# THE VERTICAL DRAWING OF GLASS TUBING.

FOR use in radio sound and television receivers, radar, electronic-control equipment, deaf aids, etc., many millions of miniature and sub-miniature thermionic valves are required annually, and of this number Messrs. Mullard, Limited, Century House, Shaftesbury-avenue, London, W.C.2, produce a very high percentage in seven factories situated in different parts of the country. One of these factories, at Blackburn, Lancashire, is the largest valve manufacturing plant in the country, and, in addition, produces what may be regarded as the raw materials of valve manufacture, which are supplied to the other factories. These raw materials include tungsten and molybdenum wire, the metal for which is reduced from the oxides of the elements and drawn through diamond dies, also made in the Blackburn factory, much of it to diameters of less than 0·0003 in.; several million yards of fine wire are produced each week.

From the point of weight, however, by far the most important raw material for the mass production of valves is glass, which is used in the form of tubing for the bulbs and bases, as well as for the stems of cathode-ray tubes. The total requirements of the Mullard organisation for glass tubing amount to many hundreds of tons annually, the majority of which is manufactured at Blackburn and supplied to its own valve-making plant as well as to the other Mullard valve factories, either as plain tubing or as finished parts.

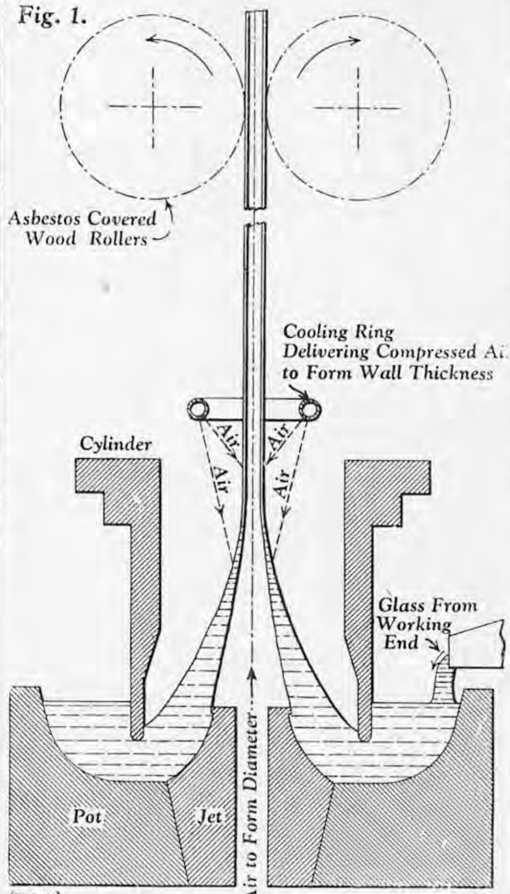
Although, by the courtesy of Mr. C. de Wit, managing director of the Blackburn works, we were able to see many of the particularly interesting operations of valve manufacture during a recent visit, we do not propose to refer to them here, but to confine our attention to the manufacture of glass tubing as carried out in the works in a plant which, as far as we are aware, is the only one of its kind in the country used in valve manufacture. The process, which is the invention of Mr. W. Schuler, of Newcastle-under-Lyme, has been in use on the Continent for several years. Three tube-making units are functioning at Blackburn, and the capacity of the installation is sufficient to meet the requirements of the whole Mullard organisation for this particular commodity.

Before describing the process in detail it may be helpful if we first give a brief general indication of the manner in which it functions. The sketch reproduced in Fig. 1, on this page, will enable the description of the process to be followed. Molten glass is supplied continuously to a small annular trough of refractory material which is rotated slowly about a vertical axis. From this trough a mass of glass is drawn upwards through a cylinder, the lower edge of which dips into the glass, so that it forms a column with a trumpet-shaped base and an axial hole. The hole is kept open by air blown upwards through it from a jet in the centre of the annular trough, while external air jets directed downwards on to the glass column near the upper end of the trumpet-shaped part, where the glass is still soft, control the wall thickness of the tube being drawn. Provision is made for the precise adjustment of the air flow through the internal and external jets, and by means of this adjustment a tube of any internal diameter and wall thickness, within certain limits, can be formed. The glass, of course, cools and solidifies as it ascends and at a height of some 20 ft. above the annular trough the tube passes between asbestos-covered wooden rollers which provide the required upward pull. The process can be continued indefinitely as long as the annular trough is kept supplied with molten glass, the only attention required, apart from feeding the glass-melting furnace, being the cutting off of convenient lengths of tubing from the upper end of the column and the adjustment of the air jets controlling the internal diameter and wall thickness.

Part of the Blackburn installation is illustrated by the photograph reproduced in Fig. 2, on Plate XXXVIII. In this, the working end of the melting furnace can be seen at the bottom towards the left, while to the right the tube-making machine can be distinguished. The machine itself is shown more clearly in Fig. 3, on Plate XXXVIII. Prominent in this illustration are the manometers, which indicate the air pressures in the ring that supplies the external jets for forming the wall thickness of the tube, as previously mentioned. By careful inspection of the upper right-hand part of this illustration the glass tube can be seen as it is drawn upwards from the machine. The tube passes through the floor into a glazed compartment on an intermediate floor above, shown in the top right-hand corner of Fig. 2. The interior of this compartment is illustrated in Fig. 4, Plate XXXVIII. At this level the tube is surrounded by a sheet-metal jacket, clearly shown in the lower part of Fig. 4 at the centre, and through this jacket air is passed for cooling purposes. Above the cooling jacket is an electronic device which indicates any variation in the diameter or wall thickness of the tube.

When the tube leaves the top of the glazed compartment through an opening in the floor of an upper room, known as the cutting room, it has become sufficiently cool to withstand, without distortion, the pressure of the two asbestos-covered wooden rollers between which it passes. These

Fig. 1.




rollers, clearly shown in Fig. 5, on Plate XXXVIII, are 8 in. in diameter and are formed with concave faces which grip the tube to support the whole of its weight and draw it up from the tube-making machine on the ground-floor level. The speed of rotation of the rollers controls the rate at which the tube is drawn and must therefore be capable of precise adjustment to suit the diameter and wall thickness of the tube. They are driven, therefore, by a 1-h.p. alternating-current motor through a P.I.V. variable-speed gear which, together, enable the peripheral speed of the rollers to be varied continuously from a minimum of 15 ft. per minute to a maximum of 55 ft. per minute. The tube, although still too hot to be handled comfortably, leaves the rollers in the finished state and has now only to be cut off in convenient lengths and passed to the stores. The cutting off is effected in a simple and expeditious manner by means of a specially-designed wooden measuring stick fitted with a bracket at one end and a small bevel-edged carborundum wheel at the other, the length between the bracket and wheel being adjustable. As the hot tube travels upwards continuously, the operator rests the bracket on the upper end and brings the wheel into momentary contact with it at the fixed distance from the bracket. As the wheel is kept cool by dipping it at intervals into cold water, a crack is started in the tube and this enables the operator to break off the tube with his left hand, on which he wears an asbestos glove. Limit gauges are provided at this level to enable the external diameter of the tubing to be checked at intervals and the wall thickness is checked by weighing samples of known length on a balance. Any adjustments found necessary are signalled down to the operators in charge of the machine.

A lead glass, containing about 30 per cent. of lead oxide, is most suitable for valve manufacture and important characteristics affected by its composition are the coefficient of expansion, and the ability of the glass to adhere to metal surfaces. The expansion coefficient of each batch made is measured and can be controlled by varying the alkali content in the charge. The raw materials used in the charge are sand free from iron, red lead, and potassium and sodium carbonates. To three parts of these materials one part of scrap glass, or cullet, as it is called, is added, and this cullet consists of scrap produced in the tube-making plant, or in the various operations of valve manufacture, so that its use does not affect the composition of the finished glass. After mixing for a fixed period in a mechanical mixer, the materials are charged into a recuperative-type tank furnace which is at present fired with town gas, although arrangements are being made for oil firing. Each of these furnaces, of which two are in use, has a capacity of about $2\frac{1}{2}$ tons of finished glass a day.

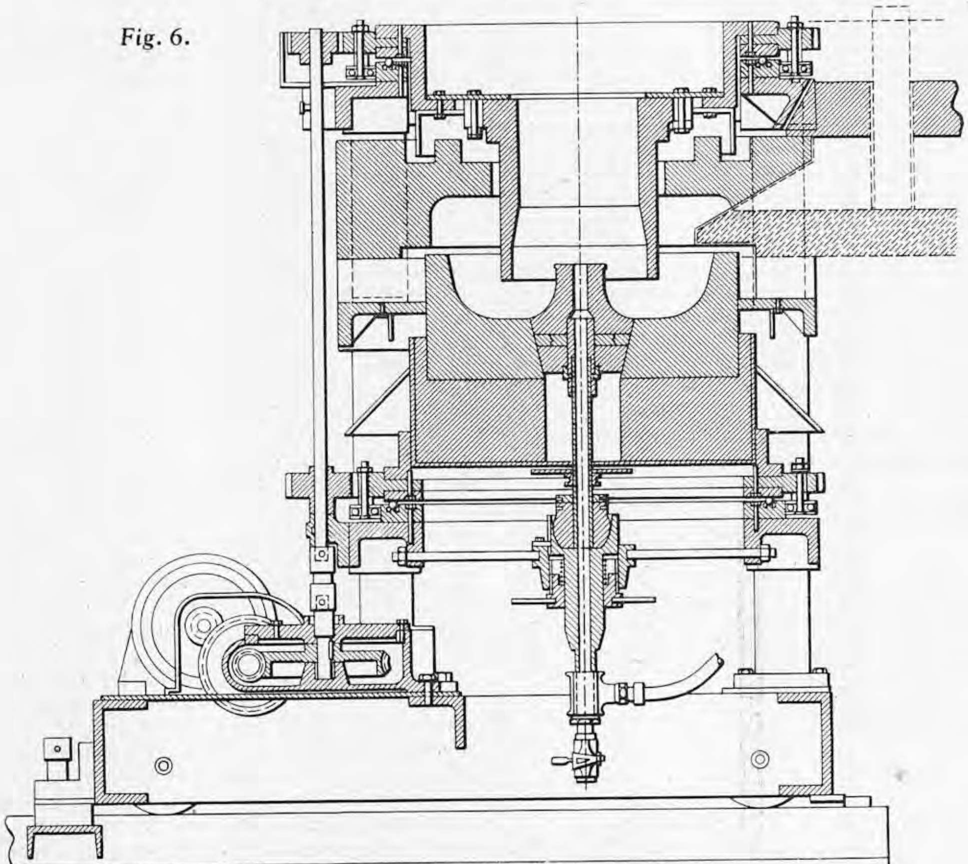
From the tank of the furnace the glass travels along the bath to the outlet end, attaining a temperature of 1,380 deg. C., at which it is quite liquid. At the outlet end, the glass flows under a refractory plate which dips well below the surface in order to hold back any scum and prevent it from entering the working end into which the glass then flows. The working end, which acts as a reservoir for the finished glass, is a chamber of octagonal form in plan, in which the glass is maintained at a temperature of about 1,130 deg. C., by gas burners. From the working end, the glass flows through a channel into the annular channel of the tube-making machine, the rate of flow being controlled by a simple form of refractory gate.

The general arrangement of the tube-making machine, the principal parts of which have already been referred to, is illustrated by the sectional elevation reproduced in Fig. 6, on page 702. It consists of a rectangular cast-iron base fitted with four vertical columns which support the stationary and rotating parts of the machine. The latter are driven by a 1-h.p. motor through spur and worm reduction gearing and a vertical shaft fitted with a spur pinion near the upper and lower ends. The lower pinion meshes with a toothed ring which supports two blocks of refractory material, the upper block forming the pot which holds the molten glass. Fitted into the centre of the pot by a ground tapered joint is the jet of refractory material through which air is supplied to form the inner diameter of the tube, as already explained. Air at a pressure of about $2\frac{1}{2}$ in. water gauge is supplied from a blower to the jet through a vertical pipe and water seal, as will be clear from Fig. 6. The outer shape of the jet block, together with the inner shape of the pot, form the annular channel from which the glass is drawn. Above the pot is a stationary cover having an aperture on one side through which glass is supplied to the pot from the working end, as indicated on the right in Fig. 6, and the fact that the pot is rotating slowly, at about 0·8 r.p.m., ensures that the incoming glass is uniformly distributed round the channel.

The upper pinion on the vertical shaft meshes with another toothed ring to which a casting in the form of a short tube with external and internal flanges is attached. A plate bolted to the internal flange supports an open-ended flanged cylinder of refractory material, the lower end of which passes through an opening in the cover of the pot and dips into the glass to a level well below that of the top of the jet; both the cylinder and the pot rotate continuously at the same speed. The relative positions of the jet and cylinder, the level of the glass, and the shape taken up by the glass as it is drawn upwards are most clearly shown in the sketch, Fig. 1; and the photographic plan view, reproduced in Fig. 7, which was taken looking down on the top of

# VERTICAL PROCESS OF GLASS-TUBE DRAWING.

*Fig. 6.*



(778.F.)

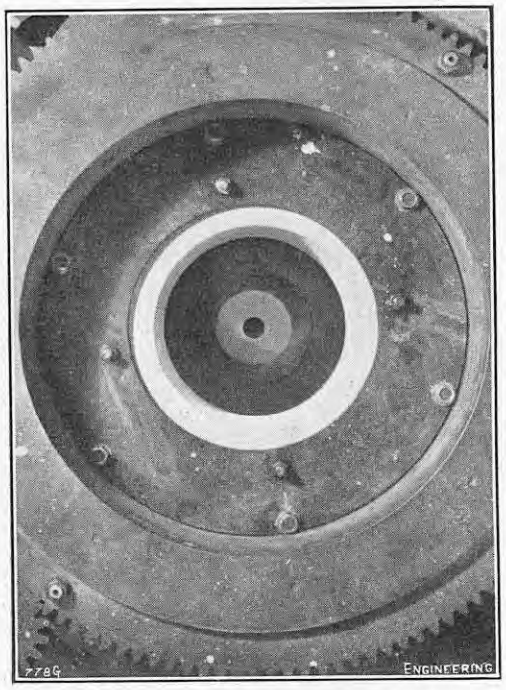
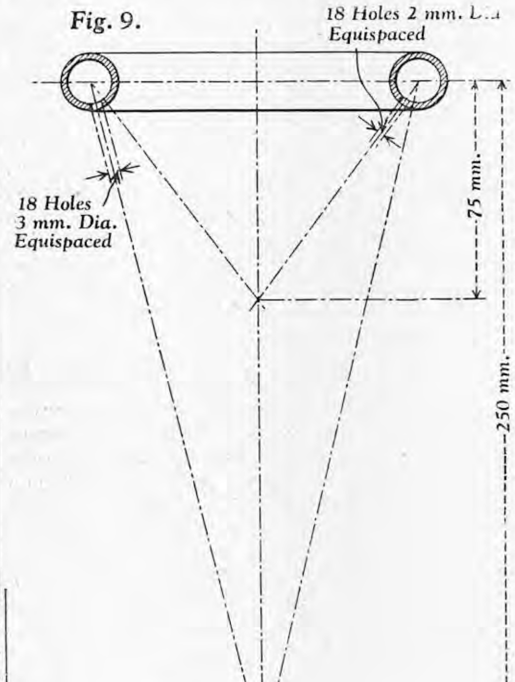


FIG. 7. PLAN VIEW LOOKING INTO POT OF DRAWING MACHINE.

*Fig. 9.*

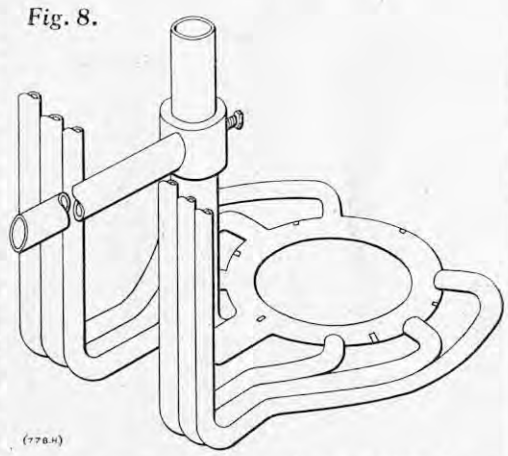



the machine while it was being set up, may also be helpful; several of the parts mentioned above will be recognised in this illustration. The glass in the pot is kept at the correct working temperature of 820 deg. C. ± 20 deg. by gas-air burners mounted on swivelling brackets which permit angular movement in the vertical and horizontal planes. The flames from the burners are directed above the pot along the sides of the cylinder and the hot gases escape through holes in the side of the stationary cover so that they do not come into contact with any part of the tube being formed.

As previously mentioned, the diameter of the tube produced is controlled by the pressure of the air supplied through the jet in the centre of the pot and the wall thickness by the air jets directed downwards from the cooling ring. These latter jets function by controlling the plane in which the glass cools and solidifies and thus the extent to which it is drawn out by the tension applied by the asbestos-covered rollers. As previously mentioned, the air for the central jet is supplied by a blower, and its pressure is raised to increase the diameter, and vice versa. The control of the jets from the cooling ring is rather more complex, it being necessary to increase the pressure of all the jets simultaneously when it is required to produce a tube of greater wall thickness, and vice versa, and to adjust it locally to correct variations in thickness at any part of the circumference that may be detected as the drawing proceeds.

How this pressure adjustment is effected may be explained with reference to Figs. 8 and 9, of which the former is an isometric sketch showing the tubular ring and its air-supply connections and also the method of supporting the tube from an extension to one of the four pillars of the drawing machine. Fig. 9 shows the arrangement of the holes in the ring through which the air issues and is directed on to the hollow column of glass as it is drawn out of the pot. It will be seen that two sets, each of 18 equally-spaced holes, are drilled in the ring at different angles to the horizontal plane so that half the jets are directed to a plane 75 mm. below the plane of the ring; the holes forming these jets are 2 mm. in diameter. The other set of jets is formed by holes 3 mm. in diameter and are directed to a plane 250 mm. below the plane of the ring. The latter is divided by radial diaphragms into six

*Fig. 8.*



separate compartments each of which has an independent air supply controlled by a valve. The whole air supply is taken from a common main connected to the factory compressed-air system through a reducing valve which can be adjusted to alter the pressure in the cooling ring as a whole. The valves in the pipes leading to the individual compartments of the ring enable the pressure in each to be adjusted independently. To facilitate the pressure adjustment, each of the six compartments of the cooling ring is connected to a mercury U-tube manometer which are all mounted side by side on a graduated panel shown on the left of the machine in Fig. 3, Plate XXXVIII.

Tubes ranging from 2 mm. to 36 mm. in diameter can be made in the machine by using four jets and two cylinders of different dimensions, but to change these components it is necessary to close down the machine. As, however, each jet and cylinder can be used for a fair range of tube diameters, the machine can be operated continuously day and night for long periods; until, in fact, it becomes necessary to renew the refractories in the tank furnace. The rate of production depends upon the diameter of the tubing being drawn, and this, in turn, is governed by the drawing rate and the air pressure. When producing tubes of small diameter, the furnace could supply more molten glass than the drawing machine could deal with. As an example of the actual production rate, we may mention that at the time of our visit tubing 16-17 mm. in diameter with a wall thickness of 1·2 to 1·4 mm. was being produced at the rate of 360 metres per hour, which is equivalent to a weight of 1·6 tons a day of 24 hours for one machine. The process, we were informed, gives a product of considerably greater dimensional accuracy than can be obtained by other tube-making processes. For instance, tubing of the size just mentioned can be produced so that the wall thickness does not depart by more than 0·03 mm. from the specified figure when measured at each end of two diameters at right angles; this uniformity of thickness, it may be remarked, is a matter of considerable importance when the tubing is to be used for blowing valve bulbs.

One matter of interest, which may be referred to in conclusion, is the operation of starting up the machine after it has been closed down for any reason—an operation which requires a certain amount of experience and manual dexterity on the part of the operators. Glass is run into the pot

# VERTICAL PROCESS OF GLASS-TUBE DRAWING.

(*For Description, see Page* 701.)

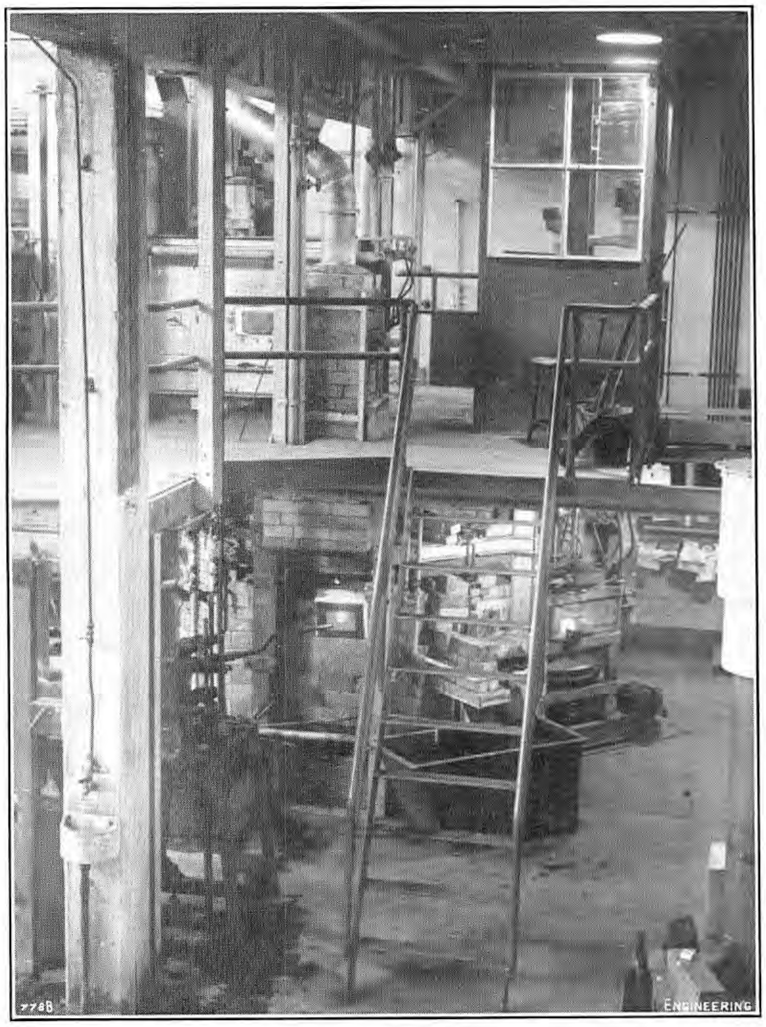


FIG. 2. GENERAL VIEW OF INSTALLATION.

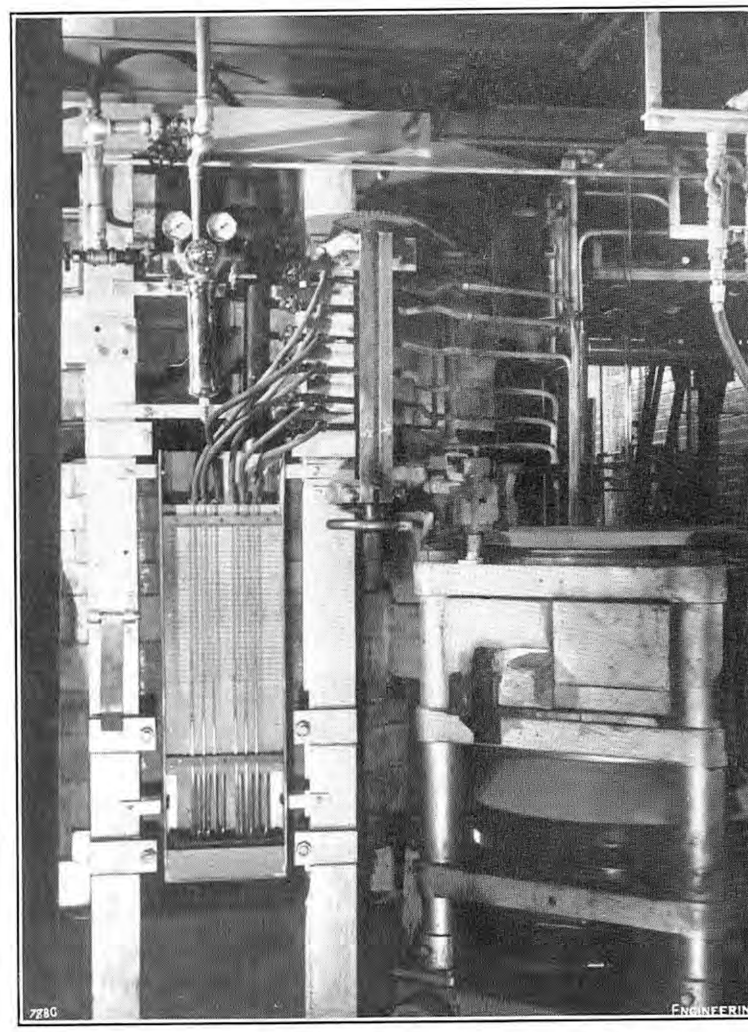


FIG. 3. DRAWING MACHINE, SHOWING AIR-PRESSURE REGULATING VALVES AND MANOMETERS.

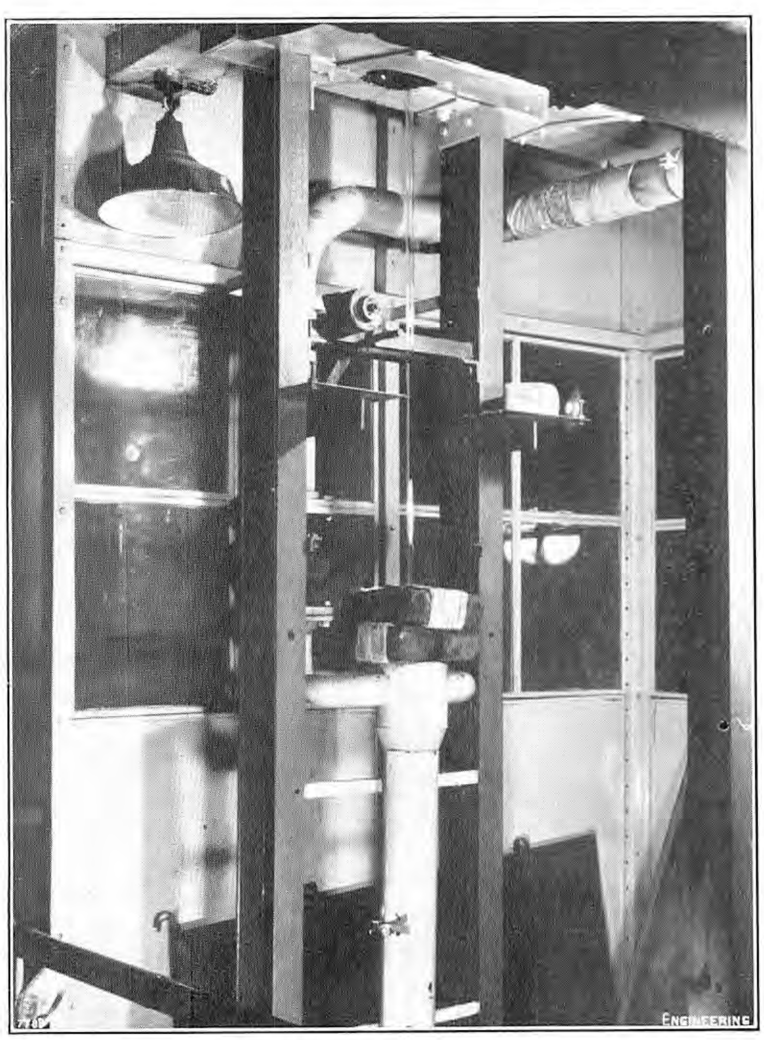


FIG. 4. INTERMEDIATE COMPARTMENT, SHOWING COOLING JACKET.

FIG. 5. CUTTING-OFF PLATFORM, SHOWING DRAWING ROLLERS.

until it reaches the level of the top of the central jet and is then formed into a "flower" shape round the jet by manipulating the glass with a rod and hook and then drawing it up by a hook. The "flower" is then broken off and the rough tube is drawn up by hand and placed between the drawing rollers. The glass in the pot is then raised to the correct level, which is about 10 mm. above the top of the jet, and the burners are adjusted to give an even flame. As the drawing proceeds, the air jets are adjusted to give the desired diameter and wall thickness. Fluctuations in these dimensions may be expected for a few hours after starting up, the output for this period being scrapped and used as cullet, large quantities of which are required for charging the tank furnace. Usually, the machine is found to settle down to normal production in about six hours.

Finally, we wish to thank Mr. A. D. Priestland, a director of the company, and Mr. W. Armistead, the manager of the tube-drawing installation at the Blackburn works, for supplying us with the information on which the above article has been based.

# LITERATURE.

*Displacement Pumps and Motors.*

By R. HADEKEL, B.Sc., A.C.G.I., A.M.I.Mech.E. [Price 25s. net.]

*Positive Displacement Pumps and Fluid Motors.*

By WARREN E. WILSON. [Price 40s. net.] Both published by Sir Isaac Pitman and Sons, Limited, Parker-street, Kingsway, London, W.C.2.

THE positive displacement principle is embodied in so many different forms of hydraulic machinery, and finds so varied a range of established applications, as to prompt the inference that specialist designers of such apparatus have far wider and more precise knowledge of the subject than can be readily obtained from the standard text-books on hydraulics. It is possible, of course, that the positive displacement principle is, superficially, so straightforward and its use so obviously dictated by the applications it serves that advances in performance have been achieved mainly by practical experience and development, supported by improved manufacturing precision, rather than based on fundamental considerations. Whatever the reason may be, the dearth of scientifically sound introductory treatments, dealing comprehensively with hydraulic displacement machines, reveals a need which the two books under review, between them, fulfil with a great measure of success.

The two authors, with different groups of readers in mind, differ correspondingly in their approach and treatment. Mr. Hadekel's work is addressed primarily to practising designers and development engineers to whom hydraulic theory is, perhaps, of less immediate utility than mechanical analysis. He therefore classifies displacement machines according to the fundamental kinematics underlying their mode of operation, and systematically examines along these lines the geometry and theoretical characteristics of machines embodying pistons, gears, vanes, and spherical or skew mechanisms. A few of the devices included to exemplify variations of the author's broad classifications are, perhaps, noteworthy rather for ingenuity than utility, but Mr. Hadekel leaves his readers in no doubt as to what constitute features of practical importance and he writes instructively about the balancing of piston pumps and motors, the constructional aspects of gear and vane machines, and the general problems of efficiency, leakage, clearance losses and operating conditions common to all positive-displacement appliances. The final chapters, which include discussions of variable-capacity devices, manual and foot pumps, and the spheres of application of various forms of displacement machines, are so brief as to suggest rather than to display Mr. Hadekel's obviously wide knowledge of these parts of his subject. A future edition of his book may afford him the opportunity to enlarge on them, and, incidentally, to correct a few typographical errors of which one—in a numerical coefficient on page 6—may be misleading.

Mr. Wilson deals with positive-displacement pumps, motors and power-transmission systems in a more pedagogic manner, as befits the President of the South Dakota School of Mines and Technology. The first half of his orthodox text-book is addressed especially to young graduate engineers, introducing them to elementary concepts of characteristic form and performance based on a system of classification which distinguishes only two major types of machine—piston and rotary—each of which may have constant or variable displacement. In the second half of the book, intended for more experienced hydraulic engineers, a theory of pump and motor performance is formulated on the basis of fundamental fluid motion and leads to elegant methods of analysing experimental data and designing machines to fulfil specified requirements. The remaining chapters deal with the general theory and some practical aspects of hydraulic clutches and transmission systems in which the merits of the differential principle are recognised and discussed.

The two books are thus complementary, the American one concerned principally with hydraulic theory and analysis, the English book with mechanisms and their practical realisation. Together they comprise an admirably comprehensive account of a form of power machinery which, notwithstanding the many purposes it already serves, offers ample scope for future development. Research engineers no less than designers should find these books useful as sources of co-ordinated knowledge and reference to specific points of detail; in which connection, a bibliography of some hundreds of references to relevant publications since 1929 is a valuable appendix to Mr. Wilson's work.

*The Magnetron.*

By R. LATHAM, M.A.Ph.D., A. H. KING, M.A. and L. RUSHFORTH, M.B.E., B.Sc., M.I.E.E. Chapman and Hall, Ltd., 37, Essex-street, London, W.C.2. [Price 18s. net.]

IT is now well known that radar had been used before the second World War to give early warning of the approach of hostile aircraft and thus enable defensive measures to be put in hand. For this application a long working range is required, so that metre wavelengths were most suitable. For many other war-time applications of radar, including aircraft interception at night, determining the precise position of ships at sea, anti-aircraft gunnery, and for showing the details of land targets in bombing raids at night, very short wavelengths, of only a few centimetres, were essential. Several methods of generating such short-wavelength radiation of adequate power were tried, but the most effective was the use of the cavity magnetron, which was originated independently in the physics department of the University of Birmingham in November, 1939, although it now appears that similar work had been done elsewhere. The work of Randall and Boot, members of a research team under Professor M. L. Oliphant, at Birmingham, led to a combination of slotted cylinders arranged symmetrically round a cylindrical anode-cathode space, the whole being machined from solid copper. This first magnetron was run as a continuous-wave oscillator producing 400 watts of radio-frequency power at a wavelength of 9·8 cm. This particular valve was of the demountable type, but the results obtained with it were so encouraging that efforts were directed to the production of sealed-off valves, both at Birmingham and in the Wembley research laboratories of the General Electric Company, Limited. Soon peak powers up to 10 kW were obtained with the early sealed-off magnetrons and many thousands of them were made, both in this country and in America, the power being increased from 5 kW to 150 kW at wavelengths of the order of 10 cm.

One chapter of the book under review is devoted to the early development of this type of multi-resonator magnetron, one of which was described in detail in ENGINEERING, vol. 161, page 361 (1946). Subsequent chapters of the book cover the properties of the anode block, in which the resonating cavities are formed, the extraction of energy from the magnetron, the electronic theory of operation, and the design and construction of cathodes. The three remaining chapters deal with constructional techniques and manufacture, performance testing and the application of the magnetron to radar. The authors' experimental work and most of their investigations on magnetrons were carried out in the research laboratories of the British Thomson-Houston Company at Rugby, but they make generous acknowledgment of the help of their colleagues at Rugby and to workers in the same field at Wembley, Birmingham, and other laboratories, including those of the Government and Service establishments. The authors worked for over five years in the development of magnetrons under the direction of Mr. L. J. Davies, who at the time was head of the vacuum-physics section at Rugby. Mr. Davies, in a particularly interesting foreword to the book, briefly explains the conditions under which the magnetron was produced during the stress of war by physicists, electrical engineers and technicians whose combined efforts were able to supply the needs of the Services for radar sets of the highest possible power and range, but he mentions that, owing to the pressing need for urgency, designs had sometimes to go into production when a better model was in sight. While acknowledging the value of the great productive capacity of the American factories, Mr. Davies points out that British research workers and production experts "provided in the magnetron an outstanding example of the application of research to production in circumstances of the utmost difficulty, making supplies available when the need was great." He finally thanks all those in this country and in America who co-operated in this work. All the Allied nationals, we feel, would wish to join him in this tribute, because there can be little doubt that the victorious outcome of the war would have been at least delayed but for the successful development of the magnetron.

*An Introduction to Mathematical Physics.*

By Dr. R. A. HOUSTOUN, M.A., F.Inst.P. Blackie and Son, Limited, 16-18, William IV-street, Charing Cross, London, W.C.2. [Price 25s. net.]

MANY university students, immediately before and just after the first World War, began their study of mathematical physics with the aid of Dr. Houstoun's *Introduction*, which covered, in six largely self-contained chapters, the indispensable classical background of the subject. Much of this remains as essential to-day as it was then, and the larger part of it has been incorporated in this new edition; but, though the first six chapters retain their original titles—Attraction, Hydrodynamics, Fourier Series and Conduction of Heat, Wave Motion, Electromagnetic Theory, and Thermodynamics—they have been subjected to a thorough revision. Moreover, the emphasis has been shifted, for whereas the original work was "intended primarily as a class book for mathematical students," the present version has been "written for students of physics" with the hope that it "may also be useful to chemists and technicians" whose grounding in the calculus has been so substantially improved in the meantime as to justify such a hope.

As the individual chapters only occupy between 30 and 50 pages, much, perforce, has had to be omitted. Thus, for instance, attention is confined to the Eulerian treatment of fluid motion, there is no discussion of the Fourier Integral, and no consideration of wave propagation in horns. Nevertheless, the selection has been wisely made on the basis of wide experience, so that everything included is really relevant. Moreover, many interesting applications and extensions of the theory are contained in the examples at the ends of the chapters, to a few of which hints are given and answers provided. Two new chapters dealing, respectively, with Quantum Theory, Minimal Principles and Relativity, have been added. These are disappointingly brief and could be expanded with advantage. The statement that the equation in $u$ on page 258 follows from the preceding equation in $r$ "on changing $r$ to $u$" is liable to be misleading, since, in fact, it follows by substituting $u = \frac{1}{r}$.

Dr. Houstoun's skill in exposition is everywhere evident, and occasional footnotes throw illuminating sidelights on points of historical interest. The book provides a sound preliminary course and one that will serve as a reliable introduction to the study of the more specialised standard treatises.

# TABULAR METHODS FOR CRITICAL-SPEED CALCULATIONS.

By A. J. Morton, M.Sc., A.M.I.Mech.E.

(*Concluded from page* 675.)

An alternative approach to the calculation of critical speeds is to consider the mass of each section to be concentrated into two parts, one at each end of the section. A rotor will then consist of a number of concentrated loads at the junction points of a series of weightless elastic sections. The quantity $w_r$ is now zero for each section and the coefficients $e_r$, $f_r$, $g_r$ and $h_r$ vanish. The first three of equations (7) reduce to :—

$$\left.\begin{aligned} y_r &= y_{r-1} + a_r\, i_{r-1} + c_r\, \mathrm{M}_{r-1} + d_r\, \mathrm{F}_{r-1} \\ i_r &= i_{r-1} + b_r\, \mathrm{M}_{r-1} + c_r\, \mathrm{F}_{r-1} \\ \mathrm{M}_r &= \mathrm{M}_{r-1} + a_r\, \mathrm{F}_{r-1} \end{aligned}\right\} \quad (9)$$

The fourth equation, which gives $\mathrm{F}_r$, is no longer correct since there is now a concentrated mass $\mathrm{W}_r$, at the point $r$, which causes a discontinuity in the shearing-force curve at this point. The increase in shearing force is $\mathrm{W}_r\, \Omega^2\, y_r$, or $10^6\, \mathrm{W}_r\, u y_r$, $\mathrm{W}_r$ being expressed in lb. weight divided by 12 $g$. The situation is as shown in Fig. 3.

The required equation is therefore

$$\mathrm{F}_r = \mathrm{F}_{r-1} + 10^6\, \mathrm{W}_r\, u\, y_r. \quad (10)$$

The second method consists of using equations (9) and (10) in precisely the same way as equations (7) were used in the first method. It is clearly a shorter procedure owing to the simpler form of the equations but, unlike the first method, it depends on assumption (*b*) referred to in the first paragraph, on page 674. It will be seen later that the second method is preferable for supported spans and the first method for overhung sections or cantilevers. Equations (9) are the ordinary elastic equations for the bending of a loaded but weightless shaft and can be derived very simply quite apart from any consideration of vibration.

Fundamental critical speeds can usually be determined with sufficient accuracy by assuming a supported span to consist of four or five uniform sections. The number of sections required in any particular case, however, will be considered in some detail later. An actual rotor may contain far more than this number of sections of different diameters, and it is often convenient to group several together and to replace each group by an "equivalent" uniform section of such proportions as to affect the critical speed as little as possible. The first step is to decide which sections are to be grouped together, and then to replace the actual total load on each group by two concentrated loads, one at each end of the group. These loads are chosen so that their sum is equal to the original total load and their centre of gravity coincides with that of the original loading. This procedure will affect the first critical speed very little if there are not less than four or five sections in the rotor as modified. It is then necessary to replace each group of sections in turn by a single uniform section the moment of inertia of which is such as to cause the least possible alteration in the deflections of the concentrated loads. How this is to be done depends upon the position of the group within the rotor.

Referring to Fig. 4, opposite, P Q R S in (*c*) and (*d*) represent the elastic curve of a vibrating rotor, the portion Q R of which is shown in (*a*) to consist of three sections which are to be replaced by a single equivalent section as in (*b*). The rotor is supported in bearings at P and S. The dotted lines show the new elastic curve when the equivalent section is introduced, the portion P Q being unchanged. In (*c*) the equivalent section has been chosen so that the new elastic curve still passes through R, it being assumed that the curve is fixed in direction at Q and that the bending moment distribution is unaltered. The slope at R will be reduced and the right-hand bearing must be considered to lie at S′, P S′ being the new line of centres. The deflection of any point on the elastic curve must now be measured from P S′ instead of P S and, in general, all deflections will have been reduced appreciably. The new rotor, therefore, will be stiffer than the original and the calculated critical speed will be high.

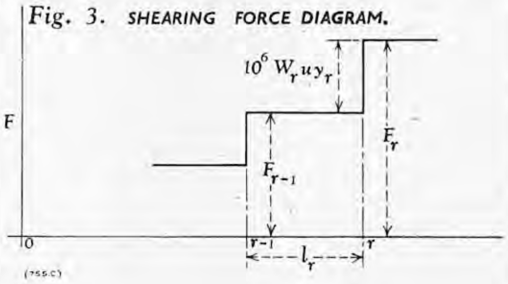
The obvious alternative is shown in (*d*), where the equivalent section has been chosen to give the same change of slope between Q and R as in the original rotor. R will consequently move to R′, and R S will be displaced parallel to itself so that S S′ = R R′. Deflections, being now measured from P S′, will, on the whole, be increased a little, so that the calculated critical speed will be a trifle low—which, more often than not, is a good fault. In general, the distance S S′ in (*d*) will be much less than in (*c*), so that the best simple criterion for a suitable equivalent section is that it should give the same change of slope as the sections which it replaces. An exception occurs when the section is adjacent to a bearing. If, for instance, the portion R S were non-existent, R being the right-hand bearing, the equivalent section Q R should obviously be selected as in (*c*), so that R and R′ coincide. The line of bearing centres would then be unchanged in the diagram and no deflections would be altered outside Q R. The suggested procedure for the two common cases is summarised below.

In the case when the group of sections is not near a bearing, the object is to find an equivalent section which will give the same change of slope as the group of sections which it replaces. Let the original sections have lengths $l_1$, $l_2$, $l_3$ . . . and diametral moments of inertia $\mathrm{I}_1$, $\mathrm{I}_2$, $\mathrm{I}_3$ . . . The required moment of inertia I for the equivalent section may be found from the expression

$$\frac{l_1 + l_2 + l_3 + \ldots}{\mathrm{I}} = \frac{l_1}{\mathrm{I}_1} + \frac{l_2}{\mathrm{I}_2} + \frac{l_3}{\mathrm{I}_3} + \ldots \quad (11)$$

Though strictly correct only if the bending moment is constant over the whole length considered, this is sufficiently accurate for most practical cases.

Fig. 3. SHEARING FORCE DIAGRAM.




In the second case when the group of sections is adjacent to an end bearing, the centre line of the equivalent section must intersect the original elastic curve at each end of the section and be parallel to it at the end remote from the bearing.

Suppose first, that only two sections are to be replaced, having lengths $l_1$ and $l_2$, the former being nearer to the bearing.

Let

$$j = \frac{l_1}{l_1 + l_2} \quad \text{and} \quad k = \frac{\mathrm{I}_2 - \mathrm{I}_1}{\mathrm{I}_1}.$$

Then

$$\mathrm{I} = \frac{\mathrm{I}_2}{1 + j^3 k}. \quad (12)$$

This formula is obtained by assuming that the bending moment is zero at the bearing and increases at a uniform rate over the whole length considered. If more than two sections are to be replaced, the same procedure may be used to replace the third section and the equivalent for the first two, and so on, until all have been taken into account.

As an example consider the rotor illustrated in Fig. 5, opposite, which forms part of a Metropolitan-Vickers turbine running at 3,000 r.p.m. The relevant data are given in Table VI, on this page. The second method will be used, for reasons given earlier. The original rotor contains 23 uniform sections of appreciable length between bearing centres, but by applying the methods outlined above these can be replaced by six sections with concentrated loads at their junction points, as in Table VII. For the present, the overhanging ends are ignored, but they will be considered in a more detailed procedure to be discussed later. The constants $a_r$, $b_r$, $c_r$ and $d_r$ for each section of the modified rotor are given in Table VIII.

Treating the rotor as if supported in a short bearing at the end 0, $y_0 = \mathrm{M}_0 = 0$. The unknowns are $i_0$ and $\mathrm{F}_0$, and the application of equations (9) and (10) to the first section gives the coefficients of Table IX. A further step gives Table X, opposite.

Table VI.—*Metropolitan-Vickers Rotor.*

| No. of Section from L.H. End. | Weight in lb. acting at Middle of Section. | Length, in. | Diametral M. of I., in.$^4$ |
|---|---|---|---|
| 1 | | 1·625 | — |
| | 1,850 | | |
| 2 | | 11·063 | — |
| 3 | 514 | 8·562 | — |
| 4 | 108 | 3·000 | — |
| 5 | 260 | 6·250 | — |
| | *Centre Line of L.H. Bearing.* | | |
| 6 | 265 | 6·375 | 1,867 |
| 7 | | 1·125 | 2,315 |
| | 368 | | |
| 8 | | 6·438 | 2,735 |
| 9 | | 2·125 | 2,834 |
| | 412 | | |
| 10 | | 4·187 | 2,925 |
| 11 | 3,420 | 11·000 | 3,026 |
| 12 | 1,100 | 6·750 | 3,320 |
| 13 | 3,580 | 11·000 | 3,433 |
| 14 | 3,318 | 9·375 | 4,120 |
| 15 | 2,659 | 8·063 | 4,620 |
| 16 | 2,537 | 7·125 | 6,430 |
| 17 | 1,270 | 9·625 | 7,870 |
| 18 | 2,537 | 7·125 | 6,430 |
| 19 | 2,659 | 8·062 | 4,620 |
| 20 | 3,318 | 9·375 | 4,120 |
| 21 | 3,580 | 11·000 | 3,433 |
| 22 | 1,100 | 6·750 | 3,320 |
| 23 | 3,420 | 11·000 | 3,026 |
| 24 | | 4·188 | 2,925 |
| | 412 | | |
| 25 | | 2·125 | 2,834 |
| 26 | | 6·437 | 2,735 |
| | 368 | | |
| 27 | | 1·125 | 2,315 |
| 28 | 265 | 6·375 | 1,867 |
| | *Centre Line of R.H. Bearing.* | | |
| 29 | 272 | 6·500 | — |
| 30 | 106 | 2·500 | — |
| 31 | 3,800 | 17·000 | — |

Table VII.—*Modified Rotor.*

| $r$. | $l_r$, in. | $\mathrm{W}_r$, $\frac{\text{lb.}}{12g}$ | $\mathrm{I}_r$, in.$^4$ |
|---|---|---|---|
| 1 | 20·25 | 11·82 | 2,790 |
| 2 | 28·75 | 23·70 | 3,240 |
| 3 | 29·38 | 21·18 | 3,110 |
| 4 | 29·37 | 23·70 | 3,110 |
| 5 | 28·75 | 11·82 | 3,240 |
| 6 | 20·25 | — | 2,790 |

Bearings at the points 0 and 6.

Table VIII.—*Constants for Modified Rotor.*

| $r$. | $a_r$. | $10^9 \times b_r$. | $10^8 \times c_r$. | $10^7 \times d_r$. |
|---|---|---|---|---|
| 1 | 20·25 | 0·2420 | 0·2451 | 0·1655 |
| 2 | 28·75 | 0·2959 | 0·425 | 0·407 |
| 3 | 29·38 | 0·1916 | 0·2810 | 0·2753 |
| 4 | 29·37 | 0·1916 | 0·2810 | 0·2753 |
| 5 | 28·75 | 0·2959 | 0·425 | 0·407 |
| 6 | 20·25 | 0·2420 | 0·2451 | 0·1655 |

Table IX.—*Coefficients for Section* 1.

| — | $i_0$. | $u\, i_0$. | $\mathrm{F}_0$. | $u\, \mathrm{F}_0$. |
|---|---|---|---|---|
| $y_1$ | 20·25 | | 0·01655 (—6) | |
| $i_1$ | 1 | | $0\cdot\overset{2}{0}2451$ (—6) | |
| $\mathrm{M}_1$ | | | 20·25 | |
| $\mathrm{F}_1$ | | 239·7 (+6) | 1 | 0·1958 |

Continuing in this way, we obtain

$$\begin{aligned} y_6 = {} & (156\cdot8 + 4{,}656\, u + 4{,}890\, u^2 + 890\, u^3 \\ & \quad + 46\cdot3\, u^4 + 0\cdot699\, u^5)\, i_0 \\ & + (5\cdot406 + 30\cdot85\, u + 14\cdot18\, u^2 + 1\cdot439 u^3 \\ & \quad + 0\cdot0503 u^4 + 0\cdot\overset{3}{0}571\, u^5)\, \mathrm{F}_0 \times 10^{-9} \\ \mathrm{M}_6 = {} & (445{,}000\, u + 1{,}250{,}000\, u^2 + 433{,}000\, u^3 \\ & \quad + 37{,}980\, u^4 + 855 u^5)\, i_0 \times 10^6 \\ & + (156\cdot8 + 4{,}660\, u + 4{,}880\, u^2 + 890\, u^3 \\ & \quad + 46\cdot4\, u^4 + 0\cdot699\, u^5)\, \mathrm{F}_0. \end{aligned}$$

Equating $\mathrm{M}_6$ and $\mathrm{F}_6$ to zero, extracting the equation for $u$ corresponding to equation (8), and solving it by trial and error, we find the smallest root to be $u = 0\cdot0282$, equivalent to 168·0 radians per second or a critical speed of 1,603 r.p.m.

Two important points should be observed. Firstly, although the equation contains powers of $u$ up to the fifth, it will be found that terms involving the cube and higher powers are insignificant on a

# CRITICAL-SPEED CALCULATIONS.

Fig. 4.

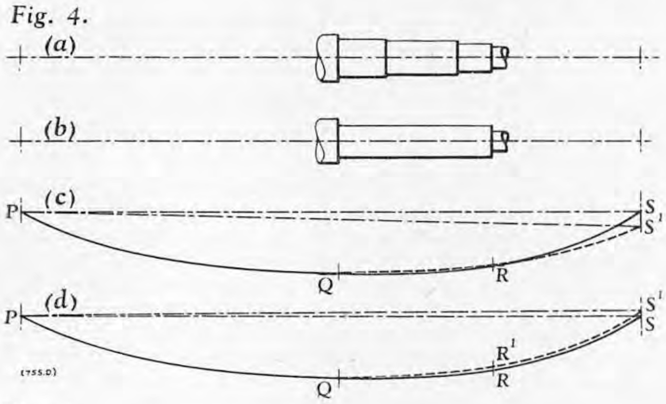



Fig. 5. METROPOLITAN-VICKERS L.P. ROTOR.

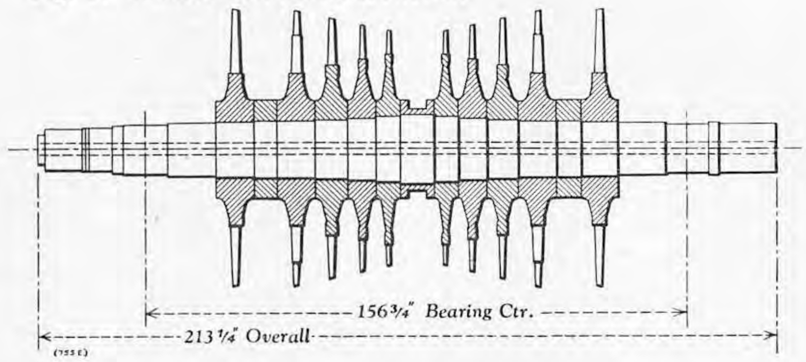



Fig. 6.

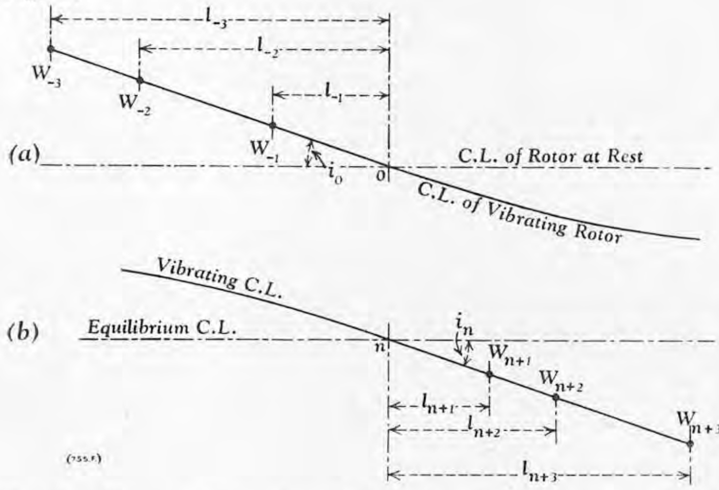
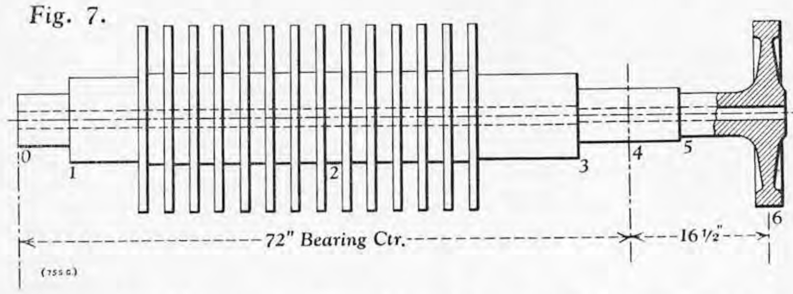



Fig. 7.




slide rule. Consequently, no terms higher than the square need be calculated in this case.

Secondly, this particular rotor, as modified in Table VII, is symmetrical. Therefore, $i_3 = 0$ and $F_3 = -F_2$ or $i_3 = F_{mid.} = 0$ where

$$F_{mid.} = \frac{F_2 + F_3}{2} = F_2 + 10^6 \frac{W_3}{2} u\, y_3.$$

Calculations for the point 3 give

$$i_3 = (1 + 6 \cdot 28\, u + 0 \cdot 649\, u^2)\, i_0$$
$$+ (0 \cdot 02489 + 0 \cdot 01671\, u + 0 \cdot \overset{3}{0}530\, u^2)\, F_0 \times 10^{-6}$$
$$F_{mid.} = (2{,}231\, u + 1{,}265\, u^2 + 67 \cdot 2\, u^3)\, i_0 \times 10^6$$
$$+ (1 + 13 \cdot 23\, u + 2 \cdot 233\, u^2 + 0 \cdot 0549\, u^3)\, F_0,$$

which, when equated to zero and solved for $u$, give a critical speed of 1,603 r.p.m. as before. Again, terms in $u^3$ are insignificant and may be omitted from the calculations. This gives a very rapid method of estimating the critical speed of a symmetrical rotor.

The foregoing example of a two-bearing rotor with no appreciable overhung masses is typical of many turbine calculations. Occasionally, however, the continuous or overhung rotor is encountered, in which case the methods already outlined require extension. A short intermediate bearing at the point $r$ imposes the condition $y_r = 0$, giving an equation of the form.

$$\phi_1 (u) \alpha_0 + \phi_2 (u) \beta_0 = 0,$$

where $\alpha_0$ and $\beta_0$ are the original unknowns, and $\phi_1$ and $\phi_2$ contain powers of $u$.

Hence,

$$\beta_0 = - \frac{\phi_1 (u)}{\phi_2 (u)} \alpha_0 = \Phi (u) \alpha_0.$$

Ordinary long division gives $\Phi(u)$ in the form of an infinite series in ascending powers of $u$, of which only four or five terms, as a rule, need be calculated. The quantities $y_r$, $i_r$, and $M_r$, already known in terms of $\alpha_0$ and $\beta_0$, can then be expressed in terms of $\alpha_0$ alone. In the expression for the shearing force $F_r$, $\beta_0$ can again be eliminated, but a new unknown makes its appearance. This is the bearing reaction $R_r$, which must be added to the expression for $F_r$. If the first method is in use, the last of equations (7) for the point in question becomes

$$F_r = 10^6\, e_r\, u\, y_{r-1} + 10^6 f_r\, u\, i_{r-1} + 10^6\, h_r\, u\, M_{r-1}$$
$$+ F_{r-1} + R_r, \quad (13)$$

and when the second method is employed, equation (10) becomes

$$F_r = F_{r-1} + R_r. \quad . \quad . \quad (14)$$

In both cases, the calculation continues normally in the $(r + 1)$th and later sections, with $\alpha_0$ and $R_r$ as unknowns instead of $\alpha_0$ and $\beta_0$.

Many rotors, such as that of Fig. 5, have short overhung ends which may be neglected in rough calculations. In more accurate work, such overhung masses can be dealt with without resort to the lengthy procedure outlined above for the case of intermediate bearings by assuming that the overhung ends are inflexible. Referring to Fig. 6(*a*), herewith, let $W_{-1}$, $W_{-2}$, $W_{-3}$, . . . be overhung masses at the left-hand end of a rotor and distant $l_{-1}$, $l_{-2}$, $l_{-3}$, . . . respectively, from the point 0 at which there is a short bearing. The elastic curve on which the masses lie is assumed to be a straight line to the left of 0 and to have a positive gradient $i_0$ at that point. The deflections of the masses are $-l_{-1} i_0$, $-l_{-2} i_0$, . . . respectively, and the corresponding inertia forces are $-W_{-1} l_{-1} \Omega^2 i_0$, $-W_{-2} l_{-2} \Omega^2 i_0$, . . . Since $\Omega^2 = 10^6 u$, the bending moment at the bearing is

$$M_0 = -10^6\, u\, i_0\, (W_{-1}\, l^2_{-1} + W_{-2}\, l^2_{-2} + \ . \ . \ .). \quad (15)$$

Also $y_0 = 0$. $i_0$ and $F_0$ remain unknown.

The calculation proceeds in the ordinary way in terms of two unknowns, but we have now departed from the assumption that $M_0$ is zero and have made a very fair approximation to its true value. The right-hand end of the rotor is shown in Fig. 6(*b*), the masses $W_{n+1}$, $W_{n+2}$, . . . lying on the elastic curve which is a straight line to the right of the bearing at $n$. Here,

$$M_n = 10^6\, u\, i_n\, (W_{n+1}\, l^2_{n+1} + W_{n+2}\, l^2_{n+2} + \ . \ . \ .). \quad (16)$$

At the right-hand bearing therefore

$$y_n = M_n - 10^6\, u\, i_n\, (W_{n+1}\, l^2_{n+1}$$
$$+ W_{n+2}\, l^2_{n+2} + \ . \ . \ .) = 0, \quad (17)$$

from which the equation for $u$ can be derived. Some indication of the accuracy to be expected from this simple treatment is given later.

TABLE X.—COEFFICIENTS FOR SECTION 2.

| — | $i_0$. | $u\, i_0$. | $u^2\, i_0$. | $F_0$. | $u\, F_0$. | $u^2\, F_0$. |
|---|---|---|---|---|---|---|
| $y_1$ | 20·75 | | | 0·01655 | | |
| $a_2\, i_1$ | 28·75 | | | 0·0705 | | |
| $c_2\, M_1$ | | | | 0·0861 | | |
| $d_2\, F_1$ | | 9·75 | | 0·0407 | $0\cdot\overset{2}{0}796$ | |
| $y_2$ | 49·00 | 9·75 | | 0·2139 | $0\cdot\overset{2}{0}796$ | |
| | | | | (—6) | (—6) | |
| $i_1$ | 1 | | | $0\cdot\overset{2}{0}2451$ | | |
| $b_2\, M_1$ | | | | $0\cdot\overset{2}{0}599$ | | |
| $c_2\, F_1$ | | 1·018 | | $0\cdot\overset{2}{0}425$ | $0\cdot\overset{3}{0}832$ | |
| $i_2$ | 1 | 1·018 | | 0·01269 | $0\cdot\overset{3}{0}832$ | |
| | | | | (—6) | (—6) | |
| $M_1$ | | | | 20·25 | | |
| $a_2\, F_1$ | | 6,890 | | 28·75 | 5·62 | |
| $M_2$ | | 6,890 | | 49·00 | 5·62 | |
| | | (+6) | | | | |
| $F_1$ | | 239·7 | | 1 | 0·1958 | |
| $10^6\, W_2\, u\, y_2$ | | 1,161 | 230·8 | | 5·07 | 0·1888 |
| | | 1,401 | 230·8 | 1 | 5·27 | 0·1888 |
| | | (+6) | (+6) | | | |

To take account of the overhung ends of the rotor discussed earlier, the quantities in brackets in equations (15) and (16) are calculated, as in Tables XI and XII.

TABLE XI.—*Calculation for L.H. Overhang.*

| $r$. | $W_r$, lb. | $W_r$, lb. / $12g$ | $l_r$, in. | $W_r l_r^2$. |
|---|---|---|---|---|
| —1 | 260 | 0·673 | 3·125 | 7 |
| —2 | 108 | 0·279 | 7·750 | 17 |
| —3 | 514 | 1·330 | 13·531 | 244 |
| —4 | 1,850 | 4·78 | 24·156 | 2,788 |
| | | | | 3,056 |

TABLE XII.—*Calculation for R.H. Overhang.*

| $r$. | $W_r$, lb. | $W_r$, lb. / $12g$ | $l_r$, in. | $W_r l_r^2$. |
|---|---|---|---|---|
| 7 | 272 | 0·704 | 3·250 | 7 |
| 8 | 106 | 0·274 | 7·750 | 16 |
| 9 | 3,800 | 9·84 | 17·500 | 3,012 |
| | | | | 3,035 |

From equation (15), $M_0 = -3{,}056\, ui_0 \times 10_6$. Also $y_0 = O$.

Equations (9) and (10) give

$$\left.\begin{aligned} y_1 &= a_1 i_0 - 10^6 c_1 \times 3{,}056\, u\, i_0 + d_1 F_0 \\ i_1 &= i_0 - 10^6 b_1 \times 3{,}056\, u\, i_0 + c_1 F_0 \\ M_1 &= -10^6 \times 3{,}056\, u\, i_0 + a_1 F_0 \\ F_1 &= F_0 + 10^6 \times W_1\, u\, y_1 \end{aligned}\right\} \quad (18)$$

which can be tabulated. The calculation can then be continued normally, using the same constants as before (Tables VII and VIII). The terms in $F_0$ are identical with those given previously at every stage until the bearing at point 6 is reached. The results, neglecting powers of $u$ above the cube, are :—

$$\left.\begin{aligned} y_6 &= (156{\cdot}8 + 4{,}303\, u + 370\, u^2 - 2{,}183\, u^3)\, i_0 \\ &\quad + (5{\cdot}406 + 30{\cdot}85\, u + 14{\cdot}18\, u^2 \\ &\qquad + 1{\cdot}439\, u^3)\, F_0 \times 10^{-6} \\ i_6 &= (1 + 174{\cdot}2\, u + 105{\cdot}5\, u^2 - 128{\cdot}0\, u^3)\, i_0 \\ &\quad + (0{\cdot}1143 + 1{\cdot}477\, u + 1{\cdot}007\, u^2 \\ &\qquad + 0{\cdot}1386\, u^3)\, F_0 \times 10^{-6} \\ M_6 &= (442{,}000\, u + 702{,}000\, u^2 \\ &\qquad - 483{,}000\, u^3)\, i_0 \times 10^6 \\ &\quad + (156{\cdot}8 + 4{,}660\, u + 4{,}880\, u^2 \\ &\qquad + 890\, u^3)\, F_0 \end{aligned}\right\} \quad (19)$$

Equation (17) gives $y_6 = M_6 - 3{,}035 u i_6 \times 10^6 = 0$. Hence

$$\frac{156{\cdot}8 + 4{,}303\, u + 370\, u^2 - 2{,}183\, u^3}{439{,}000\, u + 173{,}000\, u^2 - 803{,}000\, u^3} = \frac{5{\cdot}406 + 30{\cdot}85\, u + 14{\cdot}18\, u^2 + 1{\cdot}439\, u^3}{156{\cdot}8 + 4{,}310\, u + 400\, u^2 - 2{,}168\, u^3}$$

giving $u = 0{\cdot}0270$, $\Omega = 164{\cdot}3$ radians per second and a critical speed of 1,569 r.p.m.

The calculation has been worked through to the end to illustrate the general method, but this particular rotor, even including the overhangs, is so nearly symmetrical that almost the same result could be obtained much more quickly by equating to zero the slope and shearing force at point 3, in the manner exemplified previously. A rather neater procedure is possible if the calculation neglecting overhangs has already been performed. Equations (18) contain the same coefficients as Table IX, together with some extra terms due to the fact that $M_0$ is no longer zero. We may write, therefore,

$$\left.\begin{aligned} y_1' &= 10^6 c_1 \times 3{,}056\, u\, i_0 \\ i_1' &= 10^6 b_1 \times 3{,}056\, u\, i_0 \\ M_1' &= 10^6 \times 3{,}056\, u\, i_0 \\ F_1' &= 10^6 W_1\, u\, y' \end{aligned}\right\} \quad (20)$$

where $y_1'$, $i_1'$, $M_1'$ and $F_1'$ are to be subtracted from $y_1$, $i_1$, $M_1$ and $F_1$ in Table IX to obtain the more nearly correct quantities in equations (18). Since all the equations are linear, we may take (20) as a starting point for a supplementary calculation to obtain $y_6'$, $i_6'$, and $M_6'$, which, on being subtracted from $y_6$, $i_6$ and $M_6$, respectively, following Table X, yield equations (19). This process is a little shorter than the first alternative and has the advantage that no minus signs occur in the tabular work.

The results for the low-pressure turbine rotor may now be summarised, as follows

| | |
|---|---|
| Calculated critical speed, neglecting overhangs ... ... ... | 1,603 r.p.m. |
| Calculated critical speed, including overhangs ... ... ... | 1,569 ,, |
| Critical speed obtained by orthodox graphical method, including overhangs ... ... ... | 1,559 ,, |

The makers of the rotor, the Metropolitan-Vickers Electrical Company, Limited, inform the author that their own estimate of the critical speed is about 1,550 r.p.m. and that observation confirms the existence of a critical speed in this region. Exact observation of the critical speed of a well-balanced rotor is naturally difficult.

In most cases, the gyroscopic effect of an impulse wheel can be safely disregarded. Not only is it usually small, but it always tends to increase the critical speed, thereby raising the margin of safety for all turbines which run below their first critical speed. In certain cases, however, where heavy wheels are situated near bearings or on overhung shafts, account must be taken of their gyroscopic effects if an accurate result is required. A precessing disc always exerts a couple tending to reduce the angular deflection of the shaft. The couple is given by $K_r \Omega^2 i_r$ or $10^6 K_r\, u\, i_r$ where $K_r$ is the moment of inertia of the disc in lb. in. sec.[2] about an axis through its centre of gravity and perpendicular to the axis of rotation. This couple must always be added to the ordinary expression for $M_r$, and the modified expression used in the calculations for the $(r + 1)$th section.

The overhung rotor is seldom encountered in land and marine work, but a sketch of a fairly recently proposed design for a high-pressure marine turbine is shown in Fig. 7, on page 705. In this machine the astern turbine consists of a heavy overhung Curtis wheel, and the design may be used to illustrate the method of calculation discussed previously in relation to intermediate bearings.

The second main method is used for the supported span, starting from the data in Table XIII, which

TABLE XIII.—*Particulars of Overhung Rotor.*

| $r$. | $l_r$. | $I_r$. | $w_r$. | $W_r$. | $K_r$. |
|---|---|---|---|---|---|
| 1 | 6·00 | 62·9 | — | 1·593 | — |
| 2 | 30·00 | 598 | — | 4·00 | — |
| 3 | 30·00 | 575 | — | 1·366 | — |
| 4 | 6·00 | 63·4 | — | — | — |
| *Centre Line of R.H. Bearing.* | | | | | |
| 5 | 6·00 | 63·4 | 0·01940 | — | — |
| 6 | 10·50 | 30·4 | 0·01310 | 0·833 | 36·22 |

were obtained by simplifying the original rotor slightly by means of equation (11). The results for the right-hand bearing (point 4) are

$$\left.\begin{aligned} y_4 &= (72{\cdot}0 + 136{\cdot}6\, u + 8{\cdot}40\, u^2 + 0{\cdot}0648\, u^3)\, i_0 \\ &\quad + (4{\cdot}69 + 2{\cdot}219\, u + 0{\cdot}0427\, u^2 \\ &\qquad + 0{\cdot}02062\, u^3)\, F_0 \times 10^{-6} \\ i_4 &= (1 + 22{\cdot}50\, u + 1{\cdot}989\, u^2 + 0{\cdot}03240\, u^3)\, i_0 \\ &\quad + (0{\cdot}3509 + 0{\cdot}419\, u + 0{\cdot}01434\, u^2 \\ &\qquad + 0{\cdot}01031\, u^3)\, F_0 \times 10^{-6} \\ M_4 &= (6358\, u + 814\, u^2 + 20{\cdot}54\, u^3)\, i_0 \times 10^6 \\ &\quad + (72{\cdot}0 + 130{\cdot}5\, u + 7{\cdot}67\, u^2 \\ &\qquad + 0{\cdot}0653\, u^3)\, F_0 \\ F_4 &= (243{\cdot}8\, u + 87{\cdot}7\, u^2 + 3{\cdot}424\, u^3)\, i_0 \times 10^6 \\ &\quad + (1 + 7{\cdot}30\, u + 1{\cdot}125\, u^2 \\ &\qquad + 0{\cdot}01089\, u^3) + R_4 \end{aligned}\right\} \quad (21)$$

$R_4$ is the unknown reaction at the right-hand bearing. If there were no overhang, we could equate $y_4$ and $M_4$ to zero, giving $u = 0{\cdot}520$, $\Omega = 721$ radians per second and a critical speed of 6,890 r.p.m.

A more detailed calculation, using six sections in the span instead of four, gives a critical speed of 6,970 r.p.m., a difference of just over one per cent. Since the overhang is clearly of importance, however, this result is of academic interest only. The right-hand bearing imposes the condition $y_4 = 0$, so that the first of equations (21) gives

$$\begin{aligned} F_0 &= \frac{-(7{\cdot}20 + 136{\cdot}6u + 8{\cdot}40u^2 + 0{\cdot}0648u^3)}{(4{\cdot}69 + 2{\cdot}219\, u + 0{\cdot}0427\, u^2 + 0{\cdot}02062\, u^3)}\, i_0 \times 10^6 \\ &= (-15{\cdot}35 - 21{\cdot}88\, u + 8{\cdot}70\, u^2 - 3{\cdot}931\, u^3 \\ &\quad + 1{\cdot}782\, u^4 - 0{\cdot}808\, u^5 + 0{\cdot}366\, u^6 - + \ldots)\, i_0 \\ &\quad \times 10^6 \quad . \quad . \quad . \quad . \quad . \quad . \quad . \end{aligned} \quad (22)$$

On substituting for $F_0$, equations (21) become

$$\left.\begin{aligned} y_4 &= 0 \\ i_4 &= (-4{\cdot}39 + 8{\cdot}39\, u - 4{\cdot}35\, u^2 + 1{\cdot}982\, u^3 \\ &\qquad - 0{\cdot}901\, u^4 + 0{\cdot}408\, u^5 - 0{\cdot}184\, u^6)\, i_0 \\ M_4 &= (-1{,}105 + 2{,}781\, u - 1{,}533\, u^2 + 703\, u^3 \\ &\qquad - 319\, u^4 + 144{\cdot}8\, u^5 - 65{\cdot}7\, u^6)\, i_0 \times 10^6 \\ F_4 &= (-15{\cdot}35 + 109{\cdot}9\, u - 80{\cdot}6\, u^2 + 38{\cdot}2\, u^3 \\ &\qquad - 17{\cdot}37\, u^4 + 7{\cdot}87\, u^5 - 3{\cdot}56\, u^6)\, i_0 \\ &\qquad \times 10^6 + R_4 \end{aligned}\right\} \quad (23)$$

Powers of $u$ higher than the sixth are regarded as insignificant, and it will be found that in many cases lower powers also are negligible, the present example being comparatively tedious. Two ways of completing the calculation are compared below. In the first of these, sections 5 and 6 can be replaced by an equivalent section 5′ and the calculation completed in a single step by the second method. The required moment of intertia $I_{5'}$ is found from equation (12) to be 49·6 in.[4], the concentrated mass $W_{5'}$, at the free end, being calculated (in engineers' units) as follows :—

| | |
|---|---|
| Mass of impulse wheel ... | = 0·833 $\frac{\text{lb.}}{12g}$ |
| Half mass of equivalent section ... ... ... | = 0·140 ,, ,, |
| $W_{5'}$ | = 0·973 ,, ,, |

The constants for section 5′ are :—

$a_{5'} = 16{\cdot}50$ ; $10^6 b_{5'} = 0{\cdot}01109$ ; $10^6 c_{5'} = 0{\cdot}0915$
$10^6 d_{5'} = 0{\cdot}503$.

Equations (9) and (10) give

$$\left.\begin{aligned} y_{5'} &= (-181{\cdot}3 + 448\, u - 252{\cdot}7\, u^2 \\ &\qquad + 116{\cdot}2\, u^3 - 52{\cdot}8\, u^4 + 23{\cdot}95\, u^5 \\ &\qquad - 10{\cdot}84\, u^6)\, i_0 + 0{\cdot}503\, R_4 \times 10^{-6} \\ i_{5'} &= (-18{\cdot}04 + 49{\cdot}3\, u - 28{\cdot}72\, u^2 \\ &\qquad + 13{\cdot}26\, u^3 - 6{\cdot}03\, u^4 + 2{\cdot}733\, u^5 \\ &\qquad - 1{\cdot}238\, u^6)\, i_0 + 0{\cdot}0915\, R_4 \times 10^{-6} \\ M_{5'} &= (-1{,}358 + 4{,}595\, u - 2{,}864\, u^2 \\ &\qquad + 1{,}333\, u^3 - 606\, u^4 + 274{\cdot}6\, u^5 \\ &\qquad - 124{\cdot}5\, u^6)\, i_0 \times 10^6 + 16{\cdot}50\, R_4 \\ F_{5'} &= (-15{\cdot}35 - 66{\cdot}5\, u + 355\, u^2 - 207{\cdot}7\, u^3 \\ &\qquad + 95{\cdot}7\, u^4 - 43{\cdot}5\, u^5 + 19{\cdot}74\, u^6)\, i_0 \times 10^6 \\ &\qquad + (1 + 0{\cdot}490\, u)\, R_4 \end{aligned}\right\} \quad (24)$$

No account has yet been taken of the gyroscopic action of the impulse wheel. Disregarding this for the present, the condition for whirling, which satisfies $M_{5'} = F_{5'} = 0$, is

$$\frac{-1{,}358 + 4{,}595\, u - 2{,}864\, u^2 + 1{,}333\, u^3 - 606\, u^4 + 274{\cdot}6\, u^5 - 124{\cdot}5 u^6}{-15{\cdot}35 - 66{\cdot}5\, u + 355\, u^2 - 207{\cdot}7\, u^3 + 95{\cdot}7\, u^4 - 43{\cdot}5\, u^5 + 19{\cdot}74\, u^6} = \frac{16{\cdot}50}{1 + 490\, u},$$

giving $u = 0{\cdot}357$, $\Omega = 597{\cdot}5$ radians per second, and a critical speed of 5,710 r.p.m.

To make allowance for the gyroscopic action, the term $10^6 K_{5'}\, u\, i_{5'}$ is added to the expression for $M_{5'}$, in equations (24), giving the modified expression

$$\begin{aligned} M_{5'} &= (-1{,}358 + 3{,}941\, u - 1{,}076\, u^2 + 293\, u^3 \\ &\qquad - 125\, u^4 + 56{\cdot}1\, u^5 - 25{\cdot}5\, u^6)\, i_0 \times 10^6 \\ &\qquad + (1{\cdot}650 + 3{\cdot}315\, u)\, R_4 \end{aligned}$$

The condition for whirling is modified accordingly, the smallest value of $u$ being 0·392, giving $\Omega =$ 626 radians per second and a critical speed of 5,980 r.p.m.

As an alternative, and in the interests of greater accuracy, the overhang could be regarded as consisting of two uniform sections, number 5 and 6, as in Table XIII, with a concentrated load at the free end, and the calculation performed by the first method (equations 7). In this case, the critical speeds obtained are as follows :—

| | |
|---|---|
| Gyroscopic action neglected ... ... | 5,850 r.p.m. |
| Gyroscopic action included ... ... | 6,120 r.p.m. |

The results for the overhung rotor are summarised in Table XIV.

TABLE XIV.

| Ref. | No. of Sections. In Span. | In Overhang. | Method Used for Overhang. | Critical r.p.m. Ignoring Gyro. Effect. | Including Gyro. Effect. |
|---|---|---|---|---|---|
| *a* | 4 | 1 | Second | 5,710 | 5,950 |
| *b* | 4 | 2 | First | 5,850 | 6,120 |
| *c* | 6 | 2 | First | 5,890 | 6,170 |

In every case, the second method was used for the supported span. Details of case (c) have been omitted from the text for brevity, but the results are probably very close to the truth for this rotor. Assuming them to be correct, the results in (a) are about 3 per cent. too low and those in (b) about 0·75 per cent. too low. In all three cases, neglect of the gyroscopic action reduces the calculated critical speed by 4·5 per cent.

It has been assumed hitherto that all bearings are laterally rigid, which is usually sufficiently near the truth for practical turbine calculations, or, at least, with the usual information available, it is as good an assumption to make as any other. In cases where the flexibility of the supports is important, however, it may be dealt with as follows.

First, considering a bearing at the intermediate point $r$, let $S_r$ be the stiffness of the support in lb. wt. per in., that is, the restoring force per unit deflection exerted on the shaft at this point. The bearing reaction $R_r$ is given by $R_r = - S_r\,y_r$ and, as in the previous discussion of intermediate bearings, this quantity must be added to the expression for $F_r$. Since $R_r$ is known in terms of $y_r$ and hence in terms of the two original unknowns, the correction to $F_r$ is quite straightforward. The same unknowns are used in the calculations for later sections, and $R_r$ does not again appear directly. Secondly, when a bearing of this type is situated at the point 0, we have

$$F_0 = R_0 = -S_0\,y_0.$$

Wherever $F_0$ appears in equations (7) it is replaced by $- S_0 y_0$, so that, in the case of a short bearing exerting no angular restraint, the calculation proceeds with $y_0$ and $i_0$ as the original unknowns instead of $i_0$ and $F_0$. Thirdly, a non-rigid bearing at the final end $n$ of the rotor is treated as in the first case mentioned above, the expression for shearing force being corrected by adding the bearing reaction. The condition for whirling with a short bearing becomes

$$M_n = F_n = 0,$$

using the corrected expression for $F_n$.

Finally, it may happen that the lateral stiffness of a bearing varies with the direction of the displacement, in which case it will have maximum and minimum values in two mutually perpendicular directions. There will be two sets of critical speeds, one corresponding to vibration in each of these two planes, and they must be calculated separately using the appropriate stiffness coefficients. Where bearings of this type support a rotor in which gyroscopic action is important, or where there are two or more such bearings the principal axes of stiffness of which are not parallel to each other, the above statements are inadequate, and the problem is beyond the scope of the present article.

In order to investigate the varying degrees of accuracy attainable by dividing a rotor into different numbers of sections, both methods were applied to a simple rotor the natural frequency of which could be calculated from an exact mathematical equation. This rotor was merely a solid uniform bar with the following properties :

| | |
|---|---|
| Total length ... ... ... | 36 in. |
| Diameter ... ... ... | 1 in. |
| Density ... ... ... | 0·283 lb. per cub. in. |
| Modulus of elasticity ... | 30 × 10⁶ lb. per sq. in. |

Four methods of supporting the bar were considered, and in every case the natural frequencies obtained by the approximate methods were lower than the true natural frequencies—an important result—with the solitary exception of the approximate method applied to short overhung ends.

When the bar is considered as a cantilever supported as in Fig. 8, below, the true natural frequency is 21·847 cycles per second, or 1,310·8 cycles per minute. Table XV, below, shows the

TABLE XV.

| No. of Equal Sections. | 1 | 2 | 3 | 4 |
|---|---|---|---|---|
| Percentage error, Method I. | 30·2 | 4·1 | 0·9 | 0·2 |
| Percentage error, ,, II. | 30·3 | 10·2 | 4·7 | 3·0 |
| Values of $m_r\,l_r$ .. .. | 1·565 | 0·918 | 0·622 | 0·468 |

percentage errors in the values for the natural frequency given by the two methods, the number of equal sections in the rotor varying from 1 to 4. The value in each column of the dimensionless quantity $m_r\,l_r$ in this and subsequent tables was calculated from the approximate natural frequency given by the first method.

When the bar is simply supported at each end, as in Fig 9, the true natural frequency is 61·325 cycles per second, or 3,679·5 cycles per minute. The results of the calculations are shown in Table XVI, on this page.

When the bar is simply supported at one end and at the remote quarter-point, as in Fig. 10, the true natural frequency is 95·507 cycles per second, or 5,730·4 cycles per minute. The second method was employed for the span and both methods for the overhang. The results are compared in Table XVII, below. This case was

Fig. 8.

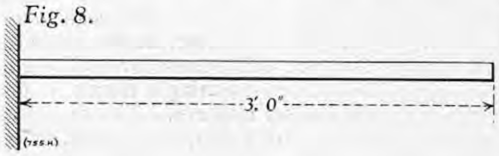



Fig. 9.

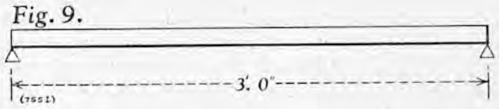



Fig. 10.

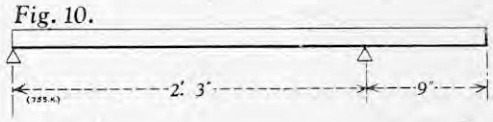
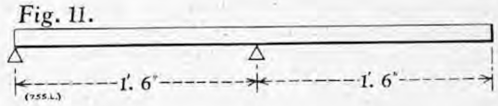



Fig. 11.




also used to test the degree of accuracy to be expected from equations (15) to (17) in the simple treatment of short overhung ends in which the overhung portion is assumed to remain perfectly straight. For an overhang of length $l$ with uniformly distributed mass $w$ per unit length, equation (16) becomes

$$M_n = 10^6\,u\,i_n \int_0^l w\,x^2\,dx$$
$$= 10^6\,u\,i_n\,\frac{w\,l^3}{3}$$
$$= 10^6\,u\,i_n\,\frac{W}{3}\,l^2,$$

where W is the mass of the overhung portion.

This is equivalent to treating the overhang as a single rigid section with one-third of its actual mass concentrated at the free end. The conditions at the right-hand bearing are

$$y_n = M_n - 10^6\,u\,i_n\,\frac{W}{3}\,l^2 = 0. \qquad (25)$$

Applying this equation to the present bar, with the span treated in three sections by the second method, we obtain for the frequency the figure of 96·7 cycles per second, which is 1·3 per cent. too high. Neglecting the overhang completely, the calculated frequency would be 14 per cent. too high, so that this simple treatment is quite effective even in a rather extreme case. Equations (15) to (17) may therefore be applied with confidence to the proportionately much smaller overhung ends of the Metropolitan-Vickers rotor considered previously.

If the bar is simply supported at one end and at its mid-point, as in Fig. 11, the true natural frequency is 56·364 cycles per second, or 3,381·8 cycles per minute. The second method was employed for the span, with three equal sections, and both methods for the overhang. The results are given in Table XVIII.

The results in Tables XV to XVIII show that while the second method may be used with confidence for a supported span having three or more sections, it is less reliable for overhung portions or cantilevers. In these cases the first method is recommended for accurate work, and the error will be barely perceptible on a slide rule provided $m_r\,l_r$ for any section does not exceed 0·5. The different characters of the errors inherent in the two methods is worthy of remark. The error in the first method is caused by neglecting all terms except the first in the infinite series of equations (5), and is a function of $(m_r\,l_r)^4$—hence the importance of choosing sections short enough to keep the numerical value of $m_r\,l_r$ below the limit already mentioned. In contrast to this, the error in the second method is due to the difference between the critical speed of the actual rotor with its distributed loading and that of the hypothetical rotor with concentrated loads, for which the calculations are strictly correct.

One final point deserves emphasis. Much time can be wasted in obtaining results to a greater degree of apparent accuracy than is warranted by the initial assumptions. In practical calculations, uncertainty usually exists regarding the exact conditions at bearings, the stiffening effect of forged or shrunk-on discs, the flexibility of hollow or re-entrant rotors and even the modulus of elasticity at high temperatures. In such cases, errors of a few per cent. are bound to occur, and figures given with greater accuracy should be viewed with suspicion until they have been thoroughly investigated.

The author is indebted to Professor L. J. Kastner, of the University College of Swansea, for many helpful suggestions, and to the Metropolitan-Vickers Electrical Company, Limited, for supplying drawings and information relating to current designs.

TABLE XVI.

| No. of equal sections .. .. | 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|
| Percentage error, Method I. .. | 39·2 | 18·9 | 5·9 | 2·6 | 0·7 | 0·0 |
| Percentage error, ,, II. .. | — | 0·9 | 0·0 | — | — | — |
| Value of $m_r\,l_r$ .. .. .. | 2·450 | 1·415 | 1·016 | 0·775 | 0·626 | 0·524 |

TABLE XVII.

| No. of equal sections in span .. .. .. | 2 | | 3 | | | |
|---|---|---|---|---|---|---|
| No. of equal sections in overhang .. .. | 1 | 2 | 1 | 2 | 3 | 4 |
| Percentage error, Method I for overhang .. | 1·0 | — | 1·0 | 0·1 | — | — |
| Percentage error, ,, II ,, .. | 7·0 | 1·4 | — | 1·5 | 0·8 | 0·2 |
| Value of $m_r\,l_r$ ,, .. | 0·975 | — | 0·975 | 0·490 | — | — |

TABLE XVIII.

| No. of equal sections in overhang .. .. | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|
| Percentage error, Method I for overhang .. .. | — | 1·6 | 0·1 | — | — |
| Percentage error, ,, II ,, .. .. | — | 7·5 | 3·2 | 1·8 | 1·1 |
| Value of $m_r\,l_r$ .. .. .. .. .. | — | 0·746 | 0·502 | — | — |

HAND APPLICATOR FOR HIGH-FREQUENCY HEATERS.—In many cases where high-frequency induction heaters are used in vacuum-tube techniques, a means of hand manipulating the work inductor of the high-frequency generator is desirable, and in some instances essential. E.M.I. Factories, Ltd., have introduced a lightweight hand applicator for use in conjunction with their induction heater model EHIOA. This unit is an improvement on the more conventional type of applicator in that it enables the operator to work at a considerable distance —under certain conditions up to 20 ft.—from the generator. Its light weight and the ease with which it can be manipulated reduce fatigue of the operator. Provision is made for water-cooling the work inductor from the generator, and heat exchangers are fitted in the applicator housing to provide cooling of the matching unit and lead-through connectors. A press-button switch in the handle of the applicator gives remote control of the generator.

# THE INSTITUTION OF NAVAL ARCHITECTS.

(*Concluded from page 676.*)

THE ninth and last paper in the programme of the 1952 Spring Meeting of the Institution of Naval Architects was delivered on the afternoon of April 4 by Mr. W. Muckle, M.Sc., and dealt with "The Scantlings of Long Deckhouses Constructed of Aluminium Alloy." As in the case of the preceding paper, the chair was occupied by Mr. L. Woollard, M.A.

### DECKHOUSES OF ALUMINIUM ALLOY.

The investigation covered by the paper, Mr. Muckle explained, dealt with the scantlings of long deckhouses which were not intended to take part in the longitudinal strength of a ship, but which, being attached to the strength deck, must have some stress transmitted to them. Experiments in two American ships had showed that these stresses were very much less than would be forecast by the ordinary theory of bending, partly as a result of "end effect"—due to the fact that the end of a deckhouse must necessarily be free from longitudinal bending stress—and partly due to the presence of door and window openings in the sides of the house. A method was developed for determining the scantlings of longitudinal material in terms of the scantlings given for steel deckhouses by the Rules of Lloyd's Register of Shipping. The paper also discussed the proportions of house side stiffeners, and the riveting of the sides to the decks; and the transverse stiffening of houses as a whole, to resist static and dynamic forces when the ship was inclined to the vertical, and the forces due to wind pressure were considered. Finally, Mr. Muckle presented a comparison of the weights of steel and aluminium-alloy houses, covering different lengths of ships (200 ft. to 600 ft.), and one or two tiers of superstructures. The weight ratio varied from 0·40 to 0·44, indicating that at least 56 per cent. of the weight of a deckhouse might be saved by constructing it of aluminium alloy instead of steel. The conclusion was reached that it was possible to make deckhouses of aluminium alloy as strong as those of steel, and that the factor of safety with the aluminium-alloy house was greater, even in the most unfavourable circumstances, than with the steel house. The greatest thickness of plating required (i.e., for the 600-ft. ship) would be 0·34 in., and it appeared that, even in the largest ships, the thickness would not exceed 0·40 in., so that there should be no difficulty in procuring plates of suitable thickness. Suitable sections were already available, rolled to the scantlings of B.S. 1161; but it was suggested that the range of sections provided by B.S.1161 might be extended with advantage.

### DISCUSSION.

The discussion was opened by Mr. B. N. Baxter, who pointed out that, in the tests on the Philip Schuyler—one of the American ships mentioned, which was 431½ ft. long overall—the main deckhouse was of steel and was about 17 per cent. of the length of the vessel. Above it were two very small deckhouses. The main dimensions were: moulded beam of ship, 56 ft. 10⅝ in.; width of main deckhouse about 39 ft.; width of upper deckhouses, about 11 ft. The main deckhouse was divided into virtually three separate parts by side openings, and it was found that the stresses in the two forward portions, as measured at a height of 6 in. above the main deck, had low values at the ends, but rose to a peak value at the centre, of about 73 per cent. of the theoretical stress. This theoretical stress was calculated on the assumption that the material in the deckhouses was ineffective. The stress values fell to about 56 per cent. at the top of the deckhouse side plating. In the deck plating forming the top of the main deckhouse, the stress values fell from about 30 per cent. of the theoretical values at the deck edge to about 7 per cent. near the deck centre. In the tests of the President Wilson, which was 608·9 ft. long overall, the main deckhouse above the boat deck was of aluminium and was about 23 per cent. of the length of the vessel. Above it was a smaller aluminium deckhouse. The main dimensions were: moulded beam of ship, 75 ft. 6 in.; width of main deckhouse, 42 ft.; width of upper deckhouse, 32 ft. The deckhouses were found to be about 60 per cent. effective in reducing the stress in the top flange of the main hull girder, and the actual reduction in the stress value was about 25 per cent. The measured stress in the top of the aluminium deckhouse was about 25 per cent. of the theoretical value.

In both experiments, and in strength experiments generally, it was found that the deck stresses decreased from the deck edge to the deck centre. Due to this reduction, and the fact that it was at the point of contact between any deckhouse and the main deck that the transference of stress took place, it was suggested that an important factor in the reduction of both tensile and compressive buckling stress was the amount by which the deckhouse side plating was set back from the main deck edge. The amount set back would not reduce appreciably the contribution of the deckhouse to the strength of the main hull girder, but it might produce an appreciable reduction in the deckhouse stresses, particularly at the corners, and thus permit a reduction in scantlings.

Dr. E. C. B. Corlett, referring to experiments which had been carried out in collaboration with the Aluminium Company of America, said that they were done for steel and aluminium superstructures on a box-girder hull, and the results confirmed the fact that Mr. Baxter mentioned. There was no difference between the aluminium superstructure and that of steel in comparison with the simple beam theory, and it was obvious that the major factor was how far the sides of the deckhouses were inset from the deck edge. If the side shell was continued up from the deck edge, there was no reason to expect that, apart from the effects of openings, there would be any stress as derived from the ordinary beam formula. In the paper, the author compared the minimum mechanical properties of aluminium alloys with the mean values for steel. In Dr. Corlett's opinion, that was illogical; he suggested that compatible stress levels should be used for the two materials, using a maximum and minimum in both cases and means in both cases. He agreed with Mr. Muckle that, from considerations of longitudinal tensile strength, it was more than sufficient to use the same scantlings for steel and aluminium; but was it reasonable to compare the buckling factors of safety for aluminium and steel, and thus to derive the required thickness of aluminium? Did the working load in the steel bear any real relationship to the buckling load as derived from the thickness of the material, which had been decided on grounds of longitudinal tensile strength? Had Lloyd's Register considered the buckling of deck plating in deriving that scantling? He suggested that they had not. In dealing with transverse material, as Mr. Muckle had said, in many cases the deflective objection was not a consideration in design. Some supposed that to increase the deflection of the deck by 15 per cent., in going from steel to aluminium, might lead to trouble with joinery work; but, calculating it, the increase of deflection in a typical deck beam was only from ⅓ to ½ in. A further factor was that the deckhouse tables of Lloyd's Register were based entirely on the use of ordinary angles; but he suggested that an aluminium channel, for instance, would give an appreciable increase in the local buckling factor of safety compared with a steel angle. In fact, by using advanced sections to replace the ordinary angles which were quoted in the Lloyd's Register tables, the scantlings derived for equal strength gave moments of inertia for the stiffener and plating combination which did meet Mr. Muckle's requirement of equal stiffness.

Professor E. V. Telfer observed that the work on the Philip Schuyler showed that the ordinary beam theory certainly did not apply to a deckhouse structure, and that the theory which Mr. Muckle had adopted from Dr. James Montgomerie only applied to a superstructure. He made a distinction between "superstructure" and "deckhouse," because the former extended out to the ship's side. It seemed a little illogical, therefore, that the rest of the paper should be based on a foundation that lacked scientific justification in the case of a deckhouse built on the deck of the ship, and away from the main structure.

Mr. A. J. Johnson thought that, in a long superstructure, end effect might be negligible over a considerable section of the centre length. The statement regarding stress relief in a superstructure, due to the cutting of openings in the house sides, was probably true in a general sense, but those effects should not be exaggerated—and, of course, such openings would be accompanied by stress concentrations of magnitudes depending upon the particular type of design. Mr. Muckle had said that the theory proposed in Lyndon Crawford's paper on "Theory of Long Ships' Superstructure" (*Trans. Soc. of Naval Arch. and Marine Eng.*, 1950) should enable the stresses in a house to be determined; but the analysis carried out in that paper was based entirely upon the concept of simple beam theory. Work being carried out by the British Shipbuilding Research Association suggested that, for the general superstructure problem, that was inadequate, and that a satisfactory solution could be achieved only upon the basis of plane stress theory. Mr. Johnson suggested, therefore, that the method proposed in that paper should be used with caution. Mr. Muckle gave 3 tons per square inch as the greatest stress ever likely to occur in the top deck of a two-tier structure. More information as to how that figure had been arrived at would be welcome.

Mr. Muckle accepted as a criterion for his calculations the results of experiments on the President Wilson, and took the stress in the top superstructure deck as 50 per cent. of the theoretical value (presumably, according to beam theory). In some respects, that criterion might be misleading. The President Wilson had a composite steel-aluminium superstructure, and the structural arrangements were not necessarily typical or in line with much British construction. In very long superstructures without expansion joints, there was some evidence that actual stresses were not far removed from those predicted by simple beam theory; therefore, the stresses and deflections given in that connection might be rather optimistic. A closer examination seemed desirable of the assumptions made regarding the boundary conditions of sheathed and unsheathed plating. The conclusion was reached that, using the same spacing of rivets, the stress in aluminium-alloy rivets connecting aluminium-alloy deckhouses would be less than half that in steel rivets. It was difficult to be sure of that, on the basis of the simple calculations used. The distribution of shearing stress along the base of a superstructure might be complex, and depended upon a number of factors. The distribution of shearing stress along the base of an aluminium deckhouse might be somewhat different in character from that for steel, and not necessarily more favourable at all positions. In the calculation for transverse rigidity of a deckhouse, the webs were assumed to be encastré at their connections to the main strength deck. Was that a valid assumption?

Mr. T. Garoszynski remarked that Mr. Muckle had shown that, in any ordinary ship, it was unlikely that the tensile stresses would reach the point of failure; therefore, the buckling resistance was really the criterion for determining the thickness of the aluminium deckhouse plating. The method which Mr. Muckle used seemed to be reliable, and therefore his table of minimum thicknesses was a good guide. His method of considering the criterion of failure of plating as the stress in the plate itself was attractive, but what sort of curve did he assume for a panel of plating with fixed edges? A rather peculiar aspect emerged from examination of the diagrams dealing with thickness. A panel of certain thickness with supported edges, when subjected to compression, would have a lower total stress than a similar panel with fixed edges, and, if stress were accepted as a criterion, the strength of a panel, say, 0·25 in. thick for steel and 0·35 in. thick for aluminium, appeared to be reduced by providing fixity at the edges. Mr. Muckle's approach to the mechanism of failure of a panel of plating under compression had been broadly confirmed by experiments carried out by Lloyd's Register. A panel of plating under compression could sustain considerable deflection without any harm, provided that the stresses in the plate were within the elastic limit. The efficiency and deflection of such a panel with riveted connections at the boundary appeared also to be in

# EXHIBITS AT THE MECHANICAL HANDLING EXHIBITION.

Fig. 9.

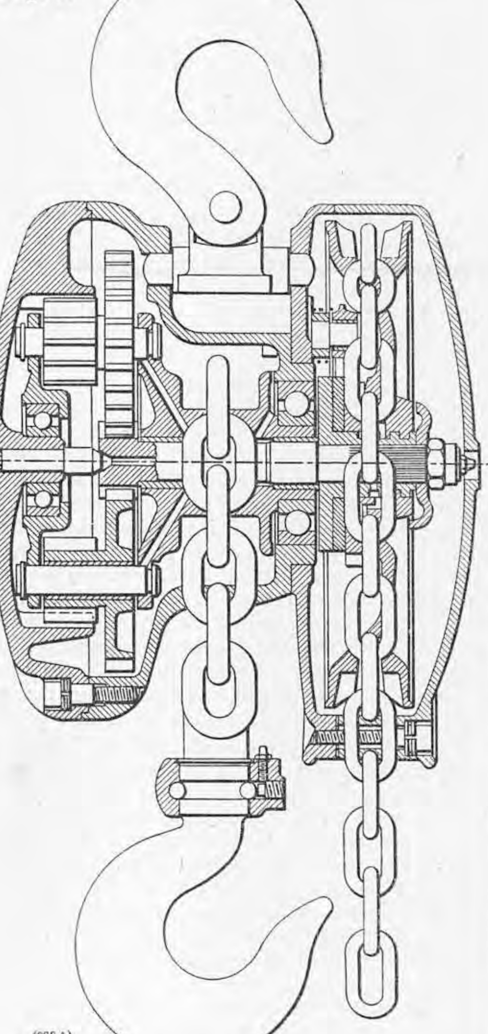


FIG. 9. GEARED PULLEY BLOCK; HERBERT MORRIS, LIMITED.

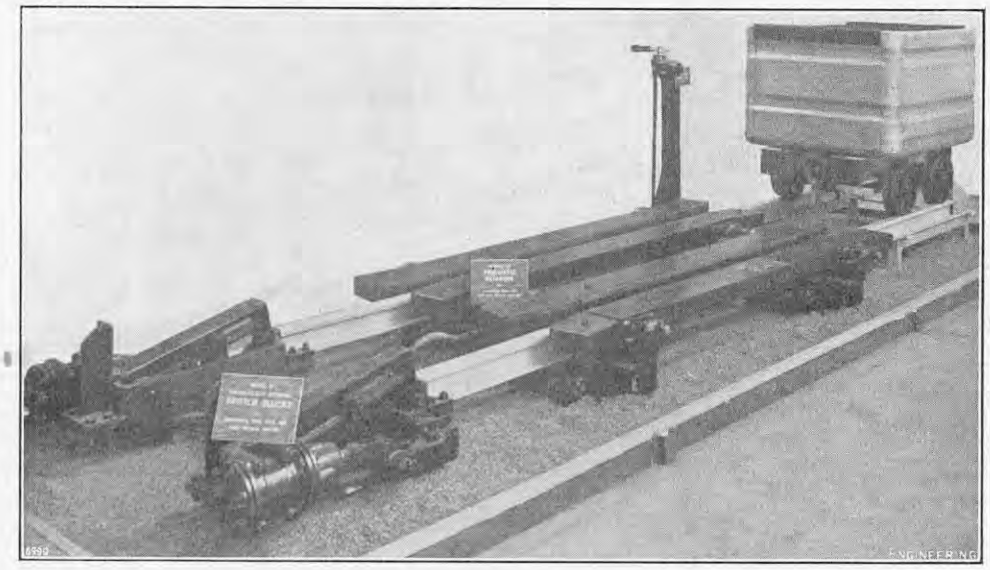


FIG. 10. RETARDER AND SCOTCH BLOCK; WESTINGHOUSE BRAKE AND SIGNAL COMPANY, LIMITED.

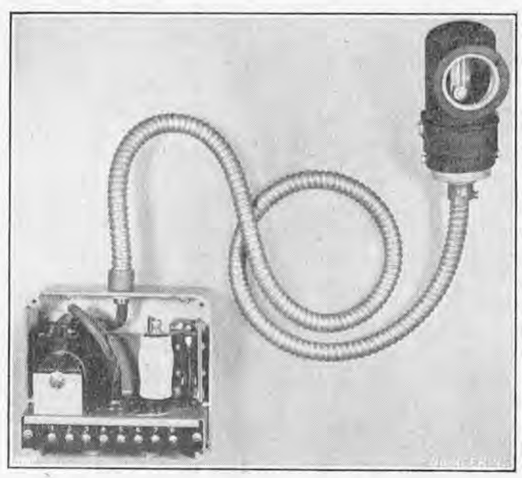


FIG. 11. PHOTO-ELECTRIC RELAY; BRITISH THOMSON-HOUSTON COMPANY, LIMITED.

reasonable agreement with the theory presented by Mr. Muckle in 1949.

Captain J. P. Thomson said that light alloys were of great benefit where magnetic compasses were concerned. The maintenance of superstructures in steel was a serious item, and the adoption of a light alloy should reduce that problem considerably. In the ships of the major oil companies there were very long gangways, and gangways 45 or 50 ft. long, in light alloy, were behaving very satisfactorily. In the future, tank lids and many similar fittings might also be made of that material.

The author, in his reply to the discussion, referred to the suggestion by Dr. Corlett that, in a large passenger ship with a promenade deck attached to side plating carried up from the main hull, there would be no reduction of bending stresses. That would be so, he thought, if the promenade deck covered a sufficient length of the structure. He was investigating, experimentally, the effect of length of superstructure on the stress distribution in it. Professor Telfer doubted the theory submitted. The paper attempted to put forward scantlings for long deckhouses in aluminium alloy. Those deckhouses were now being built, and it was not unreasonable to try to reduce to some system suitable scantlings for those houses. That might have been done by applying a lot of very complicated theory; but, as naval architects often worked on a comparative basis, they could not be fundamentally unsound in trying the calculations made on a certain theory in steel with one made on the same theory in aluminium alloy. Mr. Muckle added that he would reply in writing to the rest of the discussion.

## MECHANICAL HANDLING EXHIBITION.

(*Continued from page* 678.)

We continue our description of some of the exhibits at the third Mechanical Handling Exhibition at Olympia, which was opened on Wednesday, June 4, by the Minister of Labour, the Rt. Hon. Sir Walter Monckton, M.P. The exhibition will remain open, except on Sunday, until Saturday, June 14.

### PULLEY BLOCKS AND HOISTS.

Messrs. Herbert Morris, Limited, Loughborough, are showing a wide variety of handling equipment, including electric and hand-operated pulley blocks, hoists and trolleys, stacking machines, and a portable jib crane. One of their triple-gear pulley blocks is sectioned, as illustrated in Fig. 9, above, to show the working parts. The frame comprises three components spigoted and bolted together to form a rigid concentric unit. One of the frame members has formed on it an annular gear comprising the stationary member of an epicyclic train. Engaging with this gear are two pinions integral with two planetary gears which are both driven by a pinion cut on the driving shaft operated by the hand chain. The two planetary gears are mounted in a pinion cage integral with the load wheel, which runs on ball bearings, driving the load chain. With the exception of the annular gear, the pinions and spur gears are all machine-cut from heat-treated alloy steel. An automatic brake, of the screw and disc type, is fitted. Both hooks are forged steel stampings. To facilitate suspension, and to allow free rotation of the block, the top hook is hinged to a headed swivel pin. The load hook rotates on a ball bearing. The chains are of electrically-welded heat-treated steel. Grease-gun lubrication is provided. These compact and efficient pulley blocks are available for working loads ranging from $\frac{1}{4}$ ton to 20 tons. Also on view is an electrically-driven hoist block suspended from a four-wheel trolley designed for running on a rolled-steel joist or track. The travelling motion is obtained by pushing on the load that is being handled. It is available for working loads ranging from $\frac{1}{2}$ ton to 2 tons, with a clear height of lift of 20 ft. and a hoisting speed of 30 ft. per minute, with an alternating-current motor for operating on voltages between 200 and 500 volts. The motor is totally enclosed and detachable; the frame is extended to house the contactor and an automatic electro-mechanical brake. The motor drives, through a non-metallic helical pinion, an intermediate shaft and thence, through spur reduction gearing, the rope drum. All the rotating shafts run in ball bearings.

### PNEUMATIC GEAR FOR CONTROLLING MINE CARS.

The Westinghouse Brake and Signal Company, Limited, 82, York-way, King's Cross, London, N.1, are demonstrating examples of pneumatic handling equipment used in coal mines. Two of their working exhibits, illustrated in Fig. 10, consist of a Model 10 retarder and scotch block, for controlling the larger tubs and mine cars that are being used increasingly in coalfields in this country and abroad. The retarder comprises hinged brake bars, parallel to the running rail, arranged so that they can be brought into contact with the inside and outside of each rail tyre a few inches above rail level. To brake the wheels, the brake beams are forced together, gripping the wheels by pneumatic cylinders acting through suitable linkages. There are two brake beams on each rail, so that the pairs of wheels on either side of the mine car are gripped independently and, therefore, there is no side thrust on the wheels tending to force them out of the vertical. Since the apparatus is for use at pit bottoms, where space is restricted, the operating cylinders are located between the rails. A single control valve is required to operate the retarder, irrespective of its length. A non-working exhibit is a pneumatic ram forming part of the Westinghouse pneumatic decking system, which enables mine cars and tubs to be loaded and unloaded into the cages, with considerable savings in time and man-power. Also shown on the stand is a control panel of typical valves and components for industrial pneumatic systems. Pneumatic pressure for the working exhibits is provided by a standard Westinghouse type E.13C compressor fitted with a three-phase motor which operates from a single-phase supply through a Westinghouse static phase converter.

### Electrical Control Equipment.

The British Thomson-Houston Company, Rugby, are showing a wide range of electrical equipment for use in mechanical-handling installations, including an electric crane and hoist control, various industrial electric motors, control gear, and a working model of the Ransomes and Rapier walking dragline, which is believed to be the largest in the world. They are also demonstrating a photo-electric counter and sorter for counting cans on a moving conveyor and checking their labels. The counting mechanism consists of a type-G photo-electric relay, and an external photo-cell holder, as illustrated in Fig. 11, and a lamp projecting a beam of light across the conveyor which is received by the photo-cell. When the beam of light is interrupted by the passage of a can, the photo-electric relay energises a six-figure electromagnetic counter. This mechanism is suitable for counting up to 400 per minute, but another type of electronic counter is capable of counting at the rate of 25,000 per minute. For detecting and ejecting unlabelled cans, another photo-electric cell detects the difference in the light reflected by cans with and without labels; when an unlabelled can passes, the photo-electric relay operates an electromagnetic ejection mechanism which removes the unlabelled can from the conveyor line.

The use of Stacreep control to give stable creeping speeds with alternating-current motor drives is being displayed by the British Thomson-Houston Company, who are demonstrating a crane crab made by Messrs. Joseph Booth and Brothers, mounted on rails about 14 ft. above the ground; and also by the Wharton Crane and Hoist Company, Limited, Reddish, Stockport, in co-operation with the Metropolitan-Vickers Electrical Company, Limited, who are demonstrating a 10-ton three-motor heavy-duty overhead electric travelling crane of 40 ft. $7\frac{1}{2}$ in. span. Stacreep control consists of a spring-loaded thrustor-controlled brake with the thrustor connected across the main motor slip-ring. When the main motor is energised initially, the thrustor lifts the brake shoes clear of the drum and allows the motor to accelerate. As the motor accelerates, the rotor frequency and the speed of the thrustor motor fall. The brake is therefore applied gradually until the load and braking torque are balanced against the motor torque. Stacreep control is normally arranged to be effective on the first two notches of the controller. Thereafter the thrustor is energised from the main supply so that the brake is completely lifted.

### Electric Motors.

The Metropolitan-Vickers Electrical Company, Limited, Trafford Park, Manchester, are showing 2-h.p. and 15-h.p. motors from the KNB range of squirrel-cage motors with standardised fixing dimensions which have been developed in co-operation with other British electrical manufacturers to satisfy the need for interchangeability with American and Canadian-built motors. KNB motors are available in eight frame sizes from 1 h.p. to 20 h.p. for four-pole machines. They are also showing a 50-h.p. 500-r.p.m. totally-enclosed direct-current steelworks auxiliary motor developed recently, which is lighter and more efficient than their older types, and has better commutation, improved insulation, and a higher maximum safe speed. They are also demonstrating a 4-in. alternating-current electromagnetic Perigrip brake on a 2-h.p. squirrel-cage motor.

### Automatic Screening, Weighing and Bagging Plant.

Messrs. Robert Cort and Son, Limited, are showing an automatic screening, weighing and bagging unit for loading coke into bags, which has been developed for the gas and coke industries. In this unit, shown in Fig. 12, on page 716, the coke from an overhead storage bunker falls on to a single-deck oscillating screen, for de-breezing or re-screening before loading. The screened coke is delivered into a chute which discharges into the feeder of an automatic bagging and weighing machine. A high- and low-level electrical mechanism in the chute controls the motor driving the screen so that the latter is started and stopped automatically to maintain sufficient material in the chute to allow for continuous operation of the automatic weighing and bagging machine. The firm are also showing a single-gate rotary gas valve for use in gas distribution services and work, a heavy-duty balanced screening conveyor, and a single-deck balanced oscillating screen.

### 5-Ton Diesel Locomotive Crane.

Messrs. Thomas Smith and Sons (Rodley), Limited, Crane and Excavator Works, Rodley, Leeds, are showing a self-contained Diesel locomotive crane with a 40-ft. jib, designed to lift, with a single-fall rope, loads ranging between 5 tons at 16-ft. radius and 1 ton at 40-ft. radius. The crane is illustrated in Fig. 13, on page 716. With a 5-ton load, the maximum hoisting speed is 120 ft. per minute, the maximum travelling speed is 250 ft. per minute, and the crane can slew through a full circle in 30 seconds. Power is supplied for the various motions by a Diesel engine developing 70 brake horse-power at 1,250 r.p.m. The power unit and the machinery are carried on a steel superstructure, which rotates on a live ring of tapered rollers. The carriage is an electrically-welded steel box-type structure. Fixed axle bearings are incorporated in the construction of the carriage, and support the two rail-wheel axles. Two pairs of steel-tyred rail wheels are carried on each axle, one pair being arranged, within the side frames, to travel on 4-ft. $8\frac{1}{2}$-in. gauge tracks. The other pair of wheels are of smaller diameter, and are mounted outside the carriage side frames to enable the crane to run on wider tracks.

The drive is conveyed to the carriage through a centre pin to a pair of bevel gears which drive each axle through spur gearing. Power from the Diesel engine is transmitted smoothly to all motions through a hydraulic coupling and plate clutch. Separate hoisting and slewing clutches are fitted, and a multiple machined jaw clutch is provided for the travelling drive. From the hydraulic coupling the transmission is through a chain drive running on ball and roller bearings in an oil-tight gear case. Hoisting and lowering are controlled by the combined use of the hydraulic coupling and a rope-barrel toggle clutch. The 40-ft. jib, of double lattice construction, is provided with suspender plates on the jib head for operating a ring discharge grab.

### Mobile Mechanical Shovel.

The Chaseside Engineering Company, Limited, Station Works, Hertford, are showing a new mechanical mobile shovel with hydraulic winch control. The shovel, which is illustrated in Fig. 14, on page 716, is powered by a Fordson tractor engine. The drive to the rear axle is through a gearbox giving six forward speeds, ranging from 1·7 m.p.h. to 10·75 m.p.h. at 1,600 r.p.m., and two reverse speeds. The maximum draw-bar pull of the vehicle is 6,000 lb. Scoop capacities of $\frac{1}{2}$ cub. yard, $\frac{3}{4}$ cub. yard, and 1 cub. yard are available. Under test, the shovel has raised a 1-ton load through 10 ft. in 3·6 seconds.

The shovel is available with either a fixed jib or a movable jib for manœuvring where headroom is restricted. The side arms are pivoted on the main frame by a 2-in. diameter steel shaft at the same point as the jib mounting. To ensure long life for the scoop-trip rope, anti-friction rollers are fitted to the fairleads. The scoop is of $\frac{1}{4}$-in. steel plate with a manganese-steel toe plate and three toughened runners. Reinforced scoops for handling consolidated material, heavy-duty scoops with hardened steel teeth, and other scoops for special duties can be supplied.

The hoisting mechanism comprises a hydraulically controlled chain-driven friction winch housed in the rear end of the machine. Pressure for operating the winch control gear is supplied by a geared constant-delivery hydraulic pump using the rear-transmission oil after it has passed through a magnetic filter. To avoid the ingress of dirt, the pump and control valve are inside the main transmission housing. The winch control gear comprises a hydraulic ram which actuates a cam in which the drum-shaft bearings are mounted. This causes the cast flanges of the drum, which form two large friction wheels, to be engaged with friction rollers on the winch drive shaft. The chain drive to the latter, taken from a sprocket mounted on the side of the transmission housing, is automatically tensioned by a spring-loaded jockey pulley. When hydraulic pressure is released, the winch drum is moved away from the friction rollers, under the action of a counterbalance weight, and is brought into contact with two brake shoes. Overwinding of the winch is prevented by an automatic trip gear. The drum has a total capacity of 300 ft. of $1\frac{1}{2}$-in. circumference hoist rope.

### 10-Ton Mobile Crane.

Messrs. R. H. Neal and Company, Limited, Plant House, Ealing, London, W.5, are showing two mobile cranes, representing their full range which covers capacities from 15 cwt. to 10 tons. Their GM 15-cwt. crane is on view with a 20-ft. lattice jib and a 40-ft. telescopic extension mast. Their type R mobile slewing and derricking crane is displayed with a 75-ft. jib. It can travel with its full load, and can operate without the use of jacks and outriggers. Fig. 15, on page 716, shows the crane with a 30-ft. swan-neck jib. The version on view at Olympia, with a 75-ft. tubular-steel lattice jib, can carry a maximum load of $2\frac{1}{2}$ tons at 26-ft. radius; the crane is also available with a 60-ft. lattice jib, with a maximum load of 4 tons at 21-ft. radius, and with a 45-ft. lattice jib with a maximum load of 6 tons at 16-ft. radius. When fitted with a 30-ft. built-up box-section swan-neck jib, it can lift a 10-ton load at $11\frac{1}{2}$-ft. radius. The crane is fitted with a safe-load indicator which gives visible and audible warning when the permissible load at any radius is reached. The hoisting speeds are 30 ft. per minute with a 10-ton load, using a four-part rope; 60 ft. per minute with a 6-ton load, using a two-part rope; and 120 ft. per minute, with a 3-ton load, using a single rope. It has a slewing speed of 3 r.p.m., and a travelling speed of $5\frac{1}{4}$ m.p.h. in top gear, 3 m.p.h. in middle gear, and 1 m.p.h. in bottom gear.

The undercarriage comprises an electrically-welded steel structure of deep box section, and is mounted on eight heavy-duty pneumatic tyres. The superstructure is also electrically welded, and revolves on five hook rollers. At the rear of the superstructure is mounted the power unit, a 55 to 60 h.p. industrial oil engine, which drives a primary transmission gearbox, from which mechanical drives to the road wheels, hoisting, slewing, and derricking motions are taken through hydraulically-operated disc clutches, and totally-enclosed oil-bath gearboxes. The drive to the rear road wheels is transmitted through a reduction gearbox and a Neal dual automatic reversing differential three-wheel drive, giving three travelling speeds in either direction. Power-operated steering is provided.

The hoisting motion is fitted with a safety unit giving automatic holding of the load; it is provided with a lowering brake designed for smooth operation. High-speed power-operated gear is provided for lowering the empty hook. A single hoist drum is normally fitted, but there is provision for mounting an auxiliary hoist drum for operating a double-rope grab. Full-circle slewing is provided, through plate clutches, bevel and reduction gearing. A friction brake is fitted on the slewing shaft. The derricking motion also is fitted with an automatic safety brake. On cranes with jibs of 45-ft. diameter and less, spring-buffer telescopic back stays are provided to prevent the jib tilting backwards. There is provision for fitting an automatic cut-out to the derricking motion.

*(To be continued.)*

Precast Concrete Road Bridge at Margate.—A steel bridge 90 years old, over the main London-Ramsgate railway line has been replaced recently by a concrete bridge composed entirely of pre-cast members, which were cast in Westgate goods yard. The two main parapet girders span 62 ft. 4 in. on a skew of 32 deg., and are supported on brick abutments 27 ft. 9 in. apart. The girders are 6 ft. deep at one end, 7 ft. at the other and weigh approximately 31 tons each. The largest deck beam measures 30 ft. 9 in. by 3 ft. 6 in. by 1 ft. $7\frac{1}{2}$ in.

# ACHIEVEMENTS IN AERONAUTICS.

Fig. 1. SPEED RECORDS FOR LANDPLANES AND SEAPLANES (SEA LEVEL).

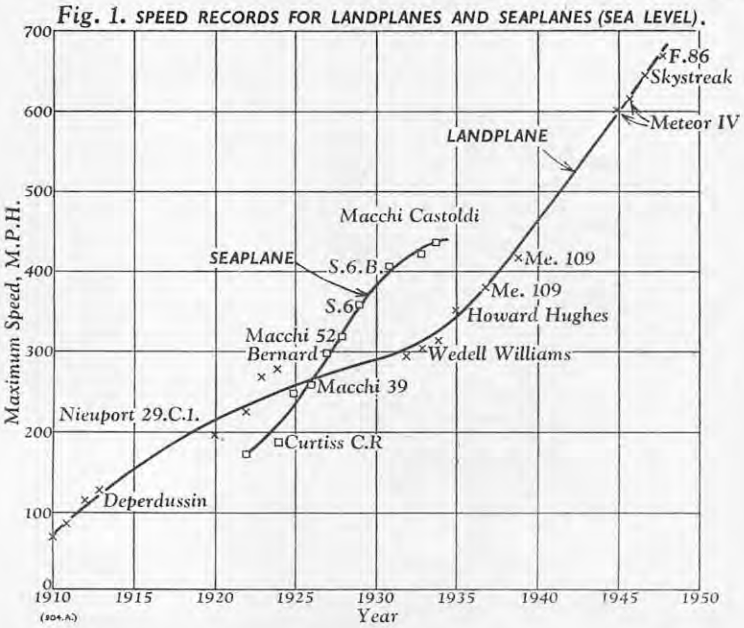



Fig. 2. MAXIMUM SPEED, FIGHTER AIRCRAFT.

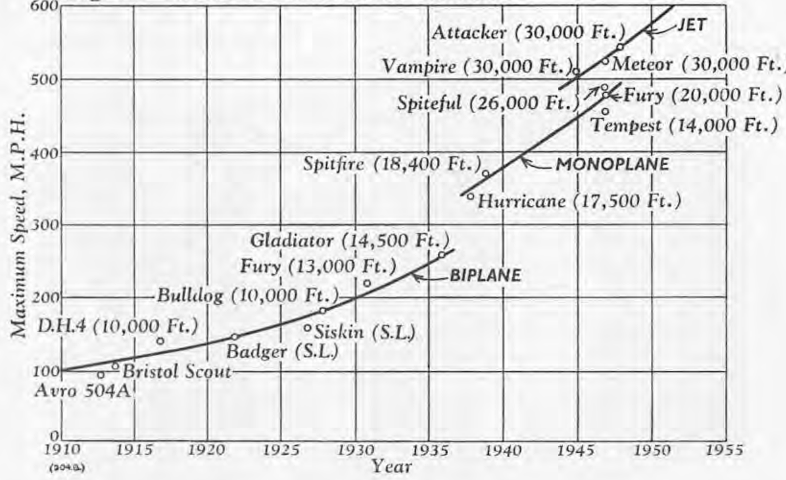
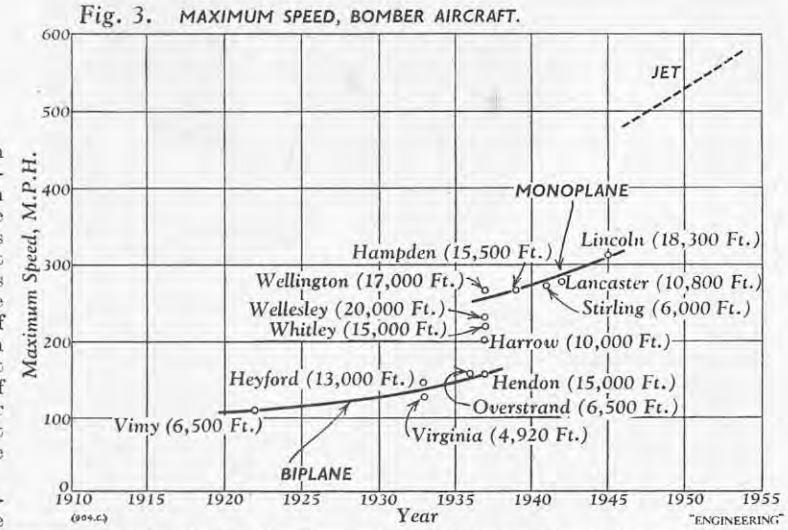



Fig. 3. MAXIMUM SPEED, BOMBER AIRCRAFT.




## PROPHECY AND ACHIEVEMENT IN AERONAUTICS.*

By SIR HARRY M. GARNER, K.B.E., C.B., M.A., F.R.Ae.S.

THERE have been a number of occasions in the history of aeronautics when engineers and scientists of outstanding ability have suggested that the end of development in one direction or another was being reached. Their fears have afterwards proved to been unfounded.

Looking at a record of aircraft speeds during the past 40 years (Fig. 1), it is generally found that a simple curve has been drawn through a set of scattered points, suggesting that progress has been smooth and continuous. In fact, progress results firstly from the gradual improvement in knowledge of materials, structures, aerodynamics and engine design, and secondly from inventions that make radical alterations to the design of the aeroplane. Examples of these inventions are the unbraced monoplane and the turbine engine, neither of which could have been produced without the steady development of new materials capable of taking high stresses. Thus progress in aeronautics may be thought of as consisting of gradual improvements broken at intervals by distinct steps.

One of the earliest problems that engaged the speculation of scientists in aeronautics was that of the so-called "square-cube" law. The weight of similar structures increases as the cube of their linear dimensions, whereas the load-bearing capacity increases as the square. Thus a structure becomes steadily weaker as the size increases. In the early days a number of theories were put forward on the limitations of weight and size of aircraft. In 1912 A. R. Low suggested that the limiting all-up weight of an aeroplane would be a little over 2,000 lb.

Lanchester, in 1914, expressed the view that a span of about 100 ft. was the best value for economic flight. It remained for Durand, 1918, to put the square-cube law in the right perspective. After pointing out that the details of design could be more refined in a large aeroplane, he concluded that there was no reason to apprehend any particular limit in size.

Under present conditions, the limiting weight would be about 1,000,000 lb. The reasons for the tremendous increase that has taken place, even since 1918, are many. Farren, in 1943, in a detailed comparison between the biplane Handley Page 0/400, the largest bomber of the first World War, and the monoplane Lancaster, the most successful British bomber of the second World War, found a large reduction in structural weight in spite of the increased complexity of retractable undercarriages, flaps, wheel brakes and other devices. Marked improvements in engine design, which enabled an increase of 70 per cent. to be made in the ratio of power to weight, were also a major factor.

The reduction of structural weight was mainly caused by better distribution of the component masses along the wings and body, improvements in materials and increases in wing loadings. Improvements in materials have had a large effect both on air-frames and engines. The strength of aluminium alloys increased from a maximum stress of 5 tons per square inch in 1900 to 25 tons per square inch in the first World War and to 30 tons per square inch in the second, with possibilities of 40 tons per square inch to-day. More significant still is the increase in proof stress from 15 tons per square inch in the first World War to nearly double that value to-day.

Increases in wing loadings, made possible by the provision of long concrete runways suitabe for high take-off and landing speeds, and the use of high-lift flaps, have made a greater contribution to improvements in aircraft than any other factor. The wing loading of the Lancaster was 50 lb. per square foot, as compared with 8 lb. per square foot for the Handley Page 0/400, and $1\frac{1}{2}$ lb. per square foot for the Wright brothers aeroplane in 1903. Wing loadings to-day for bomber and transport aircraft may be as high as 100 lb. per square foot with landing speeds of 150 m.p.h. or higher. The increase in wing loadings, combined with the improvement of materials, finally decided the question of monoplane versus biplane. Even as late as 1929, convincing reasons were put forward in favour of the biplane, but within the next ten years the monoplane with stressed-skin construction and high wing loading had become supreme both for military and civil use.

The achievement of high speed is the quality in which the aeroplane is ahead of all other forms of transport. The speed records for landplanes and seaplanes from 1910 to 1948 are shown in Fig. 1. The marked superiority of the seaplane over the landplane during the period 1927 to 1934 was caused by the stimulus of the Schneider Trophy Contest, in which the take-off and landing requirements were limited to smooth-water conditions. The seaplanes were able to take-off and land at much higher speeds than were possible with landplanes, which at this time were restricted to short runways and had not generally the advantages of wheel brakes and landing flaps.

At all stages the achievements in speed have outstripped the prophecies of the experts. Lanchester, in 1914, thought that some years would elapse before speeds much higher than 120 m.p.h. would be reached. Ten years later this speed was more than doubled. In 1923, Glauert and McKinnon Wood made a close examination of the speeds of racing aeroplanes. They concluded that "the highest speed attainable with the present type of engine is a little over 300 m.p.h. when the stalling speed does not exceed 85 m.p.h." This report seems to have been the first to draw attention to the significance of the ratio of the top speed to stalling speed. The value of 4 to 1 was one that most aircraft designers would have been happy to achieve for some years after this report was written. To-day, improvements in wing sections, the use of high-lift devices to give lower stalling speeds, and the development of engines with much higher thrusts for a given cross-sectional area, have enabled ratios of 5 to 1 and higher to be obtained. The main increase in top speed has been achieved, as the report clearly foresaw, by increases in wing loading, which have led to higher take-off and landing speeds.

Speed records for aircraft, such as those plotted in Fig. 1, have always been confined to flights near the ground. Now that flights at and beyond the speed of sound are possible the advantage of flying near the ground disappears. Because of the higher density of the air near the ground the structural loads are higher and the effect of gusts, even on the calmest day, makes flying extremely dangerous. A curve of the maximum speeds of fighter aircraft at their operational height is shown in Fig. 2. The heights start, with the early aircraft, at 10,000 ft. or lower and go up to 30,000 ft. or higher for modern aircraft. In these curves are two major discontinuities, one of which took place round about 1935 and the other round about 1945. The first was the result of great changes in shape and structure. The change to monoplanes in 1935 led to an advance in structural and aerodynamic design probably more important than at any other stage in aeronautical development. The cleanness of skin-covered metal wings and fuselages emphasised the high drag of exposed undercarriages, and the structural complexity of retractable undercarriages was seen to be worthwhile. Attention was concentrated on those parts of the aeroplane which gave high drag, such as bad nacelle fairings and windscreens. The introduction of flats led to a reduction in wing area and to still lower drag.

The second break in the maximum-speed curve was the result of the invention of the gas turbine. The turbo-jet gives a high thrust for its weight and cross-sectional area and does not need the elaborate separate cooling systems of the piston engine which create additional drag. Apart from these direct advantages, the abolition of the propeller has been of great value in removing a source of disturbance of the flow over the wings and its attendant drag, and in removing a source of instability, caused by the forward fin effect of the propeller which has to be balanced by increased fin area at the rear.

The corresponding speeds for bomber aircraft are shown in Fig. 3. There is a break round about 1935 similar to the break in fighter speeds, again the result

* The 40th Wilbur Wright Memorial Lecture, presented at a meeting of the Royal Aeronautical Society in London on Thursday, May 29. Abridged.

## LIGHTWEIGHT HIGH-PRESSURE AIR COMPRESSOR.

HYMATIC ENGINEERING COMPANY, LIMITED, REDDITCH, WORCESTERSHIRE.

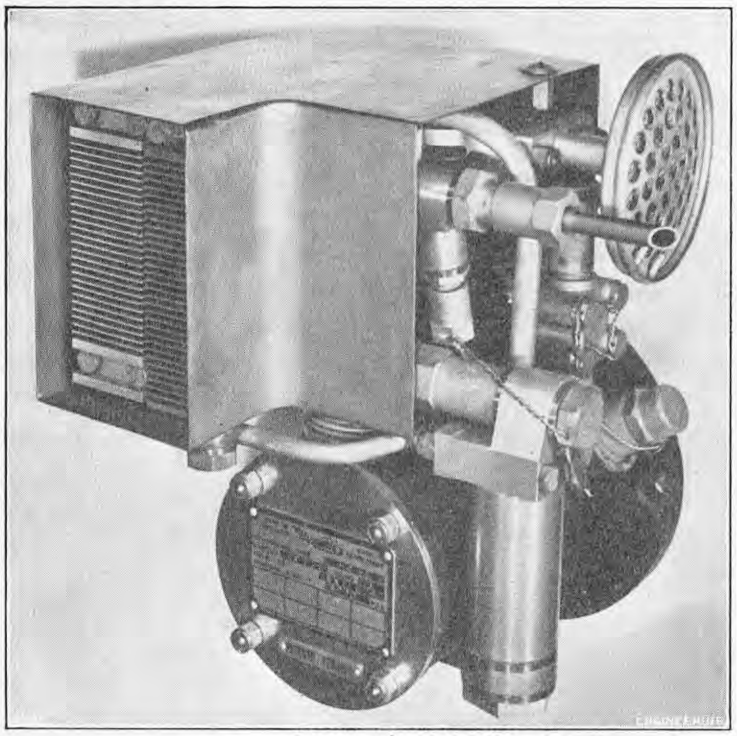


FIG. 1. COMPRESSOR WITH INTER-COOLER, ETC.

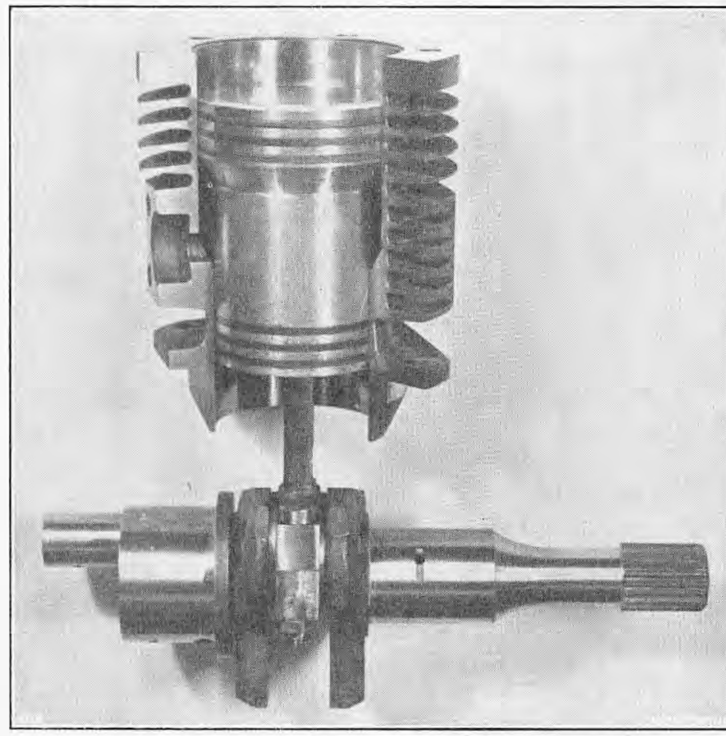


FIG. 2. CRANKSHAFT AND CYLINDER ASSEMBLY.

of the introduction of the monoplane, and a second break resulting from the introduction of the turbo-jet.

In piston-engine design much of the improvement that has taken place in the ratio of weight to power is the result of increasing power by multiplying the number of cylinders without increasing the engine scantlings in proportion and without serious increase in the weight of auxiliaries. In the smallest engines the improvement has been less marked. The first engine used by the Wright Brothers had a weight per horse-power variously given as from 7 to 15 lb. per h.p., but the Manly water-cooled radial engine, used on the Langley "Aerodrome," had the remarkably low weight per horse-power of 3·6, the weight including the radiator and petrol tank. This does not compare badly with the modern average value of 2·4 for air-cooled engines of about the same power.

The main effort of engine designers has been concentrated on engines of ever-increasing power and on the problem of maintaining power at height. The present weight of 1 lb. per horse-power for large engines is commendable, in view of the complexity of the engine with its supercharger, variable-pitch propeller and accessory drives. Improved fuels, synthesised from petroleum with the addition of tetra-ethyl-lead, have allowed high cylinder pressures to be used to give more power from a given size of cylinder. Equally important contributions were made by the new ferrous and non-ferrous alloys.

Improvements in specific fuel consumption of the piston engine have not been so spectacular. The specific consumption of the modern engine is about 20 per cent. below that of the early engines. The requirement for low consumption conflicts with that for low weight to power ratio, and the modern engine has to provide many ancillary services not provided by the earlier ones.

The pioneer work on supercharging aircraft engines was done by Rateau, who had a turbo-blower working successfully before 1918. In 1918 a Rateau type of blower was fitted by the General Electric Company to a Liberty engine, raising the power by about 60 per cent. from 230 h.p. to 365 h.p. Considerable problems at high temperature were encountered in catering for exhaust temperatures of over 800 deg. C.

Some of the earliest experiments on mechanically-driven superchargers, which eventually became the standard type in Great Britain, were made on the Armstrong-Siddeley Jaguar. The mechanically-driven supercharger was brought to its highest stage of development in the Rolls-Royce engines, notably in the Merlin series.

The supercharger has not only enabled large increases in power at height to be obtained, but has also greatly increased power for take-off by making full use of improved fuels as they became available. A useful criterion of the efficiency of an aero-engine is the horse-power per cubic inch of piston displacement. Air Commodore F. R. Banks pointed out, in 1951, that the horse-power per cubic inch has increased from 0·12 in 1909 to 1·34 in 1950, an increase of eleven times.

One of the most difficult problems, shared by engine and airframe designers is that of providing adequate cooling. The early air-cooled engines were in continuous trouble because of the low forward speed, and the engine life was short. The designers of the Supermarine and Gloster entrants for the 1931 Schneider Trophy contest, in order to reduce drag, relied on surface cooling on the wings, body and floats. The cooling was still barely adequate and the view was expressed by a number of people that the speed of aircraft might be limited by the amount of cooling that could be provided. The limit has not, in fact, yet been reached, although it has always seemed to be in sight. The most critical conditions occur on full-throttle climbs, and the engine designer has just been able to avoid trouble on modern piston-engined aircraft by improvements in cylinder design, improvement in liquid and air-cooling installations, and by substantial increases in the permissible operating temperatures for both air-cooled and liquid-cooled engine cylinders.

The gas turbine was introduced at a time when the power output for a given piston engine displacement appeared to be approaching a limit. The weight of a piston-engine propeller combination capable of giving the same thrust as a turbo-jet at 600 m.p.h. at sea level would be more than five times that of the turbo-jet. The gas turbine has introduced the problem of internally cooling the engine, calling for ingenuity in the design of the combustion chamber, turbine and, in some cases, the exhaust system.

The first indications of serious trouble from compressibility came when Hurricanes and Spitfires were dived under combat conditions, and local speeds near the speed of sound were obtained on the upper surface of the wing, causing shock waves and a breakdown in the flow. The effect of compressibility was apparent to the pilot through a rapid change of trim and a deterioration of control.

As speeds increased, the effect of compressibility became important in level flight. The breakdown of flow that occurs as the speed approaches that of sound causes a rapid increase in drag as well as loss of stability and control. After the speed of sound has been passed, the rise of drag is greatly reduced. This led to the theory of the "brick wall barrier." Scientists thought that flight in the region near the speed of sound would be highly unstable and dangerous. If sufficient thrust could be provided to enable the aircraft to pass through this dangerous region quickly there might not be time for the lack of stability and control to make itself felt. Subsequent developments have shown that the difficulties of transonic and supersonic flight are not so serious as the scientists had thought. In particular, flight near and just beyond the speed of sound has been made much easier by the use of swept-back wings, an idea put forward by German scientists during the second World War.

For transonic and supersonic flight the turbo-jet has two great advantages. It has got rid of the propeller, the worst source of compressibility troubles, and it gives a large thrust for a given cross-sectional area and weight. An attempt to make a supersonic aeroplane was sponsored by the Ministry of Aircraft Production in 1943. It failed because it was a few years in advance of its time, and, in particular, because the gas turbine was not sufficiently developed to give enough thrust for its frontal area. The static thrust per unit area of the engine that was available was only 350 lb. per square foot. To-day, gas turbines with axial compressors can be made to give a static thrust per unit area of over 1,200 lb. per square foot. The use of reheat, by burning fuel in the jet pipe, can increase the thrust considerably. There is thus to-day ample power to enable supersonic flight to be attained by aircraft that can be taken off and landed by a pilot without great difficulty.

*(To be continued.)*

## LIGHTWEIGHT HIGH-PRESSURE AIR COMPRESSOR

AN air compressor having an output of 1·4 cub. ft. of free air per minute at a pressure of 3,000 lb. per square inch, and weighing only 10 lb., complete with inter-coolers, relief valves and cowling, has recently been awarded "type approval" for use on aircraft by the Ministry of Supply. It is the first compressor for this pressure to be approved in this way. The design has been developed by the Hymatic Engineering Company, Limited, Redditch, Worcestershire, and although it is intended primarily for aircraft use it is suitable for other applications where the characteristics of compactness, light weight and high pressure are required. The development of the compressor has reached the stage where reliable operation for long periods is assured.

The compressor, known as Type HC. 51, is shown in Fig. 1, above. It is a three-stage air-cooled unit with a normal working pressure of 3,000 lb. per square inch and a maximum pressure, due to the relief-valve setting of 3,300 lb. per square inch. When running at its normal speed of 1,500 r.p.m. and with an output of 1·4 cub. ft. per minute, the air temperature is only 80 deg. C. The compressor can run at 2,000 r.p.m. for periods not exceeding 15 minutes, this permitted over-speed allowing for maximum engine speeds. Under normal atmospheric conditions a cooling-air flow of 85 cub. ft. per minute is required, but when the atmospheric temperature rises to 40 deg. C., as in the tropics, the cooling flow necessary is 150 cub. ft.

# LIGHTWEIGHT HIGH-PRESSURE AIR COMPRESSOR.

HYMATIC ENGINEERING COMPANY, LIMITED, REDDITCH, WORCESTERSHIRE.

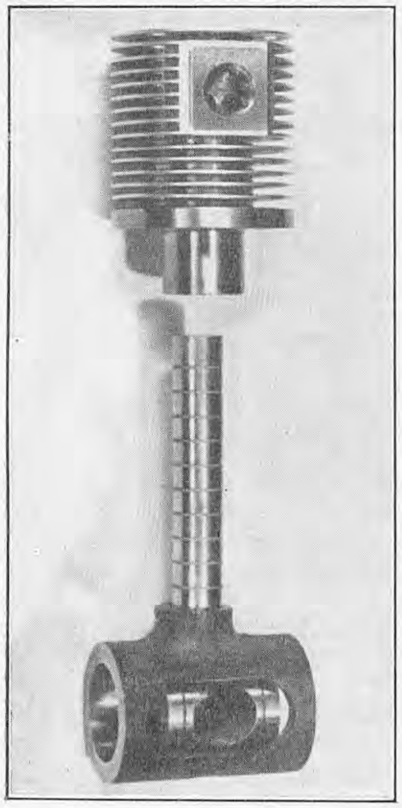


FIG. 3. THIRD-STAGE COMPONENTS.

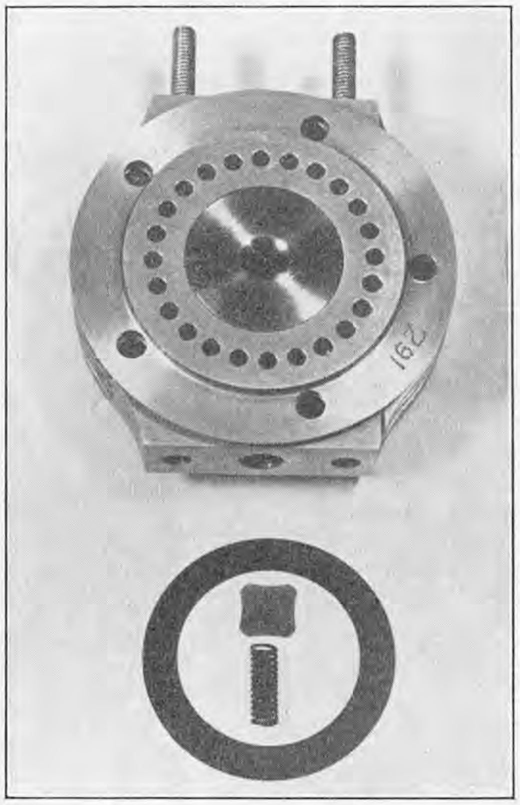


FIG. 4. FIRST-STAGE INLET VALVE AND VALVE PLATE AND SPRING.

Fig. 5.

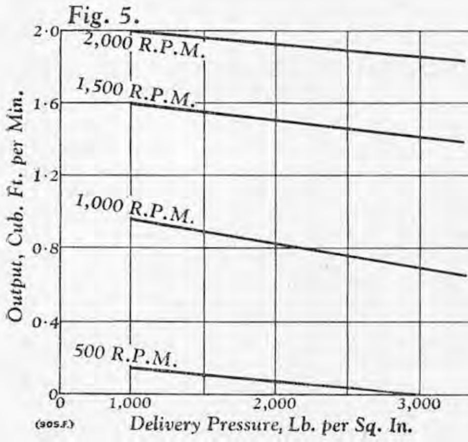



Fig. 6.

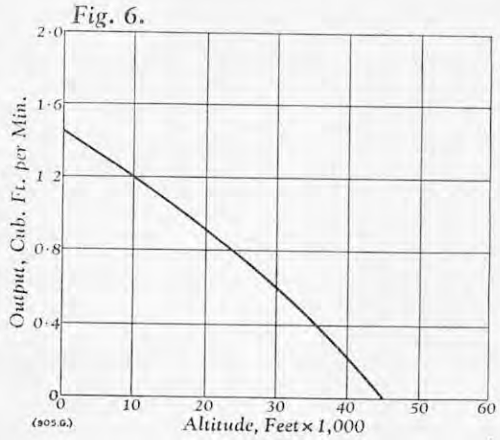
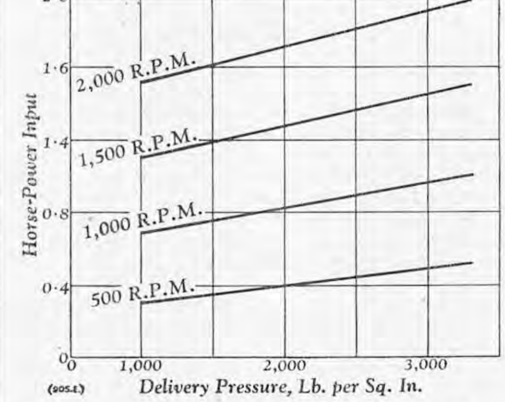



Fig. 7.




per minute. The overall dimensions, excluding the driving shaft, are 6 in. wide, 7 in. long and 8 in. high. Lubricating oil to specification DED. 2479 is supplied to the compressor at pressures of between 30 and 70 lb. per square inch from the gearbox or the engine driving the compressor.

The HC. 51 compressor embodies many of the features which have proved successful in the series of Hymatic compressors standardised in British aircraft since 1940. The most important of these features is the truncated-piston and stepped-cylinder arrangement, shown in Fig. 2, which provides excellent cooling in the second stage, the cooling-surface area being high in relation to the volume. As approximately equal work is done in each stage, the torque fluctuation is reduced and the connecting rod is usefully employed during both strokes. Several problems had to be overcome in the design of the crankshaft and piston assembly (Fig. 2). Lubrication of the upper piston rings depends on the oil which passes the lower set of rings, but at the same time it is necessary to keep to a minimum the amount of oil delivered with the air. Satisfactory control of oil, however, has been achieved and the maximum carry-over is only 5 c.c. per hour. To control the oil consumption and to minimise air losses past the piston rings, the cylinder, which is made from hardened S.28 steel, is finished to extremely fine limits. Close control is exercised over the bore dimensions as well as the concentricity, freedom from ovality and surface finish. The diameters are controlled to 0·0006 in. and combined ovality and eccentricity must not exceed the same figure. The necessity for such accuracy is apparent as the second-stage pressure is about 1,000 lb. per square inch and air at this pressure is trapped between the upper and lower sets of rings.

Air enters the first stage through a filter and then through an annular light-weight plate valve to the first-stage cylinder. After compression, the air is delivered through a plate valve to a cooler and thence to the second-stage inlet valve. Although cooling takes place in the second stage, it is still necessary to cool the air further before it enters the third stage, and finned light-alloy coolers are provided for this purpose. The third stage components, shown in Fig. 3, include a Scotch-crank mechanism to operate the plunger. The motion is thus sinusoidal, and no attempt has been made to balance out the acceleration forces of this system because they are very small and can be safely ignored. The slipper block and crosshead are made from cast iron, a departure from aircraft technique but a combination which has proved satisfactory. A similar material is used for the cylinder, which has aluminium fins bonded to it by the Al-Fin process. The piston, of nitrided steel, is $\frac{3}{8}$ in. in diameter; it has no rings and the gas seal is maintained by using a running clearance of 0·00015 in. Many hundreds of hours of development running were necessary to prove the suitability of various materials, to establish acceptable tolerances and to ensure that the final version of the compressor would meet the arduous duties to which it would be subjected under aircraft operating conditions in all parts of the world. One of the greatest difficulties is the reduction of temperatures throughout the compressor to a level which will prevent oxidation of the lubricating oil.

The parts of the first-stage inlet valve, and a valve plate and spring of the type common to all other valves in the unit, are shown in Fig. 4. The third-stage inlet valve is simply a port in the cylinder. The design of the first-stage inlet valve is particularly important because the compressor must be capable of working to 3,000 lb. per square inch at high altitudes, for which purpose it is necessary to have a valve with a very low pressure loss. The annular valve plate is located in the recess at the top of the first-stage cylinder bore (Fig. 2) and no bias spring is used. The intercoolers are made from light-alloy bar and have closely-pitched fins machined on them. These are very efficient and cool the air to within about 10 deg. of the cooling-air temperature. For example, during normal running with cooling air at 23 deg. C., the air temperature in the high-pressure intercooler is reduced from 143 deg. C. to 33 deg. C. An after-cooler, which is integral with the third-stage cylinder head, reduces the air temperature by about 40 deg. C. This permits the use of a flexible pipe between the compressor and adjacent bulkhead and also serves to reduce the third-stage cylinder temperature.

As the unit will be used on aircraft which might be parked in temperatures below freezing point, it is necessary to ensure that no water collects in the valve ports, pipes or cylinders. During normal operation, water vapour condenses at the base of the high-pressure intercooler, and if no trap were fitted it would be carried over in small drops as long as the unit was running. As soon as it stopped, water would begin to collect in the pipe between the high-pressure intercooler and the third-stage inlet. Condensation also takes place on the walls of the after-cooler, and would drain down into the final delivery-valve mechanism. These problems were discovered by dismantling a frozen unit. To protect the compressor from damage, therefore, two water traps are fitted, one between the second and third stages, shown in Fig. 1, which empties itself through a non-return valve when the unit is off-loaded, and the other at the base of the after-cooler, consisting of a gallery of sufficient size to collect the few drops of water which run down the after-cooler walls. There are two relief valves fitted to the unit, one in the second-stage delivery-valve block and the other on top of the after-cooler. This latter high-pressure valve is of particular interest because of its very small size and low weight. It is loaded by two Belleville spring washers and is set to blow off at 3,300 lb. per square inch, the closing member being a conical plug which mates with a square-edge seating.

The performance of the unit is shown in the three graphs, Figs. 5 to 7. Fig. 5 gives the output at four speeds ranging from 500 to 2,000 r.p.m. over the pressure range, 1,000 to 3,000 lb. per square inch. As would be expected the free-air delivery falls with increasing pressure. Fig. 6 shows the fall in free-air delivery with increasing altitude, and Fig. 7 shows that the power absorbed increases linearly with delivery pressure over the range covered. The peak power is 2 h.p. at 2,000 r.p.m. and 3,300 lb. per square inch. Under normal working conditions the power absorbed is 1·5 h.p. at 1,500 r.p.m. and 3,000 lb. per square inch.

The HC. 51 compressor is being developed for a variety of applications, some of them requiring increased output at high altitudes. This is achieved by boosting or supercharging, the air being obtained from the aircraft-cabin blower or the turbine engine. In another application no cooling air is available and a small high-speed centrifugal fan has been built into the compressor to make it independent of an outside source.

# NOTES FROM THE INDUSTRIAL CENTRES.

## SCOTLAND.

THE LATE MR. G. S. BELLAMY.—Mr. George S. Bellamy, mechanical and electrical engineer of the Scottish Region of British Railways, died in Glasgow on May 31 at the age of 59. Mr. Bellamy joined the service of the Midland Railway at Derby as an engineering apprentice in 1910. On the amalgamation of the railways in 1923 he was appointed freight-trains assistant of the Midland division of the London Midland & Scottish Railway Company, and during the war of 1939-1945 he became mechanical and electrical engineer for Scotland.

"AVON" AEROPLANE-ENGINE PRODUCTION IN GLASGOW.—The Minister of Supply, Mr. Duncan Sandys, in a telegram sent on May 27 to Lord Hives, of Rolls-Royce Ltd., said :—" I am most glad to learn that your Glasgow factory has delivered, exactly on time, the first Avon aero engine off the production line. Please convey my warm congratulations to all concerned in this fine performance."

YACHT BUILT OF GLASS-YARN MATS.—The yacht Salvinia, constructed of glass-yarn mats impregnated with resin, and built by the North East Coast Yacht Building and Engineering Co., Ltd., was on view in Glasgow on May 29. The yacht is to be put through sailing trials on the Clyde in the near future.

GLASGOW CORPORATION WATER DEPARTMENT.—The annual inspection of the water works of Glasgow Corporation was carried out by the members of the Water Committee and guests on Wednesday and Thursday, May 21 and 22. The Loch Katrine scheme, which at present supplies Glasgow with about 80 million gallons a day out of a total of approximately 85 million gallons a day, is now approaching its centenary. Glasgow has expanded so much, however, that in spite of increasing the capacities of Loch Katrine and the aqueducts to the city, the original gravitation scheme has proved insufficient to meet modern requirements, and has been supplemented by additional service reservoirs, pumping stations, trunk mains and water towers. The completion of the new East Main, which supplies many new housing and industrial developments, has brought about a considerable increase in consumption, and it is anticipated that the new West Main, at present under construction, will increase this still further. It is now essential to ensure that additional supplies will be available to meet the anticipated growth of the demand, and it will be necessary to obtain additional water from a new catchment outside Loch Katrine. The proposed new source of supply is Glenfinlas. This has a potential supply of 19 million gallons a day when an impounding reservoir is built, but in view of the economic situation a modified scheme has been proposed by Mr. Stanley D. Canvin, the chief engineer and general manager, by which about 7 million gallons a day will be supplied to Loch Katrine by means of an intake weir and tunnel.

## CLEVELAND AND THE NORTHERN COUNTIES.

TYNE-DOCK ORE-DISCHARGING QUAY.—The new iron-ore discharging quay at Tyne Dock, South Shields, on which work started about 18 months ago, is expected to be completed early next year. About 3,000 tons of steel will be used to construct the quay and ore-handling plant, and when the work is completed imports of iron-ore into the Tyne are expected to reach one million tons annually, this being twice the existing rate. Vessels of up to 20,000 tons deadweight capacity will be able to berth at the quay, which will be 860 ft. in length. The last report issued by the Tyne Improvement Commission on the progress of the quay states that 84 per cent. of the sheet piling, 26 per cent. of the quay piling and 78 per cent. of the bunker piling have been driven, and that 22 per cent. of concrete for the deck slab and 54 per cent. of the concrete for the bunker foundations have been placed in position. The main contractors are the Yorkshire Hennebique Contracting Co., Ltd., while Simon Handling Engineers, Ltd., are supplying the ore-handling plant.

NEW MIDDLESBROUGH BLAST FURNACE.—A blast furnace having a potential weekly output of 4,000 tons of pig-iron has been blown in at the works of the Cargo Fleet Iron Co., Ltd., Middlesbrough. The furnace is 220 ft. high and has taken two years to build ; it replaces a furnace having a productive capacity of 1,750 tons a week. The furnace was put into operation by Mrs. B. Chetwynd Talbot, wife of the chairman and managing director of the firm.

LAUNCHINGS ON THE TYNE.—The only launching activity on the Tyne this month will be the floating of a dock gate which T. W. Greenwell & Co., Ltd., Sunderland, have ordered from Vickers-Armstrongs Ltd., Walker-on-Tyne. The Tyne's output for the first six months of the year will be seven vessels aggregating 57,900 gross tons. In the corresponding period of last year, the figures were 14 vessels totalling nearly 108,000 gross tons. There is likely to be a better rate of launching on the Tyne in the second half of 1952, but it is doubtful whether last year's output of 239,700 gross tons, which was a record, will be reached.

INSPECTION OF M.S. "FRAMLINGTON COURT."—The 10,000 tons cargo motorship Framlington Court, which has been built by William Pickersgill & Sons, Ltd., for Haldin & Co., Ltd., has been open for inspection by the representatives of several firms of shipowners to demonstrate the high standard of workmanship and fitting-out achieved on Wear-built ships. The Framlington Court was launched on January 28 and is due to be handed over early this month.

HAVANNAH COAL DRIFT, HAZLERIGG.—Coal drawing has started on a small scale at the new Havannah Drift, Hazlerigg, Northumberland, where it is proposed eventually to draw 1,500 tons of saleable coal daily. The construction of the drift has taken two years and the surface buildings are modern and surrounded by lawns. About 900 miners are expected to be employed when work is in full swing and the output per man-shift at 33 cwt. will be higher than the county average. Coal is being drawn from the Low Main Seam. A belt conveyor will be installed shortly, after which output will rise steadily.

## LANCASHIRE AND SOUTH YORKSHIRE.

HIGH COAL OUTPUT.—For the nineteenth time since nationalisation, Yorkshire collieries have passed the million-tons weekly mark. This Whitsuntide " bull-week " achievement was hampered by a " go-slow " policy at Markham Main Colliery where the pit produced only 8,126 tons, compared with an average weekly output of about 14,000 tons. The packers and drawers-off are dissatisfied with a conciliation award and they have been joined in their going-slow tactics by the rest of the 2,600 miners at the colliery.

ROAD TRANSPORT OF COAL DISPLACED BY RAILWAYS.—The transport of coal, particularly from opencast sites, has been largely transferred from road haulage to the railways for the summer months, and in the Sheffield and South-Yorkshire areas some hundreds of lorries are idle. A Barnsley operator has had to suspend six drivers, and a Sheffield concern which, until recently, had 200 lorries a day engaged on hauling coal, now has only 45 lorries on the work. Road-haulage firms are critical of a policy which makes full use of them in the winter when the weather is bad and discards them when conditions are easier.

RESTRICTIONS ON EXPORTS OF STEEL.—It is understood that the Board of Trade have admitted the justification of the strong complaint made by Mr. G. M. Flather, the Master Cutler, that exports of tool steels were being unnecessarily restricted by direction from the Board of Trade. He said at the annual meeting of the Association of British Chambers of Commerce that Sheffield business men were tired of being told to " export or die " when all their efforts were " hamstrung " by Government departments.

## THE MIDLANDS.

ITALIAN MINERS FROM YORKSHIRE.—Work is being found in the West Midlands for some of the Italians who have had to leave Yorkshire because the men at the local pits would not work with them. Jobs have been found for ten of the Italians at small pits in the Gornal district, near Dudley. The men will be employed at the Dibdale collieries of Gibbons (Dudley) Ltd., which are mainly concerned with fireclay mining, though some coal is also raised. The pits are operated under licence from the National Coal Board. Only one colliery in the district—Baggeridge, which employs over 1,000 miners—is worked by the Coal Board. None of the Italians will be engaged there.

WIND TUNNEL AT COVENTRY.—Sir W. G. Armstrong Whitworth Aircraft Ltd. are to build a new wind tunnel at their works at Whitley, near Coventry. The wind tunnel, which has been designed by Dr. W. H. Hilton, who joined the company two years ago, will be capable of testing models at $2\frac{1}{2}$ times the speed of sound. It is expected to be completed in about a year's time.

THE STAFFORDSHIRE AND WORCESTERSHIRE CANAL.—The Inland Waterways Association have drawn attention to a difficulty which has arisen at three factories on the Staffordshire and Worcestershire Canal. The canal was used until 1949 for transporting considerable quantities of coal from the pits on Cannock Chase to various factories on the canal side, and to the power station at Stourport. In 1949 this traffic ceased, the Coal Board sending coal by road and rail instead of by boat. Three of the canal-side factories, the Swindon, Stourvale and Wilden works of Richard Thomas and Baldwins, Ltd., are equipped with elevators for transferring coal from boats to their stockyards. To meet the present situation, the company are having to discharge motor lorries into canal boats, and then to move the boats a few hundred yards to the elevators.

COOMBS WOOD COLLIERY.—Coombs Wood Colliery, Halesowen, which was closed at the end of May, was the last of two coal mines to remain at work in the Halesowen-Rowley Regis area, where mining was once of considerable importance. The remaining pit is the Beech Tree Colliery, Cradley, which is worked by the National Coal Board. Coombs Wood Colliery, which latterly has been operated under licence from the Coal Board, was closed because of exhaustion of its coal. It was opened 42 years ago, and at one time employed about 300 men to produce 2,500 tons of coal a week, from the celebrated Thick, or Ten Yard, seam. For the last few years, only about 35 men have been at work underground. The shaft, which is 300 yards deep, is to be filled in.

GAS SUPPLIES.—Mr. G. le B. Diamond, chairman of the West Midlands Gas Board, addressing the Regional Gas Consultative Council in Birmingham on May 26, said that the industrial demand for gas in the Board's area exceeded the production capacity by 10,000 million cub. ft. a year. The Board's development plan had been adversely affected by the steel shortage and the restriction on capital expenditure, but several large projects had been completed between October, 1951, and the end of March this year ; these included new plant at Kingswinford, Tipton and Willenhall. Further extensions to plant had been authorised. Referring to complaints which had been received from coke users about the high ash content and the quantity of " bat " in coke, Mr. Diamond said that representations had been made to the National Coal Board about the quality of the coal supplied and that the Board were taking action to alleviate the trouble.

## SOUTH-WEST ENGLAND AND SOUTH WALES.

SOUTH WALES PORTS TRAFFIC.—From January 1 to May 18 this year the South Wales ports, between them, handled a total inward and outward trade of 8,491,008 tons, compared with 7,156,306 tons in the corresponding period of last year, according to returns issued by the Docks and Inland Waterways Executive. Imports were 3,555,486 tons, compared with 3,223,909 tons and exports 4,935,522 tons, against 3,932,397 tons. On the outward side, there was a jump from 948,175 to 1,272,025 tons in coal and coke shipped to foreign destinations, while oil and spirits sent abroad amounted to 735,579 tons, against 305,280 tons last year. Tin-plate shipments were 99,449 tons, against 79,869 tons, but other iron and steel shipments fell from 113,088 tons a year ago to 88,579 tons. The improvement on the import side was in spite of the fact that, this year, no foreign coal has been received, against 255,233 tons in the corresponding period of last year. Against this, however, there was a jump of practically half a million tons—from 1,189,882 to 1,682,409 tons—in imports of oil and spirits. Iron-ore arrivals rose from 620,664 to 692,672 tons, other ores from 91,801 to 106,378 tons and partly manufactured iron and steel goods from 189,472 to 214,846 tons.

PROPOSED NEWPORT SHIPBUILDING SCHEME.—Plans for the establishment of a shipbuilding yard covering about 50 acres on the western side of the River Usk at Newport are stated to be under consideration. Such a yard would be large enough to build the largest tankers. It has been estimated that the first berth could be ready in 12 months from the placing of the contract. The promoters of the Newport scheme feel that they could be certain of work for the next 10 or 20 years and that they could overcome the problems relating to labour and materials. The site is near one of the largest aluminium rolling mills in the country.

CELLULOSE-TAPE FACTORY, GORSEINON.—Mr. Peter Thorneycroft, President of the Board of Trade, last week officially opened a new factory at Gorseinon, near Swansea, for the Minnesota Mining and Manufacturing Company. The main products at the factory will be cellulose-coated tape and " underseal," a special insulating material for spraying the underside of motor-car bodies to resist corrosion. Already, a substantial export business has been built up, and the factory is scheduled to be in full production within the next six months, employing a labour force of 400, mostly men. The factory is planned as the first of four units, which, it is hoped, will gradually come into operation within the next 10 to 15 years. The factory has cost 250,000*l.* and the plant is mostly American.

ITALIANS FOR STEEL-PLATE INDUSTRY.—Some of the Italians now being trained for coal-mining at South Wales centres may be transferred to the steel-plate industry, Mr. Owen Taylor, Controller for Wales of the Ministry of Labour, announced at a meeting of the Welsh Board for Industry at Pontypool. He did not consider that the resistance to Italian labour was any more peculiar to the South Wales coal industry than to the other coalfields.

AMALGAMATION OF ENGINEERING SOCIETIES.—On and from July 1, the South Western Society of Mining Engineers will cease to exist as a separate society and will become merged in the South Wales Institute of Engineers, which, at the same time, will become federated with the Institution of Mining Engineers. The South Wales Institute of Engineers is one of the oldest in the country, having been founded in 1857. It was granted a Royal Charter in 1881. The Institution of Mining Engineers was formed in 1889 and was incorporated by Royal Charter in 1915. It was founded as a federation of much older district institutes, of which eight are now affiliated with it. The South Western Society of Mining Engineers is of much more recent formation, having been established in 1947 "for the advancement of the science and practice of the mining of coal and other stratified deposits, and the promotion of the acquisition of the knowledge necessary for the control and direction of such mining operations."

## 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.

NORTH OF ENGLAND INSTITUTE OF MINING AND MECHANICAL ENGINEERS.—Saturday, June 7, 2.30 p.m., Neville Hall, Newcastle-upon-Tyne, 1. (i) "An Example of the Application of Time-Study Analysis to Mechanised Units," by Mr. C. D. Hornsby. (ii) "Automatic Mine Winding Practice," by Mr. O. T. Evans and Mr. P. H. Harvey.

STOKE-ON-TRENT ASSOCIATION OF ENGINEERS.—Saturday, June 7, 6 p.m., The George Hotel, Stoke-on-Trent. Annual General Meeting.

NORTH-WESTERN FUEL LUNCHEON CLUB.—Wednesday, June 11, 12.45 p.m., Engineers' Club, Albert-square, Manchester, 2. "The Intelligent Use of Electricity for Domestic Space Heating," by Mr. J. L. Rycroft.

ROYAL STATISTICAL SOCIETY.—*Study Section:* Wednesday, June 11, 6 p.m., The Electric Lamp Manufacturers' Association, 2, Savoy-hill, Strand, W.C.2. Annual General Meeting. "Measuring the Understanding of Educational Radio Talks," by Mr. J. Trenaman.

ROYAL SOCIETY.—Thursday, June 12, 4.30 p.m., Burlington House, Piccadilly, W.1. The Bakerian Lecture on "The Origin of the Solar System," by Professor H. Jeffreys, F.R.S.

WEST OF SCOTLAND IRON AND STEEL INSTITUTE and BRITISH IRON AND STEEL RESEARCH ASSOCIATION.—Friday, June 13, Institution of Engineers and Shipbuilders in Scotland, 39, Elmbank-crescent, Glasgow, C.2. All-Day Joint Meeting. 10 a.m., (i) "Some Experience with an All-Basic Tilting Furnace," by Mr. J. Mitton. (ii) "Some Measurements on Open-Hearth Furnace Flames," by Mr. G. W. van Stein Callenfels. 2.15 p.m., "The Problem of Correlating Laboratory Tests on Basic Bricks with Works Performance," by Mr. J. Mackenzie; followed by a general discussion on all three papers.

INSTITUTION OF PRODUCTION ENGINEERS.—*Eastern Counties Section:* Friday, June 13, 7.30 p.m., Garrett Memorial Hall, Ipswich. "Oil for Britain" Exhibition, arranged by the Esso Petroleum Co., Ltd., and Lecture on "Machine Lubrication," by Mr. C. J. Taylor. *Wolverhampton Graduate Section:* Tuesday, June 17, 7.30 p.m., Wolverhampton and Staffordshire Technical College, Wulfruna-street, Wolverhampton. Brains Trust Meeting on "Production Engineering Problems."

ROYAL SANITARY INSTITUTE.—Wednesday, June 18, 10.30 a.m., Central Library, High-road, Tottenham, N.17. Various papers, including "The Utilisation of Town Refuse," by Mr. H. Gurney.

ROYAL METEOROLOGICAL SOCIETY.—Wednesday, June 18, 5 p.m., 49, Cromwell-road, South Kensington, S.W.7. (i) "The Dissipation of Kinetic Energy in the Lowest Layers of the Atmosphere," by Mr. R. J. Taylor. (ii) "Structure of the Upper Westerlies: A Study of the Wind Field in the Eastern Atlantic and Western Europe in September, 1950," by Mr. R. Murray and Mr. D. H. Johnson.

## LAUNCHES AND TRIAL TRIPS.

M.S. "BURUTU PALM."—Single-screw cargo vessel, built by Short Brothers, Ltd., Sunderland, for the West African trade of the Palm Line, Ltd., London, E.C.4. Main dimensions: 425 ft. between perpendiculars by 57 ft. 9 in. by 37 ft. 2 in. to upper deck; deadweight capacity, about 8,600 tons on a mean draught of 23 ft. 9 in. N.E.M.-Doxford four-cylinder airless-injection oil engine, developing 3,000 b.h.p. at 122 r.p.m., constructed by the North Eastern Marine Engineering Co. (1938), Ltd., Wallsend-on-Tyne. Launch, April 23.

S.S. "ST. CELESTIN."—Single-screw trawler, built by Cook, Welton and Gemmell, Ltd., Beverley, Yorkshire, for Thos. Hamling and Co., Ltd., Hull. Main dimensions: 189 ft. by 32 ft. by 16 ft. 6 in.; gross tonnage, about 800; fishroom capacity, 15,640 cub. ft. Triple-expansion engine and one multitubular oil-fired boiler, constructed by Charles D. Holmes and Co., Ltd., Hull. Launch, May 12.

M.S. "WHEATFIELD."—Single-screw oil tanker, built by the Furness Shipbuilding Co., Ltd., Haverton Hill, County Durham, for Eden Tankers, Ltd., Newcastle-upon-Tyne. First vessel of an order for two. Main dimensions: 496 ft. between perpendiculars by 67 ft. 6 in. by 36 ft. 5 in.; deadweight capacity, 16,500 tons on a summer draught of 29 ft. 1 in.; oil-tank capacity, 15,600 tons. Fairfield-Doxford five-cylinder single-acting two-stroke oil engine, developing 5,500 b.h.p. at 112 r.p.m. in service, constructed by the Fairfield Shipbuilding and Engineering Co., Ltd., Govan. Speed, 14 knots. Trial trip, May 19.

S.S. "CALTEX LIVERPOOL."—Single-screw oil tanker built and engined by R. and W. Hawthorn, Leslie & Co., Ltd., Hebburn-on-Tyne, County Durham, for the Overseas Tankship (U.K.), Ltd., London, W.1. Main dimensions: 544 ft. 4 in. by 70 ft. by 39 ft. 9 in. to upper deck; deadweight capacity, about 17,250 tons. Double-reduction geared steam turbines, developing a maximum of 8,000 s.h.p., and two Yarrow water-tube boilers. Speed, 15 knots. Launch, May 22.

M.S. "WINDSOR."—Single-screw cargo vessel, built and engined by Barclay, Curle & Co., Ltd., Whiteinch, Glasgow, for the Britain Steamship Co., Ltd. (Managers: Watts Watts and Co., Ltd.), London, E.C.2. Main dimensions: 465 ft. overall by 58 ft. 6 in. by 38 ft.; gross tonnage, about 7,600. Barclay Curle-Doxford four-cylinder airless-injection oil engine developing 4,400 b.h.p. at 115 r.p.m. Service speed, 13 knots. Launch, May 23.

M.S. "DUFFIELD."—Single-screw tanker, built by Smith's Dock Co., Ltd., South Bank-on-Tees, for Hunting and Son, Ltd., Newcastle-upon-Tyne. Main dimensions: 506 ft. overall by 67 ft. by 36 ft. 3 in.; deadweight capacity, about 14,500 tons on a draught of 28 ft. 6 in. Hawthorn-Doxford four-cylinder two-stroke oil engine, developing 4,450 b.h.p. at 112 r.p.m. in service, constructed by R. and W. Hawthorn, Leslie & Co., Ltd., Newcastle-upon-Tyne. Service speed, about 12½ knots. Launch, May 23.

M.S. "HØEGH RANGER."—Single-screw oil tanker, built by Joseph L. Thompson & Sons, Ltd., Sunderland, for Leif Høegh & Co., Oslo, Norway. Main dimensions: 475 ft. between perpendiculars by 67 ft. 4½ in. by 37 ft. 4 in.; deadweight capacity, 15,135 tons on a draught of 29 ft. Four-cylinder opposed-piston oil engine constructed by William Doxford and Sons, Ltd., Sunderland. Service speed, 12½ knots. Launch, May 23.

S.S. "HAWKINGE."—Single-screw cargo vessel, built and engined by William Gray & Co., Ltd., West Hartlepool, for Constants (South Wales), Ltd., London, E.C.2. Third vessel of a series of three. Main dimensions: 320 ft. between perpendiculars by 46 ft. 4 in. by 24 ft. 3½ in. to upper deck; deadweight capacity, about 4,650 tons on a draught of 20 ft. 5¾ in. Triple-expansion steam engine, developing 1,250 i.h.p. at 75 r.p.m., and two oil-fired boilers. Speed in service, 10½ knots. Launch, May 23.

M.S. "ENNERDALE."—Single-screw tank barge, built by Cook, Welton and Gemmell, Ltd., Beverley, Yorkshire, for John Harker, Knottingley, Yorkshire, for service on inland waterways between the Humber and West Yorkshire. Fourth vessel of a series of four. Main dimensions: 132 ft. between perpendiculars by 17 ft. 6 in. by 7 ft. 9 in. Six cargo tanks having a total capacity of 275 tons. Six-cylinder oil engine working through reduction gearing and developing 120 b.h.p. at 900 r.p.m., constructed by Gleniffer Engines, Ltd., Glasgow. Launch, May 24.

M.S. "SCOTTISH EAGLE."—Single-screw oil tanker, built and engined by Swan, Hunter, and Wigham Richardson, Ltd., Newcastle-upon-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, about 15,710 tons on a summer draught of 29 ft. 11 in. Swan Hunter-Doxford six-cylinder oil engine, developing 6,400 b.h.p. at 115 r.p.m. in service. Trial speed exceeded 14½ knots. Trial trip, May 28.

## PERSONAL.

SIR CHARLES S. LILLICRAP, K.C.B., M.B.E., who retired from the post of Director of Naval Construction, Admiralty, in September, 1951, has been elected a director of J. Samuel White & Co. Ltd., Cowes, Isle of Wight.

SIR CECIL WEIR, K.B.E., M.C., D.L., has been elected President of the Institution of Production Engineers, 36, Portman-square, London, W.1, for the year 1952-53, in succession to MAJOR-GENERAL K. C. APPLEYARD, C.B.E. MR. HAROLD BURKE, M.I.Mech.E., vice-chairman of the Council for the past two years, takes office as chairman for 1952-53, in succession to MR. WALTER C. PUCKEY.

PROFESSOR A. S. T. THOMSON, of the Royal Technical College, Glasgow; the EARL OF BALFOUR, formerly chairman of the Scottish Division of the National Coal Board; PROFESSOR A. K. CAIRNCROSS, of the University of Glasgow; DR. W. J. JENKINS, representative of the Highland Panel; and MR. JOHN LANG, secretary of the Scottish Trades Union Congress, have been appointed by the Scottish Council (Development and Industry) to be members of a special committee to examine and report, with recommendations, upon those factors influencing future industrial developments which are related to power supplies. Professor Thomson is the chairman of the committee.

DR. G. E. FOXWELL, at the unanimous invitation of the Council of the Institute of Fuel, 18, Devonshire-street, Portland-place, London, W.1, has consented to serve as President of the Institute for a second term.

DR. W. J. WELLWOOD FERGUSON has been elected President of the Illuminating Engineering Society, 32, Victoria-street, London, S.W.1, for 1952-53. He will succeed the present President, MR. J. G. HOLMES, in October.

MR. W. J. PRICE, of J. T. Price & Co. Ltd., Brierley Hill, Staffordshire, has been elected President of the National Federation of Clay Industries.

MR. F. H. BROOKS, general works manager, The Wellman Smith Owen Engineering Corporation Ltd., Parnell House, Wilton-road, London, S.W.1, has been elected a director of the company.

MR. R. H. WALL, B.Sc. (Eng.), MR. C. K. WHITELEY, B.Sc., A.M.I.Mun.E., and MR. P. J. POWELL, A.M.I.C.E., have been appointed to the Colonial Engineering Service. Mr. Wall is to be senior assistant engineer (railways) in Sierra Leone, while Mr. Whiteley has been appointed an executive engineer in Tanganyika and Mr. Powell an executive engineer in the Public Works Department in Nigeria.

MR. R. H. MORGAN, of Tredegar, has been installed as President of the South Wales branch of the Association of Mining Electrical and Mechanical Engineers, in succession to MR. D. J. THOMAS.

MR. W. LINDSAY BURNS has been elected chairman of Henry Balfour & Co. Ltd., Leven, Fife. For some time he had been vice-chairman of the firm. Mr. Burns is also chairman of George Scott & Son (London) Ltd., and of Ernest Scott & Co. Ltd., and vice-chairman of Enamelled Metal Products Corporation (1933) Ltd.

MR. W. J. EVERARD, who is a representative of shipping, has been appointed a member of the Transport Users' Consultative Committee for the London Area, in place of MR. F. WHITTOCK, who has resigned.

MR. V. P. MACKAY, of the Scottish Division, National Coal Board, Lothians Area, has been appointed to the newly-created post of chief engineer of the rotating-plant department of Bruce Peebles & Co., Ltd., Edinburgh, 5. He took up his new duties on June 2.

By a decree dated April 9, 1952, the President of the French Republic has created MR. ARTHUR HILLIER, O.B.E., J.P., chairman and managing director of the Sperry Gyroscope Co. Ltd., Great West-road, Brentford, Middlesex, an Officier de la Légion d'Honneur. Mr. Hillier was made a Commander of the Order of Oranje Nassau of the Netherlands in August, 1950.

DR. GORDON S. BROWN has been appointed head of the Department of Electrical Engineering at the Massachusetts Institute of Technology, Cambridge, Massachusetts, U.S.A., in succession to DR. H. L. HAZEN, who has been appointed Dean of the Graduate School. Dr. Brown will assume his new duties on July 1.

THE BRISTOL AEROPLANE CO. LTD., are to take over another factory at the Pallion Trading Estate, Sunderland, for the manufacture of aeroplane engines. The company took over a factory on the Estate last November, in which 250 men are now working. This number will be increased to 500 when the newly-acquired factory is in production.

BARRMOOR TOOL WORKS, LTD., Bonnybridge, Stirlingshire, have leased a factory from the Ross and Cromarty County Council, at Inverasdale, Achnasheen, Ross-shire.

ALFRED BULLOWS & SONS LTD., Long-street, Walsall, Staffordshire, announce that the address of their Glasgow office has been changed to 70, Gilmour-street, Glasgow, C.5. (Telephone: South 2383.)

# EXHIBITS AT THE MECHANICAL HANDLING EXHIBITION.

(*For Description, see Page* 709.)

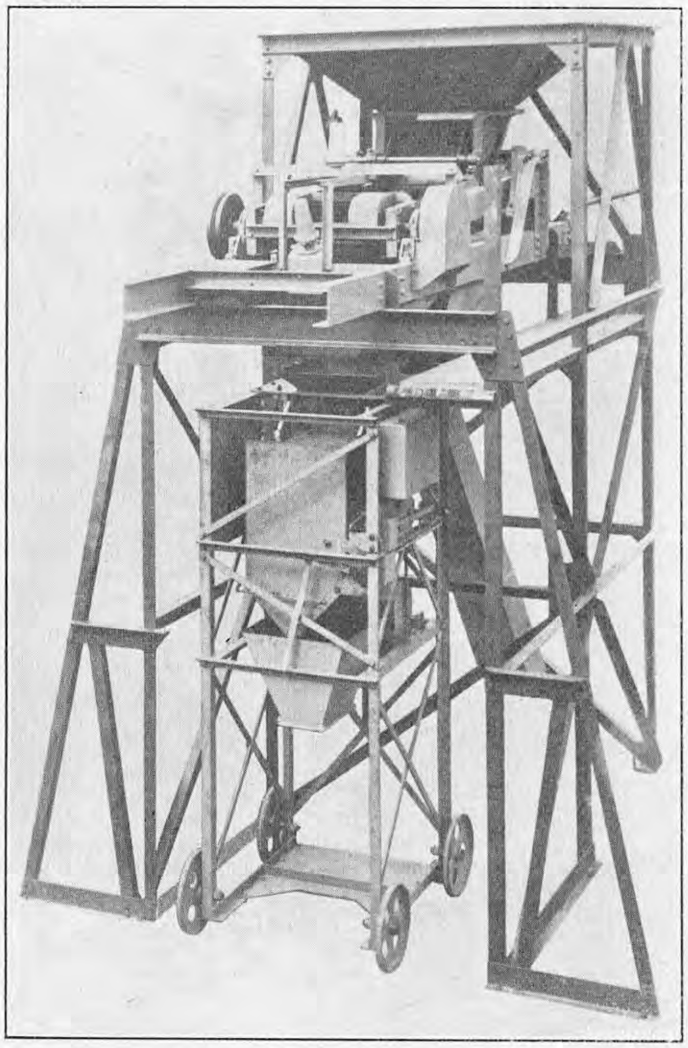


FIG. 12. AUTOMATIC SCREENING, WEIGHING AND BAGGING UNIT; ROBERT CORT AND SON, LIMITED.

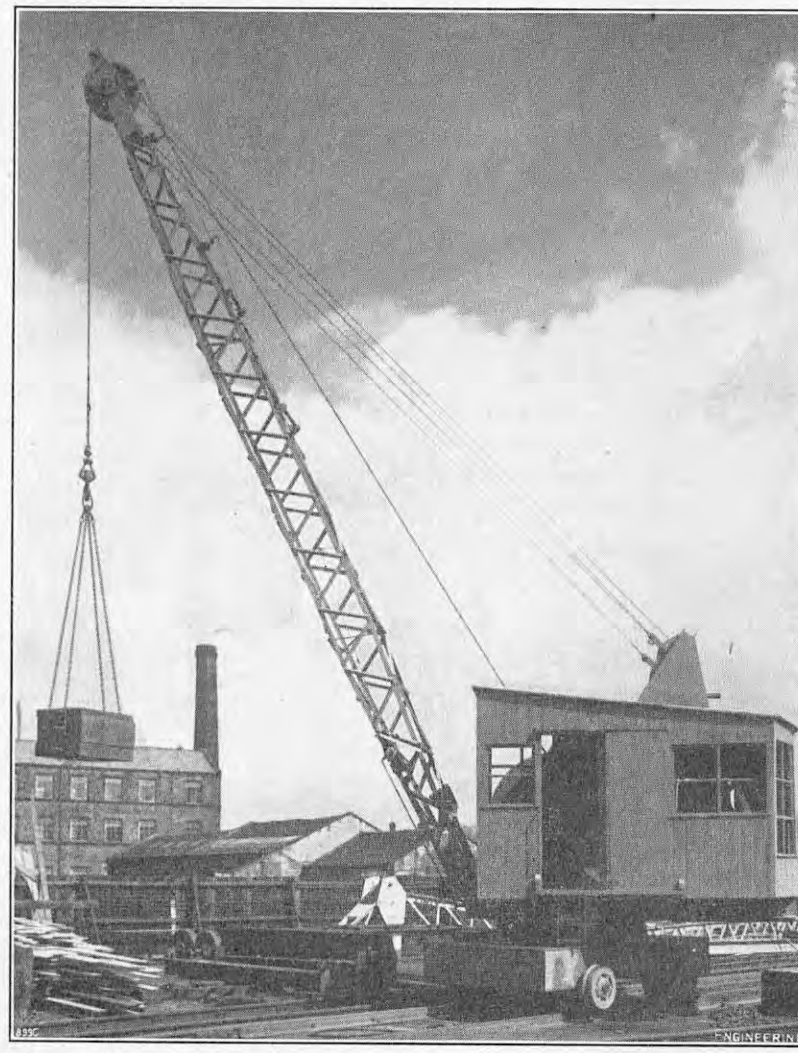


FIG. 13. 5-TON DIESEL LOCOMOTIVE CRANE; THOMAS SMITH AND SONS (RODLEY), LIMITED.

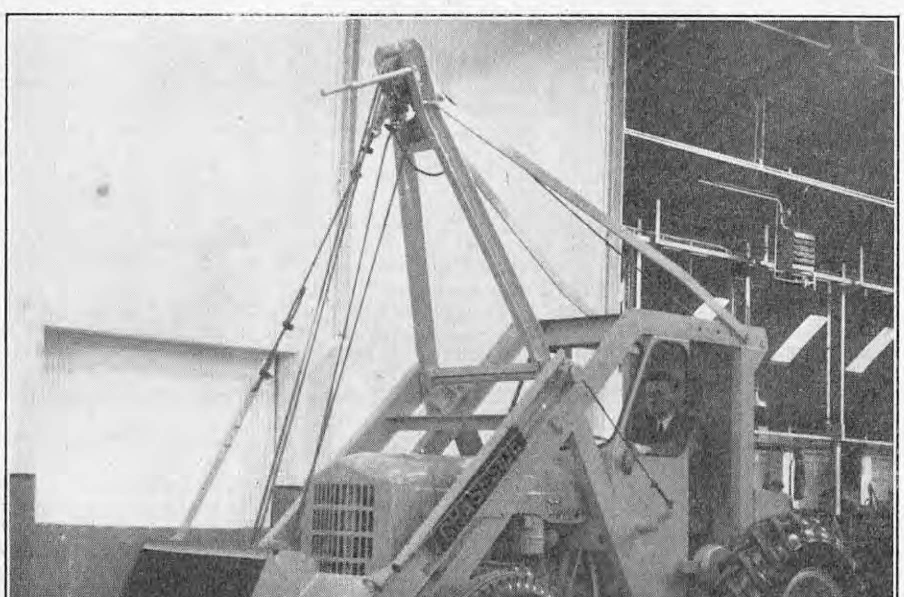


FIG. 14. MECHANICAL SHOVEL; CHASESIDE ENGINEERING COMPANY, LIMITED.

FIG. 15. 10-TON MOBILE CRANE; R.H. NEAL AND COMPANY, LIMITED.

# ENGINEERING

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*One One-Page Plate.—VERTICAL PROCESS OF GLASS-TUBE DRAWING.*



# ENGINEERING

*FRIDAY, JUNE 6, 1952.*

VOL. 173. No. 4506.


## SCIENTIFIC AND TECHNOLOGICAL MAN-POWER.

IN last week's issue of ENGINEERING, we referred very briefly to the report (Cmd. 8561) of the Committee on Scientific Man-power to the Advisory Council on Scientific Policy. That reference was no more than a record of an event; but the report deserves a rather fuller consideration than was then possible, if only because of the popular misconceptions that have beclouded the use of the term "scientist." The Committee, as we remarked a week ago, defined "scientist" as "a man or woman trained either in fundamental or applied science to the level of a university degree or equivalent qualification." At the outset, that description—the Committee, in fact, did not claim for it the more precise term of "definition"—invites controversy, for it is a moot point whether there is any qualification exactly equivalent to a university degree; at least, to a degree conferred by a university in which actual residence is a *sine qua non*. That, after all, is the feature which distinguishes a university education from most other forms of education; the difference between mere instruction or vocational training, whatever the ultimate vocation envisaged, and the true education which exemplifies the Latin origin of the word—*e*, out, *ducere*, to lead.

The report that we are considering, however, is in itself too important to give place to any philosophical or philological dissertation on the word "education"; it is concerned with the "scientist"—a term which deserves the distinction of quotation marks because, in the hands of the popular Press, it has become (as Sir Alan Herbert would say) a "witch word," used so often to bemuse that it is in some danger of becoming discredited, more especially among engineers. Let it not be thought that engineers—at least, the more broad-minded of them—take the real scientist lightly. They know full well that few scientific developments can be brought to fruition and to successful commercial production without their own aid; but they are usually, by training and experience, sufficiently imbued with an appreciation of science not to scoff at it or at its practitioners. What does cause them some concern, however, is the popular tendency—fostered, if not actually instigated, by the average uncritical newspaper—to dignify with the title of "scientist" almost anyone who is engaged in a pursuit more or less remotely allied with physics and mathematics. The Advisory Council on Scientific Policy consists, for the most part, of "real" scientists—men who have dedicated their lives to the pursuit of scientific knowledge. It is only charitable to assume that they do not realise how great is the disservice that newspaper publicity has done to the scientist, or how numerous are the claimants to that title whose only qualification is that they are engaged in doing something or other that requires scientific knowledge somewhat above the general run of an ordinary secondary school curriculum.

In many respects, the Advisory Council's report is rather a curious document. It has a certain amount to say about productivity, and appears to have swallowed, hook, line and sinker, the general thesis that "productivity" (another term that is much in need of precise definition) is, in some mysterious way, a function of the number of university graduates engaged in industry. That it should be also a function of the average age of the working population is understandable; but at this point the report introduces another definition in the statement that "we need to increase both absolutely and relatively the number of scientists in our industries—men who know how to apply the latest results of scientific research to practical problems of production." The report goes on to quote the American Institute of Management as stating that, in that country—presumably the United States alone is indicated—"75 per cent. of the presidents of 204 leading industrial companies are university graduates."

Of the seven main sections into which the report is divided, four invite particular consideration; they are the sections headed, respectively, "Supply of and Demand for Scientists," "Measures to increase the Supply of Scientists," "Quality of Scientists," and "Science and Leadership." We have quoted already from the first of these, which ends with the expression of opinion that "there is likely to be a long-term shortage of practically all kinds of scientists, and every effort should be made to increase the supply, with particular emphasis on chemists, chemical engineers, electrical engineers, mechanical engineers and physicists." The second of the sections cited opens with the fairly obvious statement that "it will be impossible to increase the supply of scientists substantially if the extra talent is not there to train, and if there is a lack of the necessary training facilities." It is remarked that "about 7 per cent. of pupils remain at school after the age of 17, and about 3 per cent. proceed to the universities." The Committee appear to disagree with the view that these figures fairly indicate the proportion who are potentially able to benefit from a university education, stating that they "have found much evidence to support the view that a large potential reserve of university students is contained in the number who leave school before the age of 17."

In this we would concur; but with the reservation that, in our opinion, not all of those who go up to universities, and, once caught in that educational machine, eventually emerge with a degree of diploma, are really up to what should be demanded as a "university standard." Evidently, the Committee thinks so, too, for in discussing the quality of scientists, they report a "remarkable unanimity among our informants that, although present-day science graduates are adequate as scientists, they tend to lack a sufficiently broad education, not only in a general sense, but also in the field of science." On this we would comment that the basic requirement in a graduate of any university, in any field of learning, is not a given absorption of knowledge, but a capacity to go on learning throughout life. Far too many graduates seem to consider that, having graduated, they have done all that should be expected of them. Industry requires more than that if it is to prosper; and most of those who, in the past, have brought prosperity to industry have done so by virtue of qualities that a university may develop, but is, perhaps, less likely to initiate. We recall the observation of an old Wykehamist that, while the alumni of his ancient College commonly rise fairly high in their eventual employments, they seldom reach the highest possible levels, because, in his opinion, their deep appreciation of the College motto, "Manners Makyth Man," was incompatible with the egotistical pushfulness that was essential to absolute eminence. Without expressing any views on this highly debatable point, we do feel that most men who make science their study do so with the subconscious expectation that they will eventually become employees rather than employers; and the whole pattern of modern organised industry tends to encourage that attitude of mind. When it is remembered that, if there is to be any great expansion of the numbers of persons trained in science, a majority of them must come from social levels which are habituated to the idea of being employees rather than employers, the wonder is not that science produces so few great industrial leaders, but that it produces as many as it has done.

On one point in particular, we would take exception to the implications—or one especial implication —of the Committee's report. In the section on "Supply of and Demand for Scientists," it is remarked that "it is not only in comparison with the United States that we [Great Britain] produce significantly fewer scientists and technologists; a similar disparity exists between this country and Switzerland, whose population and resources of indigenous wealth are very much smaller than our own." This comparison appears to ignore a most important difference—important especially in its industrial consequences. The scientifically-trained man in Switzerland, at least in the engineering field, with which this journal has direct contact, has received a training second to none in the world; but he does not assume that, because of his training, he has become, by some transformation, a person of a superior class, entitled to a higher status and emoluments far above those of his fellows who are merely craftsmen. It is probably true to say that in no industrialised country in the world is there a smaller differential between the wage of the skilled machinist, for example, and the professionally qualified graduate of technical college or university; and that is not the result of paying one by piece-work and the other a fixed salary. It is simply that a university degree or its accepted equivalent is not regarded as an exceptional qualification, but as one which a man who takes his profession seriously will naturally seek to acquire, just as the keen craftsman will provide himself with a kit of good tools—and will keep them in a state of constant readiness for use. Moreover, the university graduate himself does not expect to be regarded as being in a class apart.

It may be that the peculiar attitude of the industrialist, the commercial employer and the general public of this country towards the "scientist" (in the sense of the Committee's report) is due in part —perhaps quite a large part—to the circumstance that the principal newspapers, when they engage university-trained men, draw them mainly from the faculties of arts and letters. They do not understand science, and they fail, therefore, to differentiate between its numerous grades of knowledge and performance. They would never make the mistake of lumping together, in one medical category, a Harley-street specialist, a family doctor, and a factory first-aid man; but they seem unable to differentiate between the pure scientist, the technologist and the laboratory assistant. The Committee clearly realise this, commenting that, if more young people are to take up science as a career, there must be "a change in the climate of opinion affecting the prestige of science among school children, parents and teachers." It would be interesting to know how they propose to set about it.

# PUBLIC-HEALTH ENGINEERING.

The standard of public health in any country is of interest and importance to its neighbours. This is particularly the case when they have a common frontier, but no European country can afford to be indifferent to the hygiene and sanitary state of any other. Great Britain, with a sea barrier, is not so acutely exposed to infection as are the countries of the Continental mass but is not immune, as is shown, for instance, by the spread of foot and mouth disease. An adequate public water supply, both in quantity and quality, is one of the factors determining the standard of public health, and a polluted service in one country may have deleterious effects in another. No doubt it would be highly satisfactory if an international standard of purity for public water supply could be imposed throughout Europe but, apart from any difficulty in agreement on a definition of quality, there would not appear to be any possibility of enforcing the application of a common standard.

In spite of these difficulties, a paper entitled "Considerations Involved in the Development of International Drinking Water Standards" formed one of the main items in the Second Seminar for European Sanitary Engineers held in Rome in November, 1951. The paper, the full text of which will be found in the report on the seminar,* was presented by Professor U. A. Corti, Director of the Institut Fédéral pour l'Amenagement, l'Epuration et la Protection des Eaux, Zürich. There is a national standard for water supply in the United States but its application is obligatory only for interstate carriers; that is, broadly, for any type of traffic undertaking which transports water from one State to another. This condition arises from the fact that in water supply, as in many other matters, the individual States are autonomous. The Federal Government, however, has authority over interstate relations and power to protect one State from the effect of what one considered to be undesirable activities in another. In spite of the limited application of this Federal control, the existence of a standard has set a valuable example which many water authorities have followed and the standard is worked to in many supply services. It is possible that agreement on a European standard would have a similar effect and that many countries or supply authorities might be influenced towards the amendment of their present practice.

This consideration apart, the discussion on an international water standard may be considered to be of academic rather than practical interest. In a sense this may be said to apply to the whole seminar, although that is not to suggest that it was not of considerable value. It was sponsored by the Government of Italy, the Division of Medicine and Public Health of the Rockefeller Foundation and the Regional Office for Europe of the World Health Organisation. The first "Seminar," as these conferences are apparently to be called, was held at The Hague in 1950, and at the conclusion of the meetings a committee was set up to arrange for a third seminar this year. The report does not say so, but it is understood that the intention is to hold this third conference in this country. Seven papers were read and discussed at the Rome seminar. In addition to the matter of water supply they covered sewage treatment and the financing of sanitary works. The communication on this latter subject contained a number of recommendations, one of which was "that in every country there should be created a National Credit Fund especially designed to contribute to the financing of sanitary work."

The emphasis throughout the whole of the papers was on the importance of the work of engineers in the fields of public health and sanitation. The general subject was surveyed in a paper entitled "The Public Health Engineer in Town, Regional and General Planning," contributed by Mr. G. M. McNaughton, Chief Engineer of the Ministry of Local Government and Planning. He pointed out that experienced public-health engineers were in short supply in many European countries and suggested that the time of those available should not be taken up in the consideration of planning activities outside the scope of engineering; their specialised knowledge should be taken advantage of to the full. The engineering aspects of any development should be referred to them and it was important that they should be concerned from the start; delays were likely to occur when engineers were consulted at a late stage as their recommendations might result in major alterations.

The importance of the engineer in public health and sanitation questions, which was the keynote of the conference, was emphasised and crystallised in a practical proposal in a paper read by Professor W. F. J. M. Krul, Director of the Government Institute for Water Supply of the Netherlands. His subject was the "Formation of National and European Associations of Sanitary Engineers." He pointed out that in different European countries there were "different standards and different methods in the field of sanitary engineering." It is probable that some of these are not the best possible, and an international body, facilitating personal contacts and the interchange of information, would be of assistance in promoting good practice. The paper listed the various national institutions in existence. In some countries, such as Yugoslavia and Portugal, there was no specific association of sanitary engineers, and membership of an international institution would serve to differentiate and establish the status of the profession. The matter has certainly not been neglected in this country. The Institution of Civil Engineers has a Division of Public Health, and, in addition, one or other aspect of sanitary engineering and public health is the province of the Institution of Sanitary Engineers, the Institution of Municipal and County Engineers, the Institution of Water Engineers, the Institute of Sewage Purification and the Royal Sanitary Institute.

In view of this list, it may be considered that British public-works engineers have no need of a still further association. An international association would certainly be of greater value to some other countries, but members of the profession in the United Kingdom might profit from consultation with workers in other countries and from better access to information on Continental practice. Professor Krul suggested that the proposed association might concern itself with such questions as co-ordinated research, and international standards. Presumably, one of its activities would be the arranging of conferences similar to that at which the paper was read. The meetings so far held have been financed by outside sources, but an international association, if it is to survive, requires a stable and adequate income.

* World Health Organisation, Regional Office for Europe, Geneva.

# NOTES.

### LOCOMOTIVE TEST REPORTS.

THE Railway Executive have decided to place on sale to the public copies of bulletins to be issued from time to time of tests carried out at the Rugby and Swindon locomotive testing stations or by the mobile testing units. The first three are now available, price 10s. net each, from the Publicity Officer, Railway Executive, Room 323, 222, Marylebone-road, London, N.W.1. No. 1 deals with performance and efficiency tests (with the exhaust-steam injector) on a two-cylinder 4-6-0 mixed-traffic locomotive of the Western Region "Hall" class; No. 2 with similar tests on a two-cylinder 4-6-0 mixed-traffic locomotive of the Eastern and North Eastern Regions "B 1" class; and No. 3 with performance and efficiency tests (with a live-steam injector) on a two-cylinder 2-6-0 mixed-traffic locomotive of the London Midland Region class 4. The object of the tests is to give a complete picture of the speed and power of the locomotive, and to provide data from which the cost can be deduced, in terms of coal, of hauling different train loads at different speeds over given routes. The first three bulletins relate to representative regional types, but the next three will deal with standard locomotives of British Railways, and later bulletins will cover Diesel-electric, gas-turbine, and electric locomotives. It will then be possible to make an accurate comparison of the various forms of motive power. A section of the first two bulletins is devoted to an explanation of how the test data which have been made available are applied to a study of the possibilities of the more economical running of locomotives in relation to the operating department's requirements. The bulletins contain a large number of graphs, as well as illustrations of the locomotive, and British Railways are to be congratulated on introducing a scheme which will be welcomed by many engineers and others interested in railways.

### THE WILBUR WRIGHT LECTURE.

The Royal Aeronautical Society met on Thursday, May 29, in the lecture hall of the Institution of Civil Engineers, to honour Professor von Karman with the 14th award of the Wilbur Wright Gold Medal, which was handed to him personally by the President, before Sir Harry Garner, K.C.B., C.B., M.A., Fellow of the Society, delivered the 40th Wilbur Wright Memorial Lecture. We commence to print an abridgment of the lecture on page 711, of this issue. Speaking on "Prophecy and Achievement in Aeronautics," Sir Harry referred to the difficulties faced by earlier prophets of progress in this field, when the ultimate limits had seemed to be a few thousand pounds weight, a wing span of perhaps 100 ft., and a speed of 200 or 300 miles an hour. The square-cube law, very properly, had been regarded from the start as the basis of estimation in all attempts at forecasting the possible limits of flight performance and operational efficiency. They had not defeated the square-cube law, but the limitations which it had seemed at one time to impose had been surpassed by reason of departures from similarity, in structural form, metallurgy, aerodynamics, and engine design. The way in which the most sanguine expectations of the early designers and investigators had been surpassed was the cumulative result of all the progressive advances in applied science and technology, rather than of any one spectacular invention, with the possible exception of the gas turbine. The lecturer doubted whether any designer to-day could do much better than the Wright Brothers, with the materials and other resources available 50 years ago. In discussing the steady progress of maximum flying speeds, Sir Harry drew attention to the remarkable way in which, between 1925 and 1935, the seaplane had outstripped the land 'plane in the keen struggles for the Schneider Trophy. Looking into the future, undeterred by his study of his predecessors' shortcomings in the art of making similar forecasts, Sir Harry affirmed his faith in the seaplane or flying boat. High flying speeds, he said, had only become possible by the adoption of take-off and landing speeds higher than the limit at one time set for the ultimate speed of flight itself. High landing speeds and heavy aircraft meant enormous concrete runways, which he described as great millstones round the necks of aircraft operators, military as well as civil. The flying boat, of course, needed no runway, and, with the methods of design and construction now available, the seaplane could once again be expected to compete with the land 'plane on all counts of operational efficiency, within the limits likely to be required for civilian use. There was, however, another way of sidestepping the problem of runway length and airfield cost; not long before, the possibility that engine thrust might exceed aircraft weight would have been dismissed as the morbid dream of a mad inventor, but the prospect was now almost a reality, which might result before long in radical changes in design and in the methods of aircraft operation.

### FRENCH PIONEER OF ELECTRIC POWER DISTRIBUTION.

We have received, somewhat belatedly, details of a ceremony which took place on May 4, at the St. George's power station in the upper valley of the river Aude, in the Province of Aude, France, to honour the memory of the French pioneer of high-voltage electric power distribution, Joachim Estrade (1857-1936). In the presence of a large gathering representative of French engineering interests, a plaque was unveiled to commemorate the fact that it was from the St. George's power-station, built on his initiative, that Estrade inaugurated, on December 25, 1900, the first long-distance distribution of high-voltage alternating current. The supply, three-phase, at a frequency of 50 cycles per second and a pressure of 20,000 volts, was distributed to more than 100 townships and served over 100,000 persons within a radius of 100 kilometres from St. George's. Although this was not the first occasion on which high-voltage electricity had been transmitted over appreciable distances, it appears to have been the first time that high-voltage transmission was combined with widespread distribution at lower voltages, no mean achievement since transformers were then still of comparatively primitive design. Estrade's initial scheme, completed in 1901, comprised a main feeder, 70 km. long, with a trifurcation at Fabrozan into branches terminating at Carcassonne, Narbonne and Portel, with certain subsidiary branches. In all, 170 km. of 20,000-volt line were involved. At a number of substations along the route, the supply pressure was transformed down to 5,000 volts and, in each locality served, it was reduced again to 125 volts. There were 125 transformer-stations and more than 500 km. of high-tension lines when the scheme got under way and, by 1908, these figures had been almost doubled. Many difficulties were encountered. On occasion, lightning destroyed insulators and transformers; the cotton insulation of the transformer windings perished owing to local-atmospheric ionisation and destructive short-circuits occurred; the heavy insulators of inferior porcelain were pierced, and the sealing compounds used to repair them swelled and burst the insulators. To add to the difficulties, the wooden poles which carried the lines were not impregnated with creosote and rotted after 4 to 10 years service. Eventually, however, all these difficulties were overcome.

### OIL-TREATMENT PROCESS FOR TOUGH SYNTHETIC RUBBERS.

Further research into the field of "oil-extended" synthetic cold rubber, in which petroleum oils are added to the rubber during manufacture, holds great promise for the future and is an important outcome of the rubber-research programme of the United States. Such is the opinion of Dr. R. P. Dinsmore, vice-president in charge of research and development of the Goodyear Tire and Rubber Company, Akron, U.S.A., who delivered the seventh Foundation Lecture of the Institution of the Rubber Industry, on Friday, May 23, at Wolverhampton. Dr. Dinsmore, who had chosen as his subject "Economic and Physical Aspects of GR-S Modifications," stated that the addition of large quantities of readily-available petroleum oils, which acted as an internal lubricant, permitted the processing of the "tough" rubbers with the conventional rubber-factory equipment. Rubber chemists had long believed that the tough rubbers were superior in resilience and other properties to the soft rubbers ordinarily used. The oil-extended process overcame the tendency of tough rubbers to crack and tear under tension, as in the shaping of tyre treads. Costs were also affected because the new process could produce 125 lb. of improved rubber for the same outlay as 100 lb. of conventional rubber. Tyre-tread tests conducted by the Goodyear Company and by the United States Government, had indicated that the new oil-treated rubbers gave up to 21 per cent. longer tread wear than standard cold or GR-S rubber. Moreover, the lower build-up of heat which occurred in the oil-treated rubbers indicated them to be useful for heavy-duty motor-lorry tyres. Recent experiments of great promise had been conducted with a new tough synthetic rubber, named Alfin, developed by Professor A. A. Morton, of the Massachusetts Institute of Technology. Described as the most resilient of all the polymers of high molecular weight, Alfin was very difficult to process in ordinary circumstances and was particularly adapted to the oil-treating process. It was, moreover, a distinct possibility, concluded Dr. Dinsmore, that useful improvements to natural rubber, as well as to the synthetic materials, might result from further investigation into the oil-extension process.

# LETTER TO THE EDITOR.

## LEONARDO'S MIRROR WRITING.

TO THE EDITOR OF ENGINEERING.

SIR,—May I dispute the statement, made by Mr. K. R. Gilbert, on page 581, *ante*, in his article on Leonardo da Vinci, that the notes on Leonardo's drawings were made in mirror writing "to conceal his inventions from the inquisitive"? My attention was first directed to the subject of mirror writing many years ago when I was in charge of the machine shop here and mistakes were frequently made when articles were ordered one off "as drawn" and one off "to opposite hand." It was not always appreciated that when one thing is to the opposite hand from another, everything on it that is not symmetrical must be reversed, and in the course of time I found it was sometimes useful to have the object made "as drawn" looked at in a mirror.

About the same time, I noticed a statement in an article that Leonardo da Vinci wrote his notes in mirror writing, using this as a form of cryptogram. It occurred to me that this might not be the case and that it might be the fact that Leonardo da Vinci was actually left-handed and had developed this habit because it is the natural tendency of any person to write from the centre of the body outwards, whereas a left-handed person writing in the normal way has to write towards the centre of the body. I then made some inquiries and I found that left-handed people in certain cases do show a tendency to write mirror writing in preference to normal writing. At the present moment we have a left-handed student here who takes notes in the normal way till he gets tired and then changes to mirror writing. I then tried a number of right-handed people and asked them to experiment and see if they did not find it easier to produce mirror writing with the left hand than with the right hand. I found that if both hands are used simultaneously it is easier to write mirror writing with the left hand and normal writing with the right hand than it is to write normal writing with both hands or mirror writing with both hands; anyone who has the full use of both hands can demonstrate this readily.

This led me to think that Leonardo da Vinci wrote mirror writing simply because he was a naturally left-handed man and he had never been compelled in his infancy to write the normal cursive script as written by a right-handed man, and so was free to develop his own tendency.

Yours faithfully,
I. M. LYON.

Babcock and Wilcox, Limited,
Renfrew, Scotland.
May 26, 1952.

# OBITUARY.

## DR. F. W. CARTER, F.R.S.

WE record with regret the death, on May 29, of Dr. F. W. Carter, M.A., Sc.D., M.I.C.E., M.I.E.E., F.R.S., who from 1903 to 1946, with the British Thomson-Houston Company, Limited, Rugby, was engaged on electric railway traction and on many problems of a specialised nature. He was 81 years of age.

Frederick William Carter was born at Aston, Birmingham, on December 16, 1870. His father, Mr. J. Carter, was a die-sinker and medallist, and it was in his father's works that he acquired some of the skill of these crafts from 1885 to 1891. While engaged on this apprenticeship, he attended classes at the Birmingham Midland Institute, the Birmingham Municipal Technical School, and Mason's College. His scientific education, however, began in 1892 at St. John's College, Cambridge, from which he graduated in the Mathematical Tripos. From there he went to the Central Technical College (later the City and Guilds Engineering College) of the Imperial College of Science and Technology, where he worked for four years as a lecturer and laboratory assistant under Professor W. E. Ayrton in the electrical-engineering department.

In 1900, Dr. Carter entered industrial engineering work, proceeding first to the United States, where he worked on the general testing of electrical machinery at the Schenectady works of the General Electric Company. After a year on this, he spent the remainder of his American stay as an engineer on the company's experimental electric railway, under Mr. W. B. Potter. This early electric-railway experience was the beginning of a life-long connection with that type of engineering. Returning to England in 1903, he was engaged by the British Thomson-Houston Company as an engineer on electric railway work. In this capacity he gained experience on the design of the North Eastern Railway Company's electrified system, of the London Underground Railway's Hammersmith to City line, and of the Metropolitan Railway's installations. In later years, he turned to other mechanical and electrical problems, dealing particularly with stresses and strains in steam turbines and other machines, the causes and elimination of vibrations, the distribution of magnetic flux in electrical machines, losses from eddy currents, etc. During the first World War, Dr. Carter was chairman of the local Admiralty experiments centre, and was engaged, under the Director of Experiments and Research, in devising means for the detection and destruction of submarines. For many years, until his retirement, he was consulting engineer to the B.T.H. Company.

Dr. Carter was the author of numerous papers to engineering institutions, including one on the electric locomotive, presented to the Institution of Civil Engineers in 1916, for which he was awarded the George Stephenson Medal, and one to the same Institution on "The Running of Locomotives with Reference to the Tendency to De-Rail," for which he gained a Telford Premium in 1930. He was elected an associate member of the Institution in 1907, and became a member in 1919. He was also a member of the Institution of Electrical Engineers, having been made an associate in 1898, an associate member in 1905, and a member in 1912. He was elected a Fellow by the Royal Society in 1932.

RESEARCH FELLOWSHIP IN AERONAUTICS.—The first award of the English Electric Research Fellowship in Aeronautics, which was recently established by the English Electric Co., Ltd., at the College of Aeronautics, Cranfield, has been made to Mr. G. C. C. Smith, who is in his final year as a student of the post-graduate Diploma course at the College. Mr. Smith, whose home address is at 4, Salter-road, Summerhill, Tipton, Staffs., is a former scholar of Dudley Grammar School and a graduate of Birmingham University. The Fellowship is of the value of 500*l*., tenable for one year. Its purpose is to promote studies in aeronautical engineering, with particular reference to the problems of vibration, stability and control of aircraft. Mr. Smith will undertake a structural research project during his tenure of the Fellowship.

# PREVENTIVE MAINTENANCE.

THERE can be little doubt that, if our industries are to meet the unprecedented demands placed upon them by the need to expand arms production and at the same time increase exports, there will have to be still further increases in technical efficiency. Difficult as the task is, it has recently been made more difficult by the restrictions imposed by the Government on the supply of capital equipment. As a result, output has not only to be maintained but increased with equipment and machines which, in many cases, are well past their prime. The continued maintenance of these machines has, therefore, become of paramount importance and although many engineering firms are fully aware of this and have instituted proper maintenance programmes, there are, unfortunately, many more who have not shown the same progressive outlook, their maintenance methods being of a somewhat sketchy nature. That there is an urgent need for the wider introduction of efficient schemes for plant maintenance can hardly be contradicted, and it is fairly certain that a significant contribution towards meeting our present commitments can be made by the proper application of such schemes.

That the subject is considered to be important is indicated by the fact that a team has been sent to the United States, under the auspices of the Anglo-American Council on Productivity, to study plant engineering methods with particular reference to preventive maintenance. Their report, however, will not be available until the end of the year; as a consequence, the Production Engineering Research Association, considering the matter of vital importance and one requiring immediate discussion, staged a conference entitled "Preventive Maintenance," which was held at their headquarters in Melton Mowbray on Wednesday, May 28. Three papers were read, two during the morning session and one in the afternoon. The first of these, "Management Aspects of Preventive Maintenance," was read by Mr. Bertram White, B.Sc., Technical Director of the Federation of British Industries, and dealt with the subject in general terms, pointing out the necessity for managements to treat this subject more seriously than hitherto. After stressing the grave position in which this country found itself, Mr. White said that it had been made very clear to him that our main hope of meeting the now menacing situation was to raise still further industrial productivity. In normal times, one of the principal methods of doing this was by carrying out extensive re-equipment programmes, but the increasing demands from our export markets for capital equipment instead of consumer goods, coupled with the need to devote more machines to the defence programme had, unfortunately, prevented us from employing this means for resolving present difficulties. We must, therefore, continue to use, and use more intensively, plant which in some cases was obsolete. This would demand the highest standards of plant operation and maintenance, and whereas it was sound business at any time to put plant maintenance on a systematic basis, to-day it was of greater urgency and importance than at any other time in our history.

Mr. White then referred to the need for raising industrial productivity and pointed out that since the war we had increased the total volume of industrial productivity by approximately a half. Nevertheless, in the second half of 1951 production rose but little, if at all, and although the dislocation brought about by changeover to defence production, allied with material shortages, probably were mainly responsible for this check, we had to ensure that the rise was resumed without delay. This would entail the more intensive working of existing industrial plant and demand the highest efficiency in plant maintenance. We must, therefore, apply modern techniques of management to plant maintenance and, in so doing, replace the rule of thumb by system and method, and plan to avoid breakdowns rather than remedy them after their occurrence. To achieve this involved good organisation and this meant automatically that plant maintenance should be placed in charge of men of high calibre and that they should have the right to report at a senior level.

To take these steps alone, however, necessary as they were, would not solve the problem. We must acknowledge the need to train men for the task but, so far as he knew, little had been done to put training for planned maintenance on a sound regular footing throughout British industry. Some companies, fortunately, had made provision for training plant engineers and he hoped that these arrangements might be made known more widely, so that others might follow. The keeping of proper plant records also was important as, in addition to aiding in plant maintenance, they also assisted in other directions. In his experience, far too few firms made a regular practice of booking waiting time brought about by breakdowns so that the cause of delays and stoppages could be assessed and the remedy applied. Those who had experience knew that the establishment of such records was not difficult and that the experience and knowledge gained greatly simplified forward planning.

Mr. White then mentioned that we had heard from many quarters that the Americans were much better at this sort of thing than we were, but while we should at all times be eager to improve our knowledge and learn from others, it was his considered opinion that the best practice in this country was as good as could be found anywhere in the world. What we should strive to do was to share our knowledge more frankly and more readily. This should prove a simple matter with such a subject as preventive maintenance which engendered none of the apprehensions and difficulties involved when exchanging experience on production techniques in a competitive industrial economy. These remarks led Mr. White to make a proposal for sharing the knowledge and experience gained. In his opinion, the best way of bringing this about was through exchanges of factory visits. These visits should be the responsibility of some suitable body, so that there was a common channel for communication and making the necessary arrangements. He felt sure that the Federation of British Industries and other trade associations would give every help and encouragement, and suggested the task might be undertaken by a joint committee of the Production Engineering Research Association, the Incorporated Plant Engineers and other interested bodies.

The second paper was read by Mr. D. Lacy-Hulbert, B.Sc., A.M.I.Mech.E. It was entitled "The Productivity of Maintenance" and dealt with the subject of preventive maintenance in practical terms. Mr. Lacy-Hulbert introduced his paper by referring to the fact that, except in times of war, there was no great advantage in raising the productivity of men and machines unless the cost of converting the raw material into the finished product could be reduced. He proposed, therefore, to divide his paper into two parts, the first part dealing with the problem of making it possible for the operators to spend their time more usefully as a result of better maintenance, and the second part with the possibility of raising the productivity of the maintenance staff itself. To show that a definite saving could be achieved by proper maintenance, Mr. Lacy-Hulbert referred to the usual form of chart which indicated the output to be achieved each month. Ideally, this was a straight line, but generally, actual production did not follow this line, the production curve, as a rule, consisting of a series of straight lines at an angle greater than that of the target line interspaced with horizontal lines corresponding to machine breakdowns, etc. It was obvious, therefore, that if there were no stoppages, the line indicating actual production would rise throughout the month at a steeper angle than the target line, with resulting greater production. This was precisely the object of preventive maintenance.

Mr. Lacy-Hulbert then emphasised the fact that if the works engineer was to re-arrange his maintenance work so as to eliminate the horizontal sections, it was essential that the overall cost of his new methods should be less than the cost involved by the shut-downs. Usually, the maintenance operatives were men who had served apprenticeships as craftsmen and fundamentally were as conscientious in their work as any in the field of industry. Too often, however, they did not spend their whole time doing the type of work for which

# DEADWEIGHT VEHICLE FOR TESTING ROAD BRIDGES.

they were employed, mainly because the jobs were not properly arranged. It was, he agreed, very difficult to obtain a true idea of the output per man hour of the average maintenance worker. He estimated that, in British industry, the figure came somewhere between 50 per cent. and 75 per cent. of what it could be. There was, he thought, room for improvement, and, throughout the years, efforts had been made to evolve realistic bonus or incentive schemes for maintenance men. The main difficulty had been, of course, the non-repetitive nature of their work and the attendant difficulties of carrying out proper time studies.

Mr. Lacy-Hulbert was of the opinion, however, that, if it were possible to introduce measured time standards for maintenance, there would be a marked improvement in productivity and corresponding reductions in labour cost. His firm, therefore, were in the process of installing a scheme whereby they had been able to reduce the normal production-study techniques into an estimating procedure so that one assessor was able to deal with between 10 and 25 maintenance personnel. The procedure was essentially an individual one, target times being fixed by the estimator for each job according to the work necessary. To do this, the estimator divided each job into its constituent operations and classified each of these into specific grades, taking into account such factors as size of component, accessibility, class of fit, etc. He then allocated from prepared tables time values for each operation, according to its grade, and thus assessed the total time; and they had found that these times were sufficiently accurate to be used for bonus payment purposes. The increase in productivity which had resulted from the introduction of this system had come from three main sources, namely: the elimination of waiting time between jobs; better utilisation of maintenance equipment; and a better allocation of work as between the skilled workman and his semi-skilled assistant.

Most of the afternoon session was given up to a paper read by Mr. G. C. Oram, M.I.Mech.E., M.I.E.E., entitled "Preventive Maintenance in Action." Like Mr. Lacy-Hulbert's paper, this dealt with the practical aspects of the subject. After referring briefly to the necessity for adopting proper maintenance schemes, Mr. Oram went on to give his definition of plant maintenance. This, to be comprehensive, should, he thought, cover buildings, machinery and service equipment, each of which required its own technique and deserved the same attention as any problem of production. Plant maintenance, he suggested, should be so planned, organised and managed that the best use was made of any company's resources by avoiding interruptions and the engineer could only justify his existence by being in a position to prove that the work he was doing paid dividends. The number of years a machine had been in service did not necessarily mean that it had become old, worn out or obsolete, as these terms are defined by the quality and quantity of the work it produced.

Mr. Oram then referred to the steps to be taken in organising a scheme of plant maintenance. In the first place, it was necessary to have a plant inventory and this should take such a form as to enable the accountant to budget for its maintenance. The next step was the establishment of a suitable record system followed by the introduction of a programme of regular inspections which would take two main forms, namely, visual inspection and testing or checking. The timing of inspection was important and should be arranged so that the inspector could do the work at a stated time. It was, he thought, regular inspection followed by prompt action which constituted the important link in preventive maintenance.

Mr. Oram then described some of the measures which had been introduced by his firm and gave details of the organisation which had been established. Inspection sheets were prepared so that every item on each machine was covered and plant-record cards were introduced, orders for replacement parts being placed at the same time, so that repairs could be undertaken at a prearranged date. It was, he said, essential that there should be a clear line of authority throughout the works and in the case under review the maintenance executives were placed on an equal footing with those responsible for production. The work was tackled systematically and particular attention was paid to standardisation and simplification. Other points mentioned by Mr. Oram included the introduction of a system of standards of limits and fits to suit their class of work. In addition to the main production plant, his firm operated a large number of locomotives and associated wagons and steam cranes, and to carry out the work of maintenance involved the establishment of central workshops. These, in due course, came under the general maintenance scheme. The work carried out by the maintenance department and its effect on the general state of the plant was such that by the end of 1950 arrears of maintenance work had been reduced to negligible proportions and incoming orders were being dealt with promptly. The locomotives and cranes had been brought up to a high pitch of efficiency and the central workshops were faced with the possibility of insufficient work.

## DEADWEIGHT TRAILER FOR TESTING ROAD BRIDGES.

THE trailer shown behind a tractor in the above illustration has been adapted by the Ministry of Transport, in collaboration with the Ministry of Supply, to enable the strength of existing masonry-arch bridges to be tested. With the considerable increase in movements of abnormal indivisible loads of great weight, the Ministry of Transport and other authorities have been concerned about the strength and safety of the many masonry-arch bridges in this country. Regulations governing the construction and use of vehicles designed to carry abnormal indivisible loads now permit maximum gross loads of 150 tons, and any single bogie having two axles can be constructed in such a way that a 45-ton load is permitted on each of the axles, and the load on each wheel may be as much as $11\frac{1}{4}$ tons. Though a considerable amount of research was done both before and during the war, it did not nearly extend to loads of this magnitude, and no reliable and consistent basis exists for the calculation of bridge strength under really heavy loads, where there is filling between the arch and the road. The Ministry of Transport have accordingly undertaken a series of investigations, for which the trailer has been built.

The equipment has been built entirely from second-hand and scrap material. The well-deck trailer was originally built in 1929, being one of the first vehicles specifically designed for carrying abnormal loads. In the well, transverse timber sleepers have been secured, on which rest four longitudinal timber rail-bearers, carrying rolled-steel channels as rails. On these, four sets of Bailey bridge rocking rollers can travel from end to end of the well. The rocking rollers are made up in sets of two, each pair supporting the ends of a short transverse rocking beam, with a cylindrical bearing at its mid-span. Between these bearings rests a transverse cill beam, which in turn carries the end of a massive load slab. The other end of the slab is supported over the rear bogie of the trailer by a similar but inverted arrangement of rollers, which always remain over the back axles, while the slab can move over them. It is thus possible to move the slab to and fro in relation to the trailer, from a position in which its weight is almost equally shared by the front and rear bogies to one in which the weight is almost entirely concentrated on the rear bogie. The slab is 35 ft. long, 7 ft. 9 in. wide, and 3 ft. thick, of solid concrete, encasing four longitudinal main steel beams. It weighs 50 tons, while the trailer and fittings weigh 35 tons. Provision has also been made for the addition of kentledge to increase the weight of the movable slab to 80 tons.

It will be possible, with these arrangements, to obtain single-bogie loads ranging by small increments from 20 to 90 tons by moving the slab to different positions on the trailer. When the slab is in its extreme extended position, without kentledge, the front bogie weighs 20 tons and the rear bogie weighs 65 tons. In bridge testing, the procedure will be to place the front (20-ton) bogie on the arch under this load, and to repeat the operation with increasing loads, first under the front bogie, and then, up to a maximum, under the rear bogie. As the axles of the front and rear bogies are 25 ft. apart, bridges up to 50 ft. span can be tested readily under the effects of one bogie alone. Beyond this span, a rather more complicated procedure will be necessary. The method of supporting the movable slab on rocking rollers and transverse rocking beams is intended to give articulated suspension and springing to the rigid mass on a trailer which is very flexible, so achieving uniform distribution of load throughout the structure and avoiding jarring impacts which would rapidly cause damage. In the trial runs which have now been carried out, it has been found that these precautions have been successful. Although the original trailer has no springing, apart from its own flexibility, no perceptible shocks were felt by passengers on top of the slab during the trial runs, and small articles laid on its edge were undisturbed. Various devices have been introduced to ensure that the movable slab can be kept completely under control and secure at all times, and in place of the original brakes, hand operated by attendants walking alongside, an efficient Westinghouse system of pneumatic brakes has been introduced. Hand-operated brakes are retained for parking.

Concurrently with the construction of this loading equipment, engineers of the Ministry of Transport have been designing instruments to measure the deformation of bridges under test. It is considered necessary to measure horizontal and vertical movements of the order of 0·0005 in. in order to reach sufficiently reliable conclusions about the strength of this type of bridge. The benefits to be obtained from the series of experiments on which the Ministry, in collaboration with the Building Research Station, are embarking will, it is hoped, be considerable. Although there is at present no generally recognised and satisfactory basis for the assessment of the strength of masonry arches where there is filling between the arch and the road, it is known that these structures are able to carry with safety larger loads than present elementary theories will justify. There are so many complicating factors involved that even allowing for what has already been done, it will not be easy to devise a reasonably simple and comprehensive method of assessment applicable to all common types and sizes of arch bridge. It is, however, planned to carry out the investigation in such a way as to make it possible to give interim reports on limited ranges of the subject, thus taking immediate advantage of each stage of the work, even though wider and more accurate conclusions may be reached as the research proceeds. A reasonably accurate method of calculating strength which can be accepted by all concerned is likely to lead to savings in mileage, as abnormal vehicles now often have to make lengthy detours on account of doubtful bridges. The results of the tests are also likely to justify savings in reconstruction costs.

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"RESEARCH ON FRICTION AND WEAR": ERRATUM.—In our issues of November 23 and 30, 1951, on pages 649 and 697, respectively, of vol. 172, we reprinted a paper with the above title, by Dr. F. T. Barwell, which had been delivered a few weeks previously to the Institution of Engineers and Shipbuilders in Scotland. Our attention has been drawn to an error which appeared in the proof copies of the paper and was repeated in our reprint: in the centre column of page 698, in the issue of November 30, the mathematical expression immediately under Fig. 21 should read

$$1{,}000\left[\frac{77}{\left(\frac{C}{D}\right)^{\frac{1}{2}}}\right]\frac{\nu}{D^2}\ \text{r.p.m.}$$

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MARINE RADIO-OFFICERS' SCHOLARSHIP SCHEME.—A scholarship scheme is to be instituted by the Marconi International Marine Communication Co., Ltd., Chelmsford, Essex, to provide financial assistance to young men who wish to embark on a career at sea as radio officers. To inaugurate the scheme it has been decided to award 50 scholarships for the current year, and these have been allocated to 15 private wireless training colleges in England, Scotland and Wales. Application for consideration must be made in the first instance only to the principals of wireless training colleges. The recommended candidates may be either partly trained students who find that they cannot meet the cost of further tuition, or applicants who wish to undergo tuition but are not in a position to pay the entire fee themselves. The Marconi Marine Company undertake to meet two-thirds of the tuition fees necessary to cover study to the standard required to obtain the Postmaster General's Certificate of Proficiency in Radiotelegraphy (2nd class), possession of which qualifies the student to go to sea as a radio officer. Successful students will be required to undergo a medical examination before commencing training under the scholarship scheme, though the wearing of glasses is no bar to entry.

# WELDED DOCK GATE.

HEAD, WRIGHTSON AND COMPANY, LIMITED, THORNABY-ON-TEES.

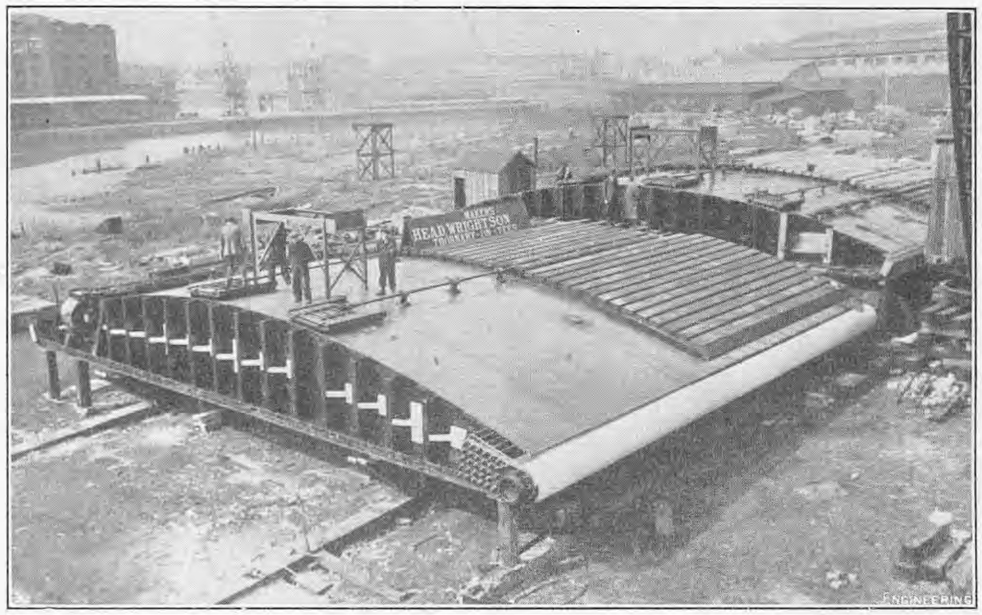


FIG. 1. DOCK GATE UNDER CONSTRUCTION.

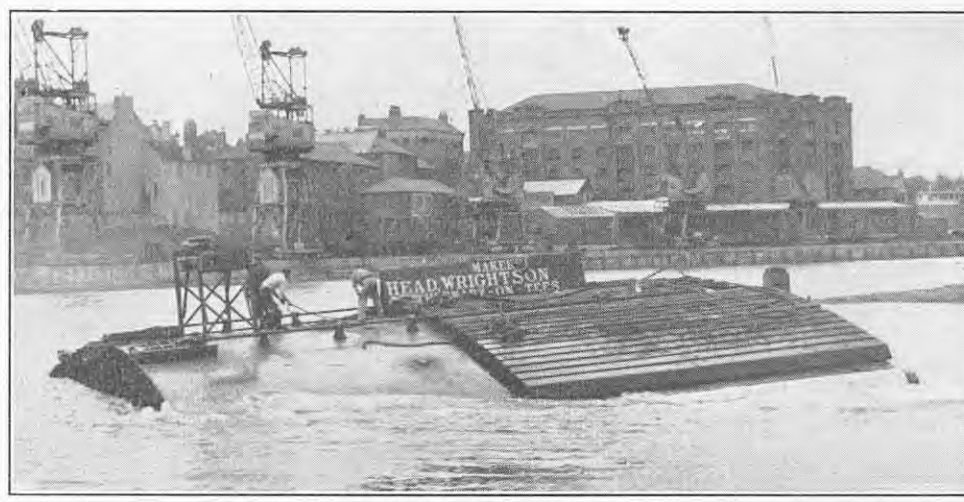


FIG. 2. GATE BEING FLOATED TO LONDON DOCKS.

## WELDED DOCK GATES FOR THE PORT OF LONDON.

THE first of a pair of all-welded lock gates was recently launched from a slipway at the Teesdale Iron Works, Thornaby-on-Tees, of Messrs. Head, Wrightson and Company, Limited, who have designed and built the gates for the Port of London Authority. Tugs towed them to the mouth of the River Tees, where a larger tug took over to continue the journey on the North Sea to the River Thames. The weight of each leaf of the welded design is 240 tons, compared with about 350 tons for the existing riveted gates at the King George V dock. The gates are to be interchangeable for any of the three positions of the 100-ft. wide entrance lock. They will be stepped into position by the Port of London Authority's floating crane. The launching ceremony, which took place on Friday, May 23, was performed by Mrs. J. A. Fisher, wife of the Port of London Divisional Engineer, in the presence of the chairman (Mr. Richard Miles) and vice-chairman (Sir John Wrightson, Bt.) of Messrs. Head, Wrightson and Company. Figs. 1 and 2, above, show the gate under construction and after launching, respectively.

Each leaf is 58 ft. long by 49 ft. 6 in. deep by 7 ft. 3 in. mould width, and consists of 17 plate ribs or decks suitably stiffened. The skin plating is butt-jointed and is composed of eight strakes on both the flat and curved sides. Vertical stiffness is provided by five plate diaphragms extending the full depth of the gate; the centre diaphragm is watertight for its full depth, and the two outer diaphragms watertight between the top of the air chamber and the second lowest chamber, thus forming four tanks in the lower air chamber and two tanks in the upper tidal chamber of the gates. The space between the bottom and second decks is also tidal on the pressure side. The heel-post and mitre-post are built from plates which are welded in the form of a channel section and a joist section, respectively. The heel, mitre and sill timbers are of greenheart. A central core plate, with stiffener brackets at deck centres, is welded directly to the web of the heel-post. Two manhole trunk-ways extend from the top deck to give access to the lower air chambers. The gates are provided with three sets of hydraulic sluices, each with an opening 3 ft. 5 in. by 2 ft. 11 in. and with a hydraulic ejector, with valves to draw from each of the four tanks of the air chambers. The upper half of each leaf is completely sheathed with elm whaling and fenders. Though the gates are of the buoyant-tank type, rollers have been fitted to suit the existing roller paths. A crocodile arm, or lever, also of welded construction, is provided to operate the gate from the existing hydraulic machinery. The workmanship in the construction of the gates has been under Lloyd's supervision. Messrs. Head, Wrightson and Company have received orders for eight further gates for the London area, following the successful installation of all-welded gates at Calais.

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CARRIAGE OF DANGEROUS GOODS IN SHIPS.—The Minister of Transport has accepted, subject to minor reservations, the recommendations made in the Report of the Departmental Committee on the Carriage of Dangerous Goods and Explosives in Ships, published in February this year. The Minister's acceptance is announced in a Notice (No. M.365) to shipowners, shipmasters, and shippers, copies of which can be obtained free from the Ministry of Transport or any Mercantile Marine Office. The Notice points out that the substances classified in the Report are not to be regarded as a full list of dangerous goods. When it is wished to ship any substance which possesses dangerous properties and which is not provided for in the Report the case should be submitted to the Ministry of Transport

# CLAMPS FOR WIRE ROPES.

SKANDINAVISKA TALURIT AB., GOTHENBURG.

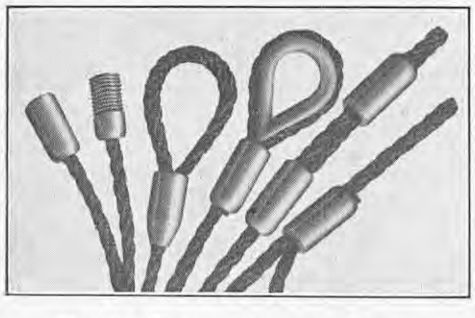


FIG. 1. TALURIT-CLAMPED ROPES.

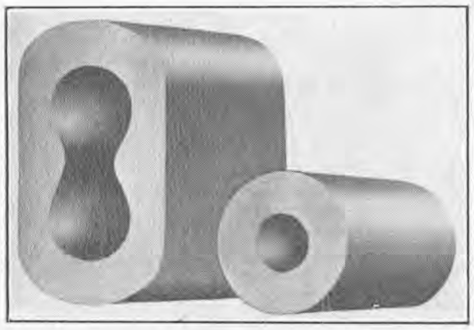


FIG. 2. FERRULES.

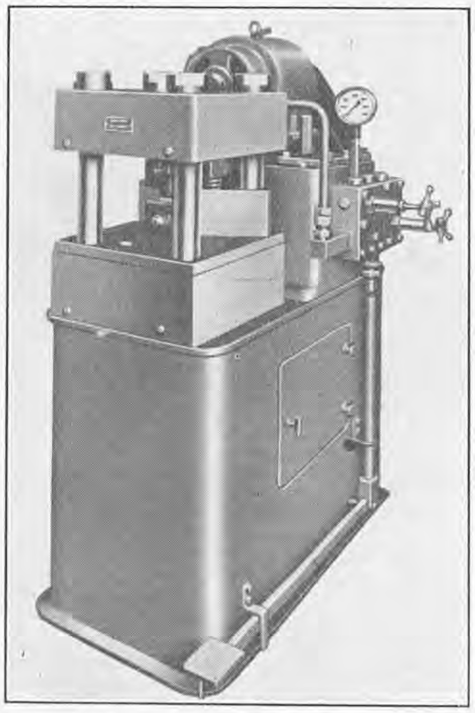


FIG. 3. SWAGING PRESS.

## WIRE-ROPE CLAMPING SYSTEM.

A METHOD of clamping steel wire ropes which obviates splicing when joins have to be made or eyelets inserted has been introduced by the Swedish company Skandinaviska Talurit AB., of Gothenburg. Tests have shown that joints produced by the Talurit system are as strong or stronger than spliced joints, and the time and material saved by adopting the process are very considerable. The method, which is essentially one of swaging a ferrule on the rope, can be used on ropes of any size up to 7 in. in circumference. Examples of Talurit joints are illustrated in Fig. 1, on this page.

The ferrules employed are made of a special copper-free aluminium alloy which obviates electro-chemical action between the aluminium and the steel. The alloy also contains some magnesium which enables it to flow freely into the interstices of the rope when compressed. Two forms of ferrule are illustrated in Fig. 2. That on the left is the type used when a loop has to be formed. In each case the process is as follows. The end of the rope is held in two clamps a short distance apart and the intervening portion is twisted by rotation of one of the clamps, sufficient twist being imparted for the rope to remain in its twisted form when it is cut by a guillotine between the clamps. Were this not done, the rope would tend to splay out when cut and would not readily pass through the ferrule. In the case of large ropes, where the above process would not be easy to carry out, the end of the rope is first annealed.

When the rope has been cut, the end is passed through the ferrule and, in the case of a loop, doubled back again, after which the thimble is inserted and the ferrule slid into position. The rope is then inserted in the press with the ferrule between the two swages and pressure is applied to mould the clamp into the required form. A hand-operated press, which functions by means of a hydraulic pump, suffices for the smaller sizes of rope. In the case of the larger sizes, a power-driven press is employed. The company manufacture a number of presses ranging in capacity from 22 tons to 1,000 tons, one of the series being illustrated in Fig. 3. It has been estimated that Talurit clamping can be completed in less than one-tenth of the time required to make a spliced joint.

The system has been subjected to extensive tests in Sweden and elsewhere and its use has been approved by Lloyd's and other bodies. Manufacturing and distributing rights in Great Britain have been acquired by Cable Covers, Limited, St. Stephen's House, Westminster, London, S.W.1, who state that no restrictions will be placed on the use of the system. Swaging presses will be made available under licence to makers and users of wire rope and these users will also be able to purchase the special ferrules and swages required by them. Others, whose requirements do not warrant the installation of presses, will be able to obtain Talurit finished ropes from the wire-rope manufacturers.

## THE BIRTHDAY HONOURS LIST.

THE Honours List, which was published yesterday, on the occasion of the official celebration of H.M. The Queen's Birthday, includes the names of engineers and others connected with technical and scientific work and with industry. Other names will be given in ENGINEERING next week.

BARONET.

Mr. Geoffrey Summers, C.B.E., M.A., J.P., D.L., director of John Summers and Sons, Limited, for political and public services in Wales.

KNIGHTS BACHELOR.

Air Commodore V. S. Brown, C.B., O.B.E., R.A.F. (Retd.), chief inspector of accidents, Ministry of Civil Aviation; Mr. W. S. Farren, C.B., M.B.E., M.I.Mech.E., F.R.Ae.S., F.R.S., technical director, A. V. Roe and Company, Limited; Mr. J. H. Keeling, deputy chairman, British European Airways Corporation; Mr. Leslie Roberts, C.B.E., chairman and managing director, Manchester Ship Canal Company; Mr. H. B. Robin Rowell, C.B.E., A.F.C., D.L., M.I.N.A., chairman and managing director, R. and W. Hawthorn, Leslie and Company, Limited; and Mr. G. H. Savage, chairman, central conference of employers and trade unions in the engineering industry.

ORDER OF THE BATH.

*Knight Commander.*—Mr. E. A. Hitchman, C.B., permanent secretary, Ministry of Materials.

*Companions.*—Rear-Admiral (E) F. E. Clemitson; Major-General C. P. Jones, C.B.E., M.C., late R.E.; Colonel A. H. Read, O.B.E., T.D., D.L., director of overseas telecommunications, General Post Office; and Mr. John Wedlake, M.B.E., director of armament supply, Admiralty.

ORDER OF ST. MICHAEL AND ST. GEORGE.

*Knight Grand Cross.*—Rt. Hon. E. G. W. Tyrwhitt; Viscount Knollys, K.C.M.G., M.B.E., D.F.C., for services as the representative of H.M. Government on the International Materials Conference.

*Knight Commander.*—Sir Cecil McAlpine Weir, K.B.E., M.C., for services as a member of the Dollar Exports Council.

ORDER OF THE BRITISH EMPIRE.

*Commander.*—Mr. L. J. Banford, director of contracts, Air Ministry; Mr. George Barrie, M.I.N.A., chairman of directors, Barclay, Curle and Co., Limited; Mr. James Bowman, chairman, Northern (Northumberland and Cumberland) Division, National Coal Board; Mr. E. C. Bowyer, director, Society of British Aircraft Constructors; Acting Air Commodore H. H. Chapman, A.M.I.E.E., R.A.F.; Mr. T. J. Drakeley, principal, Northern Polytechnic, London; Mr. G. R. Edwards, M.B.E., chief designer, Vickers-Armstrongs Limited, Weybridge; Major-General W. A. Lord, R.E.M.E.; Mr. D. M. McDiarmid, director of public works, Federation of Malaya; Mr. W. A. C. Newman, O.B.E., A.R.S.M., A.R.C.S., F.R.I.C., F.I.M., chemist and assayer, Royal Mint; Mr. L. C. B. Penwill, director and secretary, Electrical Contractors' Association; Mr. W. J. Richards, chief superintendent, Telecommunications Research Establishment, Ministry of Supply; Mr. R. L. Smith-Rose, director of radio research, Department of Scientific and Industrial Research; Mr. Herbert Sammons, managing director, D. Napier and Son, Limited, Acton; Mr. William Savage, works director and chief engineer, Ruston Bucyrus Limited; Brigadier R. F. E. Stoney, O.B.E., late R.E.; Mr. Frank Sutcliffe, manager, constructive department, H.M. Dockyard, Portsmouth; Dr. H. Sutton, F.R.Ae.S., F.I.M., director of materials, research and development (air), Ministry of Supply; Mr. C. B. Townend, chief engineer, Main Drainage Department, Middlesex County Council; Dr. D. T. A. Townend, F.R.I.C., Hon.M.Inst.Gas E., director-general, British Coal Utilisation Research Association; and Mr. J. C. L. Train, M.C., M.I.C.E., member, Railway Executive.

*Officers.*—Mr. R. O. Banister, divisional operating superintendent, Manchester, Railway Executive; Mr. B. C. Curling, lately secretary, Institute of Marine Engineers; Mr. R. D. Duncan, B.Sc. (Edin.), M.I.C.E., chief engineer, Ministry of Health and Local Government, Northern Ireland; Mr. K. R. Evans, M.A. (*Cantab.*), M.I.E.E., A.M.I.Mech.E., manager, education department, Metropolitan-Vickers Electrical Company, Limited; Mr. F. M. Fuller, B.Sc. (Eng.) (Lond.), M.I.C.E., divisional engineer, London County Council; Mr. Eric Grundy, B.Sc.Tech., M.I.E.E., manager, Ferranti, Limited; Mr. R. P. Haines, A.M.I.C.E., senior civil engineer, War Office; Mr. Robert Higgins, Ph.D. (Glas.), B.Sc., A.R.T.C., F.I.M., Assistant Professor of Metallurgy, University College, Swansea; Dr. J. O. Hughes, principal scientific officer, Royal Aircraft Establishment, Farnborough, Ministry of Supply; Mr. W. A. Jackson, M.I.E.E., director, Telephone Manufacturing Company, Limited; Mr. S. K. Janson, engineer, grade I, Armament Design Establishment, Ministry of Supply; Mr. William McFarlane, B.Sc., M.I.E.E., chief generation engineer, South West Scotland Division, British Electricity Authority; Mr. A.B.Mann, B.Sc.(Eng.)(Lond.), M.I.Mech.E., A.M.I.C.E., assistant chief engineer, Ministry of Works; Mr. F. L. Shepherd, special director, Dorman, Long and Company, Limited; and Mr. P. L. Wostear, A.M.I.E.E., lately assistant director, radio production, Ministry of Supply.

## TECHNICAL INFORMATION SERVICE FOR THE BUILDING INDUSTRY.

IN order to bring the results of building research and development work to the notice of the men actively engaged in the building industry, the Ministry of Works has developed, during the past two years, a technical information service with officers stationed at the Ministry's regional offices throughout England, Scotland and Wales. In addition to giving advice on particular problems and on recent developments in building techniques, the technical information officer endeavours to find out what difficulties are confronting the industry that call for further research work. To attract the interest of the builders, and particularly the foremen working on the site, the service has organised lectures, exhibitions and film demonstrations showing how the results of building research can be applied in practice.

In London, a special technical information service was inaugurated in April, 1951, for members of the London Master Builders' Association. The latter organisation has a financial arrangement with the Ministry of Works whereby a technical officer at Ministry headquarters, Mr. E. G. Dean, has been allocated to deal with the problems put forward by members of the Association. The service has been highly successful in encouraging members of the Association to seek the technical assistance of a specialist Government department. To foster further interest, it has been decided to issue technical bulletins, each dealing with some particular aspect of building, about three or four times a year. The first of these bulletins, on plastering, has recently been sent out to members. Further particulars of the London Master Builders' Association Technical Information Service may be obtained from the Secretary of the Association, 47, Bedford-square, London, W.C.1.

BELGIAN EXHIBITION OF AGRICULTURAL MACHINERY AND PRODUCTS.—The 33rd International Exhibition of Agricultural Machinery and Products will be held at Brussels from Sunday, February 15, to Sunday, February 22, 1953. Further particulars may be obtained from the secretary-general of the exhibition at 29, Rue de Spa, Brussels.

## LABOUR NOTES.

BETTER human relationships were needed in the mining industry above everything else, Sir Hubert Houldsworth, chairman of the National Coal Board, stated in an address at the annual conference of the National Association of Colliery Managers at Newcastle-on-Tyne on May 30. The relations between managers and men varied a great deal and nearly everywhere, Sir Hubert told the delegates, they were to a greater or less degree bedevilled by past history, ancient feuds and the memory of long-past grievances and hardships. In the last five years much had been done to correct this, but, even so, much still remained to be done. Everyone in the industry had a personal contribution to make. Every management officer who, combining justice with tact, and firmness where necessary, and with an absence of misplaced dignity, overcame a local difficulty, made a valuable contribution to the solution of this most important problem in the industry. On the other hand, each moment of petulance and each failure to try to see the other side's point of view, was a reverse.

The Board's national plan for the development of the industry, Sir Hubert emphasised, was based on existing technique and existing mechanisation, but it would be a sorry story if, by 1960 or 1965, mining techniques and machinery had not both been improved, and the productive efficiency of the industry thereby increased. The Board's forecast of future production should be regarded as the minimum of what was likely to be achieved. There must be a diligent search for new ideas and, in this connection, the Board was employing a firm of consultants in the United States to keep it in touch with developments there. The normal rate of progress was insufficient. Managements must exercise not only skill, judgment and experience, but drive. He stressed the need for a vigorous policy for the increased production of coal to be accompanied by a corresponding appreciation by all for economy in its use. Sir Hubert agreed, during the ensuing discussion, that mechanisation was not equally successful everywhere, but he rejected arguments that miners at the coal face used the machines to lighten their work rather than to increase production.

Copies of the agenda for the annual conference of the National Union of Mineworkers at Scarborough next month were issued by the union's executive council on May 29. Among the business to be discussed at the conference will be a motion submitted by the Derbyshire area which requests the Labour Party to make plans for the nationalisation of the larger engineering establishments, as well as of the banking, shipbuilding and chemical industries. The executive has placed a motion on the agenda expressing its condemnation of the Government's intention of returning the steel and road-haulage industries to private ownership. The motion states that miners will be unanimously opposed to any action which aims at destroying the unity of their industry or at defeating "the purposes of nationalisation." As was to be expected, there are several motions asking for higher wages. It is anticipated, however, that the union will seek to open negotiations with the National Coal Board on wage increases and the working of voluntary shifts on Saturdays well before the conference begins. The executive council would like, no doubt, to be able to present a favourable report to the conference on such negotiations.

Some success has attended the efforts which have been made to find other employment for those Italians who were recruited for work in British collieries, but have been debarred from engaging in the industry owing to objections raised by British miners. In all, some 130 Italians have been found jobs in other trades, principally in ironworks and forges, since the announcement by the National Coal Board a fortnight ago that those men who were unable to find work in other industries before the end of May would have to be repatriated.

There appear to be reasonable prospects of two to three hundred other Italians being placed in the building, timber, and tin-mining industries. Several more may be absorbed by firms engaged in tin-plate manufacture and there is a possibility that others will be found work on British Railways. Of the 2,400 Italians brought to Britain for work in the mines, more than half have been placed in mining employment, and, of the remainder, it is anticipated that not more than 700 will ultimately be repatriated. Endeavours to find work for the men will be continued right up to the date of their departure from Britain, and the National Coal Board will pay them the full surface rate obtaining in British mines, 6*l*. 1*s*. 6*d*. a week, until their return to Italy. As previously stated in these columns, compensation for the men is being discussed between the British and Italian Governments.

Evidence respecting the drawbacks of the present system of taxation in Britain was submitted to the Royal Commission on the Taxation of Profits and Income, on May 30. The collection of income tax by means of P.A.Y.E., in particular, came in for a good deal of criticism, mainly on the ground that it encouraged voluntary absenteeism among employees. One witness, Miss Ursula Hicks, an economist, submitted that P.A.Y.E. had a considerable disincentive effect. One of its disadvantages was that where the difference in marginal and average rates of tax was large, the additional tax to be paid on extra effort was in some cases very high indeed. Another drawback was that the current reduction or repayment of tax, following a decline in income, due to the crediting of allowances under the cumulative system, was a temptation to absenteeism. Miss Hicks considered that it must be the object of any reform to remove these two evils.

The only means of breaking the disincentive effect of P.A.Y.E., while at the same time retaining the present system of allowances to a greater or less degree, Miss Hicks stated, would be by abandoning the cumulative principle from week to week. In the United States, workpeople declared in advance what exemption units they were entitled to, according to their personal and family circumstances, and their employers made deductions from the men's earnings, according to certain simple tables. Earnings and taxation were brought into equilibrium at the end of the year when any over-deduction was repaid in the form of a bonus, with interest at 6 per cent. Another witness disputed the propriety of appealing to employees to work harder and go all out for available incentives, when every extra effort was deprived of part of its fruits by marginal taxation and every relapse was awarded a tax benefit. In his opinion, P.A.Y.E. constituted a retarding element in the country's national economy. He recommended the substitution of a proportional tax collection superimposed on a progressive tax.

The five-day annual conference of the Electrical Trades Union at Eastbourne ended on May 30. Many of the sessions were held in private. On May 29, a special resolution was submitted by the union's executive council opposing the rearmament programme on the ground that its enforcement would lead to mass unemployment and the lowering of living standards. The resolution, which also demanded a substantial reduction in armaments by international agreement, was carried by an overwhelming majority. Another resolution asked the union's executive to ensure that the Home Guard was used solely for defence, and not in connection with strikes, or for any political purpose.

Some 3,000 members of the Electrical Trades Union, employed in the electrical-contracting industry in London, came out on strike on May 29, in support of a trade dispute between their union and the National Federated Electrical Association. Mr. W. C. Stevens, the union's general secretary, said in a statement issued during the union's annual conference at Eastbourne that a number of electricians belonging to the union and employed at Battersea Park Festival Gardens ceased work recently when they were told that they were redundant. Before the union's executive council had an opportunity of inquiring into the merits of its members' complaint, a firm affiliated to the Association had been engaged to undertake the electrical work on contract. When union members employed by the firm in question refused to work, Mr. Stevens stated, the director of the Association cancelled a meeting of the Joint Industrial Council for the Electrical-Contracting Industry, which had been called to discuss wages and holidays.

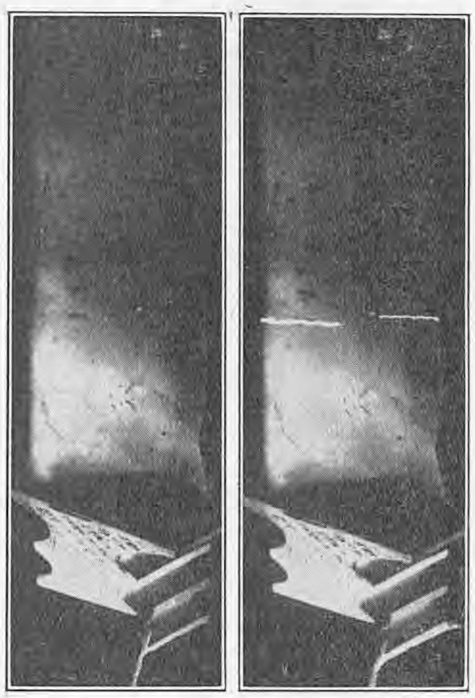
Following a meeting of the executive council and area officers of the union at Eastbourne on May 30, Mr. Stevens announced that it had been decided to extend the strike to the provinces because, although the dispute had arisen owing to difficulties between union members and employers at Battersea Park Festival Gardens, the issue now embraced the stoppage of the industry's negotiating machinery. On Wednesday last, however, representatives of the union and of the National Federated Electrical Association met in London to discuss the dispute, at the request of the Minister of Labour and National Service. Conciliation officers of the Ministry of Labour were present. It was decided that members of the union on strike should be asked to resume work during the discussions.

Demands for a substantial increase in wages were given unanimous approval at last Tuesday's session of the annual conference of the Amalgamated Union of Foundry Workers at Blackpool. The union has a membership of about 80,000 and is one of the 38 bodies affiliated to the Confederation of Shipbuilding and Engineering Unions. The resolution requested that the claim should be submitted to the employers at once and that any increase should be retrospective.

## CRACK DETECTION BY FLUORESCENT INK.

FOR detecting fine cracks in light metals, non-ferrous alloys, stainless steels and plastics, a fluorescent ink has been developed by Manchester Oil Refinery, Limited, Twining-road, Trafford Park, Manchester, 17. Though it will be particularly useful for detecting cracks in the non-magnetic materials mentioned, it can also be used on magnetic materials. The method of use is simple and rapid: the ink having been applied to the part to be examined, any cracks show up in a brilliant green colour under an ultraviolet light. At a recent demonstration, the turbine blade shown in the accompanying illustrations was inspected for cracks with the ink, the light source being provided by a manual fluorescent lamp made by Messrs. Hanovia, Limited, Slough, Buckinghamshire. The appearance of the blade before and after the application of the ink is shown on the left and right, respectively.

Glo-Mor fluorescent ink, as it is called, was developed in the firm's physics department under the direction of Dr. R. Schnurmann, and is a true solution, requiring no agitation. The part to be examined is dipped in the ink, or alternatively a few drops of the ink are poured over the surface of the test-piece. After allowing about one minute for the surface to become dry, the part is inspected in ultraviolet light. The brilliant green fluorescence of any surface cracks are seen against a duller background. To remove the fluorescent background, however, the test-piece is dipped very quickly into carbon tetrachloride, which will not remove the fluorescence from the cracks provided the dipping is not too long. If, for any reason,



a carbon tetrachloride wash is not convenient, an aqueous solution of a detergent can be used instead, but in this case a light wiping is necessary to remove the redundant ink.

Though the equipment required for examining parts with Glo-Mor ink is simple, it is essential for the parts to be thoroughly cleaned, particularly of grease. Fine cracks not visible to the naked eye are revealed; the ink is not intended for revealing larger cracks. If a crack extends throughout the cross-section of the material there is no need to remove the excess ink because the ultraviolet light can be applied to the face opposite to that to which the ink has been applied. Test-pieces which can be examined include aluminium and magnesium alloy parts of aircraft and internal-combustion engines, turbine blades (which can be inspected *in situ*), welded structures which may have shrinkage cracks or porosity, hydraulic-machinery parts, etc. Glo-Mor ink can also be used for testing surfaces for flatness, by applying the ink to the surface and moving a straightedge across it.

FACTORY FOR PRODUCTION OF ASBESTOS INSULATION.—It is proposed to establish a new asbestos factory in Glasgow for the production of Marinite by a recently-formed company with an initial issued capital of 350,000*l*., of which the Cape Asbestos Co., Ltd., will hold 53 per cent. and the Johns-Manville Corporation the remainder. The production of Marinite is expected to reach 1,000,000 sq. ft. a year. Marinite was originally intended as insulation for bulkheads in ships, but other uses for fire or vermin proofing have been developed in the United States.

# APPARATUS FOR ABRASION TESTING.

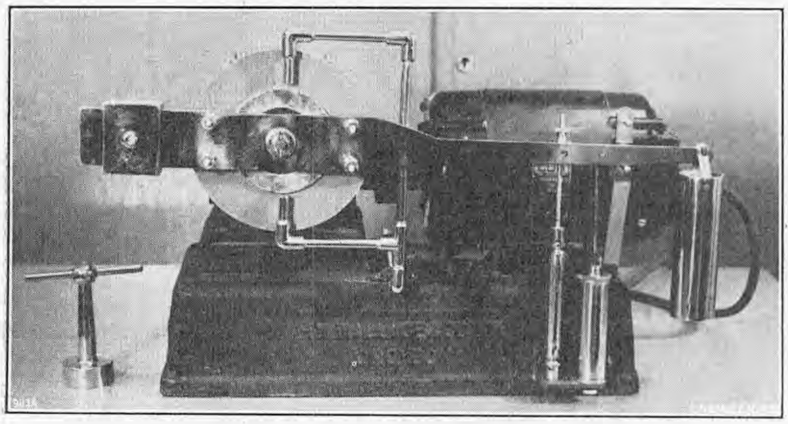


FIG. 1. DU PONT-GRASSELLI ABRASION MACHINE.

FIG. 2. TABER ABRADER.

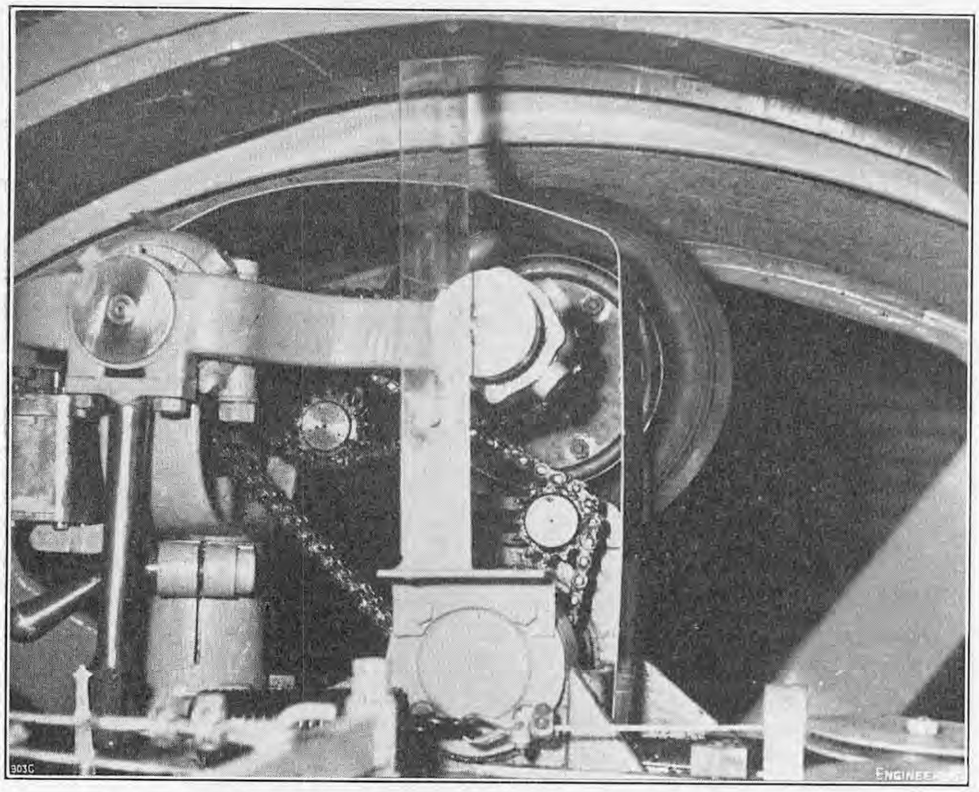


FIG. 3. SEMI-SCALE TYRE-TESTING MACHINE AT RUBBER STICHTING, DELFT.

## METHODS OF TESTING ABRASION AND WEAR IN THE NETHERLANDS.*

By P. BRABER† and G. SALOMON.‡

DURING the Symposium on Abrasion and Wear in November, 1951, an exhibition was arranged at Delft of the equipment used for abrasion-testing by the numerous institutes of the National Council for Industrial Research T.N.O. (the Dutch counterpart of the D.S.I.R. in the United Kingdom), together with some apparatus from other laboratories. Contributors were invited to make a brief statement on abrasion testing. These reports, which are edited in the present paper, will help technologists to learn about the present practice in Holland and they may also be useful as an exchange of opinion between a number of specialists. No attempt was made to obtain a complete survey, but it is believed that this paper is representative of current practice and opinions among technologists in Holland.

### I. RUBBERS, PLASTICS AND VARNISHES.

(1) *Abrasion Testing of Rubbers with the Du Pont-Grasselli Abrasion Machine*, By H. Geldof, of the Rubber Research Institute T.N.O., Delft.

For many years, this Institute has carried out the testing of rubber products, which the industry or the consumer regularly sent to be examined; therefore large series of articles such as heels, soles, conveyor belts, bicycle tyres, camelbacks, pneumatic hoses and rubber floorings have been tested by means of the Du Pont-Grasselli abrader, shown in Fig. 1, herewith, to control their abrasion-resistance. In the Du Pont-Grasselli machine, the vertical disc carries the abrasive (emery paper). Two test specimens are mounted on the inside of the bar and are pressed by a constant load against the abrading surface. To prevent rotation, the lever arm is kept in position by a bucket, loaded with shot, and a vernier spring balance. From the results obtained, specifications have been developed for the volume loss per kilogram (or cubic centimetre per horse-power-hour). The maximum values for the volume loss of the articles mentioned above, are as shown in Table I.

There is a correlation between the results of laboratory tests and service life of these articles in practice, but this correlation differs for various articles and it certainly does not allow service life to be predicted from the results of laboratory tests. It may be stated generally that a poor quality does not fulfil the requirements of the Rubber Research Institute T.N.O. As these requirements cover a wide range of applications, the I.S.O. decision to adopt the Du Pont method as a basis for standardisation, until the mechanism of abrasion is better understood, seems to be sound.

In the opinion of the Rubber Research Institute T.N.O., the expression: $mm^3/kg$. or $cm^3/h.p.$-hour is not easily understood by the purchasers; so the results of the abrasion test could be better expressed as an abrasion index, the higher values of which should denote better performance. For this purpose, standardisation of appropriate standard compounds will be necessary. From reports discussed at the I.S.O. meetings at Akron and Oxford, it is probable that results of tests with a constant-torque abrader will show improved correlation with service. For that reason, it is possible that, in the near future, this constant-torque method will be standardised.

TABLE I.

| Article. | Maximum Volume Loss. | |
|---|---|---|
| | Cub. mm. per kg. | Cub. cm. per h.p.-hour. |
| Heels: black .. .. .. | 2·5 | 675 |
| tan .. .. .. | 3 | 810 |
| Soles: black .. .. .. | 2·5 | 675 |
| tan .. .. .. | 3·5 | 945 |
| Conveyor belts: Quality A .. | 2·5 | 675 |
| ,, B .. | 4 | 1,080 |
| Tyres (bicycle) .. .. .. | 2·5 | 675 |
| Camelback .. .. .. | 1·5 | 405 |
| Pneumatic hose .. .. | 2·5 | 675 |
| Rubber flooring .. .. | 4 | 1,080 |

(2) *Abrasion Testing of Rubber-Like Flooring Materials with the Taber Abrader*, by W. J. K. Schönlau, of the Rubber-Stichting, Delft.

Fig. 2, herewith, shows the Taber abrader. The test specimen is mounted on the horizontal disc and is rotated round its vertical axis. The abrasive consists of two wheels, vertically and eccentrically positioned, which exert constant pressure on the specimen. The abraded material is removed by suction. The main difficulty which had to be surmounted in the adaptation of this "universal" instrument to our purpose was the production of a continuously-renewed surface on the abrasion wheel. It was found, in the routine testing of, for example, linoleum, that the stone discs used as abraders are clogged by the abrasive dust after a short time. The rubber discs delivered with the apparatus are expensive and are difficult to replace in Europe. They were therefore replaced by the following device.

Rubber rings, mounted on a metal wheel, were made of a compound which abrades very fast; the surface between the abrasive and the sample is therefore renewed continuously. The weight of the ring plus the metal disc is the same as that of the original wheel, so that the pressure exerted on the sample also remains the same. The mix that we found most suitable for our purpose consists of a vulcanised compound containing 300 parts of carborundum No. 180 in 100 parts of natural rubber. However, abrasives of varying hardness may be produced readily by changing the ratio of rubber to carborundum. These cheap rings are discarded after a few tests.

While duplicate runs with the stone wheels on the same flooring material showed a variation of 50 to 100 per cent., reproducibility is now satisfactory. A more systematic study of the significance of abrasion indices led us to the preliminary conclusion that the index becomes constant after about 2,000 revolutions. The following figures illustrate the decrease in the rate of abrasion during the first two readings. The measurements refer to a rubber mix containing 200 parts of wood flour and 100 parts of kaolin on 100 parts of rubber, and to a conventional sample of linoleum. The abrasive consisted of the rubber-carborundum wheel, mentioned above. The total load on the test piece was 1,000 grammes. We were using in routine work the average values obtained after about 3,000 revolutions.

* Supplementary paper presented at the Conference on Abrasion and Wear, held at the Rubber-Stichting, Delft, Holland, on November 14 and 15, 1951.

† Research Department of the Rubber-Stichting.
‡ Adviser to the Research Team of the National Council for Industrial Research T.N.O. and to Rubber-Stichting.

Additional experiments with the same rubber-wood flour mix proved, however, that the "index" is not at all constant. It gradually decreases from a value of 87 at 3,000 to 7,000 revolutions to 70 at 8,000 to 13,000 revolutions, and to about 60 at 18,000 to 23,000 revolutions. We have plotted[1]* these data on a "log. time-log. volume loss" scale and found a straight line with an exponential factor of 0·7. Buist's power law will therefore be of great value in the design of further experiments.

TABLE II.

| Material. | Specimen. | Cubic mm. Loss per 1,000 Revolutions. Duration, revolutions × $10^3$. 1. | 2. | 3-7. |
|---|---|---|---|---|
| Rubber Wood flour | 1st sample .. | 150 | 97 | 87 (82-89) |
| | 2nd sample .. | 140 | 100 | 87 (85-89) |
| Linoleum .. | 1st sample .. | 44 | 28 | 27 (26-28) |
| | 2nd sample . | 44 | 28 | 27 (26-28) |

(3) *A Semi-Scale Tyre-Testing Machine*, by P. Braber, of the Rubber-Stichting, Delft.

In testing tyre-tread mixes for resistance against abrasion on one of the many laboratory abraders, correlation with actual wear under service conditions is known to be poor; yet both manufacturing and consuming interests call for methods of rapid evaluation of tyres and tyre-tread compounds. A practical approach to solve this problem might be the development of a method of test in which the conditions prevailing in actual road-wear are imitated to a high degree. Moreover, it is felt that an increase in the scale of the experiment as compared to the usual laboratory abrasion tests might be advantageous.

Starting from these considerations, the Rubber-Stichting has developed during recent years an abrasion-testing machine, illustrated in Fig. 3, herewith, in which small tyres (10 in. by 2 in.) are abraded against an actual road surface. The tyre runs against the inside of a cylindrical drum on which the road surface is mounted. Both tyre and drum are individually driven by variable-speed motors, thus enabling any desired amount of slip within a wide range to be set up. In addition to its rotating motion, the tyre is periodically translated along the width of the road surface.

Apart from this variable slip, the following properties also are variable; pressure of the tyre on the road, the "speed" of the tyre, the inflation pressure of the tyre, and the angle between the vertical planes of the wheel and of the drum. Systematic experiments with this machine have only just begun and it is premature yet to judge whether the objective outlined above may or may not be attained. Results thus far obtained do suggest, however, that this novel approach may lead to definite advantages over the established techniques of laboratory abrasion-testing.

(4) *Abrasion Testing of Plastics with the Olsen Wearometer*, by D. J. van Wijk, of the Plastics Research Institute, T.N.O., Delft.

This apparatus, shown in Fig. 4, herewith, has been devised to the requirements of the United States Quartermaster-General by T. Olsen, especially for the testing of flooring materials and plastics. It is based on the principle that a sample, loaded with a definite weight and rotating in a horizontal plane, is abraded by carborundum powder. This abrasive is supplied continuously on to a circular metal disc, which also revolves in a horizontal plane. In order to get a frequent contact of fresh abrasive powder with the rotating sample, the latter is lifted periodically from the rotating disc which carries the abrasive, and lowered again. Abrasion is measured by the loss in thickness of the sample after a definite number of revolutions.

One of the advantages of the apparatus is that series of plastics with increasing quantities of plasticisers can be measured. As the abrasive is frequently replaced during the test, contamination of the abrasive with plasticiser, which might act as a lubricant, is a less disturbing factor. Experimental uncertainties arise, however, from two sources, namely, the length of path or the time of abrasion during each revolution is not reproducible with sufficient accuracy (actually, it increases with diminishing thickness); and the energy of abrasion is unknown, and may vary considerably.

(5) *Determination of the Mar Resistance of Organic Glasses*, by J. Heyboer, of the Plastics Research Institute, T.N.O., Delft.

In a systematic study of the mechanical properties of methylmethacrylate and some of its co-polymers,[2] the measurement of the resistance against surface damage was included in a series of technological tests.

* The numbered references are given at the end of the paper.

## APPARATUS FOR ABRASION TESTING.

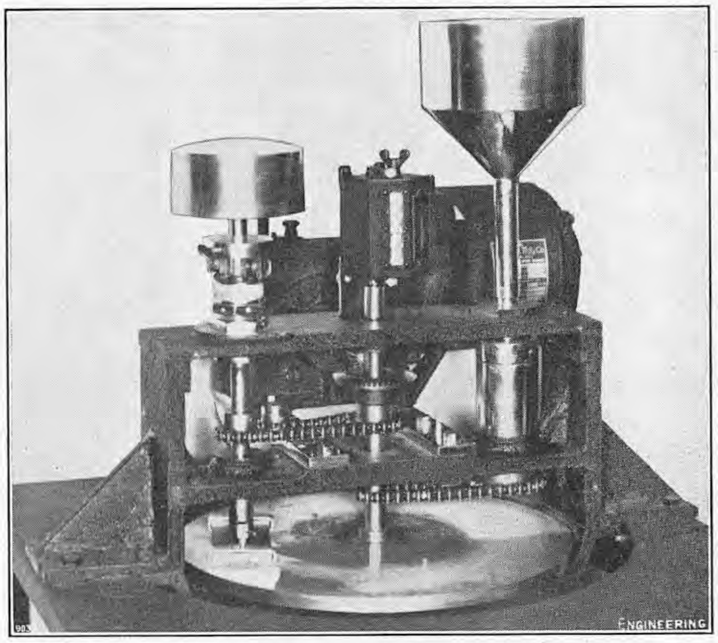


FIG. 4. OLSEN "WEAROMETER."

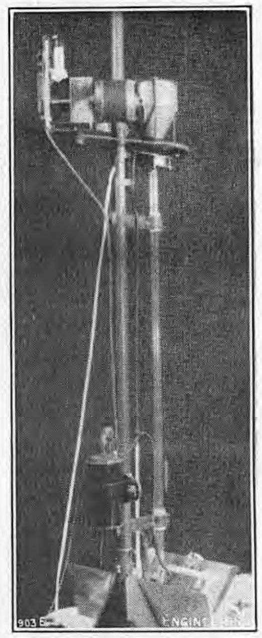


FIG. 5. MAR RESISTANCE APPARATUS.

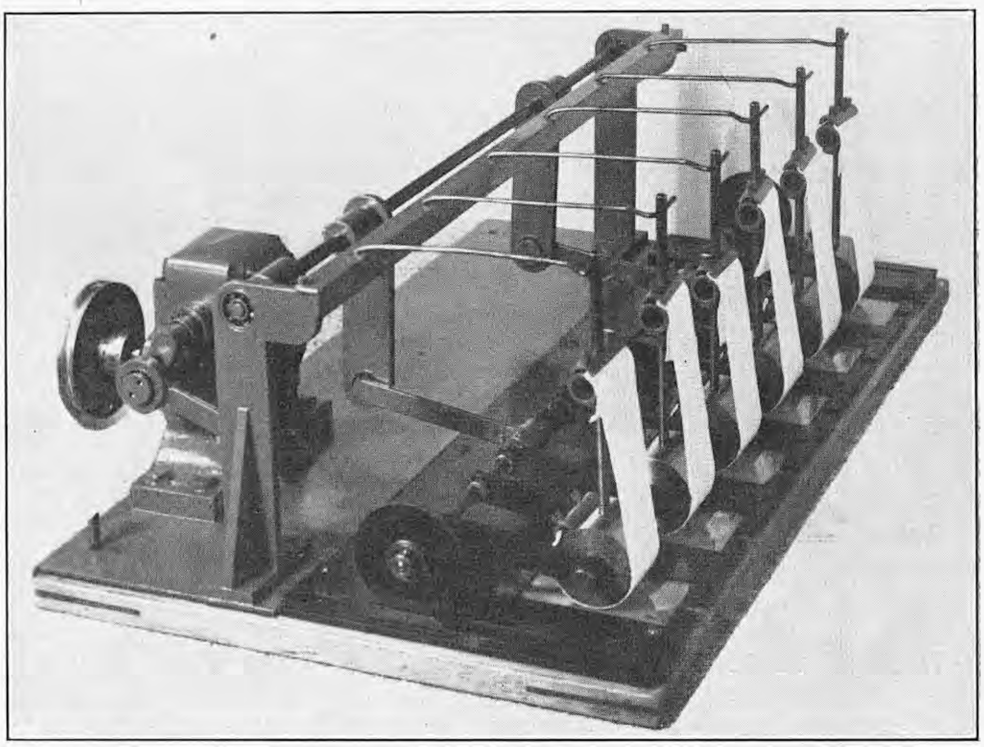


FIG. 6. APPARATUS FOR MEASURING "SOFT" ABRASION OF VARNISHED SURFACES.

Damage is produced in this standard method[3] (the Mar resistance apparatus) by a quantity of carborundum powder, which flows under an angle of 45 deg. from a rotating container on to the surface of the sample. The increase in light-scattering at the damaged spot is then measured photoelectrically.[4] This value serves as a relative index for the Mar resistance of organic glasses. The apparatus is shown in Fig. 5.

The accuracy of the method is much reduced by the firm adhesion of carborundum particles to the surface of the polymer. It is impossible to remove these particles mechanically without additional damage to the surface. A suitable means of preventing adhesion was finally found in the repeated discharge of electric sparks near the surface of the glass. The average error of the light-scattering value, measured on eight damaged spots on the same sample, is now about 2 per cent. of the absolute value.

(6) *Abrasion Testing of Varnishes*, by N. A. Brunt, of the Paint Research Institute, T.N.O., Delft.

Two types of abrasion processes can be distinguished, namely, damage due to hard abrasives such as sand and dust, and the rubbing action of apparently soft materials, for example, textiles, rubbers, or the human skin. The picture produced by these two causes of damage on varnished surfaces is different. Soft abrasion leads frequently to an increase in gloss. No satisfactory correlation between laboratory testing of resistance against "hard" abrasion and service tests has been found in this Institute, but some progress has been made recently in the estimation of resistance against "soft" abrasion. The apparatus used (Fig. 6) aims at an imitation of service conditions. It was developed on the instigation of Dr. J. Hoekstra, of Messrs. Philips, Eindhoven. A varnished surface is rubbed mechanically by a cotton cloth, stretched over a metal roller. The movement of this roller produces a constant pressure on the rubbing surfaces and continuous contact between them. Abrasion is measured by the loss of weight of the test specimen in unit time.

The method has been applied to evaluate the properties of alkyd resins with increasing quantities of hard maleic resins. The latter make the varnish hard but brittle, and therefore reduce the resistance against "soft" abrasion. Another example is the influence of pigments, which reduce the resistance of certain lacquers against "hard" abrasion, while the same surface is not damaged by "soft" abrasives. The apparatus is particularly valuable in the testing of

# APPARATUS FOR ABRASION TESTING.

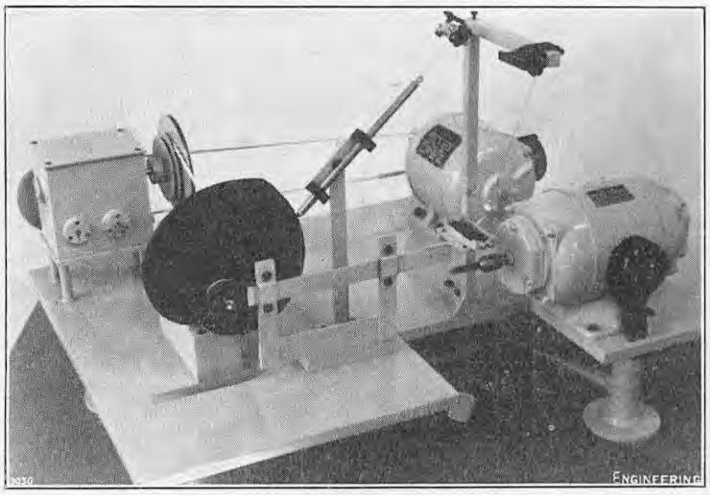



FIG. 7. APPARATUS FOR ABRASION OF FIBRES.

FIG. 8. VIBROSCOPE FOR DETERMINING MASS PER UNIT LENGTH.

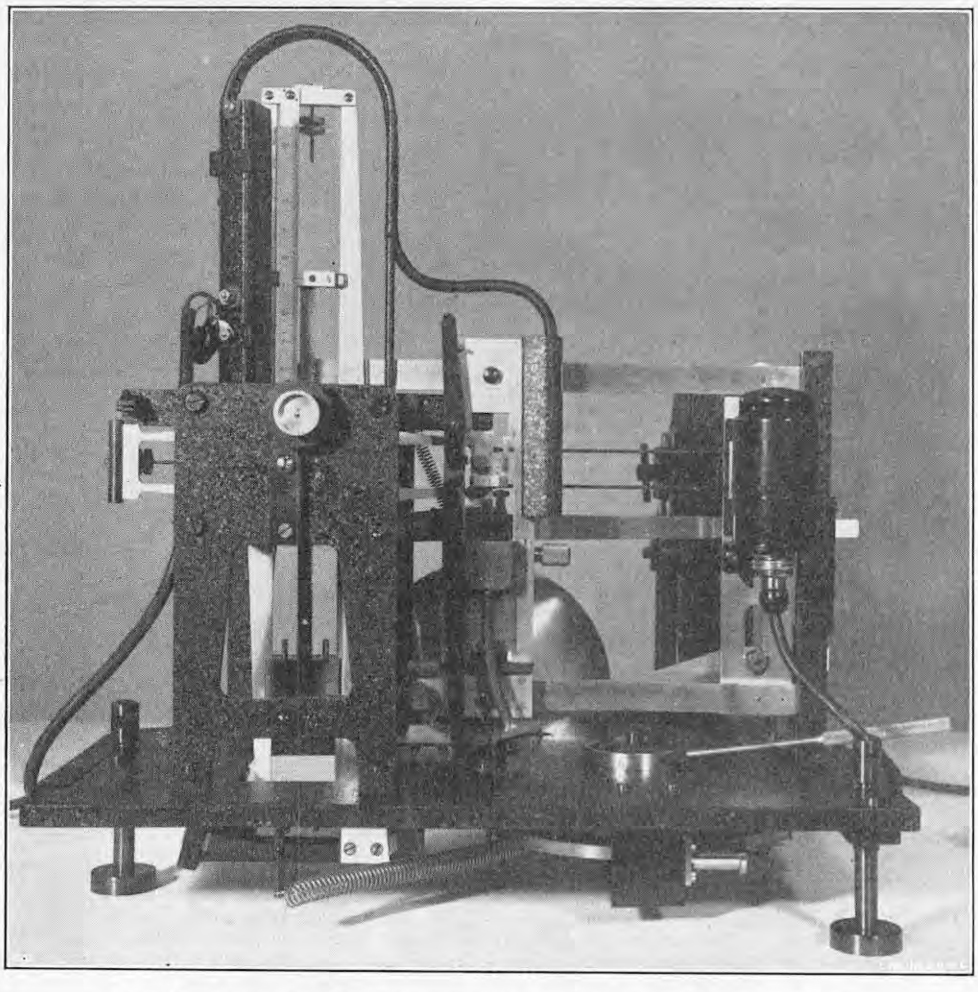


FIG. 9. APPARATUS FOR DETERMINING STRESS-STRAIN CURVE OF FIBRES.

furniture-finishing. Although the method was primarily designed for the testing of finished surfaces, it could be used as well for the testing of textiles, which are frequently subjected to this type of abrasion. In fact, cotton fabric and nylon gauze are abraded after some hours, while used as "abrasives." On the other hand, the damage caused by and done to wool, chamois leather and felt, under the same conditions, was negligible.

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## II. FIBRES, TEXTILES, LEATHER AND WOOD.

(7) *Longitudinal Abrasion of Rayon Filaments*, by V. E. Gonsalves, of the Research Laboratory A.K.U., Arnhem.

The A.K.U. abrasion apparatus,[5] shown in Fig. 7, herewith, is designed to produce a regular longitudinal abrasion of an elementary fibre over a distance of 8 cm. For this purpose, the filament is kept tight by a load and moved repeatedly up and down over an abrasive roller. The loss of matter produced by this abrasive process is deduced from a relative comparison of the fineness of the original and that of the abraded fibre. For this purpose, the linear density of the fibres is estimated with the aid of a vibroscope[6] (Fig. 8), an instrument based on the principle of acoustic resonance. Finally, the loss in strength of the abraded fibre is measured on the Heim apparatus (Fig. 9), a pendulum-type strength tester. This method is used for research work only, and no data on the correlation between laboratory tests and practical experience are yet available.

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(8) *Abrasion and Wear Testing of Textile Materials*, by W. Werker, of the Fibre Research Institute, T.N.O., Delft.

All over the world, some 50 to 60 different types of abrading apparatus may have been developed and used for predictions on serviceability of textile materials. For practical reasons, most of these use emery paper as the abrading medium, though all investigators agree that emery paper has a cutting action on fibres, while the effect of extended service primarily consists of a combination of bending and stretching forces on the individual fibres, but not on the fabric as a whole (see Dr. G. Salomon's paper* at this conference). Still, the need for a test on wear ability appears to be so great that, on comparable materials at least, abrasion tests are performed and cautious predictions on wear-in-use may be made. Comments from commercial experts on wearing quality and durability of fabrics form a range of experiences, carefully built up during years of testing, into which individual abraded samples may be fitted. While doing so, it is always borne in mind that no rigid correlation can exist.

Testing of textiles at Delft was first performed with the well-known Schopper tester,[7] illustrated in Fig. 10, on page 728. In the Schopper apparatus, the material to be tested forms a flat cone and the axis of rotation moves along a conical surface. A fixed abradant is used. Recently, the Schiefer apparatus,[8] shown in Fig. 11, has come into use, in which the contacting surfaces of the test specimen and the abradant are both flat and rotate along vertical axes. This design ensures omni-directionally uniform abrasion. Although Schiefer has designed various devices, we still prefer emery paper as a standard abrasive. Wearability of resin-treated fabrics is predicted from the folding resistance on a Köhler-Molin's paper-fatigue tester (see Salomon's paper, mentioned above). In addition, a modest construction of our own design, which consists in principle of an adjustable roller covered with emery paper, serves a twofold purpose, namely, the testing of a folded strip of fabric, thus more or less imitating abrasion at cuffs and collars; and the evaluation of the influence of tension and pressure on the rate of abrasion.

Novel features of another apparatus used in this laboratory for the abrasion of bulk materials[9] (e.g., glass, plastics, keratin, polyamides) are the continuous renewal of the abradant, and the possibility of measuring normal and tangential forces between sample and abrading medium. It is illustrated in Fig. 12, on page 728.

Promising results have been obtained recently by the United States Quartermaster-General, probably the world's largest textile consumer. Stoll, in continuation of his earlier work in Germany,[10] constructed a multi-purpose abrasion tester[11] [12] which makes separate evaluation of different types of fatigue and abrasion possible. In the case of "fatigue dress" fabrics,[13] a correlation coefficient of 0·94 between abrasion index and combat-course wear was calculated.

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(9) *Abrasion Testing of Leather;* by J. N. Gerssen, of the Leather Research Institute, T.N.O., Waalwijk, Holland.

Although numerous types of leather, such as basic materials for belts, harnesses, furniture, bags, upper leather and sole leather for shoes, are used, it is mainly in the case of leather for soles that the resistance to abrasion must be considered one of the most important requirements of quality. The measurement of abrasion resistance in the laboratory is therefore of importance, not only for the testing of this type of leather, but also for the improvement of its quality. Numerous attempts have been made, all over the world, to construct suitable machines.[14] [15]

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* This paper was printed in ENGINEERING of March 7, 1952, on page 310, *ante*.—ED., E.

The apparatus used by us (Fig. 13, opposite) is based on a new principle and was constructed in 1930 for the Government Institute for the Leather and Shoes Industry, the precursor of the present Institute. Descriptions have appeared in various publications.[15, 16, 17, 19, 22]

In contrast to other existing abrasion testers, where the sample is abraded in only one direction, our apparatus abrades leather in all possible directions. This effect is produced by rotating the sample round its own axis and moving it simultaneously along a circular track on a rotating plate, which, in turn, carries the abrasive. The test-piece moves, in fact, on a rotating plate along a sort of planetary orbit. By this design two essential advantages are gained: (i) any arbitrary point of the sample successively follows courses of a widely diverging character, i.e., straight, slightly or strongly curved tracks or even sharp corners; and (ii) the rate of displacement of one point along the abrading surface is highly variable, changing from nearly zero to a maximum value and reverting shortly thereafter to approximately zero.

Abrasion occurs on a carborundum disc covered by a specified quantity of river sand of constant particle-size. The carborundum disc serves essentially as a firm base for the sand particles, the latter actually constituting the abrasive. The pressure per square centimetre exerted on the sample during the experiment is about equal to that produced by an adult on the sole of a shoe, while the heel of the foot is raised.

Two samples are abraded continuously for 15 minutes. After that period, the sand, which has become finer and is spoiled by abraded leather powder, is replaced and the surface of the carborundum disc is reduced to its original state of smoothness by grinding off. This procedure is repeated until the sample is reduced to at least half of the original thickness. An abrasion index is now calculated from the average 15-minutes decrease of thickness.[15, 19, 23]

Correlation of these abrasion indices with wear tests is much higher than that obtained with various other apparatus in use elsewhere.[15] A series of vegetable-tanned sole leather were prepared according to various methods. Subsequent grading on the abrasion tester gave good agreement with the results obtained by wear tests.[15, 16, 18, 24, 26, 27] A chrome-tanned leather was found to be two to three times superior to a vegetable-tanned leather in wear tests, as well as on the laboratory machine. Recently, a new process, a combined vegetable and chrome tanning, has been developed and established rapidly, thanks to the aid of the Waalwijk abrasion tester, as the influence of the tanning method on abrasion resistance could be evaluated within a short time.

Numerous practical experiences were reproduced and confirmed in the course of many years of work with this machine. In addition, much insight was gained into the factors which influence the resistance against abrasion.[20, 21, 23, 25, 28] The middle layer of the leather proved to be superior to the outer layers.[21, 23] An increase in the elasticity of the leather was found to improve the abrasion resistance. This explains why wet leather has a better abrasion index than dry leather, and why hardness is an unfavourable property.[21, 25, 27]

Although correlation between laboratory tests and practical experience is very satisfactory, anomalies may occur under extreme conditions of testing. Too much flabbiness and looseness of the sample may lead to flattered results on the machine, as the sand particles can now perform rotations, which reduce the abrasive effect. Tests on the Waalwijk abrader are therefore limited to samples of sole leather of normal properties, taken from the same part of the hide, namely, the centre of the bend. The specific fibre structure of leather makes it impossible to find a (non-fibrous) standard material for reference.[19] Reliability of results depends, therefore, on the careful reproduction of experimental conditions. As two samples can be tested simultaneously, relative comparison under identical conditions is always possible.

The favourable correlation of our tests with practical experience is probably due to two factors. These are, firstly, the rotating movements during abrasion, thus simulating the abrasion of a shoe sole, which is highest as the foot, under full weight, turns round its ball.[15] The rapid abrasion generally observed with children's shoes must also be due to the great mobility of children. Secondly, abrasion is caused on our machine by sand, and not by carborundum, which cuts the fibres.

After 20 years of experience in testing with the original abrader, the apparatus has now been redesigned. In the new construction, the principal elements of the original apparatus are combined with simplifications in handling. Tests with this machine are in progress.

(10) *Abrasion Testing of Wood*, by J. L. Bienfait, of the Forest Products Research Institute T.N.O., Delft.

At the first conference on mechanical wood technology,[29] a distinction between two types of abrasion machines was made: namely, between apparatus, such as the Taber abrader (see Section 2) and the Grasselli machine (see Section 1), usable for determining abrasion as a characteristic of the material, and special tests, in which service wear is simulated. In our experience, the abrasive properties of emery paper in the Grasselli apparatus decrease rapidly; it is mainly for this reason that the Taber is preferred. The data obtained on veneer and on plywood are useful as a relative standard for internal use. The rate of abrasion between a hard beechwood and a soft fir wood, however, differs by a factor 2 only, a difference insufficient for more accurate measurements.

Among the second type of apparatus, the one developed for the testing of flooring at Princes Risborough (England) deserves mention. It produces damage by bruising and crushing as well as abrasion, and serves for qualitative estimates rather than for quantitative measurements. An apparatus with a more limited aim, the testing of wood for clogs, has been in use at Delft for some years, and is illustrated in Fig. 14, opposite. It is also used for determining the abrasion of timber for bridge planking and flooring.

The test-pieces are mounted on a wheel, which rotates eccentrically along a track made of paving bricks. The total pressure is about 30 kg. One revolution corresponds to 5 m. of contact between the test-piece and the abrading surface. The average loss in weight for eight test-pieces is determined after 500 m. for ten runs in succession. Abrasion is nearly linear with the length of the way. Differences between hard and soft woods are now much larger. It was found, for example, that the rate of abrasion for beech, fir and poplar wood increases in the ratio 1 : 6 : 8·5. Correlation with service experience seems to be reasonable. The main disadvantage of the machine, which has been designed and constructed by the central workshop of the National Council for Industrial Research, is its size and the fact that the bricks lose their roughness after a while and have then to be replaced.

Finally, it should be mentioned that the adaptation of other, already existing, methods to wood-testing was tried in vain. The Amsler machine, designed for the testing of bricks and concrete with free-falling carborundum powder (see Section 11) leads to the heating and even charring of the wood. In the sand-blasting of wood with the Vogel-Sheman apparatus, softer layers are abraded much faster than harder ones; the appearance of the abraded test-pieces is therefore irregular, and the results are of little practical value.

## APPARATUS FOR ABRASION TESTING.

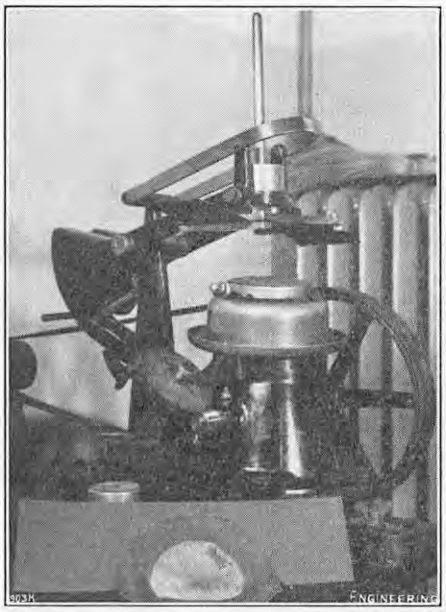

FIG. 10. SCHOPPER ABRASION APPARATUS.

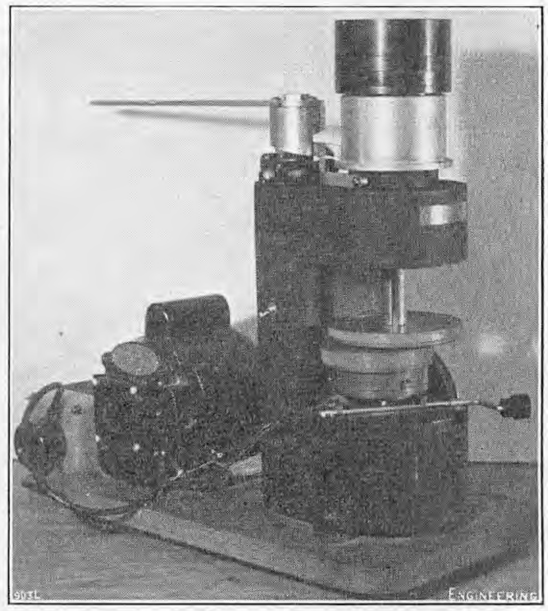

FIG. 11. SCHIEFFR ABRASION APPARATUS.

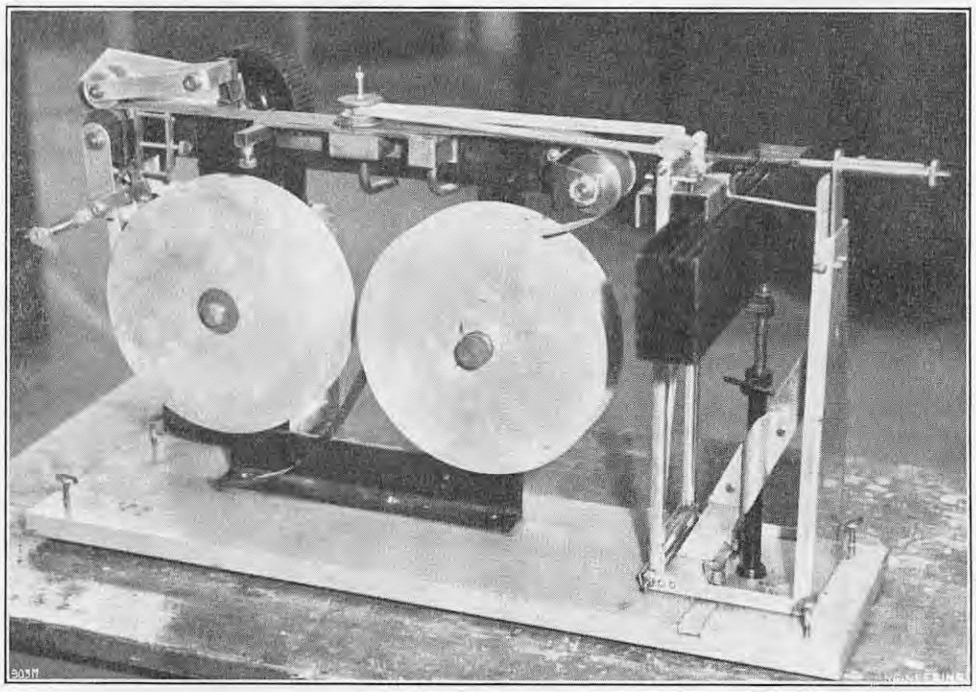

FIG. 12. GERMAN'S SPECIAL-PURPOSE ABRADER.

### III. BUILDING MATERIALS, PAVING BRICKS AND METALS.

(11) *Abrasion Testing of Building Materials*, by J. M. Pfauth, of the Institute for Building Materials, T.N.O., Delft.

The latest model of the Amsler abrader, illustrated in

# APPARATUS FOR ABRASION TESTING.

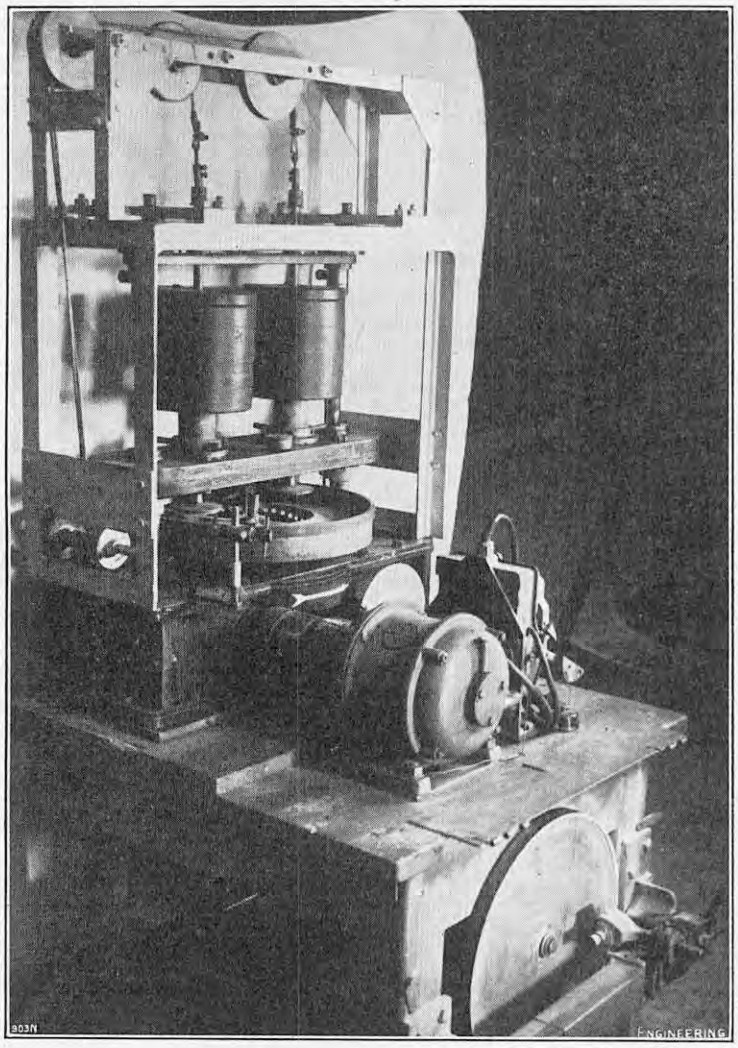

FIG. 13. MACHINE FOR MEASURING ABRASION RESISTANCE OF SOLE LEATHER.

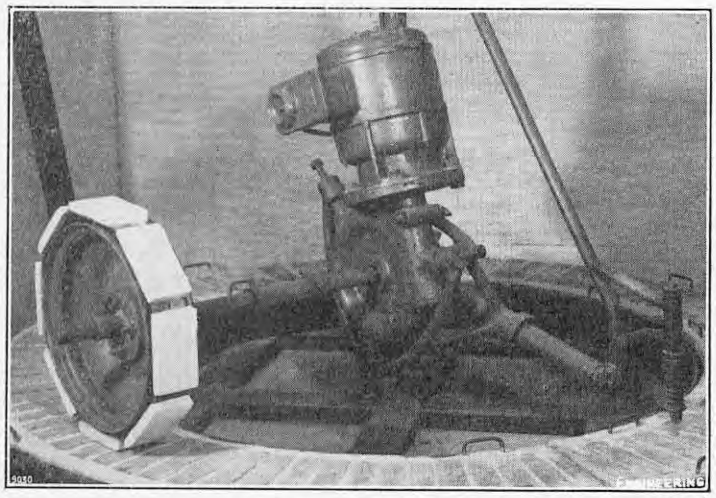

FIG. 14. MACHINE FOR TESTING WOOD FOR CLOGS.

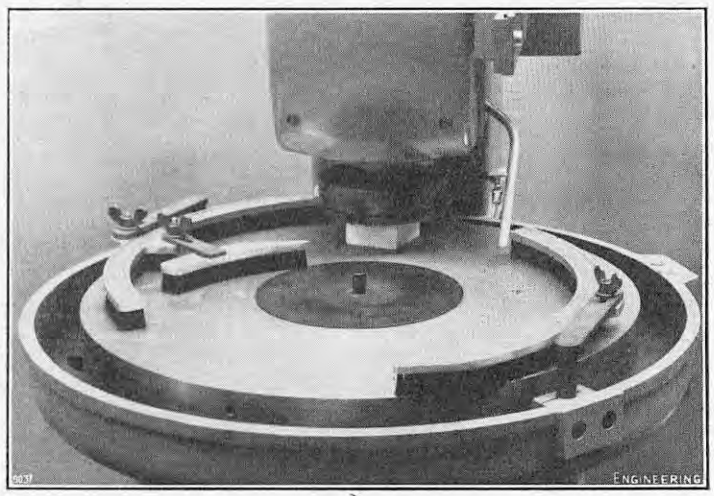

FIG. 15. AMSLER ABRADER.

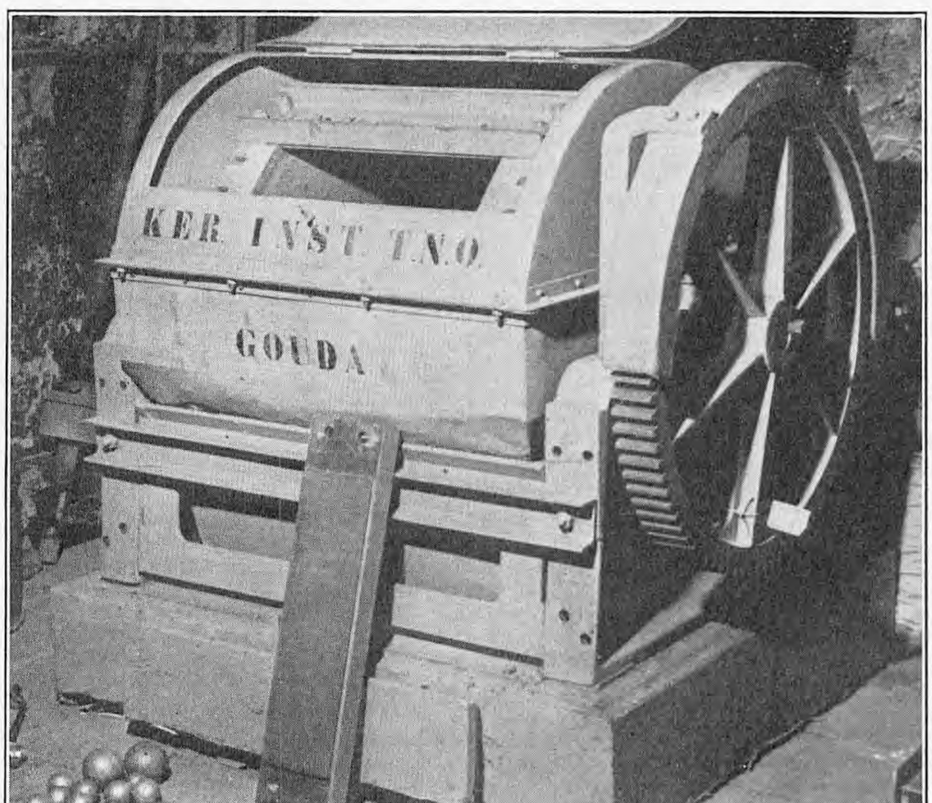


FIG. 16. RATTLER ABRASIVE APPARATUS.

Fig. 15, herewith, is used in the testing of concrete pavement slabs (30 by 30 cm.) and, in general, for the abrasion testing of hard stone and of concrete. A test-piece (surface dimensions, 71 mm. square) is ground, under a definite but variable pressure, on a revolving turntable of cast iron. The test-piece itself also revolves slowly on a vertical axis. Emery grit is used as the abrasive, and water is supplied for cooling and binding the abraded dust. The following variables are standardised, according to the Netherlands Specifications N 501 and N 502: (i) the specific pressure of the test-piece on the turntable, (ii) the distance (in metres) covered during the abrasion test, and (iii) the total quantities of emery grit and of water, which are gradually supplied. The decrease in thickness of the test-piece is taken as a measure for the rate of abrasion.

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(12) *Quality Control of Paving Bricks*, by L. L. van Breukelen, of the Ceramic Research Institute, T.N.O., Gouda.

Paving bricks in a road are exposed to two types of mechanical deformations leading to wear, namely, suddenly changing loads (impacts) which may produce cracks and finally brittle fractures, especially in too hard-burnt bricks; and surface abrasion, due to direct friction produced by the traffic, when clay, sand or dust will act as an abrasive. A laboratory test which includes both factors in such a way that significant results are obtained is difficult to design. Brittleness should be tested at different rates of deformation, and, moreover, it is not directly related to the second factor, which could eventually be measured by the resistance of bricks to sand-blasting. It is for this reason that an empirical method, the Rattler test, was introduced in 1928 by workers in the United States. The Rattler[30] apparatus used in Holland, which is shown in Fig. 16, herewith, differs only in minor details from the American type. Paving bricks are rotated in a perforated drum containing a number of cast-iron spheres. The quality of the bricks is judged from the amount of pieces knocked off and from the amount and particle-size of the abraded powder, which is collected, sieved and weighed after specified periods.

Obviously, this test contains elements of both types of deformations mentioned above, but, unfortunately, the weight of the various factors leading to the gradual destruction of the bricks is difficult to evaluate. Data on the correlation of test results with the performance of the bricks in roads are not officially known in Holland. As numerous factors, such as the dimensions of the barrel and the spheres, the hardness and the number of spheres, etc., influence the results of the test, the conditions of testing have to be rigidly standardised. The Department of Public Works, the most important purchaser of paving bricks, considers the test to be useful to prevent the purchasing of bricks of inferior quality. Apart from the Rattler test, a shatter-test and the water adsorption of bricks give important information on the strength of the material and on the influence of proper manufacturing conditions. A new electro-acoustic method for the grading of paving bricks[31] has been developed recently by the Technical Physics Department of the T.N.O.

NOTE ON THE ABRASION TESTING OF METALS.

The Metal Research Institute, T.N.O., at Delft receives numerous questions concerning the abrasion resistance of metals. Experience has shown, however, that the type of information demanded is of a diversified and frequently also of an incidental nature. It is believed by workers at the Metal Institute that such problems cannot be readily solved by measurements on only one of the conventional types of abrasion machines. Data obtained from laboratory apparatus should give information on abrasive wear as well as on wear under various conditions of lubrication. In view of the extensive experience gained in other countries, it would be desirable to have, first, some form of international agreement on the significance of the available data, before accepting measurements from any one machine as a standard for routine work. For the time being, direct microscopic observations on the grain structure of metals, and conventional tests, such as the measurement of micro-hardness, are used with some success for the elucidation of practical wear problems.

GENERAL CONCLUSIONS BY THE EDITORS OF THE PAPER.

Testing equipment should either reproduce service conditions or permit the determination of a well-defined physical quantity. Few of the machines described fulfil the first requirement and none of them the second. Nevertheless, progress is visible, and, curiously enough, mainly in the field of fibrous organic materials. The outstanding success of the Waalwijk leather abrader is due to (i) a careful analysis of the causes of mechanical wear, and (ii) limitation of the test to leather soles of normal structure.

The special-purpose wood abrader is another example of correctly reproduced service conditions. Workers at the Fibre Research Institute, Delft, have been trying for some years to break away from conventional tests by substituting, in certain cases, fatigue and folding tests for abrasion testing. It fo'lows from the remarkable successes claimed by Stoll, in Germany and the United States, with his combined abrasion and dynamic fatigue tester, that reproduction of service conditions must certainly be sought along these lines.

Much of the older research originated only from the need of purchase specifications for certain products. There was, therefore, little incentive for a more fundamental approach. In contrast, the need for improving quality is now met by the powerful tools of industrial research, of which the A.K.U. contribution to this exhibition is a visible proof.

The situation in group (i) is still governed by the readily available "general purpose" abraders. "Figures" are produced by these machines with great ease, but the volume of work necessary to give some meaning to such measurements is quite out of proportion. Metal technologists at Delft, well aware of the dubious value of abrasion "figures," are rather reluctant to adopt any test at all. In contrast, the survival of an instrument such as that used in the Rattler test for the control of paving bricks indicates the existence of a scientific "no-man's land" on the border between the producer's and the purchaser's interests.

Further progress in abrasion testing, directed towards better correlation between laboratory and service results, awaits better understanding of the basic factors determining abrasion and wear. Once these factors are known, they should be applied in laboratory tests at an intensity not exceeding the maximum values which are encountered under actual service conditions, or else the desired correlation may be lost. For the purpose of accelerated testing these maximum values may be maintained throughout the test.

The editors of this paper wish to express their appreciation to the management and staff of the institutions of the National Council for Industrial Research, T.N.O., and of the Research Laboratory, A.K.U., which have co-operated in organising the display of apparatus at the Symposium and by contributing to this survey.

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A CEMENTED CARBIDE RESISTANT TO WEAR AND CHEMICAL CORROSION.—Metro-Cutanit, Ltd., 160, Piccadilly, London, W.1, have extended their range of Cutanit cemented-carbides by the introduction of a new grade "W," which has a high resistance to wear and chemical corrosion, particularly by acids. It contains no tungsten carbide, its principal constituent being chromium carbide. The specific gravity is almost half that of normal grades of tungsten carbide and the coefficient of thermal expansion is very similar to that of steel. The latter property gives grade "W" an advantage over tungsten-carbide grades for applications in which the carbide is fixed into a steel matrix either by shrinking or brazing, particularly where it is subjected to heat during use. Unlike other cemented carbides in the Cutanit range, grade "W" is not intended for use as cutting-tool tips. A limited number of trial pieces can be supplied through the Cutanit distributors, William Jessop & Sons, Ltd., Sheffield.

SHORT BORED PILE FOUNDATION.—Building Research Station Digest No. 42, entitled "The Short Bored Pile Foundation," describes the major practical aspects of the construction, the application, and design of short bored pile foundations, for house foundations on shrinkable clays. Copies of the digest may be purchased from H.M. Stationery Office, Kingsway, London, W.C.2, price 3*d*. net.

# CHANGES IN SHIP CONSTRUCTION METHODS, 1850 TO 1950.*

By NORMAN M. HUNTER, M.Inst.N.A.

CONSIDERATION of changes in ship construction methods naturally leads one to think of the distant past when wood was the principal material used for construction. Many methods of the old shipwright craftsman are still in use to-day. The nature, strength, and means of fastening the joints of the material put a limit to the size of wooden ships. All were small; the famous Victory, Nelson's flagship, was only 186 ft. long. Few wood merchant ships exceeded 200 ft. About the beginning of the Nineteenth Century the growth of world trade and the development of steam power pointed to the necessity for larger ships and inspired shipbuilders to introduce iron ties, frames, beams, etc., and, by this composite method, to meet the demand for increased carrying capacity. Although the first iron ship was classed with Lloyd's Register in 1837, the wooden or composite ship retained popularity for many years. Steel was first tried about 1860, but its general use for shipbuilding purposes did not come in for about 35 years afterwards.

For some years, little attention was paid to improving the equipment and layout of shipyards. Good roadways for transporting materials from the machines to the building berths were the exception, and in some yards horses were used to assist in hauling heavy plates to positions alongside the building berths. The lifting appliances at the berths were wooden pole derricks carrying wooden jibs, with rope guys for swinging them by hand labour. Hoisting was by steam winch and lighting was by means of oil lamps.

The piecework method of payment introduced in the 1870's, principally in the iron department, had a great effect in improving not only the quality and speed of carrying out the work, but also the layout of the yard, its machinery and transport arrangements. Under this method of payment, the leader of each large squad of workmen in the plating department accepted the responsibility of a contractor to carry out satisfactorily the preparation and erection of his portion of the work. Payment was made by weekly draws from the contract price, after the inspection and checking of the amount of work done in that period, to the squad leader, who was responsible for the engagement and payment of his assistants and helpers. Small items of work were done at contract rates by individual platers, or by apprentices. In the case of riveting squads, the senior riveter drew the money and paid all his squad members; but caulkers and drillers usually worked individually.

The desire of both employers and craftsmen to increase output and earnings by reducing the amount of hard manual and unskilled labour brought about a gradual improvement in plant, machinery, hoisting and transporting facilities, and general layout of workshops and yards. The speed of punching machines was raised from about 14 punches per minute to about 30; punching gaps were increased in width to allow wider plates to be worked, and the speed of machines for punching some sections such as frame bars went up to about 40 to 50 per minute. Workshops were rearranged to enable an easier and quicker flow of materials through the machines necessary for their preparation, and in almost all cases machines were brought under cover. Hydraulic power was introduced to drive large bending presses, shearing machines for sections, hoists, and punching machines for shearing out manholes in plates, instead of punching around by small punch and chipping off the burrs by hand hammer and chisel. Portable hydraulic riveting machines, invented in 1871 by R. H. Tweddell, were introduced in place of the fixed machine for riveting frames and floors, and at which these items had to be pulled along for each rivet. These portable machines could put in rivets at speeds of 1,500 to 2,500 per day, where 300 to 400 per day was a good average by the hand hammer method.

In the early 1900's, electricity for light and power was gradually introduced to displace steam drive and the oil lamp. Some shipyards installed their own generating stations, but in this country the introduction of the supply of electricity in bulk by public companies stimulated the installation of this power to drive the heavy shipyard plant, and also the fitting, plumbing, woodworking, and other departments' machinery by motors on each machine. In the larger yards, at the building berths, the old wooden derrick was replaced by electrically-driven derricks or by travelling or fixed cranes capable of lifting loads of 5 tons or more. In some yards, gantries alongside or over the berths were built, having electric cranes running on top. Palmer's Shipbuilding and Iron Company, at Jarrow, installed large steel cable transporters fore and aft over some of their building berths on which ran electric

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travelling hoists; and Swan, Hunter, and Wigham Richardson, Limited, completely covered in four of their Wallsend shipyard berths with glass-roofed sheds, served by electric cranes running under the roofs.

Staging round the ships building on the berths came under review, and, though the wooden pole is still much used to-day, various other methods then came into use. In some cases, the wooden poles were replaced by single steel uprights which could be moved out and in on sliding bases to suit varying widths of ships; in other cases, steel portable trestles were employed, which could be lifted into or out of position by cranes. Some had wood platforms which could be raised and lowered by hand-worked gears. In the building of floating docks, staging was erected on steel brackets, bolted to the vertical side plating. Recently, a very ingenious system of light steel tubing, with specially-designed sockets of various types, by means of which various shapes and types of staging can easily be erected, has gained much favour for staging both outside and inside ships under construction.

Between 1906 and 1910, oxy-acetylene cutting by hand tools came into use for cutting the ends of sections, or awkward curves in plates which previously required to be punched along with small punch, the burrs being afterwards chipped off by hand chisel; and also for cutting openings in decks, etc., which previously were cut out by hand chisel. Pneumatic power also came into use about this time for working riveting, caulking, and drilling machines, which gradually, over the next few years, almost completely replaced the hand hammer and drilling brace. The painting department also benefited by the introduction of power-driven scaling hammers, steel rotary brushes, sand-blasting, and the spraying of paint.

In the shipwright department, a machine combining a hydraulic ram and electric drill came into use for making hatch covers and other similar parts, where two or more thick planks were fastened together by long through irons or bolts; this saved much hand labour. About this time also, pneumatic hand caulking tools came into use for deck-seam caulking, but the greatest improvement of seam caulking was the introduction of the electrically-driven caulking machine, with which the bulk of that work is now done. For planing the surfaces of the wood decks, an electrically-driven machine almost completely eliminated the hand plane; and recently an electric sanding machine has come into use for putting a smooth finish on the surface of the deck.

In the plating department, before 1906, with the exception of changes in methods of handling and transporting materials, no great change had come about in manufacturing methods in shipyards in this country. Up to that time, the drawing office issued to the mould loft particulars from which to draw and fair the ship's lines on the loft floor, and produce a full-size body plan from which the loftsmen made the scrieve boards showing the shape of every frame and floor. For deck beams, a cambered mould was given to the beam squad, showing length of each beam, positions of deck-plate landings, and deck girders, if any, and a mould giving particulars of beam knees. Moulds were also provided for marking the intercostals in the double bottom and their connecting angles to double bottom floors. Very little more information was given, except for specially-shaped parts of the ship's structure, and then only by special arrangement made by the foreman of the department concerned with the foreman of the mould loft.

The bars were punched before being heated in the furnace and set. Beams were marked for length and plate landings from the mould; rivet holes, spaced by rule measurement, were punched before cambering. When frames and beams were erected, they were faired into correct positions by shipwrights; and when fairing was completed, the drilling and riveting of frame brackets to tank margins and beam knees to frames was carried out. The shipwrights then lined off the plate landings for tank top, deck, and shell plating after which the platers proceeded to template from the ship the size, shape, and particulars for all rivet connections, plate by plate, putting each plate in position as it was worked.

Gradually these methods were changed; more information and templates were obtained from the mould loft to enable the work to be fabricated ready for its place in the ship's structure, and by 1910 the methods employed in many shipyards for fabricating the work had made much progress. Some yards installed multiple punching machines, which had proved useful for floating-dock construction, and used them very successfully for ship work such as deck plating, bulkheads, casings, and deck houses. One large firm with which the author was connected used this machine for tank top and also side shell plating, for which they fitted an attachment which took account of sheer.

Some Continental shipyards carried this prefabrication to great lengths. In 1911, the author visited a yard in which every part of the ship was prefabricated before the keel was laid. The work was good and the erection on the berth was quick, but the prefabricating work was slow. The craftsmen were expert and extremely careful; in most cases, they lifted all required measurements themselves from the scrieve boards, and from their working plans. Rivet holes were lined off by a sharp-pointed steel scriber and were centre-punched. The punches in the punching machines had a centre-finding point turned on them and the plater took care that this point came into the centre punch mark in the plate or bar before punching the hole. Such great care was taken when marking the work that, when a chalk line was being struck, a plank was put on its edge close to the chalk line to shield it from any stray breeze which might tend to deflect it. Although none of the British shipyards, so far as the author is aware, at that time carried out prefabrication to so great an extent, yet gradually a closer link-up between mould loft and plating department came about.

About this time, a one-man punching machine came into use, by means of which the plater alone could carry out the work of punching the plate more accurately and quickly than by the old method of employing a number of helpers to assist in moving the plate along as each hole was punched. For shearing the plate, helpers were still required, and, as no satisfactory arrangement for this operation was available, the shipyard with which the author was associated designed, manufactured, and put into operation a one-man machine at the shearing end of the punch which successfully dealt with the operation, and the necessity for employing helpers for both punching and shearing was almost completely overcome. About this time also, high-speed twist drills and radial-arm drilling machines claimed the attention of shipbuilders.

During the last 20 years, a few firms have changed their method from independent squads to specialists in each department, and payment is made for each operation separately, instead of by a contract for the completed job in the ship. For this method, they have rearranged their machines and means of transport through their shops, so that the raw material is placed on marking tables, lined off, and is then transported by overhead crane to the various machines necessary for its preparation. In some cases, castor roller bearings have been installed so that the plates can be easily moved along to or at certain machines, and when fabrication is complete separate erection squads put each part in position in the ship.

An interesting optical method of marking the plate has been put into operation recently in some Continental shipyards. By this method, special drawings for each plate are made by the drawing office to a scale of one-fifth or one-tenth full size. These are then photographed, and the negatives are placed in a projector high above the marking table and a full-sized picture is shown on the material to be marked off. One or two Continental yards and one in this country recently adopted a method of preparing and erecting shell plating first, up to about three strakes above the bilge, and dropping the frames into position afterwards. In these cases, no stage poles are used, the staging being erected on angle-iron brackets which are bolted to the plating, as has been the practice at the building of floating docks. The author fails to see what advantage is gained in this method. He considers more is to be gained in completing the internal structure first.

The latest method of ship construction, which is bringing about a revolution in shipyard layout, machinery, and plant, is by electric arc welding. This method came gradually into use after the development of the covered metal electrode about 1913, which made it possible to deposit weld metal shielded from atmospheric contamination and from being chilled by too rapid cooling. At first, all arc welding was carried out by hand tools, but now there are various makes of automatic and semi-automatic welding machines of high speed for use either in the shop or aboard ship for work in a more or less horizontal position. The fact that it is easier to weld in a down-hand position under cover has led to the provision of large and lofty fabricating sheds, equipped with cranage and handling appliances capable of dealing with large units up to 30 tons or 40 tons weight, and also the provision of storage space close to the building berths to take completed units. This method of fabrication by welding has reduced the number and type of sections required for construction. The author regrets to see that a tendency still persists to fit a riveted gunwale bar to attach the top deck stringer plate to the shell sheer strake in the otherwise all-welded ship.

A mixture of welding and riveting requires careful consideration if strength is to be maintained. From the practical point of view, the punching of rivet holes near the edge of each plate is a source of weakness, and both the punching and riveting, particularly hydraulic riveting, stretches both the bar and the plating edges. It is easily seen that no strain can be taken up by this connection till the adjoining parts of the structure have stretched, and this is a source of weakness. Welding has also greatly altered the shipyard steel-working machinery. The ordinary punching and shearing machine and the planing machine are no longer necessary. Some shipbuilders have replaced these by high-speed oxy-acetylene flame planing machines, which cut the plates to exact size and bevel the edges to the required angle for welding in one operation. Other shipbuilders still prefer to shear and plane by high-speed machines. Machinery for rolling, straightening, flanging, and joggling is still necessary, but air-compressing plant can be reduced as pneumatic riveting is no longer required, and the amount of both caulking and drilling is greatly reduced.

Against this reduction of steel-working machinery is the installation of welding plant, and as electrical consultants differed in their views as to whether alternating or direct current was the better and more economical to install, we find some shipyards equipped with alternating and others with direct. Equally good welding can be done with either type, but with alternating current on board ship, either on the building berth or when fitting out afloat, there is more danger to the operator of shock, and the lengths of the leads are more restricted than with direct current.

The author's opinion is that in the workshop, where most of the welding is done in the down-hand position and the leads to the operating tool can be kept short, alternating current for welding is satisfactory; but aboard the large ships, either on the building berth or fitting out afloat, direct current is safer, quite as economical, and a better, more universal and satisfactory servant than alternating current. The shipyard with which the author is connected is fully equipped for completely welding large ships on all berths, 'bus-bars being run along each side of each berth, supplied with direct current at from 70 to 80 volts from large rotary generators which take their driving power direct from the 6,000-volt alternating-current supply to the works.

Angle-iron smithwork in the welded ship has almost completely disappeared, and blacksmith work has been greatly reduced, so far as forging and hand welding are concerned, by the introduction of the band saw, oxy-acetylene cutting and electric welding. In the early days of iron and steel ships, stern frames were forged; this method gave place to steel casting and the latter is now in the process of being replaced by fabrication by electric welding. Changes in shipwright work methods are principally concerned with the laying of wood decks and launching arrangements.

Changes in launching are concerned principally with the means of releasing the ship on the ways. The old method of preventing the ship moving was by having a wood trigger or baulk of timber between projections bolted on the outer sides of forward lengths of fixed and sliding ways. These were released either by dropping weights, which were fitted in vertical slides above their upper ends, or by a shipwright at each one releasing it by a blow of his maul. When ships increased in size and launching weight, this arrangement was replaced in most shipyards by one or more hydraulic cylinders, bolted to the standing launchway near the midship length at either side. When the cylinder was pumped up, the end of the ram pressed against the end of a steel lever. The other end of this lever engaged with the sliding way by projecting into a steel-lined opening and prevented its movement till the water in the cylinder was released. This hydraulic launching gear is still in use, but has largely been superseded by a mechanical gear, worked by a system of levers, the controlling lever having a weight on the end which causes it to drop when a wire-rope attachment by which it is held is cut.

Aluminium alloy is at present claiming attention, principally on account of its lighter weight compared with steel for superstructures, lifeboats and in some cases masts. So changes of materials, dimensions, and methods go steadily on. In the earlier days, many details and fittings were left to the experienced judgment of the craftsmen and foremen directly at the ship, with only general instructions from the drawing office. Nowadays, with greater elaboration of organisation, but not necessarily greater efficiency, innumerable plans and instructions are issued from the drawing office for every conceivable detail.

In the old days, there were some examples of remarkable speed of construction. In 1856, the Terror, a floating battery of 2,000 tons displacement, built for the bombardment of Kronstadt, was built by Palmer's in the remarkable short time of three months. In 1890, the Tosari, a 300-ft. three-deck ship, was built at Wallsend in seven months; in 1907, the Arawa, a 460-ft. three-deck ship, was built in 8½ months; and the Salvador, a 220-ft. ship with two decks, was built in 1909 by Swan, Hunter, and Wigham Richardson, Limited, in two months. Some quick speeds were also accomplished in shipping machinery and equipment, an instance being the T.S.S. Matatua, a 448-ft. ship with five boilers, built by Workman, Clark and Company in 1907. The two sets of engines, the boilers, uptakes, funnel, two masts, all deck winches, and engine room and stokehold ventilators, were placed on board in less than 48 hours, the insulation and all fittings being complete on boilers before shipping.

## BRITISH STANDARD SPECIFICATIONS.

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

*Tubular-Steel Columns for Street Lighting.*—B.S. No. 1840, which is a new specification concerned with tubular steel columns for street lighting, constitutes one of a series of specifications for street-lighting columns. The others are B.S. No. 1249, covering cast-iron columns, a revised edition of which was issued in 1951, and B.S. No. 1308, dealing with reinforced-concrete columns. The new specification prescribes the standard heights of the light source, namely, 30 ft., 25 ft., 15 ft., and 13 ft., and contains details of the construction and the loading for which the columns are to be designed. An appendix gives designs of some typical columns. [Price 3*s*., postage included.]

*Determination of Cadmium in Copper-Cadmium Alloys.*—In response to a request for a standard method for the determination of cadmium in copper-phosphorus-cadmium alloys, as used in the manufacture of electric-traction trolley and contact wire (that specified in B.S. No. 23) a new specification, B.S. No. 1825, has been prepared and issued. The method is an electrolytic one and is suitable for cadmium contents of up to 2 per cent. The reagents required are specified, and the methods of sampling and of conducting the analysis are set out in detail. [Price 1*s*. 6*d*., postage included.]

*Heavy-Duty Solid-Fuel Cooking Ranges.*—Prepared at the request of the Ministry of Education in connection with the schools-building programme, a new specification, B.S. No. 1816, deals with heavy-duty solid-fuel cooking ranges. It covers the essential dimensional requirements and methods of test for free-standing insulated ranges measuring 48 in., 54 in., 60 in., and 72 in. wide, 22½ in. and 26 in. minimum depth, and 31 in. in height. [Price 3*s*., postage included.]

*Spanners for B.A. Hexagon Range.*—Double-ended open-jawed spanners for hexagon bolts and nuts in the British Association range are covered in a new specification, B.S. No. 1842. Details of the material from which the spanners are to be made and its hardness are given, together with the dimensions of, and the tolerances on, the jaw openings. Two categories of spanner are specified, namely, "spear-head" and "round-head." Clauses on manufacture, finish and marking are included. [Price 2*s*., postage included.]

*Code for Sampling and Analysis of Flue Gases.*—A new standard code, B.S. No. 1756, for the sampling and analysis of flue gases, has been prepared and issued as a guide to industrial fuel consumers. It covers not only flue gases from steam-raising appliances and heating boilers but also the gases evolved in the production of iron, steel and non-ferrous metals, and in the manufacture of pottery, refractories, heavy clay ware, foods, cement, glass, certain chemicals and coal gas. Methods for the determination of carbon dioxide, oxygen, carbon monoxide, hydrogen, methane, moisture, the oxides of sulphur and oxides of nitrogen are given. Among the equipment described are the Orsat apparatus and the Haldane apparatus. [Price 10*s*. 6*d*., postage included.]

## TRADE PUBLICATIONS.

*Gas and Electric Furnaces.*—A four-page leaflet dealing, in general terms, with their gas-heated and electrically-heated heat-treatment furnaces, arc and induction melting furnaces, induction-heating equipment for both forging and heat-treatment applications, and gas and air drying apparatus, has been sent to us by Birlec Ltd., Tyburn-road, Erdington, Birmingham, 24.

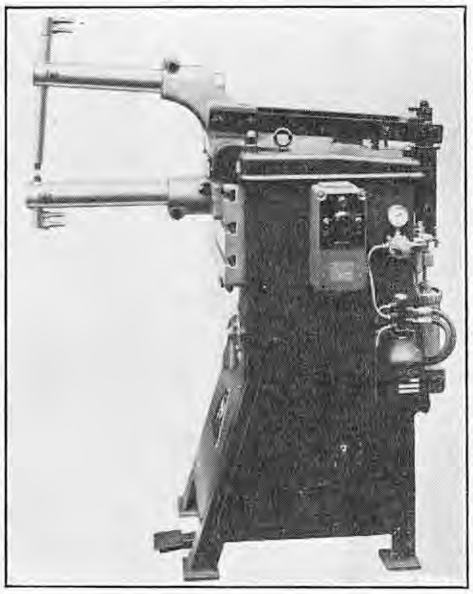
*Aluminium and Aluminium-Alloy Specifications.*—A fifth edition of their useful publication, "Specifications for Aluminium and Aluminium-Alloy Products," has now been issued by the Northern Aluminium Co. Ltd., Banbury, Oxfordshire. Its 81 pages contain a complete index of British Standard and Ministry of Supply Specifications for aluminium and aluminium-alloy products, lists and tables of proprietary-alloy names and other matters of interest.

*Metal Windows and Doors.*—Henry Hope and Sons, Ltd., Smethwick, Birmingham, have published a large catalogue of their metal windows, for drawing-office use. It gives specifications, sections and useful information on design, fixing and glazing, and it deals particularly with windows of various types; folding, casement and swing doors; and lanterns and skylights. The windows are made of galvanised solid-rolled steel bars or of bronze. The book is finely produced and replaces a similar publication of 1926. It includes a large number of constructional drawings and illustrations of some of the power stations, schools, offices, public buildings and signal-boxes in which Hope's windows have been used.

## AIR-OPERATED SPOT-WELDER.

The equipment illustrated on this page is an air-operated pivot-head spot-welder of which two models, rated at 16 kVA and 25 kVA, have recently been produced by Standard Resistance Welders, Limited, Mucklow Hill, Halesowen, Worcestershire. In contrast with the ordinary foot-operated welder, which requires continuous pressure on the pedal during the welding operation, the new machine is automatic, a momentary depression of the pedal serving to close the switch which starts the cycle of welding operations. Auxiliary controls are fitted which can be pre-set to suit requirements in any particular instance, and when the pedal is held down continuously repetitive welding at a rate up to 130 spots per minute is possible.

After such initial adjustments as are necessary have been made, depression of the pedal closes a switch and causes a solenoid-operated air-valve to admit compressed air to a cylinder, visible in the illustration, at the rear of the machine. This air imparts an upward motion to a piston which acts on the rocker arm at the top of the machine through the medium of a spring, and brings the upper electrode gently down on the



work with a predetermined pressure. The subsequent motion of the piston causes compression of the spring and also operates a limit-switch which completes the time-control circuit of the welding operation and closes the main contactor switch.

The welding cycle then commences, the compression of the spring meanwhile continuing, so that the pressure at the electrodes steadily increases. At a certain point, however, which is arranged to be that at which the weld material attains the welding temperature, compression of the spring is halted by a flange in the pressure-controlling mechanism—which is mounted above the air cylinder—coming into contact with another flange mounted at the end of the rocker arm. This results in the full pressure behind the piston being applied to the lever and, hence, to the electrodes. At the appropriate instant, the time-control switches off the current to the main contactor coil and, after a short delay to allow the heated metal time to set, the electrodes open to release the work, all the controls, meanwhile, resetting themselves automatically at their initial positions ready to begin another cycle of operations. For work on relatively heavy gauges of metal or on springy material, an additional timer is fitted to give delays of from 0·1 to 9 seconds.

The Institution of Mining and Metallurgy.—The Gold Medal of the Institution of Mining and Metallurgy, Salisbury House, Finsbury-circus, London, E.C.2, has been awarded to Dr. G. K. Williams, in recognition of the importance of his research into the metallurgy of lead and zinc. Honorary membership of the Institution has been conferred upon Mr. Edward Hooper and Mr. Edward Duffield McDermott, both of whom are past-presidents, in recognition of their services to the Institution. The "Consolidated Gold Fields of South Africa, Ltd.," Gold Medal for 1951, has been awarded to Mr. H. E. Jeffery, A.C.S.M., for his paper, "Notes on Fire Prevention and Fire-Fighting, with particular reference to the Kolar Gold Field." The "Consolidated Gold Fields" premium of 40 guineas has been awarded jointly to Mr. R. Cornthwaite and Mr. F. Juretic for their paper, "Sinking of Irwin Shaft at Roan Antelope Copper Mine." The Arthur Claudet Student's Prize has been awarded to Mr. T. A. A. Quarm and the William Frecheville student's prize to Mr. A. P. Millman.

## BOOKS RECEIVED.

*An Introduction to the Theory of Mechanics.* By Professor K. E. Bullen. Second edition. Cambridge University Press, Bentley House, 200, Euston-road, London, N.W.1. [Price 21*s*. net.]

*Fire Research.* Special Report No. 1. *The Heating of Panels by Flue Pipes.* By D. I. Lawson, L. L. Fox and C. T. Webster. H.M. Stationery Office, Kingsway, London, W.C.2. [Price 2*s*. 6*d*. net.]

*Road Research.* Note No. 13. *Recommendations for Bituminous Surfacings for Roads Carrying Tracked Vehicles.* H.M. Stationery Office, Kingsway, London, W.C.2. [Price 1*s*. net.]

*The Engineer's Approach to the Economics of Production.* By John Reid Dick. Sir Isaac Pitman and Sons, Limited, Pitman House, Parker-street, Kingsway, London, W.C.2. [Price 21*s*. net.]

*English-French Vocabulary of Aeronautical Terms.* Prepared by M. Chalmette. Bunhill Publications, Limited, 12, Bloomsbury-square, London, W.C.1. [Price 4*s*.]

*National Smoke Abatement Society. Year Book* 1952. Offices of the Society, Chandos House, Buckingham-gate, London, S.W.1. [Price 1*s*.]

*Productivity Team Report. Food Canning.* Report of a visit to the U.S.A. in 1951 of a Productivity Team representing the British Food Canning Industry. Anglo-American Council on Productivity, 21, Tothill-street, London, S.W.1. [Price 7*s*. 6*d*. post free.]

*The Institution of Mechanical Engineers. Proceedings.* January-December, 1951. Vol. 164. Offices of the Institution, Storey's Gate, St. James's Park, London, S.W.1.

*Automatic and Manual Control.* Papers contributed to the Conference at Cranfield, 1951. Butterworth's Scientific Publications, Bell-yard, Temple Bar, London, W.C.2. [Price 50*s*. net.]

*Harwell. The British Atomic Energy Research Establishment.* 1946-1951. H.M. Stationery Office, Kingsway, London, W.C.2. [Price 6*s*. net.]

*Low Temperature Physics.* Four lectures, by F. E. Simon, N. Kurti, J. F. Allen and K. Mendelssohn. Pergamon Press, Limited, 2, 3 and 5, Studio-place, Kinnerton Street, London, S.W.1. [Price 15*s*.]

*Structure in Building.* By Dr. W. Fisher Cassie and J. H. Napper. The Architectural Press, 13, Queen Anne's-gate, London, S.W.1. [Price 30*s*. net.]

*Tables of the Error Function and of its First Twenty Derivatives.* By the staff of the Computation Laboratory. Harvard University Press, Cambridge, Massachusetts, U.S.A. [Price 8 dols.]; and Oxford University Press (Geoffrey Cumberlege), Amen House, Warwick-square, London, E.C.4. [Price 52*s*. net.]

*Ferromagnetic Properties of Metals and Alloys.* By K. Hoselitz. Oxford University Press (Geoffrey Cumberlege), Amen House, Warwick-square, London, E.C.4. [Price 40*s*. net.]

*Chronicles of a Country Works.* Being a History of Messrs. Charles Burrell and Sons, Limited, traction-engine builders. By Ronald H. Clark, A.M.I. Mech.E. Percival Marshall and Company, Limited, 23, Great Queen-street, London, W.C.2. [Price 3 guineas net.]

*Die Gasturbine.* By Dipl.-Ing. J. Kruschik. Springer-Verlag, Mölkerbastei 5, Vienna 1, Austria. [Price 107*s*.]

*Transactions of the Liverpool Engineering Society.* Vol. LXXI. Seventy-sixth session, 1949-1950. Vol. LXXII. Seventy-seventh session, 1950-1951. Offices of the Society, 9, The Temple, 24, Dale-street, Liverpool.

*Manufacturing Processes.* By Professor Myron L. Begeman. Third edition. John Wiley and Sons, Incorporated, 440, Fourth-avenue, New York 16, U.S.A. [Price 6 dols.]; and Chapman and Hall, Limited, 37, Essex-street, Strand, London, W.C.2. [Price 48*s*. net.]

*Ministry of Transport. Railway Accidents. Report on the Derailment which occurred on 21st September, 1951, near Weedon in the London Midland Region, British Railways.* H.M. Stationery Office, Kingsway, London, W.C.2. [Price 3*s*. 6*d*. net.]

*Currents and Fields in Electrical Engineering.* By Professor H. E. M. Barlow. An Inaugural Lecture delivered at University College, London, 21 November, 1950. H. K. Lewis and Company, Limited, 136, Gower-street, London, W.C.1. [Price 5*s*. net.]

*Electric Lifts.* By L. J. Gooch. Second edition. Marryat and Scott, Limited, 40, Hatton-garden, London, E.C.1. [Price 15*s*. net.]

*The Anglo-American Year Book,* 1952. Edited by Phyllis Hamlin. American Chamber of Commerce in London, 7, York Buildings, Adelphi, London, W.C.2. [Price 25*s*. net.]

*Consejo Superior de Investigaciones Cientificas. Nota sobre el Calculo de Cimentaciones de Máquinas, con especial Aplicacion a los Grupos Generadores de Energia Electrica.* By Antonio Martinez Cattaneo. *Explosivos en la Construcción.* By J. P. Cebrian. Instituto Técnico de la Construcción y del Cemento, Velasquez 47, Apartado 1263, Madrid.