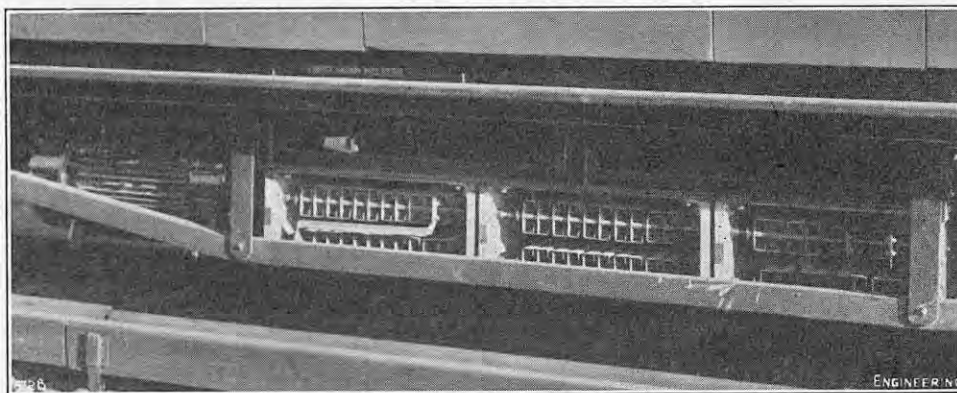


FIG. 2. MOTOR-GENERATOR SET AND STARTING RESISTANCES.

to the position indicated by the master controller when power is restored.

One of the most important features of the new equipment is the simple way in which the train can be prepared for service. All that is necessary is to release the hand brake and close one switch in each driving cab in turn and to unlock the master-switch, reversing and power handles in the cab from which the train is to be driven. When the master switch is closed power is switched on to the control and electro-pneumatic brake circuits and the automatic brake is cut in by a relay valve. This arrangement eliminates the brake isolating key and only the small key already mentioned is needed to drive the train. Both Westinghouse automatic brakes and non-interlocked electro-pneumatic brakes with self-lapping controllers are provided, a supply for the latter being obtained from the motor-generator and battery.

A power bus line and 27-core control line are carried through the train, the connection between the vehicles being made by two jumpers with plug and socket connections which are duplicated at the outer ends of the unit. In addition, there are two auxiliary jumpers between each motor coach and the adjacent trailer for carrying the heating and lighting circuits. Heating is effected by totally-enclosed thermostatically-controlled units which are fed from the traction supply. In each driving cab there are also two locally-controlled heaters. The total heating load is 40 kW. The train is lighted by incandescent lamps, which are supplied from the 73-volt circuit. Half these lamps are connected on the battery side of the reverse current contactor and therefore remain alight should the motor-generator fail. All the lighting in the passenger accommodation can be controlled from any guard's compartment. The total lighting load is 4.3 kW.

The electrical equipment was manufactured by the English Electric Company, Limited, Kingsway, London, W.C.2, and has been designed so that it can be used on either two-car or four-car units and on either suburban or express stock, the gear ratio being modified in the latter case.

WAGONS FOR SODA-ASH TRANSPORT.—British Railways are to build 180 25-ton covered hopper wagons of a special type to carry sodium tripolyphosphate and soda ash from Cheshire to factories in the north-west and eastern counties.

CONTRACTS.

MILLS SCAFFOLD CO., LTD., Highfield-road, Levenshulme, Manchester, have received a contract from British Railways (London Midland Region) for scaffolding and safety sheets in connection with the removal of roof coverings at Manchester Central station. THE DEMOLITION AND CONSTRUCTION CO., LTD., 3, St. James's-square, London, S.W.1, have received the order for the removal of the existing roof coverings.

BRITISH UNITED TRACTION LTD. have received an order for 50 double-deck trolleybus chassis for the London Transport Executive. These are similar in most respects to the 77 vehicles supplied in 1948. The chassis have a wheel-base of 18 ft. 5 in. Another order has been received from the North Zealand Electricity and Tramway Co., Ltd., a private company operating trolleybuses in Copenhagen, Denmark, for 20 left-hand drive single-deck trolleybus chassis having a wheel-base of 15 ft. 7 in. Another order is for the first ten of a contract for 27 left-hand controlled three-axle double-deck trolleybuses for the Barcelona Tramway Administration. Each vehicle has a total capacity of 76 passengers, 66 seated and 10 standing.

DAVID BROWN & SON (HUDDERSFIELD) LTD., have received an order for 416 railcar gearboxes, part of an 8-million dollar contract for 104 high-speed railway cars, placed with United Kingdom firms by the Toronto Transport Commission. The gearboxes, four of which will be incorporated in each railcar, will be similar to, though larger than, the units which the company have supplied in recent years to a number of public-transport undertakings in Western Europe and Scandinavia.

THE LATE MR. C. J. T. MACKIE.—We regret to learn of the sudden death, on January 8, of Mr. C. J. T. Mackie, who was for many years assistant secretary of the Institution of Chemical Engineers. He was 57 years of age and had been in poor health for some months. Mr. Mackie was educated at the Coopers' Company's school and obtained his first appointment in the accountants' department of the Metropolitan Water Board. During the 1914-18 war he served with the London Scottish regiment and, after demobilisation, spent some years in a secretarial post in the City of London before his appointment in 1924 as assistant secretary of the Institution of Chemical Engineers.

CONSTRUCTION OF ACTON LANE "B" POWER STATION.

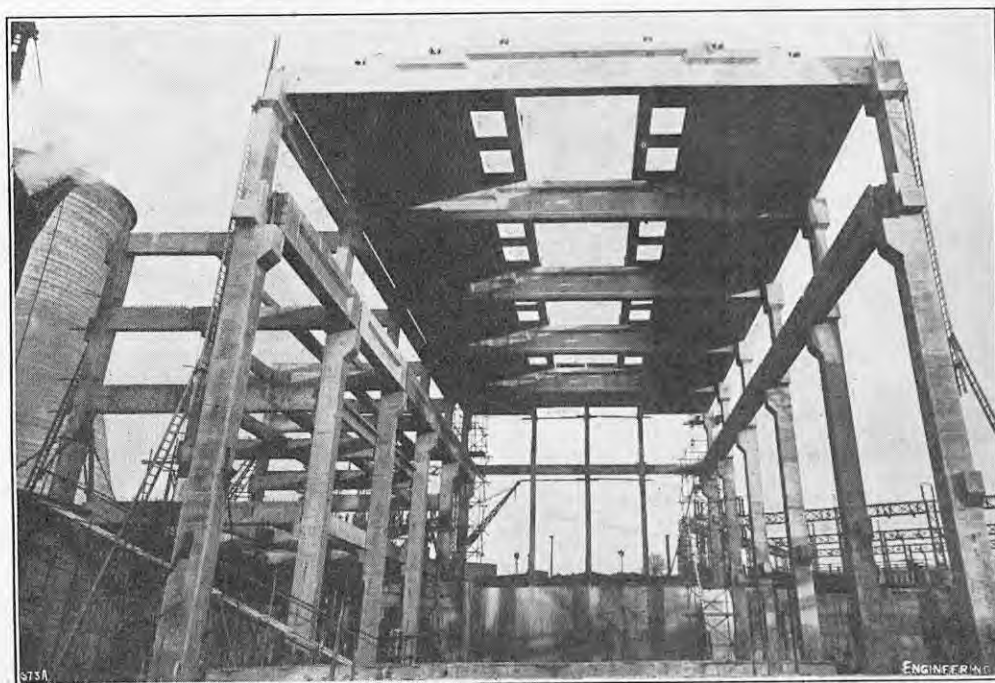


FIG. 1. STRUCTURE OF TURBINE HOUSE AT DECEMBER 10, 1951.

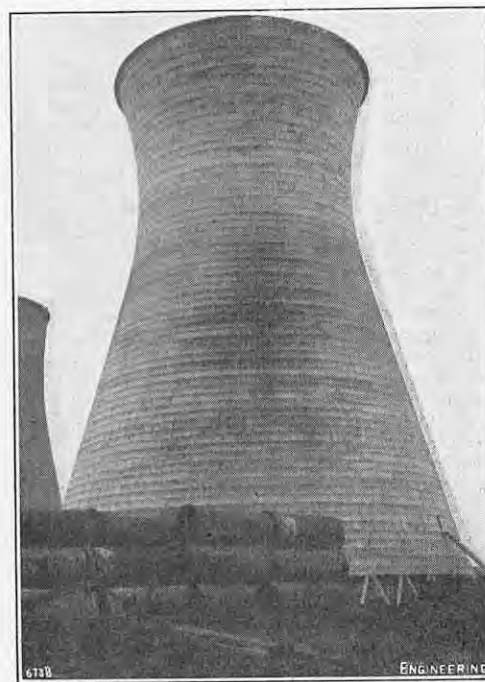


FIG. 2. NO. 1 COOLING TOWER; SHELL COMPLETED.

REINFORCED-CONCRETE CONSTRUCTION AT ACTON LANE "B" POWER STATION.

AN interesting feature of the new power station, to be known as Acton Lane "B," which is now being erected in the London Division of the British Electricity Authority, is the use of pre-cast reinforced concrete for the construction of the turbine house and switch-bays, as well as for a separate workshop building. By using this form of material it has been possible to reduce the weight of steel employed from 1,000 to 330 tons and to make a considerable saving in the shuttering and framework, compared with cast-in-situ methods. It has also been possible to employ a higher grade concrete to give a better finish and greater accuracy, while the saving in time has been considerable, as is shown by the fact that though erection was not begun until October 20, 1951, the structure is to be completed this week. A further advantage is that the design can be modified at a much later date than with steelwork. At Acton Lane, in fact, certain information with regard to some of the transformers was not available until an advanced stage in the work. Nevertheless, it was possible to design, detail and construct the necessary supporting members within a few weeks. The work was carried out by Sir Robert McAlpine and Sons, Limited, 80, Park-lane, London, W.1, with Brian Colquhoun and Partners, 18, Upper Grosvenor-street, London, W.1, as consulting engineers.

The foundations of the turbine and boiler houses are of mass concrete with reinforced-concrete retaining walls of a clear depth of 20 ft. from average ground level. These retaining walls also carry the external column loads of the boiler and switch houses. The turbine house, of which a close-up view is given in Fig. 1 and exterior and interior views in Figs. 3 and 4, respectively, on page 80, consists of one 25-ft. and ten 27-ft. bays. There are two rows of principal columns, which are 66 ft. high and are placed 63 ft. apart at 27-ft. centres. These columns, which are 30 in. by 30 in. in section to crane level and 36 in. by 18 in. above, weigh 3 tons each; and those forming the inner row have slots at certain levels to carry the beams of the adjacent switch house. The columns are supported in pockets in the floor and their ends were formed so that the maximum pressure transmitted to the concrete foundation does not exceed 3 tons per square foot. The maximum load on any main column is 764 tons.

The columns in the other row support the boiler house, which is a steel-framed building, and each sustains a load of 360 tons, in addition to the load from the turbine house. The roof is carried in a single span across the columns by pre-cast beams, 64 ft. long, 18 in. wide and 6 ft. deep at the centres, with a maximum weight of 26 tons; the undersides of the beams are 61 ft. 6 in. above the basement. The innermost units on either side of the central bay have openings to take the roof lights and the central bay has a continuous monitor roof light which was cast *in-situ*. A 70-ton electrically-operated travelling crane will run 50 ft.

above the basement on beams 26 ft. 6 in. long, 4 ft. 6 in. deep and 18 in. wide, each of which weighs 12½ tons. These beams are supported on corbels from the main columns. The generator foundations will be 24 ft. above the basement.

The switch-house is supported on the inner row of turbine-house columns and on a second row of smaller columns, 30 ft. apart and spaced at 27 ft. This building (on the left in Fig. 1) is about 60 ft. high with ten 27-ft. bays, and for the most part has four storeys, though there will be an additional storey over certain parts. Both the floor and roof are of *in-situ* concrete construction. The main floor beams in this part of the station are 30 ft. long and weigh about 7½ tons each.

All the columns and the main and secondary beams were designed as single units and were fabricated and cast in timber moulds on the ground. They were then lifted into position by two 30-ton Morgan derricks, that on one side being erected on 25-ft. steel towers, while that on the other was carried on pre-cast reinforced-concrete slabs. Special attachments were designed for the various lifts. When the members had been erected and trued in position, the concrete floors were poured, the material being run in at all points of connection to unite with the reinforcing bars, so that the beams, columns and floors became a monolithic structure. The columns were temporarily guyed in position until they had been concreted wholly into their bases and the framework was so designed that each member could be fitted into a slot or rested on a bracket without any further props or temporary supports. The structure was then safe until it was ready to receive its brickwork cladding. In fact, measurements taken while it was in this state during a high wind revealed negligible movement. The wind forces on the completed building will be absorbed by 9-in. brick walls, which will be built across the switch annex at alternate column positions throughout the height of the building.

The building was constructed in complete bays, foundation to roof, moving in an east to west direction, so that every pre-cast member was erected and positioned in one bay before the cranes moved forward. Erection was begun on October 21, 1951, and the original contract laid down that the framework of the eleven bays was to be completed within 36 weeks. By January 3, 1952, however, eight complete bays had been erected, an average of one bay in about ten days, or half the contract time; Fig. 3 shows the structure on January 1. The time required for curing before lifting varied with the percentage of load which a member had to bear when in position, the deciding factor being the pre-cast roof units, 50 per cent. of the loading of which was represented by their own weight. Casting was, however, always so far ahead of erection that in no case was it necessary for a member to be lifted in under 14 days from the placing of the concrete. In general, working drawings and bar schedules were required on site three weeks before any particular member was fabricated. The time taken for the fabrication and erection of the

framework, therefore, worked out at about five months from the starting date.

The Acton "B" station is intended to supersede the existing "A" station, which was first started up in 1899, and in which some of the 158-MW of plant now in operation dates from 1924. It is built south of the canal, partly on land formerly used as a coal store and sports ground and partly on the site of a war-damaged Ministry of Works store, the total site covering 13 acres. Rail-borne coal for the first section of 90 MW will be unloaded into the existing wagon tipplers north of the canal and conveyed by belts to the south side of the canal and thence by a new belt laid in a tunnel. From this point it will be taken by an inclined belt to the boiler-house bunkers. The contractors for this portion of the plant are Messrs. Naylor Brothers, Limited, Golborne, Lancashire. The coal store for the new station will be built on the site of the existing station and cooling towers.

The steam-raising plant in the first section of the station will consist of five boilers, three of which are now on order. Each of these boilers, which are being constructed by Mitchell Engineering, Limited, Peterborough, and will be stoker-fired, will generate 240,000 lb. of steam per hour at a pressure of 600 lb. per square inch and a temperature of 850 deg. F. Eventually, there will be three reinforced-concrete chimneys, which will be supported on the boiler-house steelwork and will be 300 ft. above ground level. To begin with, there will be two 30-MW Richardson Westgarth turbo-alternators, which will generate at 11.6 kV. The first of these sets is due to be commissioned in 1954. The circulating water will be cooled in three reinforced-concrete cooling towers, one of which is illustrated in Fig. 2. Each of these towers will be capable of cooling 2.25 million gallons of water per hour and will be provided with moisture eliminators to reduce the possibility of "carry-over" nuisance to surrounding property. The contractors for this part of the work are Messrs. J. L. Kier and Company, Limited, 7, Lygon-place, London, S.W.1.

The station will be operated as a two-shift station and is expected to have a thermal efficiency of 25.5 per cent.

TECHNICAL FILMS.—The Petroleum Films Bureau, 29, New Bond-street, London, W.1, have issued a revised catalogue giving details of the films they are prepared to lend, free of charge, to any responsible organisation. The films listed cover a very wide range of subjects and are by no means confined to petroleum and its allied subjects. They cover, for example, such diverse matters as mechanised agriculture, workshop techniques, pruning of apple trees, pest control and aviation to mention but a few. Those dealing with oil and its allied products cover the whole subject from prospecting to the finished article, including transport and storage of the crude oil, distillation and refining. Many of the films deal specifically with engineering matters and should prove helpful if used in connection with apprenticeship schemes.

NOTES FROM THE INDUSTRIAL CENTRES.

SCOTLAND.

THE LATE PROFESSOR J. R. JACK, M.B.E.—Professor James Robertson Jack, M.B.E., M.Inst.N.A., designer of the King Edward, the first passenger steamer to be fitted with turbine machinery, died on January 7 at his home in Massachusetts, U.S.A. The King Edward, which is still running on the Clyde with her original machinery, attained her jubilee last year. Professor Jack, who was born in Glasgow in 1866, was Emeritus Professor and retired head of the Department of Naval Architecture and Marine Engineering at Massachusetts Institute of Technology.

SCRAP SHORTAGE AND OUTPUT OF STEEL.—The position in Scotland arising from the shortage of steel scrap has been the subject of discussion between the General Council of the Scottish Trades Union Congress and Mr. Duncan Sandys, Minister of Supply. The Council have taken the view that the position in Scotland is radically different from that in England and Wales, as Scotland relies mainly on imported scrap. The Minister said that he was assured by the British Iron and Steel Federation that the Scottish steel industry was receiving a fair proportion of the supplies available. The only remedy was to increase the pig-iron production. It was for this reason that the development programme in the industry was framed to provide for increasing blast-furnace and coke-oven capacity.

APPEAL FOR MORE STEEL BY ABERDEEN.—The Aberdeen district committee of the Scottish Board for Industry received, on January 10, a deputation from the Confederation of Shipbuilding and Engineering Unions, which made an appeal for a larger allocation of steel for Aberdeen and the North-East to prevent further unemployment. The deputation stated that there might be an error in the new steel allocation, but, if not, the result would probably be the dismissal of between 200 and 300 employees in one Aberdeen engineering firm alone.

INDIAN COAL FOR SCOTLAND.—A shipment of about 9,000 tons of Indian coal is expected to arrive in the Clyde for distribution to the domestic market this week. Officials of the Ministry of Fuel in Edinburgh said, on January 7, that the coal is equivalent to grade 4 British coal in quality, and would be sold at about the same price as that grade. This is believed to be the first shipment of Indian coal to Scotland.

KIRK O' SHOTS TELEVISION STATION.—Low-power transmission will be probable from Kirk o' Shots when the new television programme opens in March and for a short period thereafter, according to Mr. Alec Sutherland, the organiser of television programmes. On account of unavoidable delays in the installation of certain technical equipment it would probably be impossible to begin high-power transmission when the station was officially opened. It had been decided that, instead of causing disappointment by postponing the date, every effort would be made to adhere to it and make the initial transmissions on low power.

CLEVELAND AND THE NORTHERN COUNTIES.

IRON AND STEEL MARKET POSITION.—Buyers of iron and steel are diligently seeking sellers with trifling parcels available for prompt disposal but meet with virtually no success and customers who have received their allocations for the February to March period are actively engaged in placing orders for that period.

NEW STEM FOR DAMAGED ELLERMAN LINER.—The 8,450-ton twin-screw steamer City of Hull, as a result of a collision with a jetty in Las Palmas, damaged her stem and put in to Gibraltar for temporary repairs. While the vessel was steaming to England, the builders of the ship, Vickers-Armstrongs Ltd., Naval Yard, Newcastle-upon-Tyne, at the request of her owners, Ellerman Lines Ltd., constructed a new stem weighing 29 tons, using the original drawings of 1947. On arrival in the River Tyne, the City of Hull was dry-docked at the Hebburn Yard of Palmers Hebburn Co., Ltd., and work on the cutting away of the damaged section and the fitting on of the new stem began immediately. It is expected that the ship will sail in a few days' time.

CLOSING OF HIGH-LEVEL BRIDGE, NEWCASTLE.—The Newcastle and Gateshead Joint Bridges Committee have obtained an Order from the Ministry of Transport allowing them to close the High Level Bridge over the Tyne between Newcastle and Gateshead for one month from midnight, on Saturday, January 12. In addition to the raising of the tramway rails and the resurfacing of the bridge deck and approaches with asphalt, the structure will be inspected and overhauled.

LANCASHIRE AND SOUTH YORKSHIRE.

LONGER WORKING WEEK ADVOCATED.—Members of the Sheffield branch of the Institution of Works Managers have expressed the view that the introduction of the 40-hour week has been a premature step and a blow to production. The return to a six-day 48-hour week, until the economic situation of the country justifies its reintroduction, has been advocated. The opinion has been voiced that the employees have not been educated to make the best use of their additional leisure.

LABOUR SHORTAGE.—It has been reported to the Sheffield and District Employment Committee that Sheffield industries generally have full order books and that, on account of the labour shortage, persistent efforts have been made to find employment for elderly unemployed. These, with the disabled, form the bulk of Sheffield's small total of workless. Against an aggregate of 1,142 unemployed, there are now 2,471 vacancies.

UNITED STATES STEEL FOR SHEFFIELD.—It is understood that some of the steel which is being sent to this country from the United States is destined for Sheffield, where it is needed in the cogging mills, now on short time owing to a dearth of ingots. The cogging mill at the works of Steel, Peech and Tozer Ltd., is now able to work only 12 shifts a week instead of the maximum of 17, for want of steel. Four of the firm's open-hearth furnaces have been out of production for some months because of shortage of materials, particularly scrap.

GAS SUPPLY IN SHEFFIELD.—There has been only one instance, this winter, of large users of gas in Sheffield industry being asked to reduce consumption, but, in view of growing defence needs, steps have been taken to increase gas supplies to industry. Two carburetted water-gas plants, recently brought into operation at the Neepsend gasworks, have eased the supply position.

THE QUALITY OF BLAST-FURNACE COKE.—In a paper given by Dr. H. L. Riley, director of research of the United Coke and Chemicals Co., Ltd., and two of his colleagues, at a meeting of the Coke-Oven Managers' Association, held in Sheffield on January 9, it was stated that a substantial contribution to an increased annual production of pig iron, amounting probably to some hundreds of thousands of tons, could be made by the up-grading of coke quality. The present shortage of coke meant that pig-iron producers had little or no choice in their coke purchases. The blast-furnace quality of coke produced by the iron and steel firms was much superior to that produced elsewhere. Detailed examination of cokes made in South Yorkshire and elsewhere had shown that two factors were largely responsible for the production of inferior blast-furnace coke; these were inadequate preparation of the slack charged to the coke ovens, and incomplete carbonisation. The present need for the most stringent economy in the use of any kind of fuel made it imperative that immediate action should be taken to improve the quality of these cokes, at least up to that of coke produced at steelworks' coke ovens.

GERMAN CUTLERY COMPETITION.—Mr. H. Willey, chairman and managing director of Needham, Veall and Tyzack, Ltd., cutlery manufacturers, states that a Turkish agent had recently said that he had difficulty in selling British cutlery because Germany was offering goods at a price almost 33 per cent. lower than the British. He has also disclosed that Germany is exporting 25,000l. worth of cutlery each month to British markets. In addition there is Italian competition.

THE MIDLANDS.

INDUSTRIAL SAFETY COURSE.—The industrial safety course which was held in Birmingham recently has been so successful that the organisers, the Birmingham Industrial Safety Group, have decided to repeat it. The recent course, which was the first of its kind in this country, was held at the University of Birmingham, but the buildings there are only available during the vacation period, and new premises will have to be found before the course can be repeated. The Group is strongly in favour of a permanent location.

TRADES IN WOLVERHAMPTON.—The Corporation of Wolverhampton, Staffordshire, have prepared a classified directory listing 450 firms engaged in 200 different trades in the borough. It is of interest to note that about three-quarters of the firms listed do not employ more than 20 people each, showing that Wolverhampton industry is very similar to that of Birmingham, where also the small concerns predominate. The new directory is now in the hands of the printers, and should be ready in about eight weeks. Applications for the directory, which is intended for overseas issue only, should be addressed to Mr. F. Avery, the Corporation's public relations officer.

STEEL CASTINGS PRODUCTION.—The Darlaston steel-casting firm of F. H. Lloyd & Co., Ltd., are to endeavour to increase their production of steel castings to 26,000 tons for the present year, an increase of 5,000 tons over last year's figure. The firm employ 1,500 persons, of whom, at present, about 20 per cent. are on night work. To reach the desired output, the proportion on night-shift must be raised to about 50 per cent.

PROGRESS WITH NEW RESERVOIR.—The new reservoir which is being built for the South Staffordshire Waterworks Company near Abbot's Bromley is expected to be ready for filling next winter. Work began on the reservoir in 1948. It will have a storage capacity of 4,000 million gallons, and will draw its water from the river Blythe. The reservoir will serve the Black Country area between Wolverhampton and Birmingham.

STEEL SHORTAGE.—Shortage of steel for re-rolling has compelled J. B. and S. Lees, Ltd., West Bromwich, to put their cold strip mills on short time. Their hot mill has only been working two and a half days a week for some months for the same reason. Recently, the firm's stocks have been as low as four tons, whereas 4,000 tons was the usual figure before the war.

SOUTH-WEST ENGLAND AND SOUTH WALES.

EMPLOYMENT FOR DISABLED MINERS.—Miners disabled by silicosis may be among the 500 employees to be engaged by Cambrian Dress Products Ltd., when their new factory at Alltwen, Pontardawe, begins production in May. Mr. H. Rose, chairman of the company, in a letter to Pontardawe Rural Council, said that, after visiting the district recently, he had given serious thought to the employment of silicotics. His company were prepared to make the experiment with the assistance of the Council, but wished first to ascertain what assistance the Ministry of Supply would give.

GRIT DEPOSITION AT TREFOREST ESTATE.—Denial that the Nantgarw Colliery was causing a grit nuisance at the Treforest Trading Estate was made by Mr. R. J. Barritt, divisional carbonisation general manager of the South-Western Divisional Coal Board, at a meeting of the East Wales District Committee of the Welsh Board for Industry. The plant, he said, was the most up-to-date in this country and a test of the atmosphere had shown that the monthly deposit of dust per square mile was 10 tons, whereas the figure for Cardiff was 17 tons, for Leicester 50 tons, and for Leeds 96 tons.

REDUNDANCY AT HIRWAUN.—A meeting of employees of the three firms making radio equipment at Hirwaun Trading Estate, Aberdare, discussed the redundancy of more than 1,000 employees of radio firms on the estate and urged that a deputation of all local organisations be called before an all-Wales conference on the problems of increasing unemployment. The meeting demanded the immediate direction to Hirwaun of stable industries producing for civilian needs, and the abolition of the purchase tax. It was also decided to appoint a deputation to meet the Board of Trade and the Minister for Wales on the matter.

STEEL PRODUCTION SLOWED DOWN.—On account of the lack of scrap, three 80-ton open-hearth furnaces at the Margam and Port Talbot steelworks have had to close down during the past week. The furnacemen concerned have been found other employment at the works. Further comment on the scrap-supply position came from Sir Lewis Jones, secretary of the South Wales Siemens Steel Corporation, speaking at a luncheon given in connection with the national scrap drive, at Swansea, on January 11. He said that, so far as the iron and steel industry was concerned, they were facing the biggest crisis he ever remembered in the industry. Sir Lewis warned his hearers that there might be a possibility that the West Wales works might shut down unless more scrap could be found.

SOUTH WALES SWITCHGEAR, LIMITED.—The tenth anniversary of South Wales Switchgear, Ltd., Blackwood, Monmouthshire, was celebrated by a dinner, held at the Angel Hotel, Cardiff, on January 11. The company was formed at the end of 1941 and at first was housed in a small factory employing only 30 persons. Armament work was undertaken and electrical switchgear for the Admiralty. After the war, when Government contracts were cancelled, the company undertook the manufacture of domestic electrical equipment. The switchgear development has included the range of 3.3-kV, 6.6 kV, and 11-kV switchgear up to 2,000 amperes capacity. The tenth anniversary also coincides with an important event in the company's activities, namely, the development of 33,000-volt switchgear, with which satisfactory tests have been conducted in accordance with the British Standard specification.

NOTICES OF MEETINGS.

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

INSTITUTION OF ELECTRICAL ENGINEERS.—Monday, January 21, 5.30 p.m., Savoy-place, Victoria-embankment, W.C.2. Discussion on "The Implications of the Railway Electrification Committee's Report, 1950," opened by Mr. C. M. Cock. *Measurements and Supply Sections:* Tuesday, January 22, 5.30 p.m., Savoy-place, Victoria-embankment, W.C.2. Discussion on "High-Voltage Measurements and Tests," opened by Dr. J. S. Forrest and Dr. H. Tropper. *Scottish Centre:* Tuesday, January 22, 7 p.m., 39, Elmbank-crescent, Glasgow. "Development and Design of High-Voltage Impulse Generators," by Mr. F. S. Edwards, Mr. F. R. Perry and Mr. A. S. Husbands. *Education Discussion Circle:* Wednesday, January 23, 6 p.m., Savoy-place, Victoria-embankment, W.C.2. Discussion on "Essentials of a First Course in Electricity and Magnetism," opened by Mr. H. Kayser. *Southern Centre:* Wednesday, January 23, 7.30 p.m., Royal Aeronautical Engineering College, Farnborough. "Electrical Properties of Nerve and Muscle," by Dr. W. E. Floyd.

INSTITUTION OF CIVIL ENGINEERS.—*Midlands Association:* Monday, January 21, 6.30 p.m., Offices of East Midland Gas Board, Lower Parliament-street, Nottingham. "The Structural Design of Modern Aircraft," by Professor S. C. Redshaw. *Institution:* Tuesday, January 22, 5.30 p.m., Great George-street, S.W.1. "Civil Engineering Aspects of Hydro-Electric Development in Scotland," by Mr. A. A. Fulton. *Yorkshire Association:* Friday, January 25, 7 p.m., Chemistry Lecture Theatre, University, Leeds. "Problems on the Disposal of Industrial Effluents and Domestic Wastes," by Mr. J. T. Calvert.

INSTITUTION OF PRODUCTION ENGINEERS.—*Derby Section:* Monday, January 21, 7 p.m., School of Art, Green-lane, Derby. "Construction and Use of a Management-Expenditure Summary," by Mr. C. G. Clark. *North-Eastern Section:* Monday, January 21, 7 p.m., Neville Hall, Newcastle-upon-Tyne. "Machines for Production of Pressure Diecastings and Plastics," by Mr. L. N. Jones. *Manchester Section:* Monday, January 21, 7.15 p.m., College of Technology, Sackville-street, Manchester. "Industrial Law and the Production Engineer," by Mr. H. Peter Jost. *Coventry Section:* Wednesday, January 23, 7 p.m., Geisha Café, Hertford-street, Coventry. "Planning for Batch Production," by Mr. B. C. Harrison. *South Wales and Monmouthshire Section:* Thursday, January 24, 6.45 p.m., South Wales Institute of Engineers, Park-place, Cardiff. "Manufacture of Machine Tools" (with film), by Mr. E. S. Gregory. *Leicester Section:* Thursday, January 24, 7 p.m., College of Art and Technology, The Newark, Leicester. "Refrigeration," by Mr. J. G. Adamson. *London Section:* Thursday, January 24, 7 p.m., Royal Empire Society, Northumberland-avenue, W.C.2. Open Discussion on "Training Production Engineers in the Universities and Technical Colleges."

INSTITUTION OF WORKS MANAGERS.—*Glasgow Branch:* Monday, January 21, 7.15 p.m., 39, Elmbank-crescent, Glasgow. "Youth Training," by Mr. W. G. Paterson.

INSTITUTE OF ROAD TRANSPORT ENGINEERS.—*Scottish Centre:* Monday, January 21, 7.30 p.m., North British Hotel, Edinburgh. "Development in Tyre Construction and the Use and Abuse of Tyres," by Mr. W. R. Good. *North East Centre:* Tuesday, January 22, 7 p.m., Dunelm Hotel, Durham City. "Rear Axles," by Mr. R. H. Wilson.

INSTITUTE OF REFRIGERATION.—Tuesday, January 22, 5.30 p.m., Institution of Mechanical Engineers, Storey's-gate, St. James's Park, S.W.1. "Quick Freezing," by Mr. W. V. Smedley.

INSTITUTION OF MECHANICAL ENGINEERS.—*South Wales Branch:* Tuesday, January 22, 6 p.m., Mackworth Hotel, Swansea. Joint Meeting with the SOUTH WALES INSTITUTE OF ENGINEERS. "Safe Winding in Collieries," by Mr. T. G. Dash. *Western Branch:* Wednesday, January 23, 7 p.m., Royal Fort, Bristol. Thomas Hawksley Lecture on "Some Fuel and Power Projects," by Dr. H. Roxbee Cox. *North-Western Branch:* Thursday, January 24, 6.45 p.m., Engineers' Club, Albert-square, Manchester. Annual Meeting. "The Control of Boilers Fired by Solid-Fuel in Suspension," by Mr. Llewellyn Young. *Institution:* Friday, January 25, 5.30 p.m., Storey's-gate, St. James's Park, S.W.1. "The Marine Gas Turbine from the Viewpoint of an Aeronautical Engineer," by Mr. A. Holmes Fletcher. *London Graduates' Section:* Saturday, January 26, 3 p.m., Storey's-gate, St. James's Park, S.W.1. Annual Lecture on "Mechanical Installations in Buildings," by Mr. P. T. Fletcher. **AUTOMOBILE DIVISION.**—*Scottish Centre:* Monday, January 21, 7.30 p.m., 39, Elmbank-crescent, Glasgow. "Trailers and Semi-Trailers," by Mr. A. Marenbon. *Birmingham Centre:* Tuesday, January 22, 6.45 p.m., James Watt Memorial Institute,

Birmingham. "Shock Absorbers," by Mr. J. W. Kinchin and Mr. C. R. Stock. *North-Western Centre:* Wednesday, January 23, 7.15 p.m., Walker Engineering Laboratories, University, Liverpool. "Trailers and Semi-Trailers," by Mr. A. Marenbon.

WOMEN'S ENGINEERING SOCIETY.—*Manchester Branch:* Tuesday, January 22, 6.30 p.m., Engineers' Club, Manchester. "Transformers," by Mr. J. D. Hodgetts.

ROYAL AERONAUTICAL SOCIETY.—*Graduates and Students Section:* Tuesday, January 22, 7.30 p.m., 4, Hamilton-place, W.1. "Aircraft in Agriculture," by Mr. P. H. Southwell.

ROYAL SOCIETY OF ARTS.—Wednesday, January 23, 2.30 p.m., John Adam-street, Adelphi, W.C.2. "Road Racing and the British Motor Industry," by Mr. Laurence Pomeroy.

ROYAL STATISTICAL SOCIETY.—Wednesday, January 23, 5.15 p.m., London School of Hygiene and Tropical Medicine, Keppel-street, W.C.1. "Expenditure on Road Transport and Travel," by Mr. E. Rudd. *South Wales Industrial Applications Group:* Friday, January 25, 7 p.m., Technical College, Crumlin. "Statistical Aids to Management," by Mr. L. H. C. Tippet.

ILLUMINATING ENGINEERING SOCIETY.—Wednesday, January 23, 6 p.m., General Electric Co., Ltd., Magnet House, Kingsway, W.C.2. Discussion on "Preparation and Presentation of a Technical Paper."

MANCHESTER METALLURGICAL SOCIETY.—Wednesday, January 23, 6.30 p.m., Engineers' Club, Manchester. Discussion on "Microscopy," opened by Mr. J. D. Hannah.

ASSOCIATION OF SUPERVISING ELECTRICAL ENGINEERS.—*Coventry Branch:* Wednesday, January 23, 7.15 p.m., Technical College, Coventry. "Servicing Fluorescent Lamps," by Mr. W. A. R. Stoye.

INSTITUTE OF BRITISH FOUNDRYMEN.—*Birmingham Branch:* Wednesday, January 23, 7.15 p.m., James Watt Memorial Institute, Birmingham. "Cupola Design, with Special Reference to Hot-Blast Cupolas," by Dr. I. F. Schulte. *Falkirk Section:* Friday, January 25, 7 p.m., Temperance Café, Lint Riggs, Falkirk. "Observations Relating to Foundry Practice," by Mr. W. Pollock. *West Wales Section:* Friday, January 25, 7 p.m., Technical College, Llanelli. "Steel Foundry Practice," by Mr. G. T. Hampton. *Wales and Monmouthshire Branch:* Saturday, January 26, 6 p.m., South Wales Institute of Engineers, Park-place, Cardiff. "Engineering of Castings," by Mr. G. Jones.

INSTITUTE OF MARINE ENGINEERS.—Thursday, January 24, 4 p.m., Technical College, Sunderland. "Refrigeration at Sea," by Mr. R. R. Strachan.

INSTITUTION OF STRUCTURAL ENGINEERS.—Thursday, January 24, 6 p.m., 11, Upper Belgrave-street, S.W.1. "Elastic Analysis of Two-Dimensional Rigid Frames," by Mr. Arthur Bolton. *Midland Counties Branch:* Friday, January 25, 6 p.m., James Watt Memorial Institute, Birmingham. "Notes on Soil Mechanics," by Dr. J. Kolbuszewski.

INSTITUTE OF FUEL.—*East Midland Section:* Thursday, January 24, 6.15 p.m., Gas Board's Showrooms, Nottingham. "Proving Extensions of East Midlands Coalfield," by Mr. P. L. Collinson.

INSTITUTE OF METALS.—*Birmingham Local Section:* Thursday, January 24, 7 p.m., James Watt Memorial Institute, Great Charles-street, Birmingham. Open Discussion on "Productivity."

INCORPORATED PLANT ENGINEERS.—*South Yorkshire Branch:* Thursday, January 24, 7.30 p.m., Grand Hotel, Sheffield. Brains Trust Meeting on "Fuel Problems." *Birmingham Branch:* Friday, January 25, 7.30 p.m., Imperial Hotel, Birmingham. "Selection of Earth-Moving Plant for Public Works," by Mr. J. Lachlan Sturrock.

ROYAL SANITARY INSTITUTE.—*Preston Sessional Meeting:* Friday, January 25, 10 a.m., Public Hall, Lune-street, Preston. Various papers for reading and discussion.

NORTH EAST COAST INSTITUTION OF ENGINEERS AND SHIPBUILDERS.—Friday, January 25, 6.15 p.m., Neville Hall, Newcastle-upon-Tyne. "Estimation of Ships' Engine Power from Model Experiment Results," by Mr. J. L. Kent.

JUNIOR INSTITUTION OF ENGINEERS.—Friday, January 25, 6.30 p.m., 39, Victoria-street, S.W.1. "Air Conditioning in Industry," by Mr. W. W. King.

WEST OF SCOTLAND IRON AND STEEL INSTITUTE.—Friday, January 25, 6.45 p.m., 39, Elmbank-crescent, Glasgow. "Die Forging," by Mr. J. D. Latta.

MANCHESTER ASSOCIATION OF ENGINEERS.—Friday, January 25, 6.45 p.m., Engineers' Club, Manchester. "Dust Precipitation," by Mr. G. C. Goodwin.

INSTITUTION OF CHEMICAL ENGINEERS.—*Midlands Branch:* Saturday, January 26, 3 p.m., The University, Edmund-street, Birmingham. Annual Meeting. "Preliminary Study of the Motion of Solid Particles in a Hydraulic Cyclone," by Mr. D. F. Kelsall.

PERSONAL.

SIR JOHN WOODS, G.C.B., M.V.O., has been elected a director of the English Electric Co. Ltd., and of Marconi's Wireless Telegraph Co. Ltd.

SIR FRANK NEWSON-SMITH, Bt., has been appointed an honorary vice-president of Cable and Wireless (Holdings) Ltd.

LT.-GEN. SIR CHARLES KING, K.B.E., C.B., has been appointed deputy chairman, and MAJOR R. G. HOWARD, M.B.E., J.P., MR. SIDNEY JACKSON, F.C.A., and MR. JOHN WATSON, P.P.R.I.C.S., members of the Stevenage Development Corporation.

REAR-ADMIRAL G. F. BURGHARD, D.S.O., has been lent to the Ministry of Supply as deputy controller of electronics.

MR. MATTHEW SEAMAN, M.Sc., M.I.Mech.E., has been appointed to the board of British Oxygen Engineering Ltd., Angel-road, Upper Edmonton, London, N.18, a subsidiary company of the British Oxygen Co., Ltd.

MR. W. A. GALLON, B.Sc., M.I.E.E., M.Inst.F., chief engineer, South Eastern Electricity Board, has been appointed controller of the Merseyside and North Wales generation division of the British Electricity Authority. He succeeds Mr. A. R. COOPER, M.I.E.E., M.Inst.F., now controller of the North Western division. Mr. H. B. CAMPBELL, A.M.I.Mech.E., M.Inst.F., superintendent, Cliff Quay power station, Ipswich, has been made generation engineer (construction) Eastern division.

MR. JOHN RAE has retired from the chairmanship of McKechnie Brothers Ltd., but is remaining a director. Mr. J. D. McKECHNIE has been appointed chairman but is also retaining the position of managing director.

MR. D. B. WATERS has been appointed officer-in-charge of the Scottish branch of the Road Research Laboratory, in succession to Dr. R. S. MILLARD, who has been made head of the bituminous section of the Materials Division of the Laboratory.

MR. J. R. RATCLIFF, B.Sc.(Eng.), M.I.Mech.E., of K. & L. Steelfounders and Engineers Ltd., has been elected to the board as engineering works director.

MR. A. N. DODSON has been appointed regional controller, Ministry of Fuel and Power, Midland region, in succession to Mr. M. BRODERICK. Mr. Dodson was Mr. Broderick's deputy in Birmingham in 1947 and 1948.

MR. R. P. WILLIAMS has been appointed bitumen manager, Western Division, Shell-Mex and B.P. Ltd., Refuge Assurance Buildings, 18, Baldwin-street, Bristol, in succession to Mr. A. R. PATTON, who has been transferred to the general sales side.

MR. J. T. LIDBURY has been elected a director of Hawker Aircraft Ltd., and Hawker Aircraft (Blackpool) Ltd.

MR. W. A. BOGGIA is the first holder of the newly-created position of supervisor of production and procurement at Remington Rand Ltd., Commonwealth House, 1-19, New Oxford-street, London, W.C.1.

MR. R. H. CRUICKSHANK has been appointed buyer for G. & J. Weir, Ltd., Cathcart, Glasgow, S.4, in succession to Mr. CRAWFORD T. ROBERTSON who has retired after 51 years of service.

MR. J. L. WARNOCK has been appointed financial director of Hills (West Bromwich) Ltd.

MR. E. J. LAWSON CLARK has been appointed regional manager, Dunlop Rubber Co., Ltd., in Northern Ireland in succession to Mr. P. C. A. WELSH who has retired after 45 years of service.

MR. K. R. GREEN has been appointed sales manager, scientific and industrial products, Sunvic Controls Ltd., 10, Essex-street, Strand, London, W.C.2.

MR. G. A. ADAMS has been appointed sales manager (spring division), Geo. Salter & Co. Ltd., West Bromwich, as from to-day, January 18, when Mr. G. A. BEARD leaves the company to take up another position. Mr. W. N. T. BEARDER is to represent the company in Coventry and the East Midlands from Warwick-row, Coventry.

The Hunting Group of Companies announce the appointments of Mr. W. D. CORSE as managing director of the Aircraft Operating Co. of Africa Ltd.; Mr. M. H. CURTIS as managing director, Hunting Air Travel Ltd., and Mr. S. MILLYARD as managing director, Field Aircraft Services Africa Ltd. A new company, HUNTING AEROSURVEYS (PAKISTAN) LTD., has been formed in Karachi by HUNTING AEROSURVEYS LTD., London, in conjunction with GREAVES, COTTON & CO. (PAKISTAN) LTD. The offices will be at Saifee Development Chambers, P.O. Box 726, Bunder-road, Karachi, Pakistan.

THE INTERNATIONAL TIME RECORDING CO. LTD., Beaver-lane, Hammersmith, London, W.8., have changed their name to IBM UNITED KINGDOM LTD.

THE TECHNICAL INFORMATION AND DOCUMENTS UNIT OF THE DEPARTMENT OF SCIENTIFIC AND INDUSTRIAL RESEARCH has been transferred from Lacon House, Theobalds-road, to Cunard Building, 15, Regent-street, London, S.W.1. (Telephone: WHITEhall 9788.)

The new address of the WESTMINSTER CHAMBER OF COMMERCE is Mitre House, 177, Regent-street, London, W.1. (Telephone: REGent 2851.)

CONSTRUCTION OF ACTON LANE "B" POWER STATION.

(For Description, see Page 77.)

FIG. 3. ERECTING PRE-CAST CONCRETE UNITS OF TURBINE HOUSE; JANUARY 1, 1952.

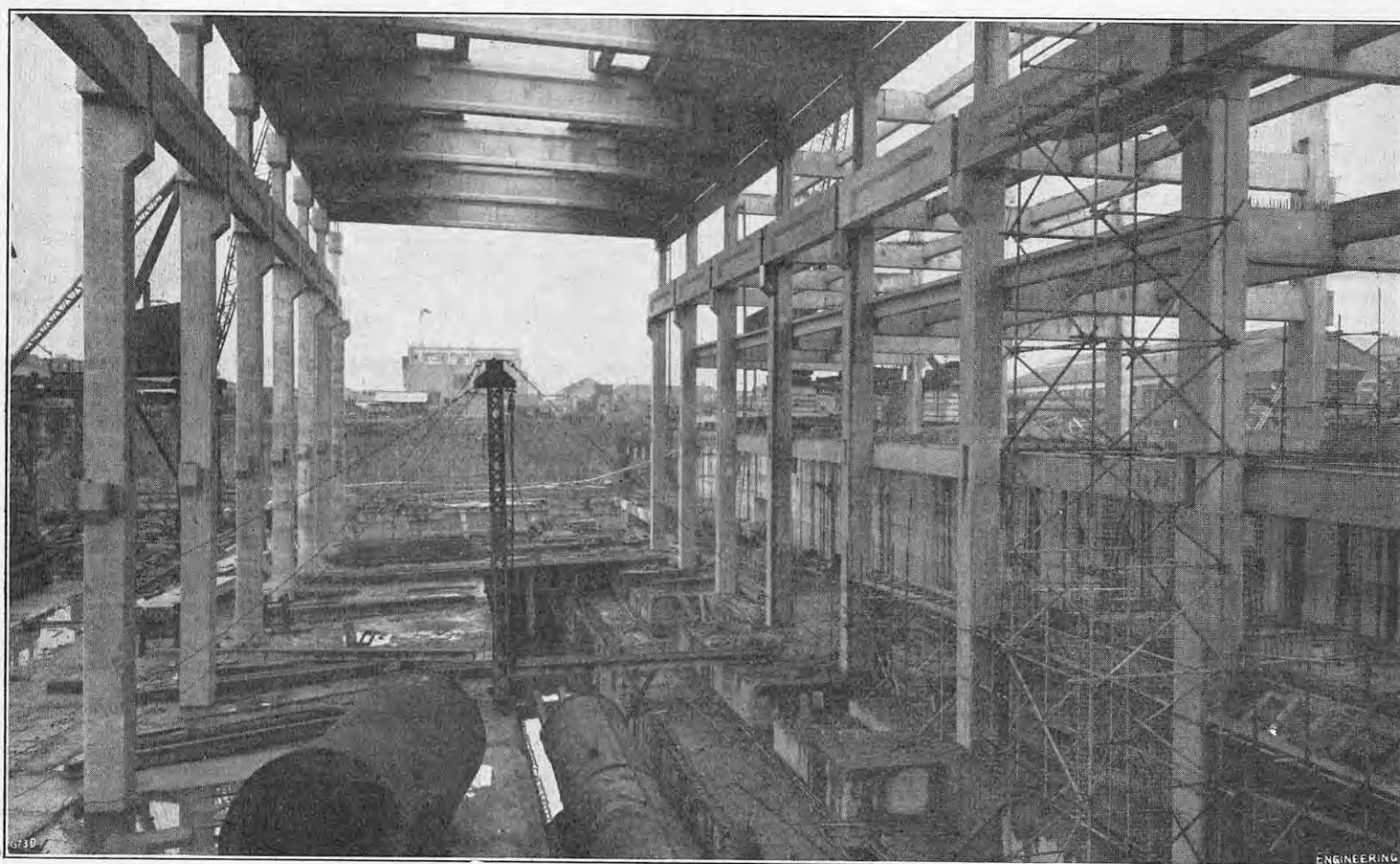


FIG. 4. INTERIOR OF TURBINE HOUSE, SHOWING CIRCULATING-WATER PIPE; DECEMBER 10, 1951.

ENGINEERING

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

Registered at the General Post Office as a Newspaper.

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

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For Canada	£5 5 0

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

ADVERTISEMENT RATES.

Terms for displayed advertisements on the green art paper wrapper, on the inside black and white pages and in the buff art paper two-colour supplement, as well as for insets, can be obtained on application to the Manager. The pages are 12 in. deep and 9 in. wide, divisible into four columns 2½ in. wide. Serial advertisements will be inserted with all practicable regularity, but absolute regularity cannot be guaranteed.

The charge for advertisements classified under the headings of "Appointments Open," "Situations Wanted," "Tenders," etc., is 10s. for the first four lines or under, and 2s. 6d. per line up to one inch. The line averages six words and when an advertisement measures an inch or more, the charge is 30s. per inch. If use is made of a box number the extra charge is 1s. per insertion, with the exception of advertisements appearing under "Situations Wanted." Series discounts for all classified advertisements can be obtained at the following rates:—5 per cent. for six; 12½ per cent. for thirteen; 25 per cent. for twenty-six; and 33½ per cent. for fifty-two insertions.

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 at least 10 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. 171.

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

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ENGINEERING

FRIDAY, JANUARY 18, 1952.

VOL. 173.

No. 4486.

COAL WINNING.

COMPARISONS unfavourable to British industry are sometimes drawn between the outputs per man in the coal mines of Great Britain and the United States. Operations in the latter country are on a considerably larger scale than in Britain, but compared with the corresponding industries in some other coal-producing countries, such as Poland and Belgium, operations in America and Britain are of the same order of magnitude. Last year, this country produced 222 million tons of coal and the United States about 450 million tons; in 1947 the United States produced 560 million tons. It is certainly desirable that the methods by which the large American outputs per head are secured should be studied and, if possible, adopted in this country, but, in fairness to British management and men, the very considerable differences in physical conditions in the two countries should be kept in mind. Of the 222 million tons of coal mined in Great Britain in 1951, something less than 11 million tons came from opencast workings. In the United States, nearly a quarter of the total output is obtained by opencast and strip mining. Further, the underground coal being worked in the United States lies much nearer to the surface than is usual in Great Britain, so that it is more easily reached through relatively inexpensive drifts or shallow shafts and headwork installations are correspondingly simple. The average depth of shaft workings is 190 ft. and the deepest shaft is only 839 ft.; in Great Britain the average depth of working is about 1,170 ft. and some shafts are as deep as 3,000 ft. In addition, the average thickness of the seams worked in the United States is 5½ ft. and in general the seams are remarkably free from major faulting. In spite of these advantages, it is stated in the

report* of the Productivity Team which visited the United States that "the average percentage recovery in underground mining is well below the British." The reason for this presumably is that United States reserves would permit the present rate of extraction to continue for several thousand years, whereas in Great Britain coal is a rapidly wasting asset and the maximum quantity possible must be recovered, even at the expense of higher costs of winning.

It is because of these differences in natural conditions that the team state in their report that "results in Britain can never, in our opinion, match those achieved in the U.S." This, however, is no reason why the details of American practice should not be studied with a view to the adoption here of any methods which may be applicable in British mines. All the members of the team are employees of the National Coal Board and must be well aware of the fact that, since its inception, the Board has devoted much attention to the problem of increasing mechanisation and has invested much capital in plant and machinery. The high output of the American miner, indicated by the fact that, in 1950, the output per man-shift in bituminous underground mines was 6·21 tons, could not be achieved without the intensive mechanisation which has been carried out; but the pursuit of the same policy here, although it raised the average output per man-shift to 1·21 tons last year compared with 1·18 tons in the best pre-war year, has not had an encouraging overall effect. The output per man-year in 1951 was 303 tons; from 1882-1892, when there was little or no mechanisation, it was 308 tons.

The non-correspondence between output per man-shift and per man-year is to be attributed to lost time, voluntary and involuntary, and to unjustifiable strikes. The physical conditions in American mines and the extensive mechanical equipment make the large output per man possible, but even with these advantages it would not be achieved without the willing co-operation of the men themselves. All, or almost all, the Anglo-American productivity reports have laid stress on the fact that the large outputs obtained, while helped by machinery, are fundamentally due to the attitude of labour, which realises that not only the prosperity of the employer, but also its own prosperity, depends on full exploitation of all mechanical aids. This coal report emphasises the same thing and expresses the opinion that "rather than machines . . . we should like to see injected into the British industry the sense of adventurous urgency which characterises the American attitude towards development."

The report gives much information about coal-cutting and transporting machinery, and about American mining methods, and recommends the adoption of such as are suitable in British mines; but, in view of the above expression of opinion, the information about the organisation and attitude of labour is probably the most important part of the report. The remarkable difference between labour conditions in the two countries is shown by the fact that while here there is a continual struggle to obtain more men and persistent efforts to introduce foreign labour, in America the pre-occupation of American managements is not "what can be done with a man," but "how to do without him." This means his substitution by machinery, and the cardinal fact is that such a policy is not opposed by the unions. A case is quoted in which the reorganisation of a mine reduced the labour force from 900 to 600; "the decision was discussed by the men and at no time . . . was there any question of union opposition." It is added that "in many

* Coal: Report of a Productivity Team representing the British Coal Mining Industry which visited the United States of America in 1951. Anglo-American Council on Productivity, 21, Tothill-street, London, S.W.1. (Price 3s. 6d. post free.)

ways union clamour has been the driving force behind much that mechanisation has already achieved." The union argument is that more mechanisation will increase wages and reduce hours, and that "more and cheaper coal will create employment in other industries for the displaced."

How far the labour attitude in this country differs from that indicated above requires no stressing and the important question is whether the report of this team, which included a number of union members, is likely to have any effect. Among the final recommendations in the report is one to the effect that further consideration should be given to "the simplification of the task of management which comes from the American union's policy of accepting proposals to transfer or reduce labour in the interests of higher productivity." This, it is to be feared, must be taken as an expression of hope rather than conviction. There are, however, specific suggestions that the simplification of the national grading and wages structure should continue to be a major objective of the British industry and that consideration should be given to the day-wage system if full advantage is to be obtained from mechanical loading. There are also important recommendations about training and about recognition of the fact "that it takes 2-3 years to get the most out of a particular combination of man and machine." Much stress is laid on the status and competence of the section foreman, who is a salaried official and more highly paid than any man under his control.

Although, as already indicated, the introduction of many American coal-getting methods into this country would not be physically possible, it is emphasised that they should be studied and that "no machine should be dismissed out of hand." The team visited twelve mines, two cleaning plants, three factories manufacturing mining equipment and one making safety equipment. They also attended six conferences and some less formal meetings. With this programme, it was not possible to study the operation of individual machines or plant in the detail necessary to come to specific conclusions about their adaptability to British conditions. Such close study could only be carried out by observers with more restricted programmes and more precise commitments. It is understood that visits of such observers are being arranged.

Among the recommendations of a technical nature actually made is that, in view of the shortage and increasing cost of timber and steel supports, the possibility of using American roof-bolting methods should be considered. The process consists in supporting the roof by bolts, varying in length from 2 ft. to 9 ft., carrying plates at their lower ends and self-locking sockets at the top. Special machines have been developed for drilling the holes in the roof. An obvious advantage of the system lies in the elimination of the conventional supports, which are one of the main obstacles in the way of the use of high-capacity loading equipment. Another recommendation is that the adoption of suitably modified American rock-dusting machines should be given serious consideration. Much attention is already being given to the modernisation of transport in British mines; it is recommended that the matter should be pursued still more energetically and, incidentally, that the transport of men by belt conveyor under suitable safeguards should be considered. The introduction of electric trolley locomotives where conditions allow is also recommended. It is recorded that in some American mines the height of the trolley wire has been as little as 4 ft. This is not likely to be permitted in Great Britain, a policy which appears to be justified by a table showing that, of 100 deaths from shock, 38 occurred with trolley wires 4 to 4½ ft. high, and only two with wires at a height of from 6 to 6½ ft. With wires over 6½ ft. there were no accidents.

THE WATER SUPPLY OF LONDON.

PROBABLY there is no capital city or "conurbation" in the world which presents quite such difficult problems of water supply as does the area briefly, but quite inaccurately, referred to in the above title as "London." In population, New York is comparable, and has its own peculiar problems of distribution; but there is a more than ample supply available if the New Yorkers are prepared to face the cost of fairly considerable engineering works and, when all is said, New York is small by comparison with the area, the total population and the resources of the United States. London, however, already contains a quarter of the population of England and Wales, its sources of supply are by no means limitless, and the possibilities of extending the catchment area of the Metropolis present complications out of proportion to the additional supplies that are likely to result. The fact that a relatively generous supply is maintained (an average of 48.33 gallons per head per day in 1950-51) and that interruptions are so rare that a large proportion of the population of London have never experienced one, unless during the recent war, suggests that the annual reports of the Metropolitan Water Board deserve to be much more widely known and widely quoted than they are.

The 48th report,* for the year ended March 31, 1951, which is the most recently issued, shows directly and by inference something of the difficulty inherent in the task of drawing 521 million tons of water in a year from the Thames, the Lee, and "from wells and other sources," filtering and purifying the greater part of it, and distributing it through nearly 8,500 miles of mains. It may be supposed, incidentally, that the origins of the present supply system probably complicate the distribution problem to an appreciable extent, even though the present year completes the half-century since the passing of the Metropolitan Water Act of 1902, under the terms of which the Metropolitan Water Board was constituted in the following year; for, although the Board have, no doubt, simplified administration by comparison with the aggregate "paper-work" of the water undertakings that they superseded, the layout of the older mains is not readily modified, even though they may have been replaced, to some extent, by pipes of larger bore.

The principal source of supply is still the River Thames, from which the Board abstracted, in the period under review, 11.72 per cent. of the natural flow and two of the suburban water companies 0.42 per cent., representing a total of slightly more than 241 million gallons per day. By comparison, the average of 49.1 million gallons taken daily from the River Lee is not particularly impressive, though it forms the second largest part, of the aggregate of 521 million tons. The average daily supply drawn from springs, wells and gravel beds was 50.7 million gallons. The quantity obtained from the Thames was slightly less than in the previous year, and from springs, wells, etc., considerably less—a reduction of roughly one-sixth, compared with 1949-50; but the Lee's contribution was considerably more, being actually 32.17 per cent. greater. The total volume supplied was 116,712 million gallons in round figures, of which by far the greater part went to the Board's direct consumers; bulk supplies were afforded to seven adjacent water undertakings, but the total thus distributed only amounted to rather less than 2,469 million gallons—approximately 2 per cent. of the grand total.

To extract and distribute this water, the Board has 295 pumping engines of various kinds, aggregating 66,786 h.p.; and, during the twelve months

to March 31, 1951, the fuel consumed in pumping amounted to 119,588 tons of coal, 732 tons of coke, and 1,206,100 gallons of oil, in addition to rather more than 46 million units of electricity. By degrees, the former steam pumping plant is being replaced by electrically-driven pumps. It is noted that an estimate of 24,250%, had been accepted during the year for the supply and installation of two electrically-driven centrifugal pumps, each capable of raising 3½ million gallons daily, at the Brixton station, together with repumping stations at the Rock Hill and Norwood reservoirs. Others are in hand for Lullingstone and Ponders End.

Though the Metropolitan Water Act was passed in 1902 and the Board was set up in 1903, some time naturally elapsed before the properties of the previously existing water companies could be transferred. This was effected in 1904, and a particularly interesting section of the present report is the tabular comparison between the plant as existing at that date and at March 31, 1951. At June, 1904, there were 44 reservoirs for unfiltered water, with a total area of 843 acres and an aggregate capacity of 4,116 million gallons. By March, 1951, the number of reservoirs had increased only to 48, but their total area was 3,023 acres and their capacity 23,635 million gallons; a comparison which shows, incidentally, that the average depth of the new reservoirs is considerably more than that of the older ones. For obvious reasons, it has not been necessary to increase in the same proportion the provision of service reservoirs for filtered water, as the need in this respect roughly corresponds to the extension of built-up areas; the actual increase was from 75, with an aggregate capacity of 245 million gallons, to 91, holding 263 million gallons.

The total length of mains rose, between 1904 and 1951, from 5,759 miles to 8,495 miles. The greater part of this is of comparatively small bore, but it is a matter of common observation that there has been, in recent years, some extensive laying of large-bore mains. A table in the present report shows that the sizes now range from 78 in. bore down to 2 in., the most-used size being 4 in. bore, which now represents rather more than three-quarters of the total mileage. The filtering capacity has been greatly extended. In 1904, there were 137 slow sand filter beds, with an aggregate area of 139 acres, but no primary filters or mechanical filters. By March 31, 1951, the number of sand filters had been increased to 165, with an area of 163.2 acres and, in addition, there were 95 primary filters and 12 mechanical filters. Finally, the comparative table notes that the number of engines had risen in the 47 years period from 235 to 295, and their aggregate horse-power from 32,177 to 66,786. It would be interesting to set beside these last-mentioned figures the total weights or volumes of the machinery at the two dates; if the relative progress in marine propelling machinery is any guide, the approximate doubling of the power should be accompanied by a reduction of at least 30 per cent. in the total weight. Such comparisons, however, are difficult to establish on a firm basis, especially where such a variety of plant is involved. In 1904, it is probably correct to assume, the constituent water companies possessed no electrically-driven pumps, whereas the Board now uses them fairly extensively; and the weight or volume of such plant, if the comparison with steam is to be a fair one, should include a proportion of the electricity generating plant which supplies the current. It is debatable, too, whether it should not take into account the provision of storage capacity for fuel. If the comparison were taken farther, to a consideration of relative capital costs, it is possible that the contrasts might be even more striking; but in that respect the Board can do no more to affect the progress of economic events than can the individual consumer.

* Metropolitan Water Board: 48th Annual Report, for the Year ended 31st March, 1951. Staples Press, Ltd., 14, Great Smith-street, Westminster, S.W.1. [Price 5s.]

NOTES.

PRESENT AND FUTURE STEEL POSITION.

The production of steel in the United Kingdom totalled 15,638,500 tons during 1951, compared with a forecast for the year of 16 million tons and an output for 1950 of 16,293,000 tons. The pig-iron output for 1951, namely, 9,669,000 tons, was slightly below the estimate of 9,735,000 tons, owing to a reduction in coke supplies in the latter months of 1951. The output for 1950 was 9,633,000 tons. In a statement issued by the British Iron and Steel Federation, it is pointed out that the steelmaking scrap, collected in the steel industry in 1951, was fully up to expectations and that the scrap collected by a special drive in the steelworks exceeded expectations. The quantity of home-bought scrap, however, was not as high as had been hoped; thus a forecast made in April, 1951, gave 4,070,000 tons as the quantity of scrap which should be obtained from this source. Actually, however, the total of home-bought scrap for 1951 was 3,860,000 tons. To sum up, the consumption of steelworks scrap, which had been 10,254,000 tons in 1950, only reached 9,140,000 tons in 1951. The outlook for 1952, the Federation's statement points out, is uncertain. If steel production is to be maintained at the 1951 level of 15,638,000 tons, an extra 570,000 tons of steelmaking pig-iron and scrap will be needed, as stocks were drawn upon to this extent during 1951. It is emphasised that it would only be in exceptionally favourable circumstances that the total scrap supplies could show any increase, this year, over the 1951 total. Taking a general view, the best result that can reasonably be hoped for is to maintain the 1951 total receipts of scrap. If, on the other hand, a more conservative view is taken, that 1952 receipts of scrap will be 100,000 tons less than in 1951, this means that for the 1952 steel output to reach 16,000,000 tons, the production of pig iron must increase by at least one million tons. This increment in the output of pig iron is considered to be well within the capacity of the additional blast furnaces now becoming available. Its achievement would require the importation of over 10 million tons of ore in 1952 and further increases in supplies of coke. Finally, it is shown that if 1,500,000 ingot tons of steel are imported in 1952, and exports are limited to 2,500,000 tons, the supply of steel to the home market (including, as in recent years, about 500,000 tons reprocessed from re-usable steel) should be about 15½ million ingot tons, compared with 14,180,000 tons in 1950 and 14,540,000 tons in 1951.

AUTOMATIC BRAKES FOR BRITISH RAILWAYS' WAGONS.

The Railway Executive are examining the practicability of fitting all freight vehicles with automatic brakes. A hundred standard 16-ton coal wagons have been provided with vacuum brakes, and comprehensive trials are being carried out. On alternate Sundays since January 6, a coal train runs from Toton sidings, Derbyshire, to London (Brent), travelling at express speeds and conveying up to 1,000 tons of coal. The empty wagons are being returned to Toton on the other alternate Sundays. Observers are travelling on the train to note the performance of the brakes. As British Railways have 1,110,000 wagons, the cost of such a conversion would be very heavy, though it would necessarily be spread over many years. Additional expenditure would also be involved on signalling and other alterations. The consequent speeding up of freight trains, however, would be a great benefit to industry and commerce; moreover, from the railway operating point of view, it would improve the facility with which all trains are routed and timed over the tracks of British Railways, since one of the chief difficulties at the present time, with only a small proportion of wagons fitted with automatic brakes, is that different classes of trains run at widely different speeds. The change now being considered would be equivalent to providing extra tracks on all routes, quite apart from the advantage of speedier transit. It would also enable the advantages of electrification to be fully realised. The news that British Railways are examining the matter will add point to the debate which is to be held at the Institution of Civil

Engineers on Wednesday, March 12 at 6 p.m.; at that joint meeting of the graduates' and students' sections of the Institutions of Civil, Mechanical and Electrical Engineers, the debate will be on the motion "That the railways no longer fulfil the inter-urban and industrial transport requirements of this country, and must be converted to trunk roads and aerodromes."

THE BRITISH HYDROMECHANICS RESEARCH ASSOCIATION.

The fourth annual report of the British Hydromechanics Research Association, covering the twelve months from October, 1950, to September, 1951, records notable progress in the work for which the Association was formed, an item of importance being the opening, on May 24, of their laboratory at Harlow, Essex. It was the first industrial building to be erected in the new town of Harlow, and comprises a main laboratory measuring 120 ft. by 72 ft., with an adjacent two-storey office block which contains also a library, drawing office, photographic dark room, and an instrument laboratory. The new laboratory was declared open by the President, the Rt. Hon. Sir John Anderson, G.C.B., F.R.S., who was re-elected to that office at the fifth annual general meeting, held on December 18, 1951, when also Dr. A. Ivanoff succeeded Mr. G. A. Wauchope as chairman. It has since been fully occupied on the Association's programme of fundamental and applied research. Among the subjects classed as fundamental research, to which attention is being devoted, is the effect of cavitation in reducing the speeds at which many hydraulic machines can be run economically, and the investigation of the process of cavitation attack, which, it appears, involves an inter-relation between corrosion and mechanical fatigue. An interim report on this subject is to be issued in the near future. Other subjects that are being studied include the performance of centrifugal pumps, for which purpose a transparent experimental pump has been constructed of clear Perspex sheet, and means provided to photograph, by the light of high-intensity flashes at a frequency of 2,000 cycles per second, the passage of tracer particles through the impeller; the formation and prevention of vortices in suction sumps; losses due to pipe friction; and the causes and effect of surges in pipelines. In connection with the last-mentioned research, arrangements had been made to carry out experiments on a 42-in. steel main belonging to the Metropolitan Water Board, but these tests had to be suspended temporarily until means could be provided to control the outflow from the test section. Other work in progress includes a study of seals for rotating shafts, the construction of a test rig for investigating the behaviour of self-acting valves, and an inquiry into the operation of the inlet valves in high-speed reciprocating pumps and fuel-injection pumps. An investigation on a larger scale has been undertaken, on behalf of a firm of consulting engineers who are members of the Association, into the performance of the overflow spillways and outlet tunnels for two reservoirs, one being for the Weir Wood Water Board, to supply the new town of Crawley, Sussex. For this purpose, a model has been made to the scale of 1:20, in a tank about 12 ft. square, the spillway and tunnel being made of clear Perspex to facilitate observation of air entrainment, and of the flow at the tunnel entrance.

PRACTICAL-TRAINING QUALIFICATIONS FOR CIVIL ENGINEERS.

The Council of the Institution of Civil Engineers have recently taken steps to ensure that the conditions under which an engineering graduate of a university (recognised by the Council) can qualify for election as an associate member by obtaining only two years' practical training and one year of engineering experience, are fulfilled in every case. In the absence of an agreement with a civil engineer to obtain practical training, a graduate must still obtain four years' engineering experience under the personal supervision or superior direction of corporate members of the Institution, but a graduate can now qualify under the shorter term only if, on application for election as associate member, he and the engineer under whom he has served certify

that an undertaking was entered into and that it has been carried out. A revised form of certificate of practical engineering training, which provides for this requirement, was therefore introduced at the beginning of this year. In a note in the January issue of the *Chartered Civil Engineer* (the bulletin of the Institution), it is stated that the Council were of the opinion that the previous form used for certifying that a person had obtained training under agreement was being used consistently in a manner for which it was not intended, there being ample evidence that it had been signed in retrospect by engineers for the sole purpose of bringing a person's qualifications into line with the requirements of the by-laws governing election, when, in fact, no undertaking to provide practical training had been given or entered into at the commencement of the period specified.

RESEARCH ON TIMBER.

Though many firms benefit from the results of research carried out at the Forest Products Research Laboratory, there are probably considerably more who could if they took the trouble to acquaint themselves of the programme of work at Princes Risborough, Buckinghamshire. The *Report of the Forest Products Research Board, with the Report of the Director of Forest Products Research, for the Year 1949*, reviews a wide range of investigations which are applicable directly to boat-building, the construction of water-cooling towers, furniture-making, pit-propping, etc., and indirectly to all industries where wood is sawn, planed, drilled, bent, used in laminated form, fabricated by means of adhesives, and otherwise used and preserved. Only a random selection can be given here, but readers who find one or more of them significant may be led to pursue the reference. A special technique was developed for recording by high-speed photography the distribution and movement of the sawdust in and around the gullets of circular saws while the latter are cutting. It revealed the effect of speed on the freedom with which the sawdust escapes. Investigations were also proceeding into the factors influencing the efficiency of boring, drilling, and rotary planing. The possibility that the cost and availability of coal-tar creosote as a wood preservative might be adversely affected by developments in the use of creosote as a fuel or as a raw material for chemical products encouraged the staff of the Laboratory to test alternative oil-type preservatives. An examination of several naval craft constructed of wood, which had deteriorated, showed that the decay was due principally to leakages of fresh water. The report suggests that the use of wood preservatives on timber in boats should be extended. Full-scale tests were carried out on a Dutch barn of shear-connector portal-frame construction, on a three-bay portion of a glasshouse based on asymmetrical laminated-timber arches, and on a variety of roof trusses. Experiments were continued on the creep of wood under shear stress and on the effect of temperature and humidity upon the rigidity modulus of wood. Measurements were made of the dielectric constant and loss tangent of ten air-dry timbers between frequencies of 1 and 60 megacycles per second. As a result of work on radio-frequency drying of wood, the conclusion was reached that it might be economical and practical to season large-dimensioned material of permeable species, such as beech and sycamore, by the "boiling" method. The report also gives a review of electrical methods of determining moisture content in wood and an illustrated description of a machine for producing curved components, that would normally be bent, by a laminated construction. This report is published by H.M. Stationery Office, Kingsway, London, W.C.2, price 2s. 6d. net.

LLOYD'S REGISTER WRECK STATISTICS.

Returns concerning steamers and motorships lost or broken up, during the first quarter of 1951, have now been issued by Lloyd's Register of Shipping, 71, Fenchurch-street, London, E.C.3. These statistics indicate that 59 vessels, making together 110,986 tons, were totally lost during the quarter, consequent upon casualty or stress of weather. Out of these totals, eight ships, aggregating 17,830 tons, were owned in Great Britain and Northern

Ireland, and of these, three foundered, one sank as a result of collision and four were wrecked. The largest of the latter, the S.S. Castledore, of 7,301 tons, became stranded on January 28, 1951, and sank near Cape de Vares, N.W. Spain, after losing her propeller. She was on a voyage, in ballast, from Hull to Torrevieja, Alicante, Spain. Another large vessel wrecked was the 6,609-ton motorship Tapti which sank on the Bac Beg Bank, Hebrides, on January 17, 1951, while on a voyage from the Irwell to the Tyne. The ship lost in collision was the 658-ton steam trawler St. Leander which capsized and sank after a collision in the River Humber on January 9, 1951. The three British ships which foundered were the steam trawler Braes o' Mar, of 227 tons, which sank on February 1, the 369-ton collier Eleth, which was also lost on February 1, and the 1,793-ton cargo steamer Solidarity, which sank on March 4; all three vessels foundered in home waters. In addition to the vessels wrecked or lost by casualty, 99 steamers and motorships were otherwise broken up or condemned during the quarter under review, and the total tonnage of these vessels was 177,236. Of these ships, 33, comprising 64,222 tons, were owned in this country. The two largest ships to be broken up were the British-owned 15,500-ton triple-screw steamer Orduna and the 11,830-ton twin-screw steamer Northumberland. The Orduna was built in 1914 and the Northumberland in 1915.

LETTER TO THE EDITOR.

CONCRETE STRUCTURES AND CORROSION.

TO THE EDITOR OF ENGINEERING.

SIR,—Some of the methods described by Mr Leslie H. Griffiths in his article on page 775 of your issue for December 21, 1951, for lining concrete tanks with rubber on the site are about 20 years old, and it may interest your readers to know how these methods were developed.

Towards the end of the first World War I was appointed chief engineer to the late Chemical and Metallurgical Corporation, just then formed to develop the Elmore process for treating complex sulphide ores found in Northern Burma with boiling brine containing 10 per cent. HCl in order to separate the lead from the zinc. The usual unit operations of heating, pumping, filtering, cooling and heat interchange, and of handling granular materials, had to be carried out in rubber-covered and lined plant, and it was discovered by me and my staff that a heavily loaded suitably accelerated rubber compound could be jointed by heating the edges and applying moderate pressure—in fact, a rubber welded joint could be made. The result of two years' research was the erection of a plant at West Ham constructed by an ordinary works staff. The method of rubber lining developed at this stage was patented by Mr. F. E. Elmore. The firm soon afterwards, however, got into financial difficulties and was ultimately taken over by Imperial Chemical Industries, Limited. These rubber researches were lost.

In 1925, I decided to retrieve this research work, but soon discovered that to sell a new rubber-lined tank was difficult, although I was often asked to line an old acid-sodden concrete or brick tank or sump. This led to the use of latex graded-sand Portland-cement plaster, which I patented and my company still uses.

Tile-lined concrete acid tanks are old, especially in Germany, but in this country it was soon discovered that a layer of tiles or acid-resisting bricks must be backed with some continuous sheath, of which self-curing compounded rubber sheet is the best so far.

Mr. Griffiths' article is welcome as showing the difficulties which have to be overcome by chemical engineers who have to handle fierce corrosives, often at high temperatures.

Yours faithfully,

NORMAN SWINDIN.

Nordac, Ltd.,
Cowley Mill Road,
Uxbridge, Middlesex.
January 3, 1952.

OBITUARY.

SIR THOMAS BELL, K.B.E.

THOUGH shipbuilding in steel is essentially an engineering undertaking, comparatively few engineers have risen to the highest posts in the direction of shipyards. This, however, was one of the distinctions of Sir Thomas Bell, formerly the managing director of Messrs. John Brown and Company's shipyard at Clydebank, whose death on January 9, at the age of 87, we regret to record.

Thomas Bell was born at Sirsawa, India, on December 21, 1865, and was the son of Imrie Bell, M.I.C.E., who was in his day a consulting engineer of international repute as a designer of lighthouses. Thomas was educated at Celle, in Hanover, and at King's College School, London, which he left in 1880 to enter Devonport Dockyard as an engineer student. He spent six years there and passed the requisite examinations to qualify for entry into the Navy as an engineer officer, but in 1886 went instead to Glasgow, where he entered the engine drawing office of J. and G. Thomson, then the proprietors of the Clydebank Shipyard. Within



Photo: Elliott & Fry, Ltd.

THE LATE SIR THOMAS BELL, K.B.E.

the ten years, 1886 to 1895, he was promoted first to leading draughtsman in charge of estimates, chief draughtsman, and then outside manager. In 1899, though only 34 years of age, he was appointed engineering manager on the acquisition of the Clydebank yard by John Brown and Company in that year. In 1903, he was made a local director. It was during his managership that the firm built the Caronia and Carmania for the Cunard Line, the Caronia with reciprocating engines and the Carmania with steam turbines; following the latter vessel's experimental propelling machinery in 1906 with the quadruple-screw turbines for the Lusitania. Three years later, in 1909, when Mr. John G. Dunlop retired from the position of managing director, Bell succeeded him. He continued in that office until his own retirement in 1935, with only a short break, in 1917-18, when he held office at the Admiralty as Deputy Controller for Dockyards and Shipbuilding. He received the K.B.E. in 1917, being one of the first recipients of that honour on the institution of the Order.

Sir Thomas was a member of long standing in several professional institutions, though it was seldom that he attended their meetings and still more seldom that he could be induced to speak thereat. He could claim 64 years' membership in the Institution of Engineers and Shipbuilders in Scotland, having joined as a graduate in 1887 and being transferred to the grade of member ten years

later. He had been a member of the Institution of Civil Engineers since 1904, and in the previous year joined the Institution of Naval Architects. In the affairs of the last-mentioned Institution he took a more active part, being elected to the Council in 1908 and made a vice-president in 1912; and it was to the Naval Architects that he delivered, in 1908, a paper that was of outstanding value at the time and is of considerable technical interest still, on "Speed Trials and Service Performance of the Cunard Turbine Steamer 'Lusitania.'" In 1934, when his retirement from active work was imminent, the Council conferred upon him the distinction of Honorary Vice-President. In addition to his long service on the Council, he had represented the Institution on the Technical Committee of Lloyd's Register and also on the General Committee of Management; on the rather curious body, with which the late A. E. Seaton was closely identified, the "Advisory Committee Appointed to Confer with the Marine Department of the Board of Trade" in the endeavour to induce that Department to modernise its regulations affecting machinery design; and on the Engineering Standards Committee and its successor, the British Engineering Standards Association, now the British Standards Institution. He was also one of the oldest liverymen of the Worshipful Company of Shipwrights, having been admitted in 1911.

As a designer, Sir Thomas Bell had been intimately concerned with a succession of the most notable ships, mercantile and naval, of the past half-century. The Carmania and Lusitania have been mentioned, but there were also the Aquitania, the battle-cruiser Tiger, the battleship Hood, and the Cunard liner Queen Mary; nor was his share in these merely supervisory or administrative, for it was his regular practice to tour the drawing offices, often stopping to discuss critically details which the draughtsmen concerned might reasonably have supposed to be beneath his notice. In general, he was naturally reserved, with an objection to personal "limelight" that was almost an obsession, though on occasion he could be outspoken and caustic and by many was regarded as "dour"; but it may be remarked that the encouragement of youth movements was one of his main interests in retirement and that to many young Clydesiders his house at Helensburgh was familiar ground. In the words of one of his former colleagues, who had attended the dinner which marked the centenary of the Clydebank shipyard in December last, "He was a great figure and was well described by Lord Weir in his centenary speech as 'that sterling character of strict integrity.'"

SIR AMOS AYRE, K.B.E.

It is with much regret that we record the sudden death on January 13, at his home in Chelsea, of Sir Amos L. Ayre, K.B.E., one of the founders of the Burntisland Shipbuilding Company, and, since 1936, chairman of the Shipbuilding Conference. He was 66 years of age.

Amos Lowrey Ayre was a native of South Shields, where he was born on July 23, 1885. He came of a family with a long tradition of seafaring, and it was a matter of some pride to him that one of his ancestors had acted as pilot to the almost legendary warship St. Michael, built in 1511 for the old Scots Navy, when she put into the Wear on her way to France, to which country she was sold in 1514. Amos Ayre did not follow the family custom of going to sea, but, on leaving school, was indentured to the shipbuilding firm of Messrs. Wood, Skinner and Company, of Newcastle-on-Tyne, with whom he served an apprenticeship of six years. Concurrently, he attended classes in naval architecture at Rutherford College and what was then Armstrong College, Newcastle (now King's College, University of Durham) and achieving the distinction of being first in the whole country in the final examination; for this he received the King's Prize. In 1907, he went to Belfast, to take up a post on the design staff of Messrs. Workman, Clark and Company, where he was concerned principally with cargo liners; and in 1909 to Dublin, as chief draughtsman to the Dublin Dockyard Company, builders of small cargo vessels and coastal craft. His next appointment, however, represented a complete change,

being at the Board of Trade, as labour manager, but it provided experience which subsequently was valuable. In 1914, on the outbreak of war, he transferred to the Admiralty and was sent to the Firth of Forth as Fleet coaling supervisor, a post which he held until 1916, when he was appointed district director for Scotland of the Admiralty Shipyard Labour Department. For these services he received the O.B.E.

At the end of the 1914-18 war, Amos Ayre, with his brother (now Sir) Wilfrid Ayre, founded the Burntisland Shipbuilding Company at Burntisland, Fife, specialising in the production of high-class cargo vessels. At first, they adhered to more or less familiar models, but before long they realised that, as the approaching depression threatened, a superior and more efficient type was needed. The outcome was the "Burntisland economy ship," for which the brothers secured a steady market. Amos Ayre continued as chairman and managing director at Burntisland until 1936, though finding that his services and experience were in increasing demand on various Government and other committees; for instance, in 1928 he was chairman of the League of Nations committee on shipbuilding statistics, in the following year a member of the International

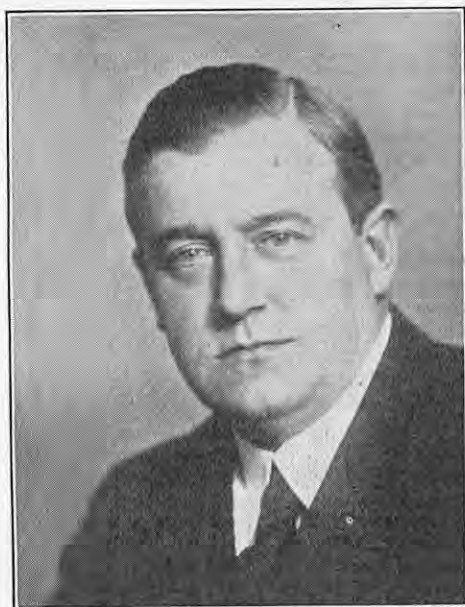


Photo: Elliott & Fry, Ltd.

THE LATE SIR AMOS AYRE, K.B.E.

Conference on the Safety of Life at Sea, in 1930-31 President of the Shipbuilding Employers' Federation, and in 1934, of the National Confederation of Employers' Organisations. He was also chairman for some years of the Board of Trade Advisory Committee on Merchant Shipping. In 1936, however, he relinquished his interest in the Burntisland Company on appointment as chairman of the newly-formed Shipbuilding Conference. In 1939, Amos Ayre was appointed Deputy Controller of Merchant Shipbuilding and Repairs in the Ministry of Shipping, and, in 1940, when the Admiralty assumed responsibility for all shipbuilding in the country, Director of Merchant Shipbuilding, a post that he held until 1944. For his services, he received the K.B.E. in 1943. After the war, he continued as chairman of the Shipbuilding Conference until his death.

Sir Amos was a vice-president of the Institution of Naval Architects, an honorary Fellow of the North-East Coast Institution of Engineers and Shipbuilders, a past Prime Warden of the Worshipful Company of Shipwrights, and, in 1946-47, was President of the Institute of Marine Engineers. In 1946, the University of Durham conferred on him the honorary degree of D.Sc.; and in 1951—a distinction which particularly gratified him—he was made an honorary freeman of South Shields, his birthplace.

PROTECTION OF TRADE SECRETS AND METHODS.

EVERY now and then the question arises, how far and by what means an employer is entitled to prevent an employee from disclosing the secrets of the firm. Assume that an employee has learnt much about the business, customers, methods and secret processes of his master. He is dismissed, or leaves on his own account "to better himself," and obtains employment with a firm who are in the same line of business as his former master. Is he entitled to place all his knowledge at the disposal of the new firm? If he does this to the detriment of that former employer, can he, or the new employer, be held accountable? The subject may be of topical interest having regard to a recent case in which a Leeds firm brought an action against another firm and two of their former employees, claiming an injunction to restrain each of them from making use of confidential drawings, photographs, and information, and to require them to deliver up drawings, photographs and other documents, and seeking an inquiry as to damages.

When the action came on in October last, a defence which had been put in was withdrawn and an order was made to the effect that "the defendants and each of them be perpetually restrained from doing whether directly or by their servants or agents or any of them or otherwise howsoever the following acts or any of them, that is to say: (1) Making any use of or disclosing any confidential information obtained from the plaintiffs or procuring such employee of the plaintiffs to disclose to them any such information; (2) infringing the plaintiffs' copyright in their manufacture, drawings and photographs of their locomotives; and that the defendants and each of them do on or before a specified date deliver up upon oath (in the case of the defendant company or their proper officer) to the plaintiffs at the offices of their solicitors all drawings, photographs and other documents which were obtained from the plaintiffs and all other drawings, photographs and other documents which reproduce any substantial part of the same." It was also ordered that inquiry be made against each of the defendants as to damages sustained by the plaintiffs by reason of the breaches of confidence, infringements of the plaintiffs' copyright, and acts of conversion committed by the defendants, referred to in the statement of claim. Finally, the defendants had to pay the plaintiffs' taxed costs.

Examining the question, in the first instance, on the footing that there is no special agreement binding the servant to keep his knowledge to himself: it was laid down so long ago as 1707 that it is an implied term in a contract of service that a servant shall act with good faith towards his master. It is a breach of that term, entitling the master to an injunction, or damages, or both, if, after leaving his employment, the servant uses against the interest of his late employer information surreptitiously gained by him during that employment; or such act may be regarded as a breach of trust or confidence without reference to any implied contract, in which event the servant will be liable to the same consequences. For instance, in the case of *Merryweather v. Moore* (1892) 2 Ch. 318, an injunction was granted restraining the clerk to a firm of engine-makers from publishing or communicating a table of dimensions of engines on the ground that it was an abuse of the confidence, necessarily existing between the defendant and his employers, to use, except for the purposes of service, the opportunities which that service gave him for gaining information. Again, in the case of *Robb v. Green* (1895) 2 Q.B. 315, the defendant, while in the plaintiff's employment, copied from his employer's books a list of customers with their addresses, his intention being to use the list, after leaving the employment, to set up a rival business and to induce the plaintiff's customers to deal with himself.

There is, however, nothing illegal in a servant, during his employment, endeavouring merely to recommend himself to his master's customers, with a view to securing their custom should he subsequently set up in business for himself. "Every one," said Lord Kenyon in the case of *Nichol v. Marlyn* (1779) 2 Esp. 732, "has a right, if he can,

to better his situation in the world: and if he does it by means not contrary to law, though the master may be eventually injured, it is *damnum absque injuria*." That Latin phrase may be freely translated that the master suffers "an injury for which the law provides no remedy."

This is a general statement of the law which appears to be founded on common sense. A man cannot divest himself of the knowledge gained by him in the pursuit of his calling. A modern illustration of these principles will be found in the case of *Worsley & Co., Ltd. v. Coopers* (1939) 1 A.E.R. 290. In that case, the defendants, prior to 1937, had been in the employment of the plaintiff company—a firm of paper merchants—and from 1934 onwards were directors of that company. One of them had travelled for the company for several years, and had prepared a sample book and price list of the papers sold by the company. The names of the mills from which the papers came were, as far as possible, kept secret. In August, 1937, they were bought out of the plaintiff company, and set up in business on their own account as paper merchants, and sent to a large number of the plaintiffs' customers a circular so worded as to be capable of creating the impression that the company they had formed, called the Cooper Kelland Paper Company, was the successor of the plaintiff company. Later, they sent out a price list arranged like that of the plaintiffs, and a "key" was sent to some of the old customers, by which they could identify a paper under its new name from the name it had borne in the plaintiff company's sample book.

An action was brought for infringement of copyright, for passing off goods of theirs as goods of the plaintiffs, for a false statement that the plaintiffs had gone out of business, and for damages for disclosure of confidential information in breach of duty or implied contract. Breach of copyright was admitted. After a protracted hearing, the judge found that there had been a "passing off" of goods of the defendants as goods of the plaintiffs, and a resultant general loss of business which would support a claim for damages. As to the last claim, however, the judge held that the confidential information which the defendants had acquired while in the employment of the plaintiff company, and the use they made of it subsequently, were not a breach of any express contract. It had been obtained openly and honestly, and was of such a nature that they were bound to acquire it and were largely responsible for it. It was not in the nature of a trade secret, and the conduct of the defendants in the use they made of it was not an actionable wrong.

The principle that a man may use the knowledge and experience gained in employment when he sets up in business for himself applies also to the case of a man who enters the employment of a new firm. It would be unreasonable to expect a man, on leaving the employ of any firm, to wipe his mind clean of all that he learned while with them. Indeed, firms advertising vacancies do not expect it, as they ask applicants to state their experience, evidently intending that, if the applicant is engaged, the experience gained by him with other firms shall be put freely at their own disposal.

Consider now how far it is possible for an employer to protect himself by a special agreement. He may employ a secret process which must not, on any account, be divulged—least of all, to a trade rival. The operations carried on in his factory may be such as to enable a servant to suggest improvements. Can the employer insist that he alone shall be entitled to make use of those improvements? Again, can he insist that the invention of a servant, made and perfected in the employer's time and with the employer's materials, shall be his and his alone?

It is a broad general principle that contracts in restraint of trade are void, as being against the public interest. To take an extreme case: an agreement between an employer and his servant which would prevent that servant from ever entering the employment of any rival firm could not be enforced. A restrictive agreement is only valid if it is reasonably necessary for the protection of the employer and is not too wide in its terms: if it is too wide, it is void.

In the case of *Morris Ltd. v. Saxelby* (1916) 32 T.I.R. 297, a man who had been employed for ten years with a firm entered into an agreement for two years which contained a covenant to the effect that, for seven years after ceasing to work for that firm, he would not assist in the United Kingdom in the sale or manufacture of the kinds of machinery manufactured by them. In an action brought to enforce this covenant, it was held (by the House of Lords) to be unreasonable. To quote the dramatic language of Lord Morris: "From the point of view of the public, one would have thought that it was not inconsistent with the public interest to 'let knowledge grow from more to more.' And under modern conditions both of society and trade, it would appear to be in the public interest to open and not to shut the markets of these islands to the skilled labour and the commercial and industrial abilities of the inhabitants: to further and not to obstruct for these *les carrières ouvertes*."

Nevertheless, a master and servant may enter into an agreement which contains a covenant that prevents the disclosure of information. So, in the case of *Summers v. Boyce & Kinmond* ((1907) 23 T.L.R. 724), the first defendant entered the service of the plaintiffs as a traveller under an agreement by which he agreed that he would not at any time thereafter "divulge or make known any of the trusts, secrets, accounts or dealings of or relating to" the plaintiffs' business. Upon leaving the plaintiffs' service, he entered the service of the second defendants, who knew of the terms of the above agreement, and he kept a list of the plaintiffs' customers in the district in which he travelled, and divulged to a considerable extent to his new employers the terms upon which the plaintiffs did business. It was held that, in these circumstances, the plaintiffs were entitled to an injunction against both defendants, and to an order for the delivery up of books and papers, and to damages. It is to be observed that in this case the second defendants knew of the agreement. Had they been ignorant of the fact that the first defendant was breaking a contract, they might have been held not liable to the plaintiffs.

Now to consider the question whether an employer is entitled to benefit by the inventive genius of his servant. One of the most interesting cases bearing on the subject is *The Worthington Pumping Engine Co. v. Moore* ((1902) 19 T.L.R. 84), which was decided by Mr. Justice Byrne. The action was brought by the company against its general manager in England with reference to certain patented improvements in the Worthington pump. It raised a question as to the right of a servant to take out a patent for an invention made by him during his contract of service as the result of materials and information supplied to him by his employers. The defendant was employed by the plaintiffs, an American corporation having a branch in England. It was part of his duty to communicate and consult with the plaintiffs' head office about any modifications and alterations in construction required to suit the demands of customers, and to offer such suggestions as might occur to him as advantageous to the plaintiff corporation in relation to the business he controlled, but there was no express stipulation in the agreement between the parties as to inventions or original suggestions which might be made by the defendant.

During his service, he took out two patents. As to one of them, the realisation of the idea and bringing it to a practical result belonged to another servant of the corporation, acting in the ordinary course of his employment under the direction of the defendant. The plaintiffs sought a declaration that the defendant was a trustee for them of the Letters Patent in question, and asked that he be ordered to assign the same to the corporation or to grant them a free licence for the whole term of the respective patents. In the course of his judgment, the judge said, "I appreciate the principle of those cases which have established that the mere existence of a contract of service does not, *per se*, disqualify a servant from taking out a patent for an invention made by him during his term of service, even though the invention may relate to subject matter germane to, and useful for, his employers in their business, and that even though the servant may have made use of his employer's time and servants

and materials in bringing his invention to completion, and may have allowed his employers to use the invention while in their employment. . . . But all the circumstances must be considered in each case—a principle made clear in *Robb v. Green* (1895) 2 Q.B. 315, and here it is impossible to say in the present case that the defendant has established the right he claims, having regard to the obligations to be implied from his contract of service. I am of opinion that his case is inconsistent with an observance of that good faith which ought properly to be inferred or implied as an obligation arising from his contract. Having regard to the nature and scope of the plaintiff's employment, to the obligations and duties arising from such employment, to the trust reposed in him, to his own conduct in endeavouring to establish a trade for his employers in the very articles which, in another action, he sought to preclude them from using, I think I should be wrong in holding that he is entitled to hold these patents as against the corporation." In the event, the corporation were held to be entitled to a declaration that the patents in question were held by the defendant in question in trust for them—but this without determining whether the patents were valid or not.

It is plain that, where a servant is under a covenant which prevents him using information acquired during service, he could not take out a patent for something based upon such information. But suppose he does do so; and suppose, further, that he sells the patent to someone who is a trade rival of his former employer. Has that former employer any right of action against that trade rival? Some light was thrown on this point in a case of *British Industrial Plastics v. Ferguson and Others* (1940) 1 A.E.R. 478. In that case, one D., who had been employed by the plaintiffs for many years, left them in 1932 under a leaving agreement, whereby he undertook *inter alia*, until a certain date, not to interest himself directly or indirectly in the manufacture or sale of certain chemicals which were used in a secret process of the plaintiffs. D. approached the defendant company and suggested that he had a secret process of his own which might be of use to them. They sent him to their patent agents, who reported that the process was patentable, and, in due course, a patent was applied for. The plaintiffs then brought an action against D., the defendant company, and its managing director. Against D. they claimed damages for breach of contract; against the other defendants they claimed damages for inducing D. to break his contract; and against all three they claimed damages for conspiracy.

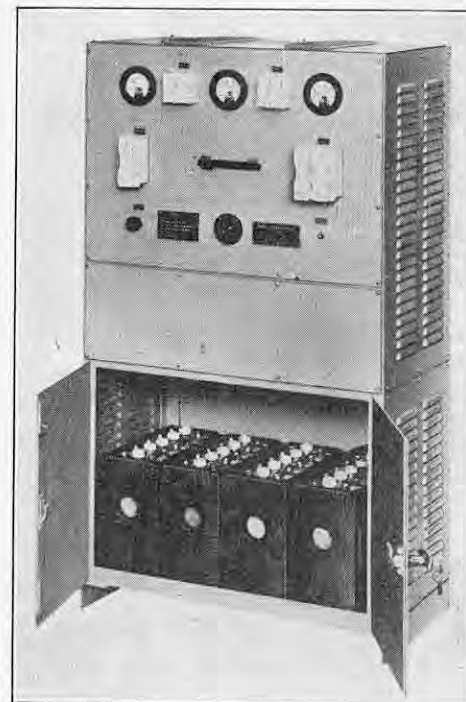
The judge who tried the case found that D. was liable in damages, assessed at 15,000*l.*, for breach of contract, but he dismissed the action against the other defendants, on the ground that they had no knowledge, when they induced the disclosure of the process to themselves, that it was the property of the plaintiffs. In fact, what happened was that these defendants, suspecting that the process might be the property of the plaintiffs, sent him to their own patent agents in the mistaken belief that, if the process was found to be patentable, it could only belong to D. himself. The judge therefore found as a fact that they acted without fraudulent intent. The case eventually reached the House of Lords, where Lord Russell of Killowen said: "The allegation that these defendants had induced D. to commit a breach of his agreement with his former employers would, if proved, undoubtedly disclose and establish a good cause of action against them."

The importance of bringing the trade rival into a case, if possible, is obvious, because the servant who has disclosed information or secret process may be, to use the language of the law, a "man of straw," but those who induced him to break his contract, or to act in defiance of that good faith which should obtain between employer and employee, may be well able to meet a heavy claim for damages.

PHYSICAL CHEMISTRY OF STRUCTURAL CHANGES IN SOLIDS.—A symposium on this subject, arranged by Professor A. R. Ubbelohde, F.R.S., is to be held at the Chemical Society, Burlington House, Piccadilly, London, W.1, on Thursday, February 7, at 2.30 and 7.30 p.m. Abstracts of the seven papers are available from the general secretary.

BATTERY UNITS FOR MINE-SHAFT SIGNALLING.

Two new types of self-contained steel-clad battery units have been developed by Nife Batteries, Limited, Redditch, Worcestershire. These units, one of which is shown in the accompanying illustration, are based on the company's tripping units, which are largely used for the protection of high-tension switchgear, and are intended to provide a source of direct-current for shaft signalling under both normal and emergency conditions. As will be seen, the control gear is carried in the upper section of a floor-mounted steel cubicle with the battery or batteries below. Charging is effected from a transformer through a selenium rectifier, the former being of the double-wound impregnated type with a tapped primary and an earth screen between the primary and secondary windings, while the latter is of the full-wave bridge-connected pattern. Control is effected by a four-position master switch, mechanical and electrical interlocks being provided to prevent incorrect switching.



The units can be operated either on a single- or dual-battery system. In the former case, the shaft signalling load is connected directly to the battery, which is maintained at full capacity by an adjustable low rate charge. Charging can, however, be effected at a higher rate in event of a prolonged interruption in the mains supply or if the low charge rate has been improperly adjusted. The state of charge can be determined at any time by pressing a test switch and noting the reading on a moving-coil ammeter marked with a red danger line. When the dual-battery system is used the signalling load is connected to one battery while the second is on open-circuit or on charge. The necessary alterations are again effected by a four-position switch and indicator lamps are provided to show which battery is on charge.

The batteries used in these units are of the nickel-cadmium type and are of all-steel construction. Their chemical reaction is completely reversible and there are no open-circuit losses.

EXECUTIVE APPOINTMENTS OF SHEEPBRIDGE ENGINEERING LTD.—The management of Sheepbridge Engineering Ltd. announce that the following general managers have been appointed to the boards of directors of their respective companies. They are: Mr. J. H. Lomas to Sheepbridge Stokes Ltd., and British Van der Horst Ltd.; Mr. H. Gunner to Sheepbridge Equipment Ltd.; Mr. Z. Z. J. Kosarski to Sheepbridge Steel Castings Ltd.; Mr. J. W. Lennox to Sintered Products Ltd.; Mr. A. E. S. Gourlay to Clews Petersen Ltd.; Mr. R. F. Elliott to Light Production Ltd.; and Mr. E. A. Macdonell to Sheepbridge Stokes Engine Liners Ltd.

NEW SIGNAL-BOX AT CARLISLE.—A new signal-box, with a 140-lever frame, has been built at Carlisle (Citadel) station by British Railways (London Midland Region) to replace the No. 5 box which, because of its age, was requiring excessive maintenance and could not have been satisfactorily altered to operate the remodelled layout that has been installed. The new frame is mounted on the operating floor, with separate counterbalance and electric-lock connections beneath.

THE ST. LAWRENCE SEAWAY.*

By THE RT. HON. C. D. HOWE.

In looking about for a subject of mutual interest, it has occurred to me as worth-while to present the Canadian viewpoint on the development of the St. Lawrence Seaway. The subject is timely, in that Canada has introduced legislation to establish an authority to undertake the building of the Seaway as an all-Canadian project, located in Canadian territory. You will recall that, more than ten years ago, Canada and the United States negotiated an agreement which provided for the building of the Seaway as a joint enterprise. Canada has let ten years go by, waiting for the United States Senate to approve the agreement "next year," so that we could get on with the job. Canada now finds that the limitations of the present canal system are hindering the development of Canadian economy to an extent that immediate action seems necessary to remove a serious bottleneck in water transportation between the Great Lakes and the Atlantic Ocean. Canadian demands for hydro-electric power are increasing at a rate that urgently requires the development of the Canadian power resources that will be made available by the development of the Seaway. We in Canada feel that the building of the Seaway and the development of the power cannot be longer deferred.

There is no lack of desire on the part of Canada to proceed with the joint project, and the door will be left open for participation by the United States, should there be ratification of the 1941 agreement early in 1952. It will be necessary in any event that we ask the United States to designate an authority to develop the United States' side of the International Rapids Power Development. The plans now being laid are the final stage of a development that has been going on for well over a century, with beneficial results for both Canada and the United States. This final stage should be undertaken now, because we have outgrown the facilities that are in existence. The present navigational channels are no longer able to support the demands that are now being placed upon them, and are still less adequate to meet growing demands to handle new traffic presently in sight. As I see it, and as I think the great majority of Canadians see it, further development of the Great Lakes-St. Lawrence navigation system, far from being a visionary scheme, is a simple necessity. It is no longer something that would be nice to have, if it could be afforded. The St. Lawrence Seaway, and all that goes with it in terms of added hydro-electric power and improved navigation, has become something that the people of Canada can no longer afford to do without.

The project in its entirety includes the proposed deepening and improving of the channels now connecting the four Upper Great Lakes, bringing them up to the navigation standards of the present Welland Ship Canal which connects Lake Erie with Lake Ontario over the Niagara escarpment. However, these channel improvements do not form part of the project presently contemplated by Canada. The 25-ft. navigation available in the Upper Great Lakes is sufficient for Canada's present purposes. The Welland Ship Canal was built by Canada on Canadian territory more than 20 years ago. It is operated without tolls and its operating expenses are paid for by Canada. It provides for 27-ft. navigation, with provision for deepening to 30-ft. navigation, as required. The navigation standards of the Welland Ship Canal are those projected for the Seaway improvements now being contemplated. The improvements that make up the project that faces Canada to-day are largely confined to that strip of the St. Lawrence River between Prescott, Ontario, opposite Ogdensburg in New York State, and Montreal, Quebec, a distance of 114 miles, which constitutes the present bottleneck of the Great Lakes-St. Lawrence route.

In this section, the great rapids in the St. Lawrence River offer at once an obstacle to navigation and an opportunity to harness power. Only the smaller part of that potential power is harnessed now, and the narrow canals that by-pass the rapids have small locks and a limiting depth of 14 ft. From Montreal to the sea, there is at present a channel 32½ ft. deep, which has made Montreal one of the world's busiest ocean ports. This ship channel below Montreal is now being deepened to 35 ft. The channels in the St. Lawrence River above Prescott are deeper than 27 ft. now. The power development planned for the International Rapids section, at or near Cornwall, will provide 27-ft. channels throughout the section, subject to minor improvements at its upper end. Above Prescott, large Lake freighters can navigate to the head of the Great Lakes. The biggest of them carry more than 20,000 tons of cargo, and are said to provide

the cheapest transportation in the world; but only small vessels, carrying 3,000 tons or less, can navigate the 114 miles between Prescott and Montreal.

The five Great Lakes are the bottle, while the St. Lawrence River between Prescott and Montreal is the neck. The Seaway project, which Canada is ready to undertake, would remove that bottleneck. The proposal is to dam the river to develop available power, which will flood out the rapids with artificial lakes, to by-pass the power dams with the short canals, and to do such other works as will provide a continuous 27-ft. navigation waterway.

Major works of the project are located at three points, namely, the International Rapids section, the Soulanges section, and the Lachine section. Of these three projects, work in the International Rapids section is the most extensive and costly. The basic power development in this section includes an upper control dam near Iroquois and a main dam and power-house above Cornwall. The 1941 treaty between our countries proposed that the navigation canal, by-passing these dams, would be on the United States side of the river, but there is nothing to prevent these canals being built on the Canadian side instead, given the basic power development. In fact, such alternative plans have been prepared.

The Soulanges section is wholly within Canada, in Quebec Province. Here the major portion of the work has already been done in connection with the existing Beauharnois power development. Thanks to the foresight of the Canadian Government, the wide power canal was designed to serve as a link in the deep-water seaway. The navigation work remaining to be done is little more than the installation of locks at the lower end of the power canal, for which provision has been made, and the dredging of connecting channels.

Finally, in the Lachine section, which is immediately above Montreal harbour, the minimum development would be for navigation only. In that event the main works would consist of channel enlargement and a 10-mile canal with locks. But, in this section also, there is potential for a large-scale power development that would provide an even better navigation link. The Province of Quebec is directly concerned with the power development, and discussions have been opened which may lead to building a combined power and navigation project.

Circumstances have changed completely since 1941, when the project was first advanced in its present form. Then, the demand for power was growing at a comparatively slow rate. It promised to take a considerable number of years for such a large new block of power to be absorbed, particularly in Ontario, and that province still had other smaller hydro-electric power sites to develop as needed. Neither Ontario nor New York felt so hard-pressed for power as to consider development of the International Rapids between them, though they were willing to take over development of the power facilities at the lower cost made possible by a joint development for power and navigation. The power benefits thus were accepted, at that time, as secondary to the navigation benefits, which offered the main incentive to undertake the project.

Now, confronted with the great post-war expansion of industry, and the present defence programme, power is a primary objective in itself. The Province of Ontario and the State of New York are so anxious to obtain additional power that, since 1948, they have themselves sought to undertake jointly a separate power development, completely independent of navigation. The application of the State of New York for permission to undertake the United States' share of such a power development has been filed with the United States Federal Power Commission, and has been denied by that body, on the grounds that power and navigation must be developed jointly. Other States in the neighbouring area have also demanded a share in such a project.

Now, too, the proposed navigation facilities take on a new importance with the continuing growth and diversity of traffic being experienced, and in anticipation of the opening of the iron-ore fields in Labrador and Quebec. The steel industries on the Great Lakes require access to a new supply of iron ore, which cannot be provided with economy until the navigation bottleneck is removed. Let us, therefore, re-appraise briefly what the deep-water project has to offer in terms of power and navigation.

The proposed power installations in the International Rapids development total about 1,640,000 kW of firm power, half for United States and half for Ontario. The chairman of the United States Federal Power Commission has testified before a Congressional Committee recently that, within a radius of about 300 miles, the project could deliver energy more cheaply than steam plants at the consuming centres. This United States' market could absorb immediately an additional 850,000 kW each year, and, in the Commission's view, this rate of expansion will be required for at least a decade. The 820,000 kW which would accrue to the United States' portion of the development at the Inter-

national Rapids thus is equal to just about one year's increase in requirements.

In Ontario also there is an inadequate reserve of generating capacity, particularly in the southern power system that would be served from facilities at the International Rapids. A recent treaty between our countries has made possible re-development at Niagara that will bring in perhaps 450,000 kW of installed capacity in 1954 or 1955, but, except for the St. Lawrence River, this is the last important source of hydro-electric power open to the southern part of the province. Meanwhile, some 520,000 kW of steam capacity are being built to meet the phenomenal demand. In this situation, the chairman of the Ontario Hydro-Electric Commission is requiring power from the St. Lawrence by 1956. The only alternative is further resort to much more costly steam generation.

The basic power development in the International Rapids section will cost about 400 million dols. at present-day prices. All those present will agree that the expenditure of 400 million dols. to provide 1,640,000 kW of firm power, and with the development located in the centre of an industrial area, is a good business investment. We can look to the sale of power to carry the capital cost of the development in the International Rapids section, except for the relatively small proportion of the project that will apply directly to navigation. Those, very briefly, are the reasons why a power development in the International Rapids section is urgently required, regardless of the navigation aspects.

Coming to the Soulanges section, I have stated that the power and navigation canal, and the power development, has been constructed already. The Beauharnois power project in this section has a potential capacity of 1,490,000 kW, of which present power installations now develop about 1,040,000 kW, or roughly two-thirds of its ultimate projected capacity. The Beauharnois development is of interest here mainly because it was begun as long ago as 1929 by private interests, and produced its first power in 1932. The power project was undertaken independently of the Seaway, though, through the intervention of the Federal Government, its works were modified to suit the Seaway plans as part of the cost of developing power. Little remains to be done in this section to complete the Seaway, other than the building of navigation locks.

In the Lachine section, another 900,000 kW of power is capable of development as part of the Seaway project, though the building of the Seaway without the power development can be undertaken without greatly increasing the cost of the Seaway, leaving the power development until a later date. The Province of Quebec has already harnessed more hydro-electric power than any other Canadian province, but here again reserve capacity is considered inadequate in the face of mounting demand. The need can be met for a time by alternative hydro-electric developments, or by a final expansion at Beauharnois. Here again, the development of 900,000 kW of power located in the heart of the Montreal industrial section at a cost of 200 million dols. is a good business investment, and it may well be that the Province of Quebec will wish to proceed with power in conjunction with navigation.

The cost of power development will thus be borne by the Provinces, and by the American authority that will own the power. The remaining cost to be borne by the Government of Canada on behalf of navigation will, at present prices, amount to between 250 and 300 million dols. That size of a navigation undertaking represents no more in terms of materials and manpower than the Welland Ship Canal, which was built as a unit in the St. Lawrence Seaway. It cost about 132 million dols. at a time when Canada had far less economic strength than to-day, yet no tolls have been levied against Welland Canal traffic to pay operating costs of the Canal and to amortise the investment.

The objective of the Seaway project is to eliminate the bottleneck that prevents the movement of large vessels between the Great Lakes and the Gulf of the St. Lawrence. This bottleneck has made for higher transportation costs for the very great volume of traffic that moves over the existing waterway, including the present 14-ft. canals. Cargoes of wheat and other bulk commodities, that move on the Great Lakes in large carriers capable of carrying 20,000 tons or more in one cargo, must be trans-shipped into boats having a maximum capacity of 3,000 tons of cargo, and again trans-shipped at Montreal, or at one of the other river ports, into ocean carriers. The economies to be effected in these movements alone would have justified completion of the deep waterway years ago.

A new factor to be considered at this time is the development of a great iron-ore project on the Quebec-Labrador border, which will have its outlet to deep water on the Gulf of the St. Lawrence. Some 250 million dols. are being spent on this project, which includes a railroad 350 miles in length and extensive harbour construction. It is anticipated that the initial de-

* Address delivered by the Rt. Hon. C. D. Howe, Canadian Minister for Trade and Commerce, to the Washington Society of Engineers at Washington, D.C., U.S.A., on November 28, 1951. Abridged.

liveries of iron ore from this project will be at the rate of 20,000,000 tons per annum. Without the deep-water development, important markets for these ores in the Great Lakes area are out of economic reach. On the other hand, Quebec-Labrador iron ore is the best possible answer to the supply problems of steel industries located on the Great Lakes.

The project would make at least a five-fold contribution in a future war. It would create a reserve of power capacity in the industrial heart of the North American Continent, where that reserve is presently inadequate for peace-time needs. The combination of power and navigation will stimulate a versatile industrial growth, giving greater capacity for the specialised production required in modern war, and permitting greater dispersal of that production. The Seaway would permit all but the largest ocean vessels to be built a thousand miles from the sea, adding flexibility and dispersal to the programme of ship-building and repair. It would provide an alternative transportation route to the railways, so hard-pressed in the late war. Above all, it would provide the best assurance of adequate supplies of iron ore to feed the steel furnaces of the east coast, as well as the Great Lakes.

All-out war brings great new demands for steel and ore, more than can be met by diversions from peace-time use. That raises the question: how vulnerable to attack are the Seaway ore route, and the power and navigation works? I think the situation is this. These works could be damaged or destroyed by a determined attack. So could any one of the existing hydro-electric power developments, steam-power plants, the locks at Sault Ste. Marie, taconite concentration plants, steel plants, or railway lines. But it would be extremely difficult to knock out all of the various alternatives at one time. The best overall defence, therefore, is to increase and disperse the most promising alternatives. On this basis, the Seaway project easily qualifies for a high priority, in both its power and its navigation features.

That pretty well answers the question, too, whether the use of scarce material and manpower for this project is warranted at this time. It is precisely in a period of preparedness such as this, which may last for many years, that works should be undertaken to add to our economic strength and productive efficiency. The alternatives to the Seaway involve other hydro-electric or steam power capacity, transportation facilities, ore concentration plants and other expedients. The material and manpower requirements would add up to a greater total than would be required by the completion of the Seaway. Moreover, these alternative facilities would be less suitable to the needs of war if it came. That is why we in Canada favour completion of the St. Lawrence project at the earliest possible date. Canadian and United States interests are so entwined and inter-related that the case for United States' participation appears just as strong, or stronger. We are anxious for full participation, anxious specifically for participation under the terms of the 1941 agreement between our two countries. Continued delay in giving that decision forces us to consider how else our objective can be achieved.

The whole project hinges on the development of the International Rapids section. Below it, the river is wholly within Canada, and Canada can and will complete the necessary works herself. Above it, and in the Great Lakes, the proposed channel improvements could be done under existing authority. As far as navigation is concerned, a new series of canals on the Canadian side could by-pass the International Rapids, just as the 14-ft. canals do now. But Ontario is in urgent need of the power. At the very minimum, then, there must be some form of international co-operation to complete the basic power development in the International Rapids. Given this basic condition, Canada could add the navigation facilities and complete the other essential parts of the seaway.

Rather than proceed on this course, however, Canada would much prefer ratification of the 1941 agreement. The main reason for the preference is simply that work could start almost immediately after ratification. Any other procedure involves a new series of legal and engineering preparations, formal and informal consultations, perhaps public hearings, and other formalities which might easily take up a year or two. Failing early ratification, therefore, the Canadian Government has decided to undertake the so-called all-Canadian seaway, and to invite the necessary co-operation with respect to an international power development. It has been suggested in some irresponsible quarters that Canada could not and would not undertake such a large project alone. I trust that the official announcement will put an end to that kind of talk. There is no bluff about Canada's attitude. We would need and would seek the co-operation of a designated agency in the United States to develop the international power. With that, we can and will complete the other essential works in the St. Lawrence River.

LABOUR NOTES.

THE shortage of engineer officers in the merchant navy is commented upon in the winter issue of the *Marine Engineer Officers' Magazine*, the official journal of the Marine Engineers' Association, which was published on Monday last. It is stated that for a very considerable period, the shipping industry has had to cope with a serious shortage of engineer officers, with the result that there are now many foreign-going ships sailing with only one certificated engineer officer. In such ships, the second officer has a Ministry of Transport dispensation allowing him to sail in that capacity. On the other hand, the journal adds, promotion in the merchant navy has never before been so rapid. Even in ships of the liner class, it is now quite usual for a junior to be promoted to junior second officer immediately he obtains his second-class certificate. In like manner, the possession of a first-class certificate leads to speedy promotion to the senior ranks.

Promotion automatically brings substantial improvements in rates of pay, but, in spite of this, it is found that a great number of newly-certificated engineer officers are leaving the industry to take up employment on shore. It would seem, therefore, the journal continues, that increased rates of pay are not alone sufficient inducement to retain any large proportion of certificated engineers in the merchant navy, and it is stated that the Marine Engineer Officers' Association has tried over a period of years to impress upon shipowners that increased rates of pay, without fundamental changes in conditions of service, are not enough. The shortage of juniors is also acute. Many leave the industry after only one voyage "feeling that they are being exploited by reason of having to work twelve-hour watches in port." The curtailment of liberty brought about by "nights aboard" is resented by seniors and juniors alike and the journal expresses the hope that the negotiations now being conducted between the Association and the shipowners, through the medium of the National Maritime Board, will lead to some method of granting adequate compensation for "nights aboard."

Suggestions for obtaining suitable recruits for the industry are put forward by the journal, which states that it is well known now that the entry of junior engineer officers into the merchant navy is restricted to young men who have served an apprenticeship in heavy engineering. Each applicant has to satisfy a Ministry of Transport surveyor that his apprenticeship has been served in an approved trade, and applicants are graded according to their technical education and the nature of the work on which they have been employed. This system has made it impossible for garage hands and others with some slight engineering background to sign on as junior engineers. It has also gone far towards weeding out undesirable elements. The journal is of the opinion, however, that apprentices who have been trained in the toolrooms of firms engaged in the light-engineering industries should be admitted into the profession, provided that such apprentices can satisfy the Ministry of Transport surveyor that their training and education is such as will enable them to obtain certificates of competency eventually.

It is stated that these views have been placed before the Ministry of Transport by the Association, and that it has been informed that the matter is now under consideration. The Ministry, on its side, has suggested that certain modifications should be made in the existing regulations for the examination of engineer officers, with a view to providing greater encouragement to young men possessing a sound technical education. Branches of the Association have been given an opportunity for discussing the Ministry's suggested modifications and no adverse comments have been received. Accordingly, the Association has informed the Ministry of Transport that it is prepared to agree to the suggestions.

About five hundred Italians are now in the employment of British Railways on the London Midland, Southern, Western and Eastern Regions, and the Railway Executive is planning to increase the number of such persons up to a total of one thousand in the near future. No Italians have been allocated to the North Eastern Region so far. The Executive has also expressed its intention of not increasing the number of Italians at work in the Yorkshire area. Just under a hundred Italians commenced their employment with British Railways at Doncaster on Monday last. They will be used in "mobile groups" in the area between that town and the Lincolnshire coast, and will receive a basic weekly wage of 5*l.* 1*s.*, the current rate of pay for lengthmen, lengthmen-platelayers and relayers. The men will be given every encouragement to take advantage of local educational facilities but no special arrangements for their instruction in the English

language are being made. When at work on the railways, orders are given to them through interpreters.

Greater rewards for skill and enterprise were urged by Mr. R. R. Stokes, M.P. for Ipswich, during the course of a speech in his constituency on Monday last. Mr. Stokes, who occupied the offices of Minister of Works and Lord Privy Seal in the Labour Government, said that the gap between the earnings of skilled persons and those in unskilled occupations must be widened so as to provide more incentives for efficiency and make the attainment of skill worth the effort involved. Earned incomes must be relieved by raising the upper limit at which a proportion of earned income is allowed to be taken free of tax and, in this connection, he suggested an upper limit of 5,000*l.* A year or so ago, it was estimated that this concession would cost the Treasury about ten million pounds per annum. Taxation was now so high that it had become the cause of inflation on its own account.

To assist Britain's endeavours to balance her overseas indebtedness, Mr. Stokes suggested that exporters should be encouraged to charge as much as they could obtain and it must be made clear that no stigma attached to profits so earned, provided that they were properly used. He considered that far too little was charged in many instances for some exports. He urged that the excess profits tax should be abolished and suggested the reintroduction of a limit on dividends. The cost of the defence programme should be spread over a longer period than three years. This would enable a reduction to be made in both direct and indirect taxation.

It was reported on Monday last that the Ministry of Labour were taking steps to end the labour dispute at the works of the E.N.V. Engineering Company, Limited, Willesden, London, N.W.10, where over a thousand employees have been on strike for nearly ten weeks. The stoppage is stated to have commenced when the firm rejected a demand by their men for the dismissal of a particular foreman. The executive body of the Amalgamated Engineering Union, to which the employees belong, informed the Ministry that an immediate return to work would be recommended if an assurance were given that the foreman in question was relieved of his supervisory duties while the discussions between the parties to the dispute were in progress. A meeting of the strikers on Monday agreed to this course of action.

A statement that there would be no direction of labour was made by Mr. Duncan Sandys, the Minister of Supply, in a speech at Preston on Monday last. As time passed, however, there would be an increased need for the transfer of employees between different firms in the same industry, or from one type of work to another within the same firm, owing to the growing requirements of the nation's defence programme. There was no lack of jobs. Any persons who were out of employment at the present time could find work of high national importance in connection with the defence programme. Referring to his visit to the works of the English Electric Company, Limited, at Preston, Mr. Sandys said that the production of the Canberra jet bomber and of certain other types of defence equipment had fallen behind the programme which had been planned a year ago, mainly owing to the shortage of labour. He could assure employees who were considering entering the aircraft industry that they had no reason to fear unemployment when the rearmament programme was concluded. There was, in fact, an enormous unsatisfied demand for British aircraft, both at home and abroad, and that applied also to the United States.

The supply of steel was dealt with at some length by Mr. Sandys, who expressed his sympathy with the surprise which many people were feeling that this metal should be in short supply. He suggested that the answer to the mystery lay in the exhaustion of the stocks of many firms owing to the very heavy demands made upon them during the past year. Any expectations by firms engaged on exports that the Government's allocation scheme would resolve all their problems were "unfounded." There were, in fact, but few firms which could not claim some form of priority and most consumers failed to understand that cuts applied under the scheme would appear the more severe because of the lack of stocks in hand. If a cut of 15 per cent. were imposed, that would be a reduction on deliveries; if, on top of that, a firm had been consuming additional quantities from stock, perhaps another 15 per cent., that would make a total of 30 per cent. less steel available to them. The Ministry of Supply would endeavour to rectify, in the second allocation period, any lack of balance which might be shown to exist in the first period.

TRAILERS AND SEMI-TRAILERS.

Fig. 1. SEMI-TRAILER TURNING CIRCLES.

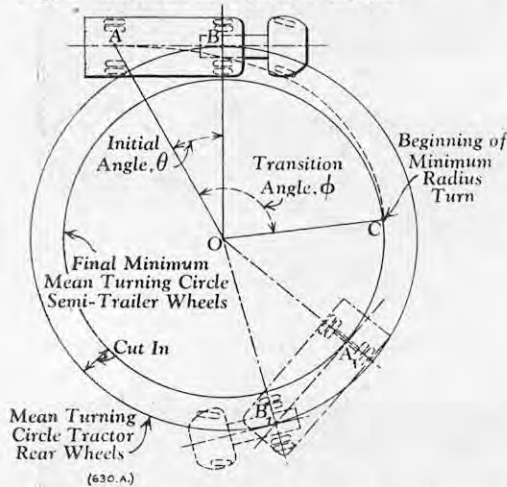


Fig. 2. FULL TRAILER TURNING CIRCLES.

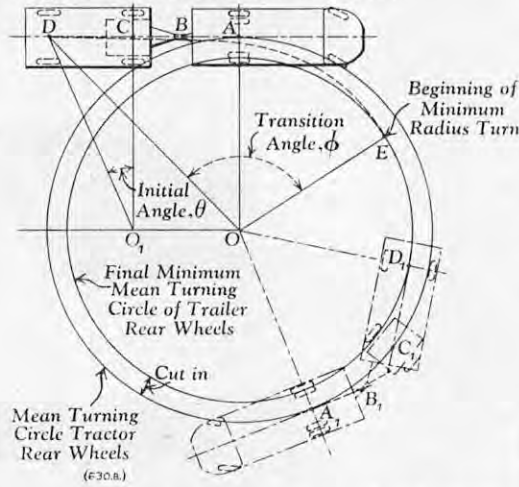
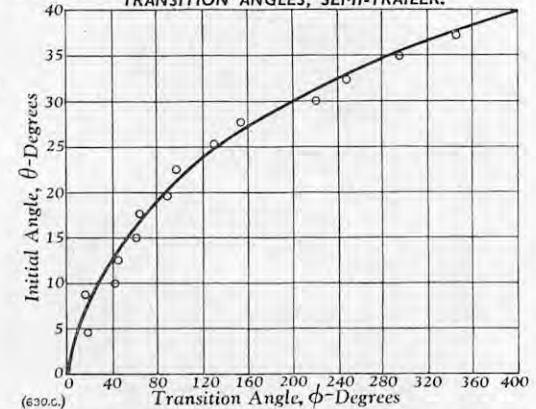


Fig. 3. RELATION BETWEEN INITIAL AND TRANSITION ANGLES, SEMI-TRAILER.



TRAILERS AND SEMI-TRAILERS.*

By ARTHUR MARENBO.

As generally understood, a trailer is a vehicle designed to be drawn by a motor vehicle, and it may be either a full trailer or a semi-trailer. On a semi-trailer there is no drawbar, the front end of the unit resting on the tractor, imposing on it part of its own weight and of the load being carried. There is a definite overlapping of the two structures, and, in fact, it is often referred to as a superimposed trailer. In the same way, a full trailer may be called a drawbar trailer. A full trailer is complete in itself, being attached to the towing vehicle by some form of drawbar, and generally carrying all the load on its own wheels. A balanced-axle trailer, such as a two-wheeler or a trailer fitted with an adhesion-type drawbar, may impose some load on to the motive unit, but it is not usual to classify these as semi-trailers. It should not be taken for granted that a trailer can have no motive power nor any driven wheels of its own. An Austrian concern has recently introduced a farm trailer, the front axle of which can be driven from the tractor, and recent patent applications indicate that further developments may take place in this field. An American company markets what it calls the "power package." This is a self-contained petrol engine which is fitted under a semi-trailer to drive its rear axle and can be brought into operation by remote control when hard going is encountered.

Neglecting the effects of such factors as road camber and centrifugal force, the course followed by a semi-trailer combination when traversing a circular path will be as shown diagrammatically in Fig. 1, herewith. The tendency is for the semi-trailer axle to align itself so that it points towards the centre about which the tractor is turning. There is a transitional period of "cutting in" until the axle has so aligned itself, and then it tends to maintain a path of minimum constant radius about this same centre. If L = distance between the king-pin B and the rear axle A; R = mean turning radius of tractor rear wheels; and R_1 = final mean turning radius of semi-trailer wheels, then

$$\text{Cut in} = R - R_1 = R - \sqrt{R^2 - L^2} \\ = \frac{L}{\tan \theta} - \sqrt{\left(\frac{L}{\tan \theta}\right)^2 - L^2}.$$

It will be seen, however, that this formula only holds good so long as the semi-trailer wheelbase is less than the radius of the tractor turning-circle. If it is greater, the rear axle moves from side to side of the centre point instead of rotating about it. Fig. 1 has been drawn on the basis that the vehicle has been halted facing straight ahead, the steering wheels locked over before re-starting, and any transitional path of the tractor has been disregarded. Angle AOB has been called the initial angle θ , and angle AOC, which indicates the rotation that has taken place before the minimum turning circle is reached, the transition angle ϕ . It would appear that these two angles are interdependent, and the approximate relation between them is shown in Fig. 3, herewith. In Fig. 1, for the sake of simplicity, the king-pin is shown mounted directly over the tractor rear axle. If, as is general practice, it is mounted 6 in. to 12 in. forward, it will mean only a very slight increase in

the effective radius of the path described by the king-pin. The "cut in" will be slightly reduced, but the difference will be so small as to be negligible for practical purposes.

The behaviour of a four-wheeled full trailer with turntable steering when traversing a circular course is shown diagrammatically in Fig. 2, herewith. Both the front and rear axles tend to set themselves so that they point to the common centre of gyration and it will be seen that if the drawbar is of suitable length, so that AB is equal to BC, the trailer front wheels, after a short transitional path, will assume the same turning circle as the tractor rear wheels. If AB is less than BC, "cut in" will take place and if it is greater the front wheels will circle outside the tractor rear wheels. If $AB = BC$ and $CD = L$, then:—

$$\text{Cut in} = R - R_1 = R - \sqrt{R^2 - L^2} \\ = \frac{L}{\tan \theta} - \sqrt{\left(\frac{L}{\tan \theta}\right)^2 - L^2}.$$

Theoretically, by suitably arranging these two dimensions and the trailer wheelbase, it should be possible to make the rear wheels of the trailer track with those of the towing vehicle, so that there is no effective "cut in." In practice, this may not be possible or advisable for a variety of reasons, but it is a point worth noting, and most certainly more consideration should be given than at present to the matching of prime mover and trailer, so as to produce a combination with the best tracking characteristics.

Further consideration of Fig. 2 will show that if the trailer rear axle is made to swivel and is connected to the front axle so that it rotates equally but in the opposite direction, $O C_1 D_1$ will be an isosceles triangle; $O C_1$ and $O D_1$ will then be equal, so that C_1 and D_1 will lie on the same circle with O as the centre. Accordingly, the front and rear axles will track, and it thus becomes a relatively simple matter to build a tracking trailer. By suitably adjusting overhang and drawbar dimensions, a second trailer can be made to track with the first one, and a tracking road train assembled. Continental manufacturers regard the avoidance of tyre scrub as being of such prime importance that other considerations often take second place, and this is possibly the reason for the somewhat unusual axle arrangement of the Italian Bartoletti trailer. This has interconnected swivelling front and rear axles, and a fixed centre axle. However, by far the most interesting Continental tracking trailers are those which have been developed for passenger transport, such as the Italian Viberti, illustrated in Fig. 4, on page 90. Loading level considerations favour the use of Ackerman steering, and a stabiliser is fitted to the rear wheels to avoid snaking. There is also a device to disconnect the rear steering so that the trailer can be man-handled easily when uncoupled.

Italy seems to be the only country in which the fully tracking semi-trailer is used to any extent. Fig. 5, on page 90, shows the Italian Orlandi semi-trailer, having steerable stub axles interconnected with the "fifth" wheel. American fire-truck semi-trailers also have steerable wheels, but these are controlled by a rear steersman. On the other hand, considerable progress has been made both in the United States of America and on the Continent in the design of tandem-axle semi-trailers which track to a limited degree. In the American Hoobler form of construction, for example, the undercarriage is attached to the semi-trailer both by the sliding turntable and the two drawpoles attached to its swivelling front axle, as shown diagrammatically in Fig. 7, on page 90. When turning, the front wheels remain parallel to the semi-trailer, while the whole

assembly pivots. A tank semi-trailer fitted with this form of undercarriage is illustrated in Fig. 6, on page 90. The logging bogie shown diagrammatically in Fig. 8, on page 90, also comes in this category, although strictly speaking this does not become a semi-trailer until it is loaded. There are swivel bolsters both on the tractor and the bogie on which the logs rest, and the log load actually constitutes the body of the semi-trailer. The bogie is left free to slide along the steering pole, which is connected to a coupler at the rear of the tractor. As will be seen, this arrangement gives a degree of steering to the rear bogie which can be increased at will by fitting the coupler farther out from the back of the tractor. The development of a normal semi-trailer with a swivelling rear bogie steered in this manner seems quite feasible.

A number of tandem-axle assemblies incorporate features primarily intended to reduce tyre scrub, but which may improve tracking of the semi-trailer to a limited degree. The American Fruehauf gravity-suspension tandem-axle unit has a most interesting tracking feature that may well be the forerunner of a new fashion in semi-trailer design. The axles are shackle-mounted to levers attached to the torsion springs, so that they have a limited amount of side movement. It is said to be "gravity cushioned," as any side movement of the axles is accompanied by a rise in the body level, which will be opposed by the force of gravity; this is shown diagrammatically in Figs. 11, 12 and 13, on page 91, Figs. 11 and 12 showing the relative positions of the components with the axle in the normal position and the trailer empty and loaded, respectively, and Fig. 13 the position during a turn, with the axle moved to one side. The natural tendency is for the axles of a tandem bogie to run straight ahead. Hence, if they are permitted some side movement during a turn, they will follow a curve of greater radius than if they were fixed. Accordingly there will be less "cut in" and a greater degree of tracking, accompanied by a reduction in tyre scrub. In view of the importance which Continental designers place upon the latter feature, it is not altogether surprising that many tandem units which permit axle side float have been exhibited at recent shows. German manufacturers appear to favour the use of rubber as a connecting link between the axles and springs as a means of achieving this objective. However, designs of this nature are still in the minority, and the favourite Continental approach to the question is to provide Ackerman steered rear wheels on the tandem bogie. It should be mentioned that the Fruehauf design goes a step farther than permitting side movement of the axle, the torsion springs and shackles being set at an angle to the longitudinal axis of the semi-trailer, so that any side movement of the axle also slews it round slightly. During a turn the axles no longer remain parallel, but to a limited extent steer into the curve being traversed.

To be able to disconnect the semi-trailer quickly from its tractive unit is an obvious advantage and a typical fifth-wheel assembly incorporating a quick release is shown diagrammatically in Figs. 14 and 15, on page 91. During coupling the king-pin is guided by the V-shaped opening until the locking jaws secure it in position, the fifth-wheel mounting allowing it to tilt down towards the rear so as to form a ramp to raise the front end of the semi-trailer to the required coupling level. Some semi-trailers have manually-operated vertical-lift landing gear, but fold-back or automatically-operated jockey wheels are in wide use which do not utilise the fifth-wheel arrangement outlined. In the Scammell system, for instance, a retractable undercarriage with flanged rollers is fitted to the front end of the semi-trailer. During coupling the rollers run up guides attached to the tractor frame until they are locked automatically in position, the lower part of the carriage folding back. The braking

* Paper presented at a meeting of the Automobile Division of the Institution of Mechanical Engineers, held in London on Tuesday, December 11, 1951. Abridged.

TRAILERS AND SEMI-TRAILERS.

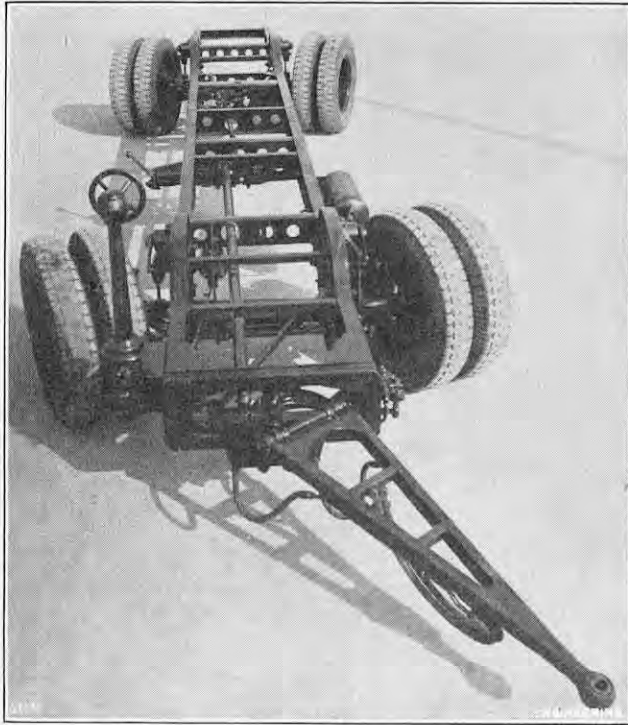


FIG. 4. VIBERTI FOUR-WHEEL TRACKING TRAILER.

Fig. 7. STEERING ARRANGEMENT OF 'HOOBLER' UNDERCARRIAGE.

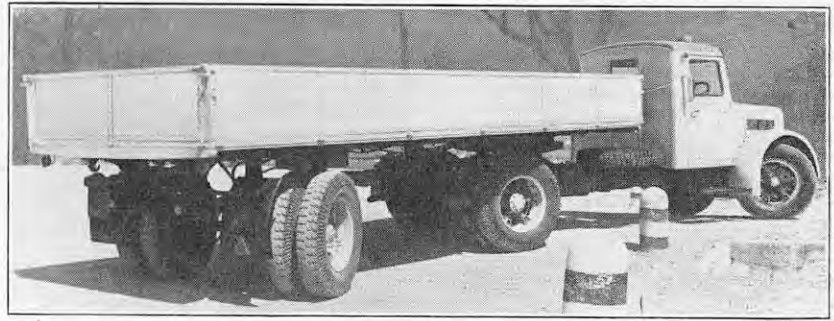
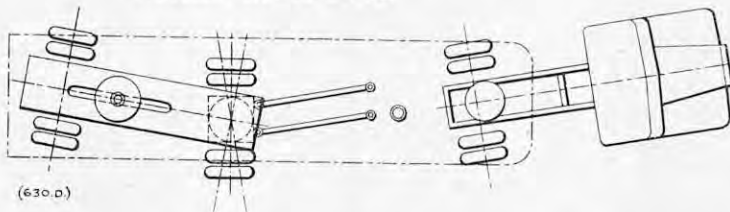


FIG. 5. ORLANDI TRACKING SEMI-TRAILER.

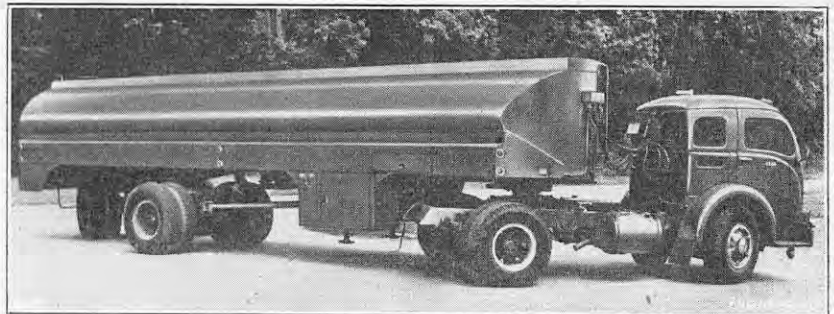
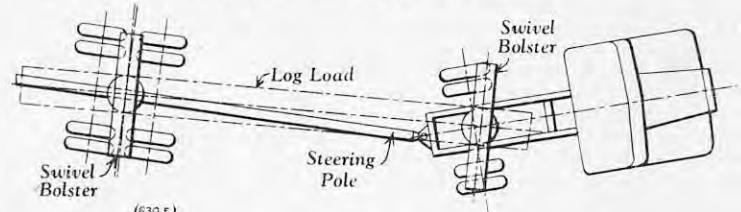


FIG. 6. SEMI-TRAILER WITH HOOBLER UNDERCARRIAGE.

Fig. 8. STEERING ARRANGEMENT OF LOGGING BOGIE.



and lighting systems are coupled during this operation. Most of the well-known American manufacturers list some form of automatic support gear, but it does not appear to be in such wide use as the non-automatic type. The D.A.F. trailer, which is manufactured in Holland, has hydraulically-operated landing gear which is lowered by hand, but is retracted mechanically upon coupling. The fifth wheel shown in Fig. 14 is mounted on a transverse shaft so that it can rock longitudinally, but a universal mounting, which also allows the fifth wheel to oscillate transversely so as to relieve the tractor and semi-trailer frames of any twisting stress, is common on tankers and very heavy-duty outfits. It is also possible to provide a gravity-cushioned mounting. In this case, the fifth wheel is hinged on a cranked shaft that can itself swing to and fro in brackets mounted to the tractor frame. As this shaft oscillates it raises the fifth wheel and the front end of the semi-trailer, so that starting and stopping shocks are thus, to some extent, cushioned by gravity. For shuttling semi-trailers within their loading-dock areas without having to operate the landing gear, some American operators use a tractor with very short wheelbase, fitted with a hydraulically-elevated fifth wheel.

Although many special trailers do feature front wheels steered through an Ackerman linkage, turntable steering is almost universal on standard models. As can be imagined, there are many designs, but gradually the old idea of using a king-pin with central bolster plates and concentric wheel plates, or turntable rings, is being abandoned. A popular modern method is to utilise large-diameter interlocking rings with balls or rollers interposed between them, and entirely to dispense with the king-pin. The earliest designs appear to be of German origin, but nearly every trailer manufacturer now lists some form of ball or roller bearing turntable. A friction-free turntable is very desirable, as not only does it facilitate manhandling, but it also helps to prevent "snaking." At one time, the oscillation of the trailer behind the towing vehicle was regarded as a major drawback to full trailer operation, but improved design now appears to have overcome the difficulty as far as the comparatively low operational speeds in Great Britain are concerned. However, it is a possible difficulty which must be faced, and interesting research work on this subject was carried out in Germany prior to 1939. It would

appear that lateral flexibility in the draw-hook itself or looseness in the fit of the drawbar eye, either friction or play in the trailer steering, any tendency of the trailer to overrun the towing vehicle, too short a drawbar, or too short a trailer wheelbase, are all factors which tend to set up "snaking." Frictional damping of the drawbar eye about the coupling or braking the trailer front wheels will tend to suppress the oscillation, but braking the rear wheels has little effect. It is aggravated by higher speeds, but, in the case of a two-wheeled trailer, snaking is reduced if the centre of gravity is well forward of the axle. In the author's view a solid unsprung drawbar and coupler are preferable to the sprung variety, as any springing always opens up the possibility of resonant vibrations being set up.

The usual hook or jaw coupling cannot be regarded as entirely satisfactory. The drawbar eye is made a reasonably loose fit on the coupling to allow for easy hitching and unhitching, and this tolerance permits a sufficient degree of universal movement for main road work. However, such an arrangement will tend to wear rapidly, to be noisy, and to set up snaking. To counter this, some American manufacturers produce so-called shockless couplings, in which a buffer, actuated either by vacuum or air pressure, exerts a predetermined pressure against the drawbar eye once it is in position. An interesting German jaw-pattern coupler incorporates a rounded boss on which the drawbar eye sits, and a spring-loaded ball-headed pin to secure it in position. A great deal of ingenuity has been displayed in the development of automatic locking devices which prevent the drawbar eye from jumping out of the coupler, but the whole principle of having a loose-fitting joint seems to be wrong. The difficulty may be aggravated when use off the road makes it necessary to allow for a higher degree of universal movement. It may well be that a form of ball coupling, as used on caravans and light two-wheel trailers, would be preferable to present-day accepted practice. It might also be worth while to consider a universally-mounted coupling into which the drawbar is rigidly locked. All the movement would then take place in the properly designed close-fitting universal, which would not have to be taken apart when the trailer was uncoupled.

If the fifth wheel is mounted directly over the tractor

rear axle, there may be a tendency when going uphill to reduce the weight on the front wheels. For this, if for no other reason, it is customary to have a forward mounting, usually of from 6 in. to 12 in. This offset may be increased if necessary, and sometimes it will help to produce an outfit of greater carrying capacity, as the tractor front axle will be carrying more of the imposed load. Again, there will be less tendency to "jack knife," as side thrust will be taken up by both tractor front and rear axles. As already discussed, tracking is little affected by a forward mounting, and, in fact, may be improved. However, there may be disadvantages as far as the coupling and uncoupling of the semi-trailer is concerned, and the physical dimensions of the tractor and semi-trailer often make it impossible to increase the forward mounting beyond 12 in.

The springing systems employed are very varied, and although the usual semi-elliptic laminated spring predominates, there are many examples of coil, rubber, and torsion-bar springing. Where a single axle mounting is concerned, the standard British practice is to use simple semi-elliptic springs, fixed at one end and free to move at the other. American manufacturers, on the other hand, usually position the axle with radius rods, leaving both ends of the springs free to move. A very common layout in Great Britain and on the Continent employs leaf springs for each axle, with the adjacent ends of the springs at each side joined through shackles to a balance beam. Continental manufacturers often fit twin tyres to the forward axle and single tyres to the rear, the balance beam having unequal arms so as to distribute the load accordingly. Another Continental device is to lock the balance beam in position, with one axle clear of the ground when the vehicle is empty, the tandem-axle assembly thus being converted to a single-axle, and tyre scrub avoided. On a typical equivalent American arrangement, the springs are free at each end and the axle housings are positioned by radius rods. The axles themselves may be left free to rotate in these housings but connected together by a member, sometimes in the form of a torsion bar, which absorbs brake torque.

The relatively simple single inverted centrally-mounted spring system is used both in Great Britain and the United States. Rubber blocks, inserted in the housings on top and to each side of the spring ends,

TRAILERS AND SEMI-TRAILERS.

Fig. 9.

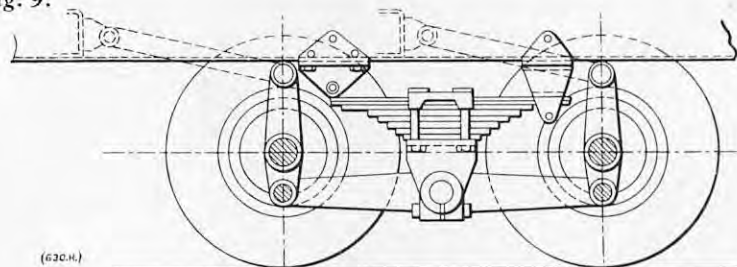


Fig. 10.

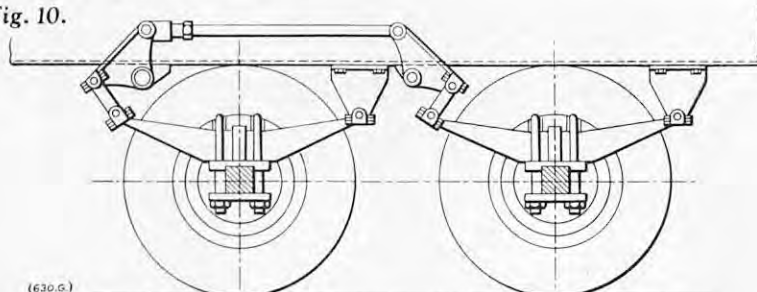
TORSION-SPRING GRAVITY SUSPENSION
AXLE MOUNTING.

Fig. 11.

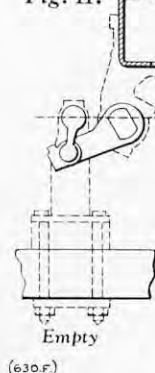


Fig. 12.

Rise in Frame Level
as Axle is Displaced

Fig. 13.

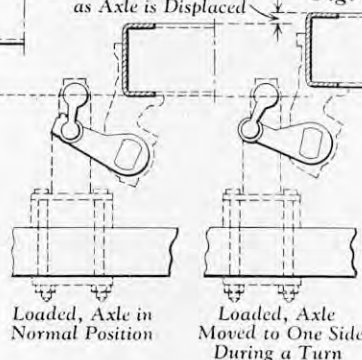


Fig. 14.

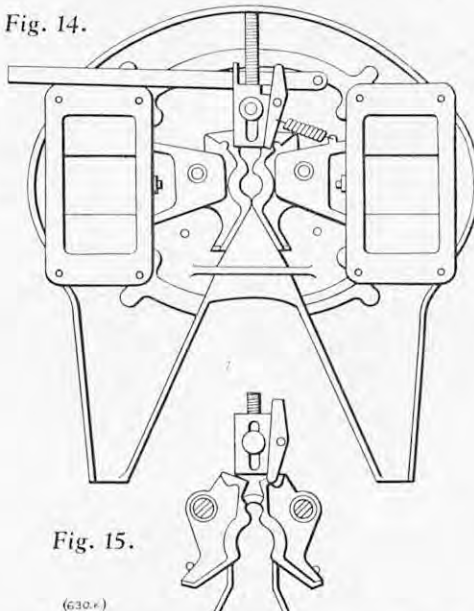


Fig. 16.

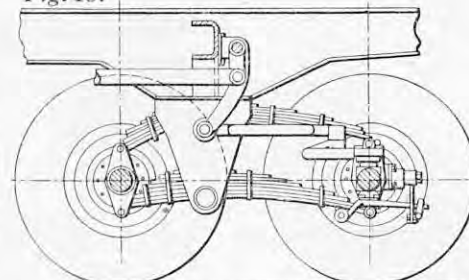
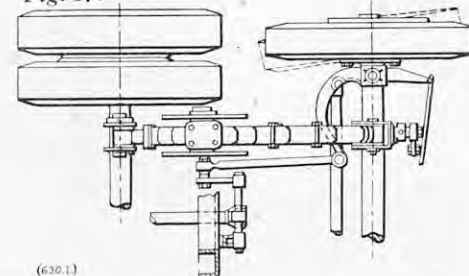


Fig. 17.



allow a limited amount of movement which relieves the springs of twist. The springs carry the load and take all the brake torque, but very satisfactory results are obtained in spite of this. Curiously enough, this is the spring mounting that is adopted on many American logging bogies, which sometimes operate under such arduous conditions that the brakes have to be water-cooled. On the American Trailmobile system, the rear ends of the two springs are coupled together by rocker beams; and the bell-crank compensating device, shown diagrammatically in Fig. 10, herewith, is used both in the United States and in Germany. The manufacturers claim that the Hendrickson tandem system, illustrated in Fig. 9, herewith, which was developed in the United States, is used by more than 35 trailer manufacturers. The attachment of the axle brackets to the equaliser beams is by ball and socket joints. The system shown in Figs. 16 and 17, on this page, is representative of many Continental designs in which the rear wheels are steered. The Crane and the Scammell systems utilise stub axles and give independent wheel movements, the spring in the latter case being composed of alternate rubber and metal discs. Trailer manufacturers do not necessarily have to limit themselves to two axles in tandem. A favourite practice is to mount two short oscillating axles in line, as on the D.A.F. semi-trailer and some Dyson models, and there are nearly as many variations of this four-wheel-in-line mounting as there are of the tandem assembly. Alternatively, there can be two rows of oscillating axles.

(To be continued.)

NEW PREMISES OF THE BUILDING CENTRE.—To cater for the great increase in the post-war activities of the Building Centre, new premises have been taken over in Store-street, Tottenham Court-road, W.C.1. The Building Centre, it will be recalled, was founded in 1931 and its first premises were situated in Bond-street and the Grafton Galleries. Subsequently, these were destroyed by enemy action and in 1942 the Centre moved into the old buildings of the Royal Institute of British Architects in Conduit-street, which also were damaged by enemy action. The latest premises were acquired in 1950 and the Centre moved into them in December, 1951. Originally, the building was designed as a garage and is believed to be one of the first reinforced-concrete buildings constructed in London. Although damaged by blast during the war, it suffered no serious structural damage, the work of restoration being confined largely to the installation of a new stairway and passenger-lift well and extensive redecoration. There are four floors and a basement, all of which have been laid out attractively for the exhibition of the many different fittings and materials used in connection with the erection and equipment of buildings. The Centre maintains its own technical staff and the facilities provided include a lecture theatre, cinema, a council room and general offices.

LAUNCHES AND TRIAL TRIPS.

M.S. "ALCINOUS."—Single-screw cargo and passenger vessel, built by Vickers-Armstrongs Ltd., Walker-on-Tyne, for the China Mutual Steam Navigation Co., Ltd. (Managers: Alfred Holt & Co.), Liverpool. Main dimensions: 487 ft. overall by 62 ft. by 35 ft. 3 in.; deadweight capacity, about 9,000 tons on a draught of 28 ft.; gross tonnage, 8,300. Kincaid-B. and W. seven-cylinder Diesel engine developing 7,000/7,600 b.h.p. and a service speed of 15½ knots, constructed by John G. Kincaid & Co., Ltd., Greenock. Launch, November 27.

S.S. "FRAGUM."—Single-screw vessel for carrying bitumen in bulk, built and engined by Smith's Dock Co., Ltd., South Bank-on-Tees, for the Anglo-Saxon Petroleum Co., Ltd., London, E.C.3. Main dimensions: 315 ft. between perpendiculars by 46 ft. by 19 ft. 6 in. to harbour deck; deadweight capacity, about 3,350 tons on a draught of 17 ft. Triple-expansion reciprocating steam engine, developing 1,600 i.h.p. at 135 r.p.m. and a speed of about 11 knots in service. Launch, November 28.

H.M.S. "EDDYBAY."—Single-screw vessel for carrying oil in bulk, built by the Caledon Shipbuilding and Engineering Co., Ltd., Dundee, for the Naval Stores Department, Admiralty, London, S.W.1. Second vessel of two. Main dimensions: 286 ft. overall by 44 ft. by 18 ft. 6 in.; deadweight capacity, 2,095 tons on a draught of 17 ft. 2 in.; gross tonnage, 2,157. Triple-expansion steam engine developing 1,750 i.h.p. at 227 r.p.m., constructed by Lobnitz & Co., Ltd., Renfrew; and two oil-burning cylindrical boilers constructed by the Caledon Co. Speed in service, 12 knots. Launch, November 29.

M.S. "EBRO."—Single-screw cargo vessel, carrying twelve passengers, built and engined by Harland and Wolff, Ltd., Govan, for the Royal Mail Lines, Ltd., London, E.C.3. Main dimensions: 415 ft. between perpendiculars by 58 ft. 6 in. by 38 ft. 4 in. to shelter deck; gross tonnage, 5,500. Harland-B. and W. six-cylinder single-acting two-stroke Diesel engine. Launch, November 29.

M.S. "CLUTHA RIVER."—Single-screw oil tanker, built and engined by R. and W. Hawthorn, Leslie & Co., Ltd., Hebburn-on-Tyne, County Durham, for the British Empire Steam Navigation Co., Ltd. (Managers: Houlder Brothers & Co., Ltd.), London, E.C.3. Main dimensions: 557 ft. overall by 70 ft. by 39 ft. 6 in. to upper deck; deadweight capacity, 18,000 tons; draught, 30 ft. 6 in. Hawthorn-Doxford six-cylinder opposed-piston oil engine, developing 7,600 b.h.p. at 114 r.p.m. in service. Speed, 15 knots. Launch, November 29.

M.S. "SUHAIL."—Single-screw oil tanker, built by the Furness Shipbuilding Co., Ltd., Haverton Hill, County Durham, for the Afran Transport Co., Monrovia, Liberia, a subsidiary of the Gulf Oil Corporation, New York. First vessel of an order for three. Main dimensions: 560 ft. between perpendiculars by 80 ft. by 42 ft. 3 in.; deadweight capacity, 24,400 tons on a summer draught of 32 ft. 3½ in.; oil-tank capacity, 23,550 tons. Hawthorn-Doxford six-cylinder single-acting two-stroke opposed-piston oil engine, developing 6,600 b.h.p. at 115 r.p.m. in service, constructed by R. and W. Hawthorn, Leslie & Co., Ltd., Newcastle-upon-Tyne. Speed, 14 knots. Launch, November 29.

M.S. "KING MALCOLM."—Single-screw cargo vessel, built and engined by Harland and Wolff, Ltd., Belfast, for the King Line, Ltd., London, E.C.3. First vessel of an order for two. Main dimensions: 467 ft. overall by 59 ft. by 39 ft. 9 in.; gross tonnage, 5,770. Harland-B. and W. six-cylinder single-acting four-stroke Diesel engine. Launch, November 29.

M.S. "LONDON ENDURANCE."—Single-screw oil tanker, built by Sir James Laing and Sons, Ltd., Sunderland, for the London and Overseas Freighters, Ltd., London, W.1. Second vessel of a series of three for these owners. Main dimensions: 475 ft. between perpendiculars by 67 ft. 4½ in. by 37 ft. 4 in.; deadweight capacity, about 15,300 tons on a summer draught of 29 ft. Doxford four-cylinder opposed-piston oil engine, developing 4,250 b.h.p. at 110 r.p.m., constructed by the North Eastern Marine Engineering Co. (1938), Ltd., Sunderland. Service speed, 12½ knots. Launch, December 28.

M.S. "SCOTTISH LION."—Single-screw oil tanker, built by Swan, Hunter, and Wigham Richardson, Ltd., Wallsend-on-Tyne, for the Scottish Tanker Co., Ltd. (Managers: Cayzer, Irvine & Co., Ltd.), London, E.C.3. Main dimensions: 515 ft. between perpendiculars by 69 ft. 6 in. by 38 ft. 4½ in.; deadweight capacity, 16,250 tons on a draught of about 30 ft.; gross tonnage, 11,250; oil-tank capacity, 745,000 cub. ft. Wallsend-Doxford six-cylinder two-stroke opposed-piston oil engine, developing 6,400 b.h.p. at 115 r.p.m., constructed by the Wallsend Slipway and Engineering Co., Ltd. Speed, 14 knots. Launch, November 30.

M.S. "CHARLTON VENUS."—Single-screw oil tanker, built and engined by William Doxford and Sons, Ltd., Sunderland, for the Charlton Steam Shipping Co., Ltd. (Managers: Chandris (England), Ltd.), London, E.C.3. Main dimensions: 505 ft. by 69 ft. 9 in. by 39 ft.; deadweight capacity, 16,740 tons on a draught of 30 ft. Doxford five-cylinder opposed-piston oil engine, developing 6,450 b.h.p. at 117 r.p.m. and a service speed of about 14 knots. Trial trip, December 29.

SHORTCOMINGS OF STRUCTURAL ANALYSIS.

Fig. 9. BEHAVIOUR OF CONTINUOUS BEAM.

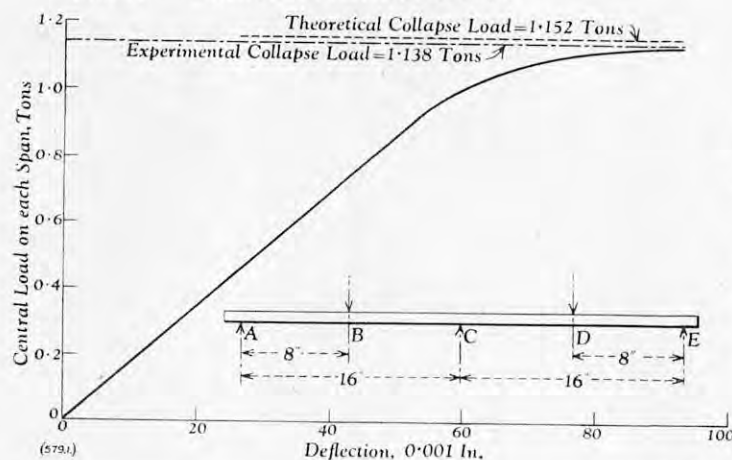


Fig. 10. CONTINUOUS BEAM WITH SINKING SUPPORT.

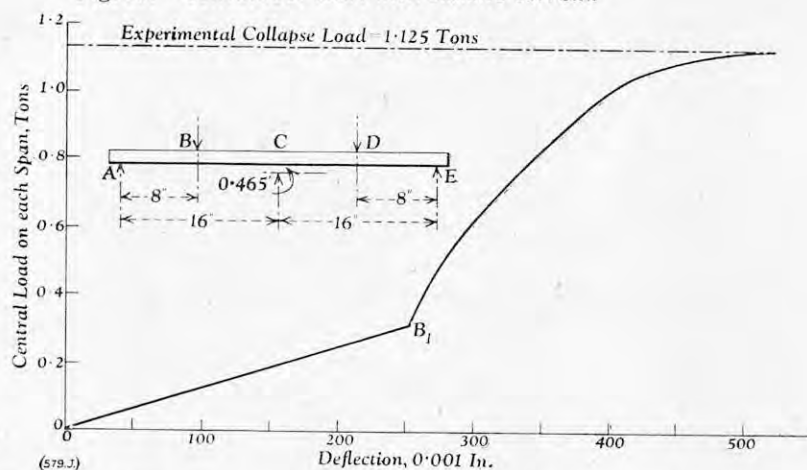
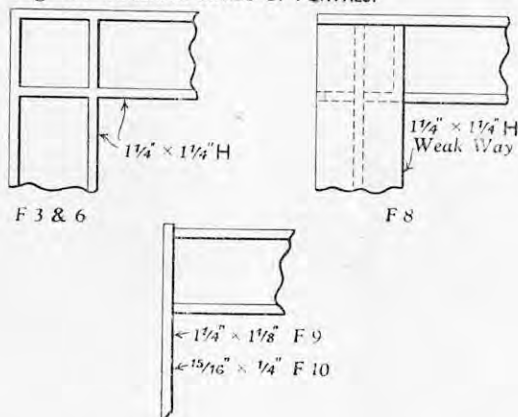


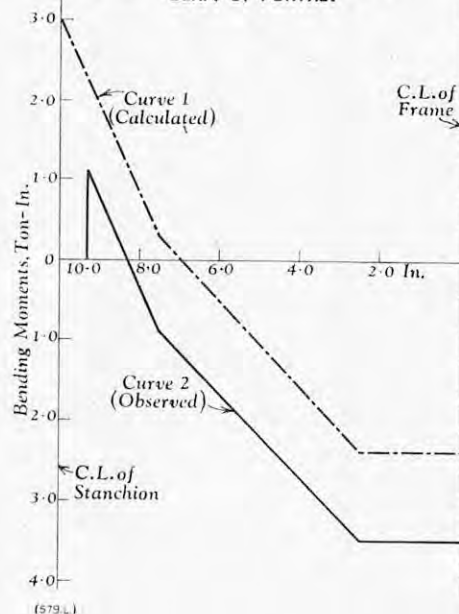
Fig. 11. COLLAPSE LOADS OF PORTALS.



No.	Calculated	Observed
F 3	1.56	1.55
F 6	2.91	3.03
F 8	2.72	2.79
F 9	1.81	1.70
F 10	1.89	1.81

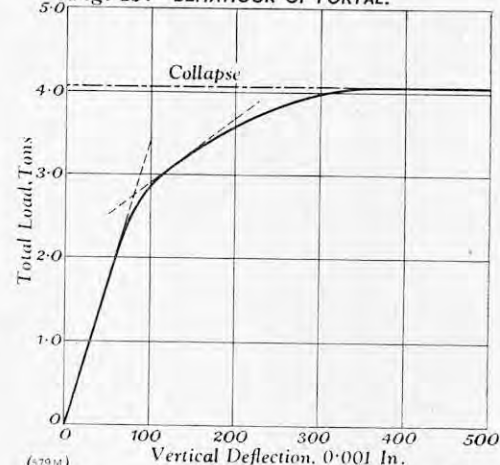
(579.1)

Fig. 12. BENDING MOMENTS IN BEAM OF PORTAL.



(579.2)

Fig. 13. BEHAVIOUR OF PORTAL.



(579.3)

SHORTCOMINGS OF STRUCTURAL ANALYSIS.*

By PROFESSOR J. F. BAKER, O.B.E., M.A., Sc.D.

(Concluded from page 59.)

We have recently carried out, at Cambridge, a number of tests on beams to demonstrate how accurately the real failing load of a structure can be estimated. Small square beams, $\frac{1}{4}$ in. side, were prepared from 1 in. square bars of rolled mild steel in the "as received" condition. Table IV, shows the results of three tests. In the first, E 1, the ends of the beam were fixed as rigidly as practicable. A central concentrated load was applied and, as shown in the first line of Table IV, collapse occurred when the load

TABLE IV.—Collapse Loads (lb.) of Fixed-Ended Beams.

No.	Width, in.	Depth, in.	Ratio of End to Central Moment in Elastic Range.	Collapse Load, lb.
E 1	0.254	0.253	0.912	258
E 2	0.249	0.255	0.746	263
E 3	0.250	0.256	0.490	269

reached the magnitude of 258 lb. The ends of this beam were fixed as well as possible, but they were not completely *encastré*, as may be seen from col. 4, which shows that the ratio of end moment to central moment while the beam was still elastic was 0.912 instead of unity, as it would have been had the ends been completely fixed. This lack of complete fixity, which makes nonsense of exact elastic analysis, has no effect on the collapse load of the structure so long as the ends of the beam are so attached to the abutments that the full plastic moment of the section can be developed. This was shown by repeating the test with beams con-

nected to the abutments with different degrees of fixity. Two of these are shown in Table IV; beam E 2 had ends so fixed that the ratio of end moment to central moment in the elastic range was reduced to 0.746. In spite of that, the collapse load only changed from 258 to 263 lb. and, in the case of beam E 3, where the end fixity was such that the ratio of elastic moment was no more than 0.490, the collapse load only changed to 269 lb. The small variations in the dimensions of the beam, shown in cols. 2 and 3, are almost sufficient to explain the slight discrepancies in the collapse loads, so that these tests form a conclusive demonstration that the degree of stiffness of connections has no effect on the collapse load of a structure.

In the same way, while it is not difficult to show theoretically that relative sinking of supports has no effect on collapse load, it may be more convincing to illustrate the point from the results of tests. Two-span continuous beams were subjected to concentrated loads, as shown in Fig. 9, herewith. In the first test, the supports A, C and E were at the same level; the loads were increased until collapse occurred and, from the curve of deflection against load, it will be seen that this happened at 1.138 tons, whereas the calculated collapse load was 1.152 tons. The test was repeated on a similar beam, but this time the central support C was lowered by 0.465 in.; a distance so chosen that the yield stress would be reached in the extreme fibres between the loads before contact was established with the central support, so that, according to elastic theory, the beam would have failed when this occurred under a load of about 0.3 tons. Real failure or collapse did not, of course, occur here and the behaviour of the beam can be seen clearly from Fig. 10. At the point B₁ on the curve, the beam came into contact with the support C and the rate of growth of deflections decreased; thereafter the deflections did not become large until the beam collapsed at 1.125 tons, which is close enough to the 1.138 tons determined for the first beam to show that sinking of supports has no effect on the collapse load of a ductile beam.

These results are of the utmost importance because the designer cannot be certain that the structure built from his designs will not suffer small relative sinking and spreading of the supports or, even when using welding, some lack of complete rigidity in the joints.

It is a very short step from the continuous beam to the rectangular portal frame, the beam of which is subjected to a symmetrical system of transverse loads. About 15 years ago, when our investigation into the plastic behaviour of structures began, one of the first series of tests, which I described to you in the earlier paper,* was on a group of portals made up of beams of the same I-section, connected by welded joints to stanchions of various sizes, as in Fig. 11. The results of the tests on these quite practical, though small-scale, structures in which, undoubtedly, there was not complete rigidity at the joints, in which the feet of the stanchions could not have been perfectly fixed, as would have been assumed in elastic design, and between which some spread and deflection probably took place, are shown in Fig. 11, together with the collapse loads calculated from a knowledge of the full plastic moments of the sections used in fabricating the portals. Remembering the discrepancies met with in elastic analysis, it will be seen that these results are remarkably close. It was this surprising agreement which emboldened us to continue what has now become a comprehensive and somewhat protracted investigation into the full implications of plastic behaviour.

Before leaving the rectangular portal subjected to vertical loads only, it will be well to consider one further case. A portal, similar to F3, was subjected to four equal point loads. The bending-moment diagram in the beam when the total load was 2.15 tons and the portal was still within the elastic range, is shown as curve 2 in Fig. 12, herewith, and there it can be compared with the theoretical bending-moment diagram, curve 1, calculated on the assumption that all joints were rigid and that there was no imperfection at the supports. It will be noticed that this theoretical curve indicates the greatest bending moment occurring at the end of the beam, so that first yield would be expected there. The observed curve shows that, in fact, the greatest bending moment occurred at the centre of the beam, due to the practical imperfections in the joints. Observation showed that yield did actually occur at the centre of the beam, but the beauty of the plastic theory is that it does not matter in the least where first yield occurs. Something of the

* The 20th Andrew Laing Memorial Lecture, delivered before the North-East Coast Institution of Engineers and Shipbuilders in Newcastle-upon-Tyne on Friday, November 9, 1951. Abridged.

* Loc. cit.

SHORTCOMINGS OF STRUCTURAL ANALYSIS.

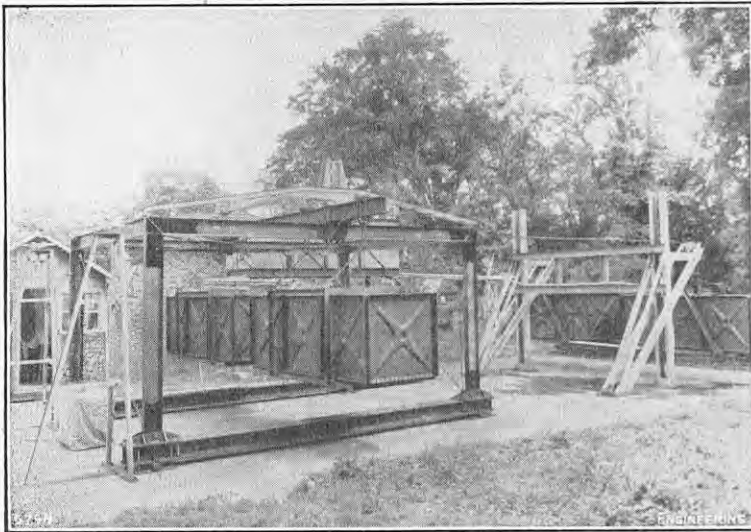


FIG. 14. APPLYING LOAD TO RECTANGULAR PORTAL.

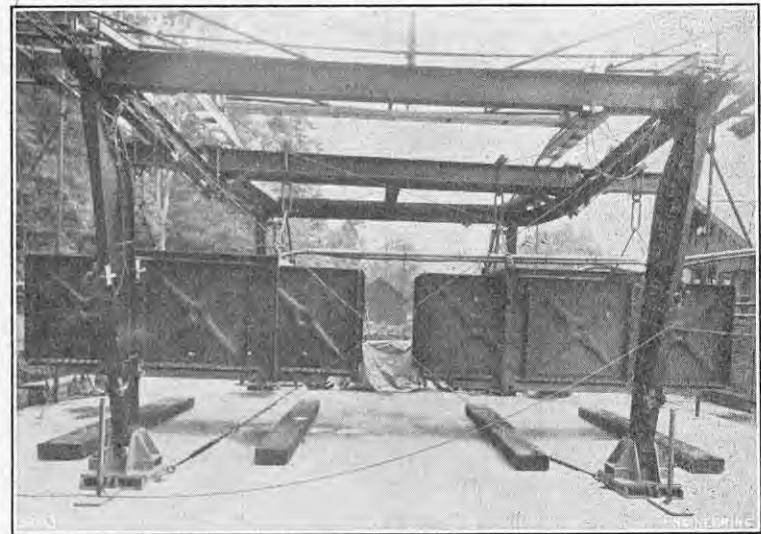
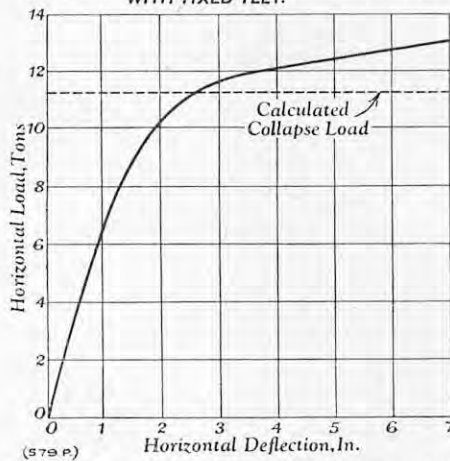


FIG. 15. PORTAL AFTER COLLAPSE.

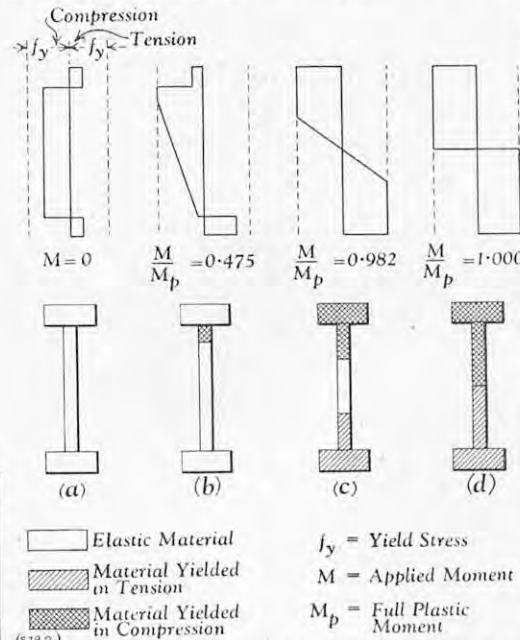
Fig. 16. BEHAVIOUR OF FULL-SCALE PORTAL WITH FIXED FEET.



behaviour of the portal can be seen from a study of Fig. 13, which shows the load-deflection curve. Up to a load of 2.15 tons, a linear relation exists between load and deflection, indicating that the structure was elastic. At the load of 2.15 tons, the slope of the curve starts to decrease, indicating that yield has occurred somewhere in the frame. We know, in this case, that this yield was in the outer fibres at the centre of the beam. As the load is increased, further yield occurs until, at a load of 2.90 tons, a second linear stage begins. This shows that the central section of the beam had become fully plastic and that, under loads in excess of 2.90 tons, the moment of resistance of the centre of the beam is sensibly constant. This new linear range continues until the applied load is 3.35 tons, but thereafter the rate of change of deflection again increases, showing that yielding has now begun at the ends of the beam. This continues until the whole of the end sections become plastic under a load of 4.03 tons, a virtual mechanism is formed, and the deflections grow so large that collapse can be said to have occurred. The calculated collapse load was 4.19 tons. Many more structures, of various kinds, both small-scale and full-scale, have now been tested under more complex loading conditions and the simple plastic theory has proved itself in every case to be a sound basis for estimating the useful strength.

As all the tests so far described have been on small-scale beams and portals, it may be more convincing to conclude this part of the evidence with a short account of the behaviour of full-scale structures. A number of rectangular portals having spans of 16 ft. and heights of 8 ft., built up of 8 in. by 4 in. joists, have been tested. One, with fixed feet, is illustrated in Fig. 14, where it will be seen that a vertical central load and a horizontal load at the level of the beam were applied. In the first test on a similar portal, but with pinned feet, the horizontal and vertical loads applied were kept equal and it was calculated that collapse would occur when each load was 5.65 tons. As the test loads were slowly applied, definite signs of creep were detected at about 4 tons, but the structure continued to support load until 5.75 tons had been reached, that is, only one-tenth of a ton more than the calculated load, when the side-sway deflection was observed to be increasing rapidly and, after about

Fig. 17. BEHAVIOUR OF INITIALLY STRESSED BEAM.



three minutes, the frame collapsed. The form of the structure after collapse is clear from Fig. 15. As it was failing, it was observed to move rapidly through a distance of approximately 1 ft. in the horizontal direction before the leeward stanchions became unstable and deflected laterally.

Such extraordinarily close agreement between observed and calculated collapse loads was not found for the portals with fixed feet. From the observed horizontal deflections for a case in which the ratio of horizontal to vertical loads was 2 (Fig. 16) it will be seen that a load appreciably above the calculated collapse load of 11.50 tons was supported. The reason for this is the onset of strain-hardening as the plastic hinges are developed at the feet of the stanchions, so preventing the catastrophic deflection found in the pin-based frame. This state of affairs has been confirmed in many tests on more complex structures. The effect of strain-hardening can be taken into account in the calculation of collapse load, but, for design purposes, the simple plastic theory has so far proved quite satisfactory enough, since it gives a good indication of the stage beyond which the structure develops large permanent deformations.

The results of these experiments on welded structures demonstrate, among many other things, that the residual stress systems set up by welding, which can be such an anxiety in the elastic range, have no effect on the ultimate strength of a structure. Residual stresses form a self-equilibrating system and so, if they increase the total stress and hasten yield in some parts of a member, they must equally decrease the total stress and delay yield in other parts. The ultimate resistance of the member will thus be unchanged, a conclusion which is to be expected if the problem is regarded from the point of view of strain energy.

The case of a built-up I-beam, in which the web is initially stressed by residual stresses to a uniform

compression equal to 0.6 times the yield stress, has been studied. The area of each flange was equal to the area of the web, so that the conditions of internal equilibrium required that both flanges were stressed to 0.3 times the yield stress. If a bending moment is applied and gradually increased the sequence of events shown in Fig. 17 follows. The state of the beam for different values of the applied sagging moment M can be seen. A compressive plastic zone is first developed at the top of the web (Fig. 17 (b)). Then, when $M = 0.652 M_p$, the lower tension flange yields. As the bending moment is further increased, the extent of the compressive plastic zone in the web remains practically constant, but a tensile plastic zone develops until, when the bending moment is $0.982 M_p$, the top flange yields in compression (Fig. 17 (c)). At this stage, the stress distribution becomes symmetrical about the geometric centre-line and, for higher bending moments, the stress distribution is exactly the same as for a beam without any initial internal stresses; that is to say, their effect has been completely eradicated, so that the value of the full plastic moment is exactly what it would have been in a beam free from residual stresses (Fig. 17 (d)).

In this case, as in all the others discussed, it has been assumed that instability of the web or flange has not occurred. It would clearly be unreasonable to expect the plastic theory to give an accurate measure of ultimate load if parts of the structure had failed prematurely from some other cause. Conditions of elastic and plastic instability are being studied intensively, but it is not yet possible to give simple comprehensive rules for the use of the designer. There are clear indications, however, that these rules will not be particularly irksome. If you are prepared to accept this assurance, you will see what a dependable tool is the plastic theory. It gives the designer an accurate measure of the ultimate strength of a structure; gone are the distressing uncertainties of elastic calculations which are vitiated by slight sinking of supports, flexibility at connections, residual stresses, and all those imperfections which must be present in a real structure.

The only purpose of this lecture has been to draw attention to this advantage, but, had it not already lasted too long, it would be possible to continue and show that a consideration of plastic behaviour makes the direct design of redundant static structures not only a possibility for the first time, but a matter of relative simplicity.

In conclusion, to show that I am not alone in my views and that the engineer, in placing undue confidence in elastic analysis, has taken a retrograde step, let me quote what A. E. H. Love wrote in 1892 in his classic work *A Treatise on the Mathematical Theory of Elasticity*:—"There exists no adequate mathematical theory of set, or of after-strain, or in fact of any of the phenomena exhibited by materials strained beyond their elastic limits . . . Yet it is imperatively necessary that effects which cannot be calculated exactly should be taken into account in constructions, and it is in this sense that elastic theory is at this time behind engineering practice."

AMERICAN INDUSTRY IN NORTHERN IRELAND.—Speaking at Londonderry recently, the Prime Minister of Northern Ireland, Sir Basil Brooke, stated that an American firm, Messrs. Behr Manning Incorporated, of New York State, were to set up a new industry in Belfast for the manufacture of industrial abrasives.

AIR INTAKES FOR AIRCRAFT GAS TURBINES.*

By J. SEDDON, Ph.D., A.F.R.Ae.S.

THE first duty of a compressor intake is to deliver a prescribed quantity of air to the engine with maximum pressure energy. In addition, the intake must interfere as little as possible with the aircraft characteristics. The problem of internal flow can be studied almost entirely by wind-tunnel or full-scale tests at low speeds, because on a subsonic aircraft it can normally be assumed that the internal flow is everywhere subsonic; the application of corrections for compressibility is a relatively straightforward process. The study of external flow is much more dependent on the direct evidence of tests at high Mach number, owing to areas of supersonic flow on the body which cannot be reproduced at low test velocities. Most of the problems of intake design are connected with flow processes occurring in the immediate neighbourhood of the entry, where the separation between the internal and external flow takes place. Four distinct types of flow pattern at entry occur under different flight conditions. The distinguishing parameter is the entry velocity ratio (the ratio of flight speed V_0 to mean entry velocity V_1) and the values typifying the four regimes are $\frac{V_0}{V_1} = 0, 1, 2$ and 3 , corresponding to the static, climb, level flight and dive conditions, respectively. In practice each of these terms covers a range of values near the typical one.

In the static case, the air accelerates into the entry from all directions. The velocity over any wetted surface external to the duct is low, and so the effect of the external boundary layer is generally negligible. On the other hand, the pressure gradients round the lips are severe. This leads to rapid boundary-layer development just inside the entry or, in some cases, to separation. The lip radius will play a major part in determining the extent of losses arising in this way. As the aircraft speed is increased, with V_1 more or less constant, the relative acceleration into the intake decreases rapidly until, in the climb condition, the air flows into the entry with practically no change in speed or direction. Most designs show a minimum loss near this condition. In the third regime, that of level flight at or near top speed, the air decelerates to about half speed between the free stream and the entry. Losses in the boundary layer on the wetted surfaces ahead of the entry now accumulate at much higher velocity than that inside the duct, and the adverse pressure gradient accompanying the pre-entry retardation may cause the boundary layer to separate. A high-velocity region on the outside of the lip determines the critical Mach number of the intake. The excess velocity is accounted for partly by the thickness and shape of the lip and partly by the pre-entry retardation which effectively sets the lip at a positive incidence. In the dive case, with a non-Pitot type of intake there is an increased tendency for the boundary layer to separate in the region of adverse pressure gradient. This may lead to aircraft vibration and other effects of separated flow.

The losses in a subsonic air intake may be incurred by friction on the walls of the duct, and on those surfaces ahead of the entry which are wetted by the intake flow; by turbulent mixing as the result of flow separation caused by bends, over-rapid diffusion, sudden expansion (for example, into a plenum chamber), or the adverse pressure gradient imposed by the entry; or from the drag of blockages either in the duct or in front of the entry (for example, the blade roots of a conventional propeller installation). A new intake design of doubtful efficiency will usually be given a low-speed wind-tunnel test. This provides a check on the suitability of the chosen entry area, an opportunity to modify the detailed shape of the duct, and the data necessary to decide whether a boundary layer by-pass will be required. The most important factor is the quantity and state of external boundary layer taken into the duct from the approach surfaces. Fig. 1 shows a correlation of wind-tunnel model results for direct inlets (i.e., no plenum chambers or propeller-turbines) on this basis. The intake ram efficiency, i.e., the mean total head at the compressor relative to the atmospheric static pressure, divided by the free stream dynamic head, in the design top-speed condition is plotted against the ratio of the approach-surface area S to the entry area A_1 , designated the position ratio. For Pitot-type intakes the position ratio is zero by definition. Wing-root intakes have values of $\frac{S}{A_1}$ varying between about 3 and 12 according to their proximity to the side of the body, and whether a boundary layer by-pass is provided, etc. For side intakes the value varies between about 5 and 20. The scatter of results represents the differences of internal duct loss as between one arrangement and another and are generally of the

AIR INTAKES FOR AIRCRAFT.

Fig. 1.

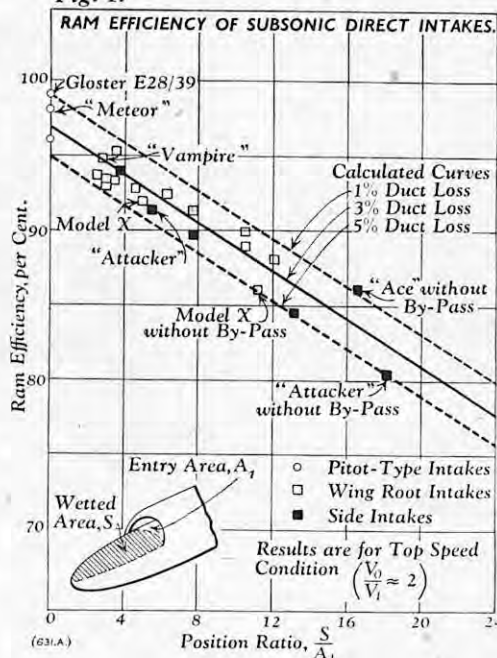
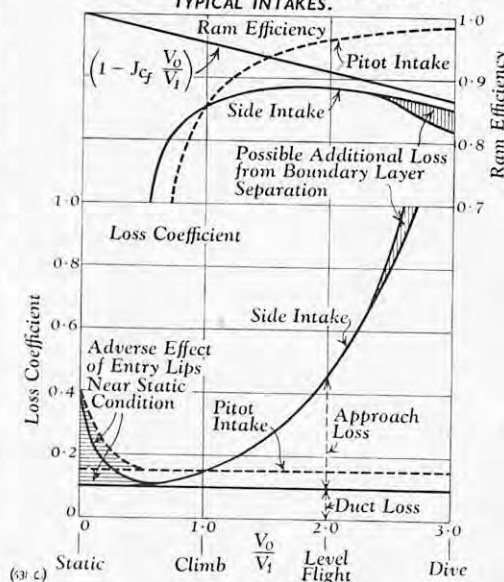


Fig. 3. PRESSURE CHARACTERISTICS OF TYPICAL INTAKES.



order of ± 2 per cent. For each increase of wetted area equal to the entry area, the efficiency drops by rather less than 1 per cent. The variation with $\frac{S}{A_1}$ can be calculated. If an allowance of 3 per cent. is made for the average internal duct loss, the calculation provides a good mean line to the experimental points; the region bounded by lines calculated for 1 per cent. and 5 per cent. duct loss encloses practically all the results.

Most developed intakes show efficiencies of more than 90 per cent. To achieve this result often requires the use of a boundary layer by-pass, as in the Vickers-Armstrongs Attacker aircraft, which removes a proportion of the approach boundary layer and so reduces the effective position ratio of the intake. With a full set of measurements of intake loss both with and without a by-pass, the effective position ratio can be deduced for the case with the by-pass present. The proportionate reduction in $\frac{S}{A_1}$ defines the by-pass efficiency, which for the Attacker is about 70 per cent. The use of a by-pass improves the ram efficiency of the intake by about 11 per cent. A 100-per cent. efficient by-pass would effectively convert the intake to the Pitot type.

In the plenum chamber installation of an engine with a double-sided centrifugal compressor, owing to space restrictions, it is never possible to diffuse efficiently in the intake duct up to the full cross-sectional area of the plenum chamber. In practice there has invariably been a very rapid expansion from the duct into the chamber. An analysis of flight tests made mainly by Messrs. Rolls-Royce Limited, showed that in practice the total loss is about twice the theoretical expansion loss. This emphasises the importance of providing a large duct area before the plenum chamber.

Fig. 2. RAM EFFICIENCY OF SUBSONIC INTAKES. (B)

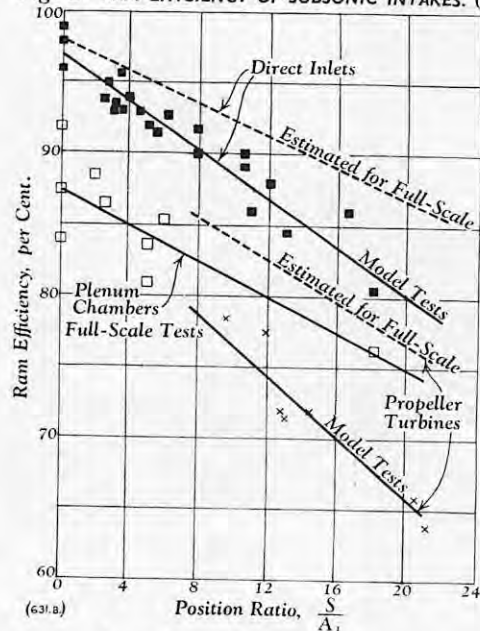
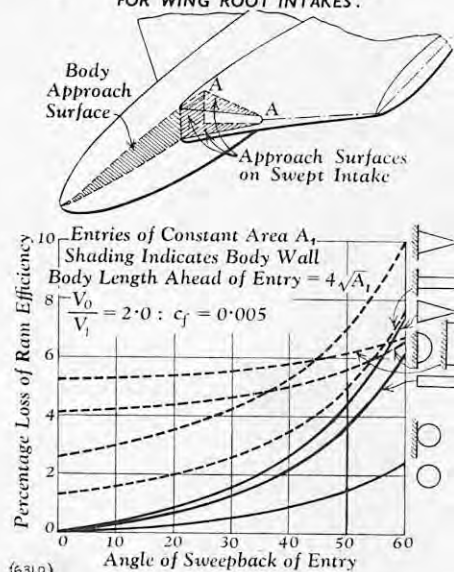


Fig. 4. CALCULATED APPROACH LOSS FOR WING ROOT INTAKES.



Wind-tunnel model tests have shown that in a propeller-turbine installation having the conventional arrangement of an annular intake close behind the propellers, the total intake loss may be about 25 per cent. ram, of which 15 per cent. is attributable to the blade roots. The flow over the roots is complicated in character because of the large thickness/chord ratio of the root sections and the centrifugal forces acting on the boundary layer. There is little advantage to be gained by having flared roots with large root chords, and if this involves an increase of actual section thickness, the effect may be detrimental. Modern blade development is in the direction of producing thinner roots, and this is a surer way of reducing the intake loss. A good modern four-blade propeller on an engine like the Mamba may be expected to give a loss of about 8 per cent. ram in the intake. An alternative way of obtaining an increase of intake efficiency with a propeller-turbine installation is by a ducted spinner, which gives a large reduction in velocity over the blade roots and effectively converts the intake itself to a Pitot type. The main disadvantages of the ducted spinner are its weight and the difficulty of providing satisfactory protection against ice.

The pressure recovery of a subsonic intake in high-speed flight depends primarily on three factors: (i) the intake position ratio; (ii) whether the engine has a direct inlet or a plenum chamber; and (iii) whether propulsion is by pure jet or propeller. Fig. 2 shows the percentage ram efficiencies of the three main classes of intake plotted on a position-ratio basis. The plenum-chamber results are converted to a common and reasonably average set of conditions at the duct exit, and the propeller-turbine results to a common blade-root blockage ratio of a typical order. Position ratio for the propeller-turbine intakes is defined on the total surface area of the spinner. For direct inlets and propeller-turbines, where the results are from low-speed model tests, an estimated curve for the full-scale

* Paper read before the Royal Aeronautical Society on Thursday, December 6, 1951. Abridged.

AIR INTAKES FOR AIRCRAFT.

Fig. 5. CONVENTIONAL INTAKE.

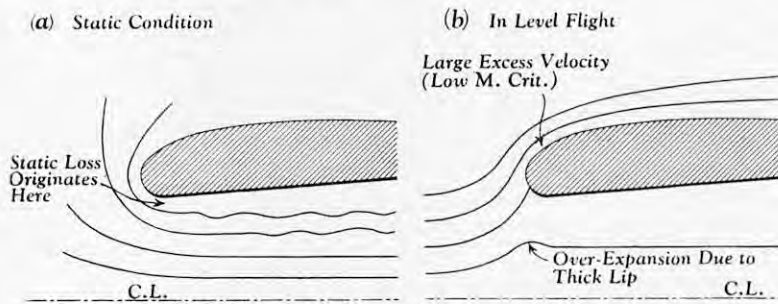


Fig. 6. SLOTTED INTAKE.

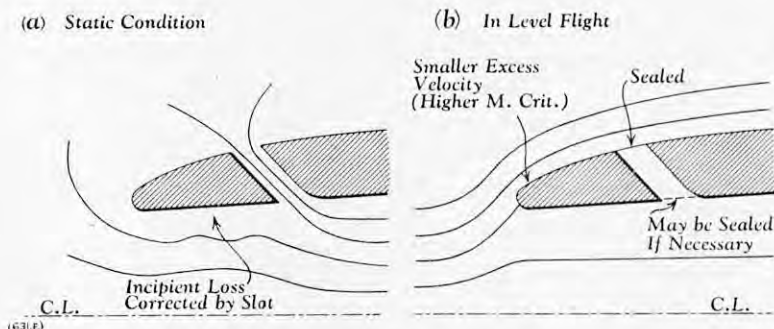
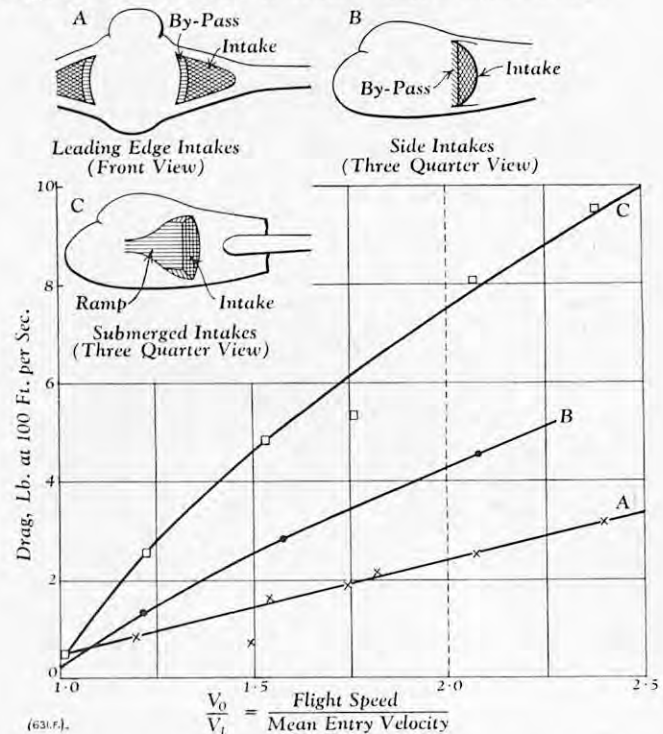


Fig. 7. EXTERNAL DRAG OF INTAKES AT LOW MACH NUMBER.



variation is also given, which allows for Reynolds-number effects on the effective skin-friction coefficient and blade-root drag coefficient. The Vampire intake (96 per cent.) has a low position ratio and a direct inlet. Cases such as the Meteor (88 per cent.) and Attacker (85 per cent.), these being values converted to constant plenum-chamber conditions, are dominated by the plenum-chamber loss. Propeller-turbine intakes (82 per cent. in a typical case) have the blade-root loss, which is 8 to 10 per cent. for the average propeller, and also a high position ratio. No radical change is to be expected up to sonic flight speed, since the relevant flow field, in most cases, is wholly subsonic. At supersonic speeds the deceleration to compressor velocity must take place, in part, through a shock system in which further loss is incurred. At speeds only slightly above a Mach number of 1.0, it may be that this loss will add to the subsonic losses without further complication. Later the interference effects between shock wave and boundary layer are likely to become important.

A simple semi-empirical theory of intake loss for subsonic intakes of the direct or fully-ducted type provides a method of estimating the ram efficiency of a new design over the range of flight conditions from climb ($V_0/V_1 = 1.0$) through level flight ($V_0/V_1 = 2.0$) up to the highest velocity ratio which avoids boundary layer separation ahead of the entry. If the additional lip losses in ground running are known, the complete characteristic from $V_0/V_1 = 0$ can be constructed. In

Fig. 3, opposite, the loss coefficient, i.e., the total head loss divided by the mean dynamic head at entry, and the ram efficiency are plotted against the entry-velocity ratio. Curves are given for typical Pitot and side intakes. The Pitot intake has a constant loss coefficient and a ram efficiency which tends to 100 per cent. as the velocity ratio increases indefinitely. The loss coefficient of the side intake has a minimum value near $V_0/V_1 = 1.0$ and in this region the intake is likely to be more efficient than the Pitot type, because it has a shorter duct. At top speed the loss coefficient is several times its minimum value. The curve of ram efficiency reaches a maximum and then decreases. The Pitot intake should have as large an entry as possible in order to operate at a high value of V_0/V_1 in the top-speed condition. With a side intake the entry size is limited by the need to design fairly close to optimum efficiency. A change of entry area changes the whole characteristic. External consideration and the requirements at low flight speeds have a large influence on the choice of design velocity ratio. As V_0/V_1 tends to zero, the loss coefficient of either intake rises. This is because lip losses occur at low forward speeds.

On a straight-winged aircraft, the wing leading edge provides an alternative region of Pitot pressure for the

designer unable to find room for an entry in the nose. Even if the intake is in the wing root it is normally less affected by the fuselage boundary layer than one which is built on to the side of the body. In the case of swept-back wings, if the entry velocity-ratio is near unity, sweepback as such has no effect on intake efficiency. At high forward speed, however, when the air is retarded in front of the entry, by analogy with a yawed Pitot tube, the internal pressure falls off with increasing angle. The swept leading-edge intake has a non-zero position ratio and therefore gives a lower ram efficiency than a similar unswept intake.

The amount of loss depends not only on the angle of sweepback but also on the shape of entry. Fig. 4, opposite, shows the results of calculation of the variation of approach loss with angle of sweepback for entries of various shapes, both when isolated and also when adjacent to a body of fixed length. For circular entries the loss from sweepback is relatively small—about 2 per cent. ram at 60 deg. either with or without body. With entries of large spanwise elongation the loss is 2 to 3 per cent. at 40 deg. and 6 to 7 per cent. at 60 deg. The body effect with these shapes is small. Conversely, for entries elongated vertically, the body effect is large but the effect of sweepback is small. The results assume no boundary-layer lip or by-pass. Where necessary, special forms of by-pass can be devised to reduce the loss caused by sweepback. Against the lower internal efficiency of a swept intake must be set a possible advantage in improved external flow; for whereas on a high subsonic swept-wing design the intake in almost any other position is a liability, the wing-root intake provides potentially a useful form of blending between wing and body. The flow round it has something of the character both of that on the isolated swept wing and of that on the three-dimensional body.

The submerged intake developed a few years ago by the American National Advisory Committee for Aeronautics (N.A.C.A.) has an entry submerged within the general fuselage contour, approached by way of a long, gently-sloping ramp with a narrow entry and divergent side walls with sharp edges. The divergent side walls, cutting across the lines of flow, set up a vortex motion which, in turn, sweeps the ramp boundary layer sideways and carries a proportion of it out past the ends of the entry. Thus the ramp works as a kind of boundary-layer by-pass. The efficiency obtained is similar to that given by a protruding side intake in the corresponding position, equipped with a conventional by-pass. Although the more conventional layout must pay something for its efficiency by drag in the by-pass duct, the submerged intake carries a drag penalty in the form of energy loss in the vortex motion on the ramp and in the mixing process behind the entry.

In order to get the best performance at high speeds, intake lips need to be fairly sharp. Some degree of sharpness may have to be sacrificed, however, to avoid excessive loss under ground-running conditions. When the duct is parallel just inside the entry, a lip

radius equal to 10 per cent. of the entry width is needed to keep the loss coefficient down to about 0.02, which is equivalent to about 4 per cent. in thrust. Divergence in the duct close behind the lip is a bad feature, while a small amount of convergence has a marked effect in suppressing flow separation tendencies. As entry lips get thinner and entry area smaller it becomes increasingly difficult to restrict ground-running losses to tolerable limits by suitable choice of lip radii. One solution is to provide an auxiliary inlet which functions only under static and low-speed conditions. On a number of plenum-chamber installations this has been done by fitting one or more spring-loaded doors in the wall of the plenum chamber, which open inwards automatically when running up on the ground, and are arranged to close at a convenient value of forward speed as the ram pressure builds up inside. Improvements of up to 15 per cent. in static thrust have been obtained in this way. An alternative arrangement suitable for fully ducted intakes is the slotted intake shown in Fig. 6, in comparison with the conventional intake, Fig. 5. In addition to providing auxiliary entry area, the slot works in a manner analogous to that of a wing leading-edge slot for lift control, the inside of the duct corresponding to the upper surface of a wing. The slot should eject backwards into the duct and be of sufficient length/width ratio to have good directional control of the air. The ideal form is a narrow slot using as much of the intake perimeter as possible. The outer end of the slot must be sealed, possibly by a hinged flap operating automatically. The use of a slotted intake will make possible a smaller main entry and thinner lips.

When the plane of the entry is not normal to the axis of the duct, as with an intake in the leading edge of a swept-back wing, the average direction of flow at the entry under static conditions is more or less normal to the entry plane, so that effectively the air requires to be turned through an angle roughly equal to the angle of obliquity of the entry. Separation is likely to occur inside the rearward end of the entry. Guide vanes or auxiliary inlets may be used to improve the flow.

In model tests of twin-intake systems, as, for example, a pair of wing-root or body-side intakes leading into a common duct or plenum chamber, it has been observed that if the total duct flow is reduced below a critical value the distribution of flow between the two intakes becomes unsymmetrical. The asymmetry develops rapidly, often to the state where the flow in one duct is actually reversed in direction. This results in a highly unsymmetrical velocity distribution at the compressor, a reduced pressure recovery and the possibility in flight of oscillating flow resulting in aircraft vibration. The appropriate flight condition would be in a dive at high speed, or on suddenly throttling back the engine while flying at moderate speeds. Such flow instability is always an inherent possibility in a ducted system having a rising pressure characteristic; with a side intake, the pressure at zero flow is below the Pitot value, and as the flow is

increased, the pressure first rises to a maximum and then falls. Instability is possible in the range between zero flow and the value for which the intake pressure is a maximum.

It is desirable with twin intakes that the critical flow ratio, below which instability occurs, shall be as low as possible. A large amount of diffusion in the duct increases the critical value. For this reason, plenum-chamber intakes are more susceptible to instability than direct inlets. A good boundary layer by-pass, in addition to increasing the intake efficiency, will reduce the possibility of flow instability.

Modern research on intake drag must be centred on the effects of compressibility at high subsonic and at supersonic Mach numbers. Low-speed wind-tunnel tests are useful in defining the basic pressure field in subsonic flow, but there is a great need for experimental evidence at the appropriate Mach numbers. The conventional type of boundary layer by-pass, consisting of a narrow ducted slot separating the main intake from the neighbouring wall, is difficult to install and to lead away efficiently. Friction loss adds up quickly, so the duct needs to be short. This usually means that it is not too well shaped and probably discharges back into the external stream at a fairly large angle. Model tests of a few cases have shown that the drag may nullify the improvement in thrust obtained from the by-pass. Results from three models with different intakes are shown in Fig. 7, on page 95. The external drag measured is the sum of profile drag and by-pass drag. In all cases the profile drag is small, as shown by the results at $\frac{V_0}{V_1} = 1$, where the by-pass does little work.

The by-pass drag at top speed ($\frac{V_0}{V_1}$ about 2) therefore, is roughly 2 lb. at 100 ft. per second for the pair of wing-root intakes, 4 lb. for the side intakes and 7 lb. for the submerged intakes. For the submerged intakes there is no by-pass in the conventional sense of a boundary-layer duct; the result indicates the order of loss in the vorticity set up by the ramp and in the disturbed flow immediately behind the entry. It is not to be inferred that drags of this magnitude are general and unavoidable, since in the particular cases tested no attempt was made to reduce the drag by detailed modification.

A good subsonic intake will have a critical Mach number at least as high as that of the aircraft wing. This is not easily achieved because the local conditions at the intake lip are often more stringent than those on the wing, since it is effectively at a considerable incidence to the flow, which exaggerates the suction peak. An intake fairing designed for a given critical Mach number requires to have a certain minimum thickness, a certain optimum length, and good shape, within fairly narrow limits. The minimum thickness is that which is necessary to carry the thrust force on the outside of the fairing without exceeding the value of suction coefficient corresponding to the stated critical Mach number; it can be calculated from momentum considerations. If the fairing is short the suction level is high over its whole length. Lengthening the fairing reduces the suction up to a certain stage, but beyond this a further increase in length gives rise to a high suction peak near the leading edge. Methods of calculating the optimum length are available. The criterion of good shape is the "constant velocity profile," calculable in terms of flow ratio and critical Mach number, and corresponding to both minimum thickness and optimum length. Thus, taking the critical Mach number as the criterion, present knowledge shows how to obtain the best design for a given set of conditions—entry area, maximum fairing area and entry-velocity ratio—so long as these conditions are reasonably normal. Much more experimental evidence is needed before it can be determined quantitatively how the drag builds up above the critical Mach number and in the supersonic range.

CONFERENCE ON FUEL AND POWER SHORTAGE.—The proceedings of the conference on "Meeting the Fuel and Power Shortage," held in London on October 9 and 10, 1951, have been published, and copies may be obtained from the Director, Combustion Engineering Association, 6, Duke-street, St. James's, London, S.W.1, at 10s. 6d. each.

PROHIBITED USES OF COPPER AND ZINC.—Manufacturers of goods in which the use of copper, zinc and their alloys was banned by a Ministry of Supply Order in November last, (household appliances and electrical, gas and builders' fittings were among the articles listed) are to have a further period in which to finish partly-made goods containing these metals. The original Order (The Copper and Zinc Prohibited Uses (Ministry of Supply) (No. 2) Order, 1951, S.I. 1951 No. 1960) gave them until February 1, 1952, to use up stocks of fabricated or partly-processed zinc and copper. A new Order is to be made extending this period until February 20 and making amendments to the list of prohibited articles.

NOTES ON NEW BOOKS.

Traffic Control and Road Accident Prevention.

By CAPTAIN ATHELSTAN POPKESS, O.B.E. Chapman and Hall, Limited, 37, Essex-street, London, W.C.2. [Price 37s. 6d. net.]

THE author of this book is the Chief Constable of Nottingham and his work is addressed to the police rather than to engineers. It contains much information about road-accident investigation, the manner in which reports should be prepared, and the value of photographs and sketches in setting out the nature and elucidating the causes of accidents. The rights and duties of the police are clearly explained. This brief explanation of the nature of the book does not, however, give an adequate idea of its contents. Questions of road layout, lighting, and the effects of different types of surface are dealt with in detail, vehicle condition, as a factor contributing to accidents, is considered, and information is given about brake testing. It is stated that, in 1937, more than 11,000 accidents could be attributed to slippery roads and questions of road surfaces and skidding are dealt with in considerable detail. Two valuable tables are given listing the skidding resistance of various types of road surface, and the opinion is expressed that highway authorities frequently sacrifice non-skid properties in favour of hard wear. An interesting chapter of the book deals with methods of estimating the speed of a vehicle, prior to an accident, from the skid marks on the road, diagrams being given of the impressions made by 126 different tyres. These should be of assistance in identifying a vehicle concerned in an accident and which does not stop. This question of road surface is by no means the only aspect of its subject which is treated in detail in the book and although as stated at the outset it is primarily addressed to the police, it should be of interest and value to anyone concerned with any aspect of road transport.

Refrigeration Engineering.

By PROFESSOR H. J. MACINTYRE and PROFESSOR F. W. HUTCHINSON. Second edition. John Wiley and Sons, Incorporated, 440, Fourth-avenue, New York 16, U.S.A. [Price 6.50 dols.]; and Chapman and Hall, Limited, 37, Essex-street, London, W.C.2. [Price 52s. net.]

It is hardly to be expected that a contradiction of Newton's First Law of Motion should be found in the second edition of a book issued under the names of two university professors, with acknowledgments in the preface of the assistance given by ten other professors in its revision; yet, on the seventh page of the present work, it is "demonstrated" that a constant force is necessary to maintain the steady motion of a fluid flowing in a frictionless pipe. When the reader finds, later in the same chapter, the equally astonishing statement that "enthalpy will have energy significance only for a fluid in steady and continuous motion," and the assertion that, when such a fluid is brought to rest without change of pressure or temperature, its enthalpy will have been increased from $U + PV$ to $U + 2PV$, he may well wonder how far the book may be trusted on any other theoretical question. Enough has been said to show that the volume is not an ideal text-book for students, apart from the lack of lucidity with which thermodynamical principles are expounded. Readers already equipped with a sound theoretical knowledge may find it interesting as a review of the whole field of industrial refrigeration and cooling processes, with brief particulars of the principal kinds of apparatus employed, descriptions of the insulation of machinery and storage spaces, calculations of heat losses, and some discussion of the design of air-ducts. It will be found most useful, perhaps, as a work of reference, on account of the large number of tables and charts giving the properties of various substances of interest to designers of refrigerating apparatus. These occupy altogether more than a fifth of the book. Much use is made of charts in which the logarithm of the pressure is plotted against the total heat of the substances; but these are wrongly referred to as Mollier diagrams, for the use of log P as an ordinate, which has the great practical advantage of making equal ratios of expansion correspond with equal intervals on the chart, was due to the late Professor H. L. Callendar, who adopted it in his treatise on *The Properties of Steam* more than 30 years ago.

THE ELLIOTT-HAGAN CONTROL SYSTEM FOR STEAM PLANTS.—Messrs. Elliott Brothers (London), Ltd., Lewisham, London, S.E.13, and Messrs. James Gordon & Co., Ltd., Stanmore, Middlesex, announce that they have jointly designed the Elliott-Hagan control system for steam plants. This system, which is available from both companies, embodies the experience of the first firm in instrumentation and of the second in steam plants.

TRADE PUBLICATIONS.

Milling, and Other Equipment.—The Sturtevant Engineering Co., Ltd., Southern House, Cannon-street, London, E.C.4, have sent us a series of descriptive brochures relating to milling, crushing and mixing equipment of their manufacture. Each publication contains a short account of the design, mode of operation, specification and application of the equipment described, and is profusely illustrated. These brochures supersede earlier descriptive publications now out of print.

Cutting and Wrapping Machines.—Ranges of hand-operated, semi-automatic and fully-automatic paper-cutting and trimming machines, manufactured by Pivano & Co., Ltd., Italy for whom the sole British agents are Jenner Bindery Products, Ltd., 6, Marlborough-place, Brighton, Sussex, are described in an illustrated leaflet issued by the latter company. All the machines can be supplied at present from stock in Britain. Postal wrapping and enveloping machines, manufactured by Craig Kemp, Ltd., and book-covering machines, are the subjects of other leaflets also available from Jenner Bindery Products, Ltd.

Bin Vibrators.—An outline of their range of electromagnetic bin vibrators is given in a leaflet issued recently by the Magnetic Equipment Co., Cosham, Portsmouth. These units, which were described in *ENGINEERING*, vol. 172, page 768 (1951), are designed to operate in resonance with the supply frequency and are claimed to give a powerful vibrating force with small power consumption. Three sizes are available, the smallest being intended for use with packing machines having a hopper volume of approximately 7 cub. ft. The next larger size is suitable for hopper volumes up to 50 cub. ft., and the third size is intended for still larger applications.

Solenoids.—Encased solenoids suitable for mounting in a variety of positions and capable of giving either a thrust or a pull, when energised by single-phase alternating current of 50 cycles per second frequency, are described in a leaflet, No. 22/51, issued by Westool, Ltd., St. Helen's Auckland, County Durham. Solenoids of five different ratings are available for any one of eight different ranges of voltage between 190 and 550 volts. Charts and tables are reproduced by which the model appropriate to any particular purpose may be selected. The maximum working stroke is 1½ in. in all cases and the motive force ranges from 10 to 50 lb. or, at its maximum, 40 to 110 lb., according to the rating. Permissible maximum "on" and minimum "off" periods of the current are also quoted in each case.

BOOKS RECEIVED.

Ministry of Transport. Railway Accidents. Report on the Collision which occurred on 11th July, 1951, near Fishguard and Goodwick in the Western Region British Railways. H.M. Stationery Office, Kingsway, London, W.C.2. [Price 6d. net.]

Forty-Third Annual Report of the Hydro-Electric Power Commission of Ontario for the Year Ended December 31st, 1950. Offices of the Commission, Room 634, 620, University-avenue, Toronto 2, Ontario, Canada.

Forty-Sixth Annual Report of the Rand Water Board to His Excellency the Governor-General. Financial Year ended 31st March, 1951. The Secretary, Rand Water Board, P.O. Box 1127, Johannesburg, South Africa. [Gratis.]

Manuel de Ventilation. Chauffage, Conditionnement d'Air, Tirage Mécanique, Dépoussiérage et Séchage. Second revised edition. Gauthier-Villars, 55, Quai des Grands-Augustins, Paris (6e), France. [Price 1500 francs.]

Centrali Elettriche. By PROFESSOR MARIO MAINARDIS. Second revised and enlarged edition. Ulrico Hoepli, Milan, Italy. [Price 3500 lire.]

Port of London Authority. Handbook of Tide Tables, Particulars of Docks, &c., 1952. Port of London Authority, London, E.C.3. [Price 3s., post free.]

Modern Naval Architecture. By W. MUCKLE. Temple Press, Limited, Bowling Green-lane, London, E.C.1. [Price 9s. 6d. net.]

Nigeria. Annual Report on the Public Works Department for the Year 1949-50. The Government Printer, Lagos, Nigeria; and the Crown Agents for the Colonies, 4, Millbank, Westminster, London, S.W.1. [Price 9d. net.]

Overseas Economic Surveys. Economic and Commercial Conditions in Canada. By R. KEITH JOYSON. H.M. Stationery Office, Kingsway, London, W.C.2. [Price 6s. 6d. net.]

Laying Drain Pipes. Ministry of Works Advisory Leaflet No. 24, 1951. H.M. Stationery Office, Kingsway, London, W.C.2. [Price 3d. net.]

Prism and Lens Making. A Textbook for Optical Glass-workers. Second edition. By F. TWYMAN. Hilger and Watts Limited, Hilger Division, 98, St. Pancras-way, London, N.W.1. [Price 58s. net; postage 1s.]

"Mechanical World" Electrical Year Book, 1952. A Collection of Electrical Engineering Notes, Rules, Tables and Data. Emmott and Company, Limited, 31, King-street West, Manchester, 3. [Price 3s. net.]