

## FATIGUE AND CREEP TESTING OF AIRCRAFT-ENGINE MATERIALS.

A DESIGN problem that has arisen with the development of the gas-turbine engine is that of deciding how the fatigue life of turbine blades is influenced by creep effects due to the high centrifugal loads and high temperatures to which they are subjected. Such information can only be obtained by systematic investigation under repre-

specimens; an Avery reversed-bending machine for strip material; an Avery pulsator fatigue machine for applying repeated tension-compression loads superimposed on a static axial load, often used for testing full-scale components; and an Amsler repeated-impact machine, largely employed for assessing how the strength of bolts and studs is affected by various methods of thread forming.

Adjacent to the fatigue laboratory is a room provided with automatic temperature and humidity control, to enable stress-lacquer tests to be carried out on engine components under static load. Avery

bridge torsional-damping machine, a Hounsfield impact machine, a Carpenter torsional-impact machine, and an Amsler wear-and-abrasion testing machine. For expediting the experimental work, the department is provided with a machine shop, adequately equipped with lathes, milling and grinding machines; and a heat-treatment section, equipped with three Efco heat-treatment furnaces with automatic temperature and atmosphere control. One of these furnaces is suitable for temperatures up to 1,250 deg. C.; the other two furnaces provide temperatures up to 1,000 deg. C., and are fitted with a nitriding box and equipment. Other furnace equipment includes an automatically-controlled Wild-Barfield furnace for temperatures up to 650 deg. C., and two Baird and Tatlock tempering ovens for temperatures up to 300 deg. C. Vickers and Jackman-Brinell hardness-testing machines are installed in the heat-treatment section.

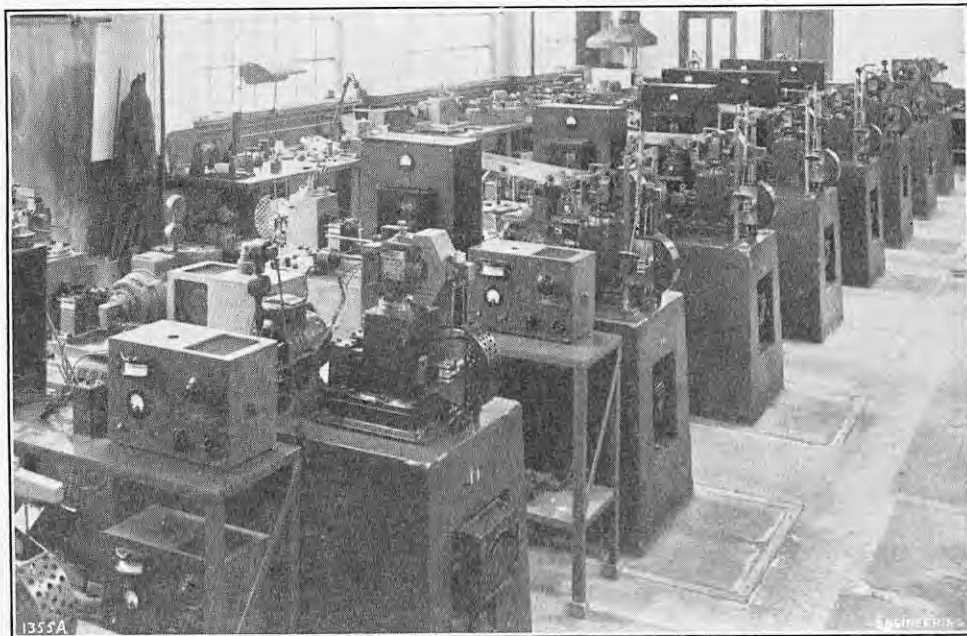


FIG. 1. FATIGUE-TESTING LABORATORY.

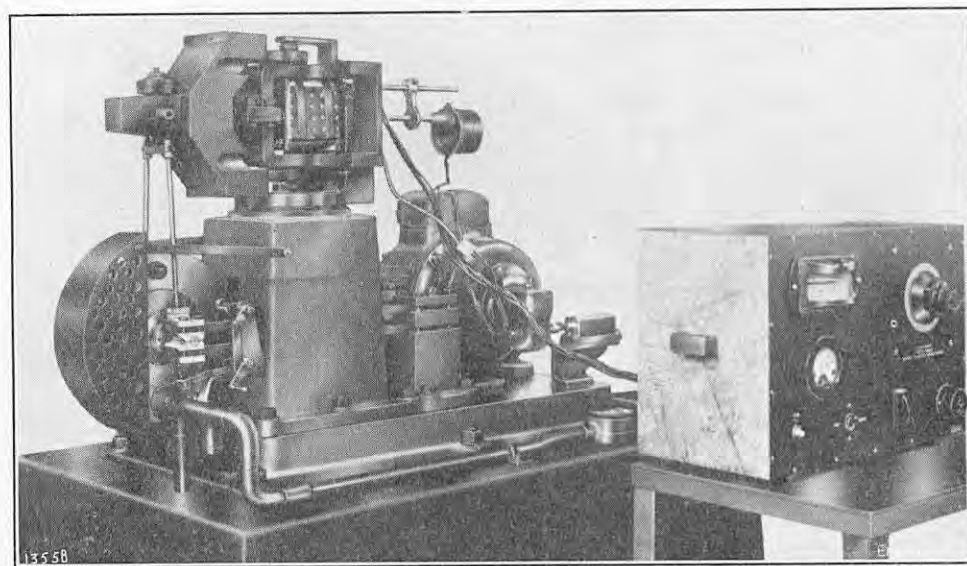


FIG. 2. N.P.L.-BRISTOL COMBINED-STRESS FATIGUE-TESTING MACHINE.

sentative conditions of temperature and load. To carry out such investigations on new high-temperature alloys, the Engine Division of the Bristol Aeroplane Company, Limited, Filton, Bristol, have built up, over the last 12 years, a mechanical-testing research department of unusually wide scope. Fig. 1 shows part of the fatigue-testing laboratory, in which there are 18 combined-stress fatigue machines; 15 of these machines are equipped for testing at high temperatures, and eight can, in addition, superimpose a static tensile load on a test-piece subjected to reversed-bending stresses. For carrying out fatigue tests on materials for engine components not exposed to high temperatures, the fatigue laboratory is also equipped with six N.P.L. Wöhler-type rotating-beam machines; five Bristol rotating-cantilever machines for very small

and Buckton static tension and compression machines and an Avery torsion machine are used for this purpose. The tensile machines are also used for determining the stress/strain curves, using a Tuckerman extensometer, of various materials at atmospheric and elevated temperatures. In another room are 36 creep machines—12 Metropolitan-Vickers machines fitted with sensitive extensometers of the Martens mirror type, for determining time-extension curves at temperatures up to 900 deg. C., and 24 Denison machines, with Bristol extensometers, less sensitive than the Martens type, but suitable for comparing time-extension curves of various experimental alloys at temperatures up to 800 deg. C. The Denison machine can also be used for carrying out time-to-rupture tests.

The research department also possesses a Cam-

### COMBINED STATIC TENSILE AND REVERSED-BENDING MACHINE.

The N.P.L.-Bristol combined-stress fatigue-testing machines that have been developed for superimposing creep effects on reversed-bending stresses are of particular interest, since they are believed to be the only machines of their kind. Fig. 2 shows one of these machines fitted with an automatically-controlled furnace capable of maintaining the test-piece at a temperature of up to 800 deg. C. In this machine, hollow cylindrical test specimens can be tested under loads of the same kind as those acting on a working turbine blade: reversed-bending vibratory loading, a steady tension representing the heavy centrifugal load, and steady bending representing the load imposed by the gas flow. The stresses arising from gas-flow loads, however, are small in comparison with the vibratory stresses and steady tension, and are often neglected. The machine of the constant-stress type has been developed from the well-known combined bending and torsional machine of Dr. H. J. Gough and Mr. H. V. Pollard,\* and it can, in fact, be used for combined bending and torsion tests if the static-tension loading linkage is removed. The test specimen employed, with 1-in. square ends, is larger than that used in the original National Physical Laboratory machine.

The mechanism of the machine is shown in Fig. 3, on page 354. The machine is mounted on a concrete block isolated from the shop floor by a 2-in. deep compressed-cork anti-vibration lining; the machine bed was designed by Messrs. W. Christie and Grey, Limited, 4, Lloyd's-avenue, London, E.C.3. The standard test specimen, screwed at each end, is mounted at one end in a test-piece holder carried on a rotatable baseplate which can be set at any angle for carrying out reversed torsion bending tests. When the machine is arranged for applying a steady tension in addition to reversed-bending loads, the baseplate is locked at 0 deg. so that the test specimen is parallel to the longitudinal axis of the machine. The central portion of the test specimen is enclosed in a small electric furnace. The free end of the specimen is gripped in a loading-arm assembly which is coupled by two driving struts to two longitudinal cantilever spring systems supporting a flywheel to which out-of-balance weights can be attached. The entire loading-arm, flywheel and spring assembly forms a vibrating system. The speed of the flywheel, which is belt-driven from a  $\frac{1}{4}$ -h.p. synchronous motor, is set to the natural frequency of vibration of the system (by suitable selection of the driving-pulley diameters) so that the out-of-balance forces set up by the rotating flywheel are transmitted directly to the test specimen, which can be loaded in reversed bending up to a maximum stress of  $\pm 35$  tons per

\* "The Strength of Metals Under Combined Alternating Stresses," by H. J. Gough and H. V. Pollard. *Proc. I.Mech.E.*, vol. 131, page 3 (1935).



square inch, in increments of  $\pm 0.25$  tons per square inch. Below one of the cantilever springs is a micro-switch which switches off the furnace and driving motor when the vibration amplitude increases after a fatigue crack has begun to develop, but before the fracture is complete. The number of cycles is recorded on a counter driven through reduction gearing by the electric motor.

In setting up the apparatus for a test, after the test specimen has been attached to the head of the machine and the furnace has been mounted, the free end of the specimen is secured to the loading arm, not yet assembled on the driving struts. The weight of the loading arm imposes a static bending moment on the specimen; before the driving struts are attached, therefore, this bending moment is removed by counterbalancing the weight of the loading arm, which is linked temporarily to one end of a balance lever pivoted on the cross-member spanning between the two front columns of the machine. After balance has been attained, the driving struts are connected to the loading arm, and the balance lever is removed, unless the test specimen is to be loaded with a steady bending moment in addition to reversed bending. It is possible to apply a steady bending stress on the specimen of up to 10 tons per square inch.

The arrangement for applying steady tension is as follows: a long tensile-loading lever can be loaded at the end remote from the specimen by suspended weights, and applies, through a bell-crank and loading pins, a steady longitudinal load on the side pieces of the loading-arm assembly. The tension-loading system is calibrated statically by means of an extensometer, using a standard test specimen. Tensile stresses from 1 ton per square inch up to 20 tons per square inch, in 0.1-ton increments, can be applied to the test specimen.

The standard test specimen used by the Bristol Company for determining design data is prepared from bar material; the bore is first drilled and the ends are coned. After reaming, the bore is placed on a mandrel, and the outside diameter is turned, thus ensuring that the specimen is truly concentric over the critical section. Finally, screw threads are cut in the ends. The bore accommodates a thermocouple for temperature control. The 800-deg. furnace surrounding the specimen consists of a platinum coil wound on a hollow refractory former and enclosed in a refractory casing. The furnace is automatically maintained at a steady temperature to within  $\pm 3$  deg. C. by a Cambridge potentiometer controller responding to signals from the thermocouple.

In addition to the eight combined tension and reversed-bending machines, there are two combined reversed-torsion and bending machines fitted with furnaces capable of producing temperatures up to 800 deg. C., and five reversed torsion and bending machines with a different type of furnace, capable of giving temperatures up to 300 deg. C., to within  $\pm 2.5$  deg., for testing light-alloy materials for piston engines. In the 300-deg. furnace, a Nichrome or Chromel A wire element is used.

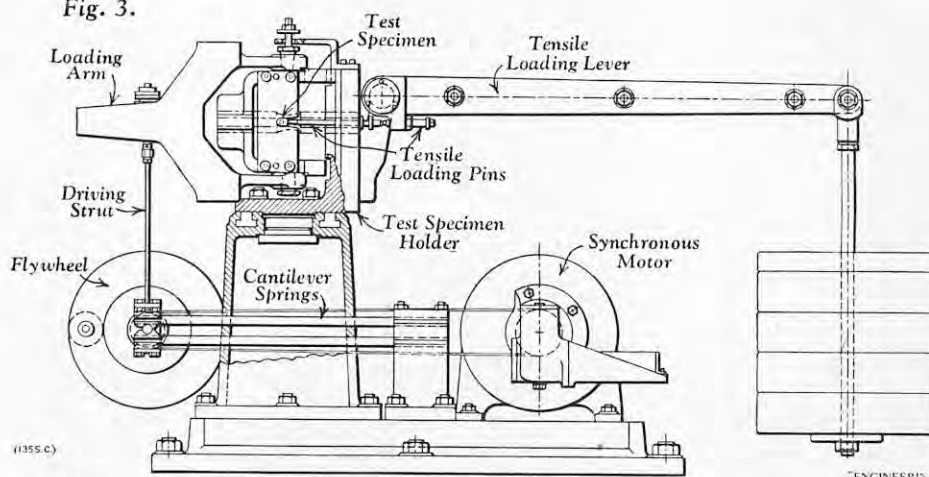
#### TEST PROCEDURE.

In carrying out a combined steady-tension and reversed-bend test at high temperature, the furnace is brought up to the required temperature and the test specimen, unloaded, is soaked for at least one hour at that temperature. The tensile load is then applied, and the flywheel driving motor is switched on. During the first few cycles, in order to prevent shock loads on the specimen, the movement of the cantilever springs is restrained by rubber buffers, which are gradually released by the test observer as the system gathers speed. Finally, the micro-switch is adjusted to trip at the required amplitude.

To provide systematic data on the effect of static tension on the fatigue strength of a material over a

## FATIGUE AND CREEP TESTING.

Fig. 3.

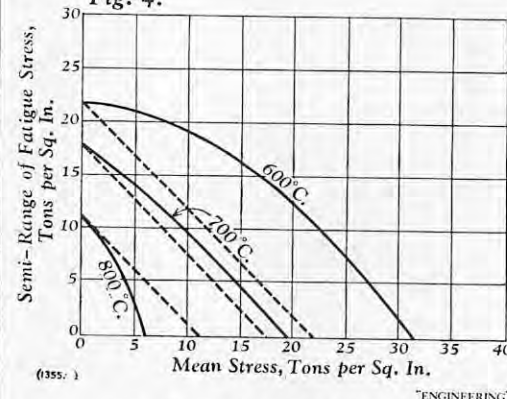


range of high temperatures, a series of endurance runs, usually extending up to 1,000 hours, or 120 million cycles, are carried out, firstly at room temperature, at zero mean stress and two or three values of tensile mean stress. The procedure is then repeated at a range of ascending temperatures, say, at 500 deg., 600 deg., 700 deg., and 800 deg. C. There is some difficulty in deciding what are reasonable magnitudes for the higher values of mean stress for a given temperature range. Experience has shown, however, that if failures predominantly due to creep are to be avoided, the algebraic sum of the maximum fatigue stress plus the steady mean stress must not exceed the stress-to-rupture for the endurance time and the temperature under consideration.

For each of the endurance runs at a particular temperature and mean stress, a conventional "S-N" curve of reversed bending stress is plotted against the number of cycles to failure. From these curves it is then possible to plot, for the various temperatures that have been explored, curves of the reversed bending stress corresponding to a given value of endurance against the mean tensile stress. The final point on the curve, at which no reversed stress can be tolerated by the specimen, is taken as the "stress-to-rupture" value for the life and temperature under consideration, determined from creep tests carried out in the adjacent laboratory. The Bristol Company have found that a smooth curve can satisfactorily be drawn through the fatigue test points and the appropriate stress-to-rupture. Some typical curves for Nimonic 80, corresponding to a life of 300 hours, are reproduced in Fig. 4. The dotted lines indicate a constant value of reversed stress plus mean stress, and it can be seen that the curves become increasingly steep at the higher temperature, indicating the increasing influence of creep.

**CHLORINATED-RUBBER PAINTS.**—Brief particulars of the manufacture, properties, and chief applications of chlorinated-rubber paints are to be found in a memorandum written by Mr. M. W. Heilbrun, B.Sc., technical director of Allweather Paints, Ltd. In making chlorinated rubber, the latex is dissolved in a suitable solvent and the solution, at a temperature of from 80 deg. to 90 deg. C., is exposed to the action of chlorine until the molecules are saturated. The chlorinated rubber is then discharged into hot water and precipitated. The product is finally washed, stabilised, and dried, and, when subsequently dissolved in a suitable solvent mixture to which appropriate pigments are added, chlorinated-rubber paint is produced. These paints are remarkably resistant to the action of alkalis, acids, water and oxidising agents, properties which are due mainly to the chemical inertness of the chlorinated rubber and its impermeability. Hence, the paints are recommended for the protection of iron and steel surfaces and for painting concrete, cement, asbestos and similar materials, the paint being applied by brushing, spraying or dipping. Copies of the memorandum are obtainable on request from Allweather Paints, Ltd., 36, Great Queen-street, London, W.C.2.

Fig. 4.



## LITERATURE.

### Light.

By PROFESSOR R. W. DITCHBURN. Blackie and Son, Limited, 17, Stanhope-street, Glasgow, C.4. [Price 45s.]

THE six volumes of "The Student's Physics" have a firmly established reputation as university texts and, with the appearance of this work—which is actually Vol. I—the most conspicuous gap in the series has now been filled. The title chosen, however, is too comprehensive, as geometrical, physiological and meteorological optics are omitted, while photometry is dismissed with a mention. Moreover, apart from an appendix on the adjustment of the Michelson interferometer, few practical details are given. To have included them would have unduly enlarged the volume and it is, in any case, generally preferable to acquire experimental techniques in a laboratory. What Professor Ditchburn has provided, however, is much more than a conventional account of classical physical optics plus a perfunctory concluding chapter on advances made within the past half century, appended as an afterthought. He has "tried to describe the wave theory in such a way that the quantum theory may appear as a natural development rather than as an alternative theory," and this attempt to exhibit the dual aspects of radiation as complementary rather than as conflicting is a valuable and original feature of his book.

A brief, but attractively written, historical introduction is followed by two chapters on progressive wave motion and the superposition of wave motions. Chapter IV opens with a classification of sources of light and types of spectra, discusses the Michelson interferometer and the visibility of fringes, introduces Fourier's series, Fourier's integral and the Gaussian wave group, and gives due prominence to group velocity and the representation of light by wave groups. This is followed by a systematic treatment of the main phenomena of interference and diffraction and a chapter on Huygen's and Fermat's principles, in which attention



is directed to the relation between wave and ray optics and the relation of rays to wave groups. The manner in which diffraction imposes an inescapable limit on the sharpness of optical images and the accuracy of optical measurements is clearly expounded in Chapter VIII, together with the Abbé theory of microscope vision and the more recent phase-contrast microscopy. Measurements with interferometers form the subject of Chapter IX: these include the testing of optical components and gauges, the determination of refractive index, the measurement of wave length, the determination of the metre in terms of wave length and the investigation of hyperfine structure.

A brief account of successive refinements in methods for measuring the velocity of light from 1676 to the present day is followed by a most interesting chapter on relativistic optics. After a description of the production and properties of polarised light, there are four chapters on the electromagnetic theory of light and its interpretation of reflection and refraction, absorption and dispersion, and the complexities of propagation in anisotropic media. Chapter XVII, on the interaction of radiation and matter, is devoted mainly to the experimental basis of the quantum theory, the photo-electric effect, the Rutherford-Bohr atom, the Compton effect, and the fundamental contributions of Planck and Einstein. The next chapter, on the quantum theory of radiation, shows how quantum principles came to be applied to the radiation itself, and to the atoms in their respective stationary states. It contains a clear exposition of the uncertainty principle, and an introduction to wave mechanics and quantum statistics. The concluding chapter is devoted to interaction processes in relation to quantum mechanics; it includes a qualitative discussion of the Zeeman, Stark and Raman effects and a mathematical appendix outlining the Dirac theory of the interaction between radiation and matter in its application to the absorption, emission and scattering of light, together with the related problem of dispersion.

The earlier portion of the text more than covers ordinary degree requirements, and the latter part is suitable for honours courses. Its usefulness to students is enhanced by the carefully selected references and by the numerous examples to which answers are provided. Very few misprints were noted, though the reference at the foot of page 527 is obviously incorrect and reference 17.5 is, presumably, to Maxwell's *Treatise on Electricity and Magnetism*; "G. B. Stokes," on page 637, should read G. G. Stokes, and the initials of the fourth Baron Rayleigh were R. J., not W. C. as stated on page 551, or J. C., as stated in the index. The five plates (two in colours) are admirably reproduced, and the cost of the book is remarkably low.

"EVERSHED NEWS."—Messrs. Evershed and Vignoles Ltd., Acton Lane Works, Chiswick, London, W.4, have joined the ranks of those electrical firms who publish some form of periodical for the information of their staffs and customers. The first issue of the new publication, which is entitled *Evershed News*, is described as a pictorial edition of news and notes, facts and figures, practice and policy pertinent to instruments, employees, dealers, agents and customers of the organisation.

ELECTRIC MOTORS.—Higgs Motors, Ltd., Witton, Birmingham, 6, have sent us a copy of their 1953 catalogue, covering their whole range of industrial electric motors from  $\frac{1}{8}$  h.p. to 700 h.p. The catalogue contains a complete list of prices, power outputs, and ratings, and among the range of units available are loom motors, variable-speed motors, commutator motors, geared motors, stator and rotor units, and alternating-current generators. A section that deals with some uses for electric motors in industry. Full details of design features are provided and the dimensions of flange mountings, baseplates and slides, are given in tabulated form. The catalogue is available on application to the head office or any branch office of the company.

## ONE-DIMENSIONAL IRREVERSIBLE GAS FLOW IN NOZZLES.

By Y. R. MAYHEW and G. F. C. ROGERS.

THE theory of reversible, adiabatic, one-dimensional gas flow was developed as early as 1839, by Saint-Venant. In recent years, a number of papers dealing with irreversible adiabatic gas flow have been published, which show that there exists a considerable amount of misunderstanding in the interpretation of certain of the results obtained. The confusion is mainly due to the engineer's practical, though fundamentally unsound, procedure of employing overall or polytropic isentropic efficiencies, which are incompatible with the assumption of one-dimensional flow.

Irreversibilities in flow are due to viscous effects which cause frictional heating of the flowing gas and which must give rise to a velocity profile. Strictly speaking, therefore, viscosity cannot be included in a one-dimensional treatment. Fortunately, since the simplicity of one-dimensional treatment is too valuable to be lightly discarded, a method of overcoming the difficulty is available. The velocity gradient is only of significant magnitude in the boundary layer, so that viscous forces are appreciable in this region alone. A good approximation to the real flow may be made, therefore, by assuming that the viscous forces are equivalent to shear forces tangential to the wall, and that the main flow is undisturbed by viscous effects. The gas properties and velocity can thus be assumed to be constant across the duct and the equation of motion can be formulated for one-dimensional flow. The remaining equations used in the analysis are independent of whether the flow is reversible or not.

The authors claim no originality for the analysis, which is merely a special case of the comprehensive treatment of one-dimensional flow presented by Shapiro and Hawthorne.\* This article is mainly restricted to a discussion of accelerated, irreversible, adiabatic flow through a converging duct and the basic assumptions are that the flow is one-dimensional, i.e., all properties are constant over any cross-section of the flow and area changes along the duct are gradual; that the flow is steady, i.e., the properties at any cross-section do not vary with respect to time; and that the gas is perfect. The notation used is given below.

### NOTATION.

A = Duct area.  
 $C_p$  = Specific heat at constant pressure.  
 D = Duct diameter.  
 $f$  = Friction factor.  
 M = Mach number.  
 P = Absolute pressure.  
 Q = Rate of mass flow.  
 R = Gas constant.  
 T = Absolute temperature.  
 V = Stream velocity.  
 $x$  = Direction of flow.  
 $X = \frac{\gamma - 1}{2}$ .  
 $Y = \frac{\gamma f}{2 \tan \sigma}$ .  
 $\gamma$  = Ratio of specific heats.  
 $\rho$  = Density.  
 $\tau$  = Shear stress.  
 $\sigma$  = Semi-angle of divergence or convergence.

### Suffixes.

$t$  = Total or stagnation value.  
 $w$  = Wall.  
 $c$  = Critical section.  
 1 = Entrance section.  
 2 = Exit section.

\* "The Mechanics and Thermodynamics of Steady One-Dimensional Gas Flow," by Ascher H. Shapiro and W. R. Hawthorne. *J. of App. Mechanics*, Trans. A.S.M.E., vol. 69, page A-317 (1947).

### BASIC EQUATIONS.

Following the method of Shapiro and Hawthorne, all the basic equations are put into logarithmic differential form.

$$\text{Gas Law.} \quad \frac{P}{\rho} = R T,$$

therefore

$$\frac{dP}{P} = \frac{d\rho}{\rho} + \frac{dT}{T}. \quad (1)$$

$$\text{Mach Number.}^* \text{ By definition, } M^2 = \frac{V^2}{\gamma R T},$$

therefore

$$\frac{dM^2}{M^2} = \frac{dV^2}{V^2} - \frac{dT}{T}. \quad (2)$$

$$\text{Continuity.} \quad \rho A V = \text{constant, hence}$$

$$\frac{d\rho}{\rho} + \frac{dA}{A} + \frac{dV}{V} = 0. \quad (3)$$

$$\text{Energy.} \quad C_p dT + d\left(\frac{V^2}{2}\right) = 0.$$

$$\text{But } R = \frac{C_p(\gamma - 1)}{\gamma} \text{ and}$$

$$\gamma R T = \frac{V^2}{M^2} = C_p(\gamma - 1) T, \text{ hence}$$

$$\frac{dT}{T} + \frac{\gamma - 1}{2} M^2 \frac{dV^2}{V^2} = 0. \quad (4)$$

*Momentum (or Equation of Motion).* With reference to Fig. 1, on page 356, the momentum equation can be written as

$$P A + \left(P + \frac{dP}{2}\right) dA - (P + dP)(A + dA) - \tau_w dA_w \cos \sigma = Q(V + dV) - QV,$$

where  $dA_w$  is the surface area of the element upon which the shear stress  $\tau_w$  acts. Neglecting terms of the second order, and writing  $\rho A V$  for  $Q$ , this becomes

$$\frac{dP}{\rho} + d\left(\frac{V^2}{2}\right) + \frac{\tau_w}{\rho A} dA_w \cos \sigma = 0.$$

A friction coefficient defined by  $\tau_w = \frac{f \rho V^2}{2}$  may be introduced, and  $dA_w$  can be expanded to give

$$dA_w = \pi \left(D + \frac{dD}{2}\right) \frac{dx}{\cos \sigma} = \frac{4 A dx}{D \cos \sigma}.$$

Then the momentum equation becomes

$$\frac{dP}{\rho} + d\left(\frac{V^2}{2}\right) + 4f \left(\frac{V^2}{2}\right) \frac{dx}{D} = 0,$$

or

$$\frac{dP}{P} + \frac{\rho}{P} d\left(\frac{V^2}{2}\right) + \frac{4f}{P} \frac{\rho V^2}{2} \frac{dx}{D} = 0.$$

Also

$$\frac{\gamma P}{\rho} = \frac{V^2}{M^2} \text{ or } \rho V^2 = \gamma P M^2, \text{ and hence}$$

$$\frac{dP}{P} + \frac{\gamma M^2}{2} \frac{dV^2}{V^2} + 4f \frac{\gamma M^2}{2} \frac{dx}{D} = 0. \quad (5)$$

It can easily be shown that, when  $f = 0$ , and only then, equations (4) and (5) are identical, i.e., in the absence of non-conservative forces the energy equation can be substituted for the momentum equation.

Since any nozzle can be considered to be made up of a large number of straight-sided elements of semi-angle  $\sigma$  (see Fig. 1), the variables  $(A, \sigma)$  may be substituted for the pair  $(x, D)$  which describe the area change in the duct. We have

$$\frac{dD}{dx} = \pm 2 \tan \sigma \text{ and } \frac{dA}{A} = \frac{2 dD}{D}.$$

Hence,

$$\frac{1}{\tan \sigma} \frac{dA}{A} = \pm 4 \frac{dx}{D},$$

where (+) refers to a divergent duct and (−) to a

\* Note that here Mach number is not defined as the ratio of gas velocity to sonic velocity, but is used merely to put the velocity in non-dimensional form.





The overall isentropic efficiency is given by

$$\eta_0 = \frac{T_{1t} - T_2}{(T_{1t} - T_2)_{\text{Isen.}}} = \frac{1 - \frac{1}{1 + X M_2^2}}{1 - \left(\frac{P_2}{P_{1t}}\right)^{\frac{\gamma-1}{\gamma}}}. \quad (20)$$

Consequently, when the relationship between  $M_2$  and  $M_1$  has been found, the variation of efficiency with pressure ratio can easily be calculated. This has been plotted in Fig. 3, opposite, for the same values of  $\frac{A_1}{A_2}$ ,  $\gamma$  and  $\frac{f}{\tan \sigma}$ . The polytropic, or small-stage, efficiency was found to vary in a similar way, though it is of slightly smaller magnitude.

The results of the analysis may be summarised as follows:

(1) For constant inlet total temperature and pressure, the mass flow per unit area increases to a maximum value at  $M_2 = 1$ , as for isentropic flow.

(2) Both the overall isentropic efficiency and the polytropic efficiency increase as the pressure ratio,  $\frac{P_2}{P_{1t}}$ , decreases.

positive, but not infinite, and consequently  $(1 - M^2)$  must be greater than zero. Thus, not only is it impossible to accelerate the flow in a convergent nozzle to a value of  $M > 1$ , but it is not even possible to reach the condition  $M = 1$  at the exit. If, however, the nozzle discharges into a medium which offers little resistance to the ejected stream, so that  $f$  is negligible, then, since the stream will eventually reach a point where  $\frac{dA}{dx} = 0$ , the condition  $M = 1$  may be reached a short distance downstream of the exit. It should be noted that, even for reversible flow, unless  $\frac{dA}{dx} = 0$  at the nozzle exit, the Mach number will reach unity downstream of the exit.

**Divergent Duct.**—In this case,  $\frac{dA}{A}$  is positive, and again  $\frac{dV}{V}$  is positive for accelerated flow, though not infinite. But the term in the brackets can be either positive or negative; if it is positive,  $M$  must be greater than unity, and if it is negative,

less than unity.\* This, however, will not be a maximum in the mathematical sense, i.e.,

$$\frac{d\left(\frac{Q\sqrt{T_{1t}}}{A_2 P_{1t}}\right)}{dM_2} \neq 0.$$

It follows that some difficulty exists in defining "critical" conditions. It is felt that a minimum of ambiguity results from the adoption of the usual definition that critical conditions exist at a section where  $M = 1$ . It has been shown that the critical temperature ratio, which will be defined as the ratio of the temperature at the critical section to the inlet total temperature  $\left(\frac{T_c}{T_{1t}}\right)$ , will always have the unique

value  $\frac{2}{(\gamma + 1)}$ , whatever the irreversibility. Also, for any given upstream total temperature, the stream velocity at the critical section will have a unique value independent of the friction. The critical pressure ratio  $\frac{P_c}{P_{1t}}$ , on the other hand, will be decreased by friction. The uncertainty arises

Fig. 5. VARIATION OF MASS FLOW WITH PRESSURE RATIO ASSUMING A CONSTANT ISENTROPIC EFFICIENCY.

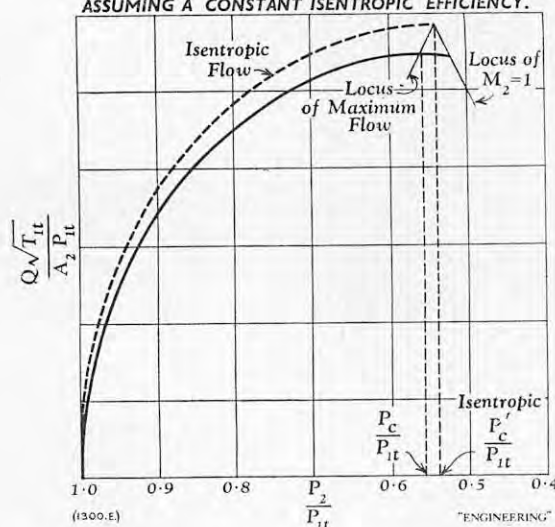


Fig. 6. TEMPERATURE-ENTROPY DIAGRAM FOR FIG. 5.

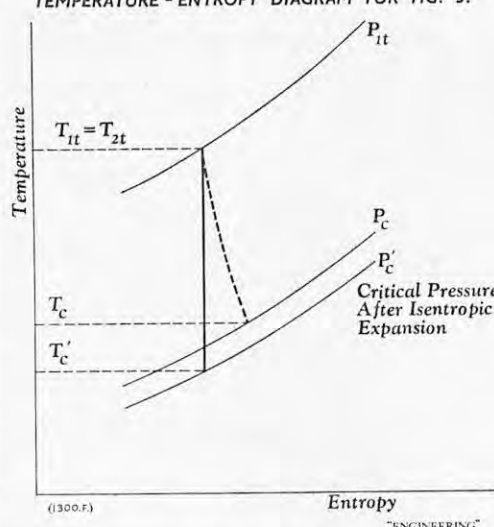
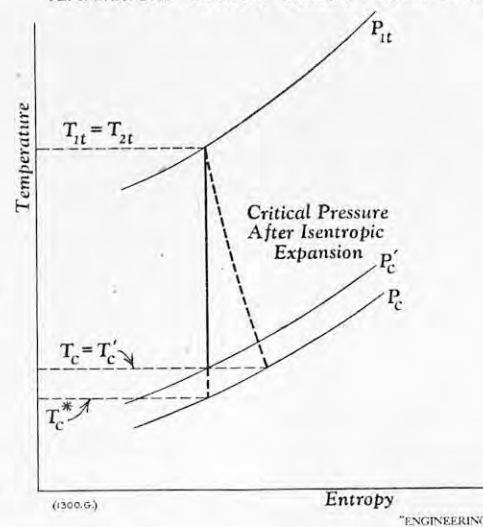


Fig. 7. TEMPERATURE-ENTROPY DIAGRAM FOR FIG. 2.



(3) The pressure ratio  $\frac{P_2}{P_{1t}}$  at which  $M_2 = 1$ , decreases with increased friction and hence, with decrease of overall isentropic efficiency.

(4) The temperature ratio  $\frac{T_2}{T_{1t}}$  is independent of the efficiency and depends only on the exit Mach number.

#### CRITICAL CONDITIONS.

The calculations in the previous section have merely shown that, for the particular case of  $\frac{f}{\tan \sigma} = \text{constant}$ , the mass flow is less than the maximum possible for the given inlet conditions if  $M$  is either smaller or greater than unity at the exit of a convergent nozzle. Nothing has been said so far of whether the conditions  $M_2 \geq 1$  can, in fact, be reached. To decide this, reference may be made to equation (11), but it is preferable to re-substitute the variables  $(x, D)$  for  $(\sigma, A)$ . Equation (11) then becomes:

$$\frac{dV}{V} = -\frac{1}{1 - M^2} \left( \frac{dA}{A} - 2\gamma f M^2 \frac{dx}{D} \right). \quad (11a)$$

In this form, the equation is applicable to either a convergent or divergent duct, or to a convergent-divergent duct with no discontinuity. These three cases will now be considered.

**Convergent Duct.**—Since  $\frac{dA}{A}$  is negative, or possibly zero at the exit, the term in brackets is always negative. For accelerated flow,  $\frac{dV}{V}$  is

$M$  must be less than unity. It follows that, if the value of the bracket changes sign along a divergent duct in which the flow is continuously accelerating, the Mach number at the section where the change of sign occurs must be unity; Fig. 4, opposite, illustrates this point.

**Convergent-Divergent Duct.**—It is clear from the argument relating to a convergent duct that the Mach number at the throat of a convergent-divergent duct will be less than unity. If there is no discontinuity in the area change, there must be a portion downstream of the throat in which

$$\left( \frac{dA}{A} - 2\gamma f M^2 \frac{dx}{D} \right) < 0.$$

Hence the flow can be accelerated to a value of  $M = 1$  in this portion of the divergent part. Whether or not  $M$  can exceed unity in the divergent part depends upon the magnitude of the divergence.

For  $M$  to exceed unity,  $\frac{dA}{A} > 2\gamma f M^2 \frac{dx}{D}$ . It is easily shown that this implies that the angle of divergence must be greater than a certain minimum value given by  $\sigma = \tan^{-1} \left( \frac{\gamma f}{2} \right)$ .

We may now revert to the question posed at the beginning of this section, as to the possibility of reaching the condition  $M \geq 1$  in a convergent nozzle. It is now clear that, not only is it impossible to reach  $M > 1$ , but that, for irreversible flow, it is not even possible to reach  $M = 1$  in the plane of the exit. Hence the mass flow increases to a maximum when  $M_2$  reaches a maximum value which is slightly

because the maximum mass flow per unit exit area will be reached when the pressure ratio  $\frac{P_2}{P_{1t}}$

is slightly larger than  $\frac{P_c}{P_{1t}}$ , the exact difference being unknown. A reduction of the pressure outside a convergent nozzle from this value of  $P_2$  to  $P_c$  or lower, will simply result in the formation of a critical section downstream of the exit, the exact location of which is uncertain; no change in mass flow will result.

At no stage in the argument has it been suggested that, at a section where  $M = 1$ , the stream velocity equals the local sonic velocity. The conclusions reached are independent of physical arguments based on the conception of signals being transmitted upstream in the form of pressure waves. Consequently, the question whether the velocity of sound in a viscous fluid is, in fact,  $\sqrt{\gamma R T}$  need not be discussed; it is clear from the work of Truesdell,† that this question is one of considerable difficulty.

The definition  $M = \frac{V}{\sqrt{\gamma R T}}$  is a matter of convenience, and any definition which would render the equations dimensionless would yield equal simplification and generality. Thus, for example, an alternative definition  $M' = \frac{V}{\sqrt{T}}$  would be equally

\* It must be remembered that suffix 2 refers to conditions at the plane of the exit.

† "On the Velocity of Sound in Fluids," by C. Truesdell. Readers' Forum, *Jl. of the Aeronautical Sciences*, July, 1951, page 501.



acceptable. The value of  $M'$  at the singularity would then be  $\sqrt{\gamma R}$  instead of unity.

#### EFFECT OF USING CONSTANT EFFICIENCIES.

Several authors have investigated nozzle characteristics, assuming constant overall isentropic efficiencies or constant polytropic efficiencies. Some of the conclusions reached in these investigations are discussed below.

Moyes has rightly shown\* that, if either a constant overall isentropic efficiency or polytropic efficiency is assumed, the mathematical maximum mass flow per unit area is reached when  $M_2 < 1$ . He then decided to use the term "critical" to refer to the state at which this mathematical maximum is reached, and showed that, on this basis, the "critical" pressure ratio and temperature ratio were both increased by frictional loss. His results are summarised in Figs. 5 and 6, on page 357.

Working on the assumption that sonic velocity is given by  $\sqrt{\gamma R T}$ , Moyes used the usual physical argument to suggest that it is not physically possible for the "critical" state to be reached at "subsonic" velocities. He rightly suggested, however, that if the efficiency were permitted to vary with pressure ratio, it was possible for the mathematical maximum mass flow to be reached when  $M_2 = 1$ , and he concluded that the efficiency must in fact vary in such a way as to fulfil this condition. His analysis did not involve the momentum equation, and no check was applied as to whether  $M_2$  can assume the value of unity. No valid argument was presented why "sonic" velocity must be reached at the exit section or why the actual maximum mass flow per unit area should be the mathematical maximum.

Naylor† concentrates on determining the consequence of using a polytropic efficiency for the expansion, and agrees with Moyes that, on this basis, the mathematical maximum mass flow per unit area is reached when  $M_2 < 1$  and that the critical pressure ratio increases with decrease of efficiency. Unlike Moyes, however, he fails to appreciate the reason for this result. Naylor, noting that the maximum occurs when the velocity reaches a value  $\sqrt{(n-1)C_p T}$ , where  $n$  is the index of polytropic expansion, goes on to suggest that the sonic velocity under these conditions is also  $\sqrt{(n-1)C_p T}$ . He defines Mach number as the ratio of stream velocity to sonic velocity, and this enables him to conclude that the maximum mass flow occurs when a Mach number of unity is reached. His derivation of the sonic velocity is, however, open to question and leads to certain anomalies which were pointed out by Kestin and Owczarek.‡

To sum up: irreversible flow cannot be satisfactorily described without using the equation of motion. It has been shown that, with the assumptions made here for determining the equation of motion, both the overall isentropic and polytropic efficiencies vary with pressure ratio. Conversely, if a constant value of either of these is assumed in any analysis of the flow, the equation of motion will not, in general, be satisfied, and the conclusions will be erroneous. This is the fundamental cause of the confusion. Further, arguments based on the transmittance of disturbances upstream, whether with a "sonic" velocity  $\sqrt{\gamma R T}$  or some other velocity of propagation, fail to prove that a sonic section must form at the throat or exit.

#### POSSIBLE USE OF ISENTROPIC EFFICIENCY FOR A CONVERGENT NOZZLE.

Since an overall isentropic efficiency, which is assumed constant over the working range of pressure

ratio, is too convenient a means of dealing with frictional loss for it to be discarded by practical engineers, it is necessary to see how it may be used to reduce the inconsistencies to a minimum. In the first place, it must be assumed, as an approximation, that the critical conditions occur in the plane of the nozzle exit, i.e., that  $M_2 = 1$ . The basic points satisfied by the following procedure are that the critical pressure ratio decreases with decrease of efficiency; and that the critical temperature ratio is independent of the efficiency.

The overall isentropic efficiency is to be defined by

$$\eta_0 = \frac{T_{1t} - T_c}{T_{1t} - T_c^*}$$

where  $T_c^*$  refers to the final temperature resulting from an isentropic expansion down to the actual critical pressure  $P_c$  (see Fig. 7, page 357).  $T_c$  is

found from the relation  $\frac{T_c}{T_{1t}} = \frac{2}{(\gamma+1)}$ , and the assumption of a value for  $\eta_0$  then enables  $T_c^*$  to be determined. The critical pressure ratio is found from

$$\frac{P_c}{P_{1t}} = \left( \frac{T_c^*}{T_{1t}} \right)^{\frac{\gamma}{\gamma-1}}$$

This will be seen to be less than  $\left( \frac{T_c}{T_{1t}} \right)^{\frac{\gamma}{\gamma-1}}$ , the value of the critical pressure ratio for isentropic flow.

If the value of  $\frac{P_c}{P_{1t}}$  is greater than  $\frac{P_2}{P_{1t}}$ , where  $P_2$  is the pressure downstream of the exit, the nozzle is choking and the pressure in the plane of the exit must be  $P_c$ . Thus, since  $P_c$  and  $T_c$  are known, the value of  $\rho_c$  is determined.  $V_c$  is equal to  $\sqrt{\gamma R T_c}$ , and, consequently, the mass flow per unit area of exit can be found from  $\frac{Q}{A_2} = \rho_c V_c$ .

The area of the nozzle exit must be made slightly larger than  $A_2$  to allow for the boundary layer; the actual allowance must be found by experiment.

If, on the other hand,  $\frac{P_c}{P_{1t}}$  is less than  $\frac{P_2}{P_{1t}}$  then the exit pressure will be  $P_2$  and the nozzle is not passing the maximum mass flow possible under the given inlet conditions. The exit density and velocity depend upon  $T_2$ , which can be found by first determining  $T_2^*$  from

$$\frac{T_2^*}{T_{1t}} = \left( \frac{P_2}{P_{1t}} \right)^{\frac{\gamma-1}{\gamma}}$$

$T_2$  can then be found for the assumed value of  $\eta_0$ , and, consequently,  $\rho_2$  and  $V_2$  are determined by

$$\rho_2 = \frac{P_2}{R T_2} \quad \text{and} \quad V_2 = \sqrt{2 C_p (T_{1t} - T_2)}$$

The mass flow per unit area can then be determined as before.

The fact that this method does not give a mathematical maximum mass flow per unit area when  $M_2 = 1$  is relatively unimportant, as the change of mass flow with pressure ratio in this region of Mach number is quite small. Also, the allowance to be made for the boundary layer in  $A_2$  is not known with any degree of accuracy.

#### CONCLUSIONS.

It is obvious that one-dimensional analysis can give results of only restricted validity. When it is used, however, it is important to satisfy all the fundamental equations, and, in particular, the equation of motion. The exact equations of flow will then depend upon the shape of the nozzle and the way in which the friction varies with Reynolds number and Mach number.

One-dimensional theory indicates that the mass flow through a convergent nozzle with constant upstream conditions will reach a mathematical

maximum when the Mach number reaches unity at the exit, but that the mathematical maximum cannot be reached in practice. Critical conditions can be reached at a proper nozzle throat (i.e.,  $\frac{dA}{dx} = 0$ ) only if the flow is isentropic. In the case of irreversible flow, whether through a convergent nozzle or a convergent-divergent one, a critical section will normally form just beyond the throat. For practical purposes, it is a reasonable approximation to assume that the critical conditions are reached at the exit or throat. Such an approximation will yield a maximum mass flow slightly greater than the value actually attained.

## RADIO-TELEPHONE DEVELOPMENTS IN TURKEY.

A NEW radio-telephone link between Turkey, Western Europe and the United States was opened to the public on Monday, February 16, the necessary equipment having been designed and installed by Standard Telephones and Cables, Limited, Aldwych, London, W.C.2, in collaboration with the Turkish Posts and Telegraphs Administration. The equipment is housed in a number of major radio stations, which are connected by underground cables to a central office in Ankara, where the circuits are controlled. In addition to the radio-telephone equipment, these stations will contain apparatus which will enable the existing radio-telegraphic service from Istanbul to be increased and teleprinter working to be introduced.

The new transmitting station at Ankara houses two 40-kW peak-power transmitters, one for the telephone and the other for the telegraph service. The telephone transmitter uses the single side-band method of operation, the relatively complex circuits for which are contained in a small unit operating on a fixed frequency. The output of this unit is converted to the frequency required—which is different during the day and night—in the transmitter proper the power employed being either 4 kW or 40 kW according to whether the propagation conditions are good or bad, thus ensuring economy in running costs. The telegraph and telephone transmitters are interchangeable, so that the former can be used as a stand-by. When employed for telegraphy, the single side-band unit is replaced by a frequency-shift apparatus. This enables signals to be sent out during both "active" and "idle" periods on slightly different frequencies, so that the two can be distinguished at the distant receiver. The sending of a signal during the "idle" periods helps to suppress the noise and interference which might otherwise cause the receiving teleprinter to operate incorrectly. The effective power of the transmitters is increased by as much as 50 times by using high-efficiency rhombic aerials. A number of these are provided for the service to different places and there are also omnidirectional aerials for special purposes.

At the Ankara receiving station there is a triple diversity single side-band receiver, which consists of three receivers working on the same frequency from separate aerials. This enables the best signal to be selected at any time, thus compensating for fading and increasing the reliability. The Ankara station also houses a number of telegraph receivers on which the diversity principle is used, special arrangements being made for reasons of economy to enable them to work simultaneously from one aerial system. The radio stations are connected to the terminating equipment in the central office at Ankara by multi-core cables. This terminating equipment incorporates special voice-operated electronic circuits, which enable the transmission path to be switched and the echoes, which may occur on short-wave radio-telephone systems, to be avoided. The different levels of incoming speech are adjusted automatically by amplifiers. Scrambling apparatus is installed at both the transmitting and receiving ends to ensure secrecy during telephone conversations. Power for operating both the transmitters and receivers is obtained from the mains, Diesel engine-driven generators, manufactured by Messrs. Ruston and Hornsby, Limited, being installed as a stand-by.

\* "The Critical Flow Conditions of a Gas in a Convergent Passage and the Influence of Frictional Losses," by S. J. Moyes. *R. & M. No. 2045* (1942.).

† "The Critical Flow of a Gas through a Convergent Nozzle," by V. D. Naylor. *Aircraft Engineering*, June, 1951, page 160.

‡ Letters published in *Aircraft Engineering*, October, 1951, page 306.



## THE ENGINEERING OUTLOOK.

### VIII.—THE AIRCRAFT INDUSTRY.

IN 1953, the aircraft industry stands on the threshold of unparalleled peace-time prosperity. The production programmes for military aircraft have been reduced, but orders on hand for home and overseas are as large as manufacturers can hope to cope with over the next few years. As the military aircraft now in production go into service, the Royal Air Force will regain the superiority in operational equipment which it had at the end of the war, for these aircraft are technologically in advance of those of any other country, and it will be some years before foreign competitors can possibly overtake the British lead. Production difficulties have been smoothed by the granting of "super-priority" to a high proportion of the aircraft on order, civil as well as military. Shortages of suitable labour continue to set a limit to output, but recruitment has now been speeding up; in 1952, the labour force rose by 30,000, or 30 per cent., as shown in Fig. 1, on page 361.

When re-armament began in the autumn of 1950, the demands made upon the emaciated aircraft industry caused, in Mr. Winston Churchill's words, "acute indigestion"; recovery is now fairly complete, but the industry required very careful nursing in 1952. The experience has brought home the necessity of maintaining capacity at all times at a level which will permit rapid expansion, with sufficient adaptability to meet the changes which result from rapid technological progress. In September, 1950, the number employed had been allowed to sink to 149,000, and the nucleus of skilled men remaining proved too small a foundation on which to build an industry which was expected to handle Government orders averaging 400% millions a year (at 1950 prices) over the three years to 1954. The initial period of re-equipment and re-organisation, which was scheduled to last for nine months, dragged on, as a result of the shortages of machine tools and materials, but mainly of manpower, until well into 1952. While, moreover, the resources of the industry were being mobilised for re-armament, the production of civil aircraft had to be curtailed, though, for the first time in 20 years, British makers had established a lead in air-liner design, and promising export opportunities were opening up. Early in 1952, therefore, the Government decided to spread the defence programme over three years instead of four. Later in the year, it was decided that even the amended programme could not be carried out without grave danger to the British economy. Defence production will not be greatly accelerated, therefore, but will be kept fairly stable at a lower level.

The provision made for aircraft and stores in the Air Estimates for 1953-54 is considerably larger than in 1952-53—195% millions, compared with 161% millions. The sum earmarked for new aircraft in 1953-54 is 140% millions, 29% millions more than in 1952-53. The outlay on radio, radar and electrical equipment in 1953-54 is doubled, at 42% millions. In the Memorandum accompanying the Estimates, however, it is pointed out that, in comparing the estimates with those of other years, allowances must be made for the general rise in prices and for the payments to contractors for work done on orders cancelled. The sum of 13% millions has been provided to meet such payments in 1953-54.

The cut in the programme has only affected to a limited extent the orders actually in hand; much of the reduction is accounted for by Meteor and Vampire fighters, which have been superseded by later types. Orders have also been reduced, however, for the Venom fighter, the Vickers Varsity, Boulton Paul Balliol and Percival Pembroke trainers, none of which has been outmoded; and surprisingly, orders for the Canberra light bomber have also been cut. This appears to be the result of tactical considerations; it is not, as the Royal Air Force have made clear, any reflection on the excellence of the aircraft. The companies at present making the Canberra will not, in any case, reduce their production until their workpeople can be employed on other types of aircraft. The Gloster Aircraft Company, due to the curtailment

of the order for Meteors, has been the most seriously affected; about 1,600 workpeople were originally concerned but, as a result of a Brazilian order for Meteors, it was found possible to retain most of them. Many of those who had already been dismissed were absorbed by other aircraft companies.

To make the most effective use of available capacity, civil as well as military orders have been spread throughout the industry. Short Brothers and Harland, Limited, of Belfast, for instance, are constructing Comet II airliners as well as the Canberra. When their first Canberra was completed in October, 1952, Rear-Admiral M. S. Slattery, chairman of the company, said that there were 40,000 unemployed in Belfast, and that at least 5,000 could be engaged in the company's factories if production orders were received. Preparations for the production of Comets are now well in hand; output will begin in the summer of 1954 and by the end of 1955 the company will be able to produce a Comet a week.

In addition to the English Electric Company, who designed the Canberra, A. V. Roe and Company and Handley Page, Limited, are also making Canberra bombers. Saunders-Roe, Limited, are producing wings for the Vickers Viscount airliner; Folland Aircraft, Limited, are making parts for the Hawker Hunter; the Rolls-Royce Avon turbo-jet engine, which has received "super-priority," is being made by the Bristol Aeroplane Company and by D. Napier and Sons, Limited. Within the Hawker Siddeley Group, there has been considerable interchange of work; Armstrong Whitworth and Company, for instance, are producing the NF II night fighter, which is fundamentally a redesigned Gloster Meteor, and Brockworth Engineering, Limited, a new company, are producing the Armstrong-Siddeley Sapphire engine.

The new Government policy is something more than an expedient trimming of the defence programme to meet the economic situation. It is based on a new concept of air power, which recognises that tactical needs may be satisfied by fewer but up-to-date weapons, and that a large fleet of civil air liners is essential if rapid mobility of men and materials is to be achieved. The latter consideration coincides conveniently with the opportunities now opening out for the British jet-engined airliners, and "super-priority" rating, which already covered eight types of military aircraft, has been extended to the de Havilland Comet, the Vickers Viscount and the Bristol Britannia.

#### AIRCRAFT FOR THE ROYAL AIR FORCE.

The military aircraft at present on the super-priority list are the Hawker Hunter and the Supermarine Swift swept-wing day fighters, the Gloster Javelin delta-wing all-weather fighter, the Fairey Gannet anti-submarine aircraft, the English Electric Company's twin-jet Canberra bomber, the Vickers Valiant four-jet bomber, the delta-wing four-jet Avro Vulcan bomber, and the Handley Page crescent-wing HP.80.

The speed with which new types of military aircraft are being brought from the design stage to quantity production reflects much credit upon the industry. The Government's decision to place orders at early stages was a bold one, but has been amply justified. The danger of ordering "straight off the drawing board" is not now so great as might appear. Mr. W. C. Puckey, Deputy Controller of Supplies (Aircraft Production), Ministry of Supply, who presided over the conference on "Problems of Aircraft Production" held by the Institution of Production Engineers in January, said that he believed "one of the most important problems confronting us, in both civil and military skies, is to get a production programme settled at an early date. . . . Two things are tremendously important: one, confidence in the supplier, and two, a realisation that aerodynamically performance may now be calculated within close limits and could be available to the customer long before prototype flight." So far as the Hawker and Swift are concerned, there is a very clear line of evolution. The Hunter has evolved through the swept-wing P1081 and P1052 from the straight-wing Sea Hawk and P1040. The Swift, which will be the first of the new types to go into service with the Royal Air Force, has developed through the swept-wing 510 and 535

types, from the straight-wing Attacker. The Swift and earlier versions of the Hunter have the Avon turbo-jet engine, but the later Hunter is fitted with the Armstrong Siddeley Sapphire.

The Gloster GA5 Javelin, which was the first delta-wing aircraft to be ordered by the R.A.F., and the first multi-jet delta-wing aircraft to fly, has two Sapphire engines. This all-weather fighter is designed to attack high-flying bombers with which the lighter Swift and Hunter interceptor fighters will be unable to cope. It is difficult to detect hostile aircraft visually at 40,000 ft. and the Javelin, like the de Havilland 110, carries its own radar. This detection apparatus is costly, however, and aircraft equipped with it cannot be produced in large quantity. The Javelin must, therefore, be reserved solely to meet the risk of the small high-flying bomber force, while visual interception will continue to be the basis of defence against mass raids. The de Havilland 110, designed to a similar specification, retains the twin-boom fuselage of the Venom, and has exceeded the speed of sound in a shallow dive. It has been subjected to competitive trials against the Javelin, but so far has not been ordered for the R.A.F. It is thought that, if the de Havilland Company could have offered earlier delivery than the Gloster Company, the de Havilland 110 might have been ordered, since the Javelin, as a production project, was not so far advanced. Even the lighter interceptors, the Swift and the Hunter, are extremely expensive. Considerable interest, therefore, is centring in the efforts of Folland Aircraft, Limited, to build a fighter which can carry out most of the functions of more complex machines, while being considerably cheaper. Folland Aircraft, Limited, who hitherto have been engaged mainly on sub-contract work, thought that this left them in too vulnerable a position, and resolved to develop a product of their own, which they did without any financial backing from the Government. Mr. W. E. W. Petter, who designed the Canberra bomber for the English Electric Company, is in charge of the project. Weight-saving is achieved by simplifying equipment, and the new aircraft, which will be capable of supersonic speed, may be faster and have a more rapid rate of climb than the more complex single-seater fighters.

Very considerable advances have been made in bomber development. The piston-engined Avro Lincolns in service are already being replaced by the Canberra, and before long squadrons will be receiving the Vickers Valiant four-jet bomber. The Canberra made aviation history in August when the B5 version crossed the Atlantic both ways in a single day. The Valiant, with four Avon engines, has an extremely high operational ceiling, probably over 50,000 ft. and, in range and bomb-load, compares well with new American projected aircraft with a larger number of engines. Even more remarkable are the two latest bombers to be added to the super-priority list. The Avro Vulcan, which has been under secret development since 1947 as the Avro 698 and made its maiden flight as recently as August, was described by Mr. Duncan Sandys, the Minister of Supply, as "another dramatic leap in the history of aviation." A number were ordered for the R.A.F. before the prototype began flight trials. The Government had some insurance against failure of the Vulcan in the Short SA4. This new bomber, with four Avon engines, is of more conventional layout and the wings are not swept back. In accordance with Air Ministry policy, Short Brothers were asked to build an aircraft which would not depart unduly from orthodoxy, but which would be capable of relatively high performance. The SA4 should prove useful as a research aircraft for testing new weapons and equipment.

Sir Roy Dobson, managing director of A. V. Roe and Company, has stated that "the Vulcan flies faster, higher, and farther with a bigger load more economically than anything in the world." The Vulcan is the first bomber to fly with delta wings; the decision to adopt this wing formation and to dispense with the tailplane, according to Mr. Sandys, was an act of faith for which designers and manufacturers deserved the highest praise. Confidence in the delta wing seems to extend beyond the Iron Curtain, since it has been announced recently that a bomber of this type has been developed in Russia.



The future may not lie altogether with the delta wing, however; the Handley Page HP.80, which made its maiden flight on Christmas Eve, has a wing of crescent or scimitar shape, which is claimed to reduce drag at high speed and great height, and to give good control qualities and stability at all speeds and altitudes. Handley Page, Limited, make the same claim as A. V. Roe and Company make for the Vulcan, namely, that no other bomber flies as fast, as far and as high with as great a bomb load. It has been announced recently that the Vulcan is to be fitted with Bristol Olympus engines, which will give it even greater power than the original four Sapphires. The Government have been criticised on the ground that to build three different types of bomber, each capable of flying at about the speed of sound on operational missions at heights of 50,000 ft., was unnecessary. Each of these aircraft, Lord Ogmore said in the House of Lords, cost about 11. million, and there was a limit to what the British taxpayer could pay for aircraft. Mr. Duncan Sandys justified the Government policy on the score that, "in equipping an air force it is, as in racing, risky to put all your money on one horse, or to try to spot the winner too long before the race." More recently, Lord de L'Isle and Dudley, the Secretary of State for Air, has said that the Valiant was the first design in the world for a jet bomber and "inevitably later specifications had called for higher performances. It was impossible to predict until an aircraft had been in service whether its performance would match requirements. The Government would have been wrong not to be bold and order from the drawing board the two later designs of the Victor and the Vulcan." He added that the cost of the new bombers was not 11. million each, but only between 300,000l. and 400,000l.

#### TRANSPORT AIRCRAFT.

The design and development work which has gone into the new bombers is likely to be of great value to civil aviation. Handley Page, Limited, have on the drawing board a jet air-liner, the HP.97, which is based on the HP.80 and will be able to carry up to 150 persons over long distances at almost sonic speed. It has been designed primarily with the London-New York route in mind. Both luxury and tourist versions have been planned. Vickers-Armstrongs, Limited, have announced two new projects, a military transport and an air-liner based on the Valiant bomber. The military transport, the Vickers 1000, will have the same wing pattern as the Valiant, with the engines totally enclosed. The air-liner, the VC7, will be able to operate over both trans-Continental and trans-European routes. It will seat between 100 and 150 passengers according to the interior layout, and should be ready for quantity production by 1958 or 1959. Both the Vickers 1000 and the VC7 are to have the Rolls-Royce Conway by-pass jet engine, the latest and probably the most powerful engine in the world. The existence of the Conway was announced as recently as October, 1952, and little is known about its performance. The by-pass principle is said to give greater efficiency over wider ranges of speed and height.

The development of these aircraft will go far towards implementing the new Government policy, announced in July, 1952, by Mr. Churchill, of achieving a high degree of air mobility for troops and equipment as an essential weapon of the prolonged cold war. This policy completely reverses the decision, taken before the re-armament programme was launched, to cut expenditure on the Air Transport Command of the Royal Air Force, which, as a result, is considerably reduced in size and badly equipped. The main types of aircraft at present in use are the Handley Page Hastings, the Vickers Valetta and the Douglas Dakota. To these, however, will shortly be added the Blackburn Beverley freighter, which is going into quantity production, and which will carry out the heavy duties of transporting tanks and guns.

In recent years, the Royal Navy has not been so fortunate as the Royal Air Force in the aircraft at its disposal. In the House of Lords, on February 18, Lord Pakenham contended that the Royal Navy had never had aircraft worthy of itself, no matter

what Government had been in power, and that British naval aircraft compared badly with those of other countries. Lord Mancroft, for the Government, admitted that he was not satisfied with the state of naval aviation, and said that "there was no complacency in the Government about this vexed question." In one respect at least, however, British naval aircraft are not inferior. The new Fairey Gannet, which has been ordered by the Royal Australian Navy as well as the Royal Navy, is second to none in its anti-submarine role. It has the Armstrong-Siddeley Double Mamba engine (ASDM3) which can run on ordinary Diesel fuel, such as is used in the auxiliary engines of the aircraft carrier. This may be a significant development in naval aviation, since it may eliminate the complications which arise from the present necessity of carrying special aircraft fuel, with separate storage compartments, pumps and pipes.

The helicopter is occupying an increasingly important place in military tactics, but hitherto has been badly neglected by the British aircraft industry. Lord de L'Isle and Dudley has stated that the Government would have liked to develop different types of helicopter, but that they were limited by finance, and considered it best to concentrate on the production of offensive aircraft. The S 55 helicopter of Westland Aircraft, Limited, which crossed the Atlantic in July, has been ordered by the Royal Navy and the Royal Air Force; as with the S 51, its development was a private venture. Lord Aberconway, chairman of Westland Aircraft, said recently that, as the complexity of helicopters increased, it was becoming impracticable for private enterprise to undertake even preliminary work on larger types than those at present made by his firm. The S 55 is to be built in France for both military and civilian use, and up to 500 are to be made in Paris or Marseilles at a cost of about 50,000l. each. One of the latest helicopter projects is that of the Bristol Aeroplane Company, the Bristol 173, which is the first British twin-engined type. British European Airways propose to use this machine for services to the Scottish islands. The Fairey Aviation Company have a somewhat more revolutionary helicopter under development. The Fairey Rotodyne has a power system which consists of two gas-turbine units driving auxiliary compressors, and combines features of rotary-wing and fixed-wing aircraft. It can carry a load of 13,000 lb. at a cruising speed of 175 knots. A smaller helicopter, the Saunders-Roe Skeeter, is now being produced in several versions for civil and military training duties. Percival Aircraft, Limited, are another company who are developing helicopters.

Guided missiles now play a very important part in air strategy, and eventually will greatly reduce the need for fighter aircraft. Such weapons can now steer themselves with great accuracy, and, in the words of Mr. Sandys, can "twist and turn with four or five times the degree of manoeuvrability of a fighter aircraft." Some British types have already been evolved which can travel at more than 2,000 miles an hour and can rise to heights that no piloted bomber can achieve; and, as Air Commodore F. R. Banks observed in his presidential address to the Junior Institution of Engineers in December, they are much cheaper than a modern fighter. The Hawker Siddeley Group, Vickers-Armstrongs, Limited, Fairey Aviation, Limited, the English Electric Company, the Bristol Aeroplane Company, and de Havilland Propellers, Limited, are all making the airframes and engines of guided missiles. The rate at which development can proceed is restricted by the difficulty of finding sufficient electronic engineers, but nevertheless, it has increased rapidly. The testing of guided missiles at the Woomera range, in Australia, is being greatly extended in 1953.

#### EXPORT PROSPECTS.

Preoccupation with home re-armament requirements in 1952 has necessarily depressed exports of aircraft; Figs. 2 to 5, opposite, show how the volume of exports has dropped. Because of the rise in prices, the value of aircraft exports increased in 1952 to over 43l. millions (Fig. 6). This is already about equivalent to the exports of the shipbuilding industry, and, with the increased emphasis on exports in the Government's new policy, it is expected to rise to 60l. millions in 1953.

According to Lord de L'Isle and Dudley, it may rise to 200l. millions in five years. This is due largely to the new opportunities which are opening up for British jet-engined civil air-liners, but exports of military aircraft are likely to continue at a high level. Since the war, military aircraft, principally fighters, have predominated in the British export trade. The air forces of Sweden, Norway, France, Belgium, Switzerland, the Netherlands, South Africa, India, Pakistan, New Zealand, Canada, Australia, Argentina and Egypt have all been equipped with British aircraft. British manufacturers still have orders in hand for some of the older-style jet-engined fighters. Recently, a barter deal was completed with Brazil under which 70 Gloster Meteors are to be supplied in return for 15,000 tons of cotton. This contract comes at an opportune moment for the Gloster Aircraft Company, since it will enable them to retain the services of many workpeople who otherwise would have been discharged as a result of the cut in Government re-armament orders. In consequence, the company will have an intact organisation when work begins on the Javelins.

Export prospects for the new British fighters are also good. The London Mission of the United States Mutual Security Agency informed the Ministry of Supply in January that it was prepared to place an order valued at 70 million dols. for Hawker Hunter fighters, to be supplied to the countries of the North Atlantic Treaty Organisation under the "off-shore procurement" programme. There are some difficulties to be overcome before a definite contract is signed, but they are not thought to be insuperable. One of them is that, under existing United States law, delivery of aircraft under the current programme must be made before July 1, 1955. It is difficult to see how this can be done, if the requirements of the Royal Air Force are to be met in full. The United States authorities have also indicated that they are interested in the Supermarine Swift, though they thought that certain modifications were necessary before it could be included in the purchasing programme. The Gloster Javelin has also been considered for inclusion, and it is expected that it will be tested shortly by United States test pilots, who will assess its suitability for N.A.T.O. forces. If it is approved, its production may be undertaken in Italy by the Fiat Company. In that case, the only payments which will accrue to the United Kingdom will be royalties. It is unlikely, however, that the British aircraft constructors could undertake the production of Javelins additional to Royal Air Force requirements for a long time.

Several Western European countries, including Italy, are already making British fighters under licence. In Australia and Canada, fighters are being made under both British and American licences. A sufficient indication of the excellence of British jet-engined aircraft is the fact that the Canberra bomber, as well as a wide range of engines, is being made in the United States. The Curtiss-Wright Aircraft Company hold the licence for development of all the Armstrong-Siddeley gas-turbines, including the Sapphire, Mamba, Double Mamba and Pythou. They also hold the licence for the Bristol Olympus, which, like the Sapphire, is in production for United States military aircraft.

#### BRITISH CIVIL AIRCRAFT.

The most striking opportunities for British aircraft are in civil aviation. During the war, by agreement of the Allies, the development of transport aircraft was left to United States constructors. In consequence, they established a lead in this field which enabled them to dominate world markets in the immediate post-war years, when the civil airlines were building up their fleets. The faith of the British aircraft constructors in the jet engine, however, and the courageous backing of the Government, have led to the development in the United Kingdom of several types of jet-engined air-liners, all with operating costs considerably below those of piston-engined aircraft, before American projects had advanced much beyond the drawing-board stage. The extent of the British lead is not easily assessed, and, though considerable, it will not be automatically maintained. In January, two Bills were laid before the United



States Congress, urging the Government to subsidise the building of prototype jet air-liners in the United States; and, meanwhile, aircraft constructors in that country are doing their utmost to speed up the designs which they have on hand. In an effort to maintain their markets, they are holding out the lure of very long credit terms. Work on one of the American projects, the DC.8 of the Douglas Aircraft Company, does not appear to have been going too well. In 1952, it was predicted that a prototype would be flying within a year, and that the air-liner would be in service in 1957. There has been some difficulty, however, over the Pratt and Whitney 57 engines, four of which are to supply the power. The earliest date before the first production aircraft can be completed is 1958. The new DC.8 is designed to carry from 70 to 120 passengers at a cruising speed of 560 miles an hour, with a still-air range of 2,500 miles.

The Lockheed Corporation, as a stop-gap measure, are fitting their Super-Constellation air-liner with "turbo-compound" engines. The modified aircraft will be available in 1955, but, though the company have announced a project, a true jet aircraft is not likely to be available before 1958 at the earliest.

An obstacle which British constructors have to face is the fact that a high proportion of the aircraft in operation are American, and American operators, naturally, would prefer to buy American aircraft. More serious, however, is the opposition of the aircraft constructors in the United States; they have been the main objectors to American acceptance of British standards of airworthiness for jet aircraft. Although, two years ago, it was agreed that British certificates of airworthiness for piston-engined aircraft should be accepted in the United States, no agreement was reached on standards for jet-engined aircraft. Meanwhile, the Americans have been in no hurry to evolve their own standards or to accept those of the International Civil Aviation Organisation; in consequence, British jet aircraft could be excluded from the United States on a technicality. Some progress towards an agreement was made at a conference in Washington in January, when officials of the British Air Registration Board met members of the Civil Aeronautics Authority of the United States. Additional evidence on some points was requested by the Americans; if this can be provided satisfactorily, there will remain little difference between the British and

carry from 80 to 100 passengers. Arrangement are in hand for a third production line at Chester to supplement those at Hatfield and Belfast.

The turbo-propeller Vickers Viscount air-liner has also been selling well overseas. An order from Trans-Canada Airlines for 15, valued at 11.5 million dols., is the largest dollar order since the war for any British engineering product. The Viscount 701 is to go into service with British European Airways on April 1. A newer version, the Viscount 800, of which 12 have been ordered at a cost of 41. millions, will be delivered to B.E.A. by October, 1955. The Viscount 800 is a short-range aircraft which can carry 66 to 82 tourist passengers over distances of up to 450 miles at a cost of 10d. a ton-mile. The full range is 1,000 miles with a payload of 10,300 lb. It may prove possible to operate the Viscount 800 at 1d. per passenger-mile; if so, a very rapid expansion in air travel may be expected. Even as it is, the market for the Viscount 800 may be quite considerable. A large proportion of air traffic is carried over comparatively short distances, and many routes are still served by the Douglas DC.3. The Viscount 800, if not merely a modern replacement of the DC.3, should be able to carry

Fig. 1.

EMPLOYMENT IN THE AIRCRAFT INDUSTRY: TO DECEMBER 31.

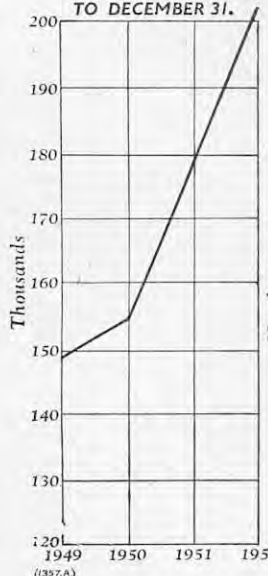
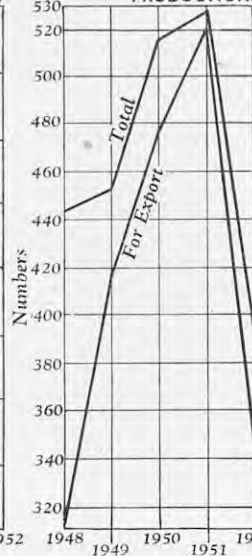


Fig. 2. YEARLY PRODUCTION.



FIGS. 2 TO 5, PRODUCTION OF CIVIL AND MILITARY AIRCRAFT FOR EXPORT.

Fig. 3. YEARLY PRODUCTION.

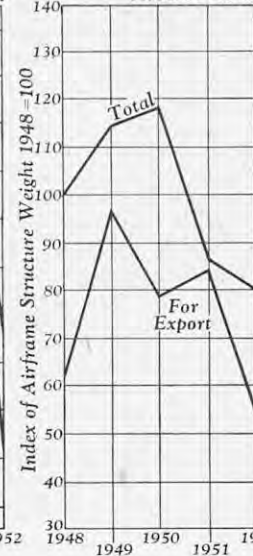


Fig. 4. QUARTERLY PRODUCTION.

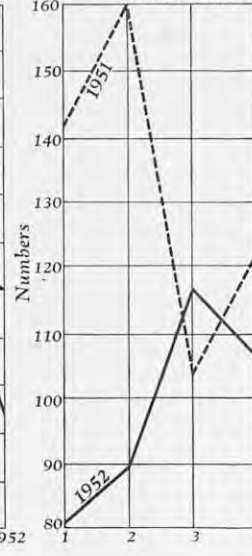


Fig. 5. QUARTERLY PRODUCTION.

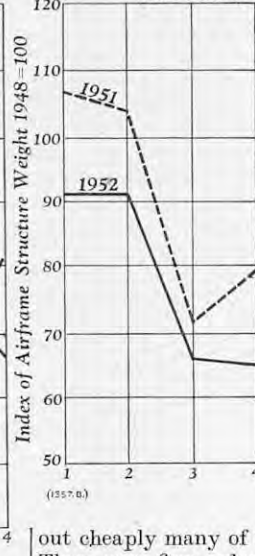
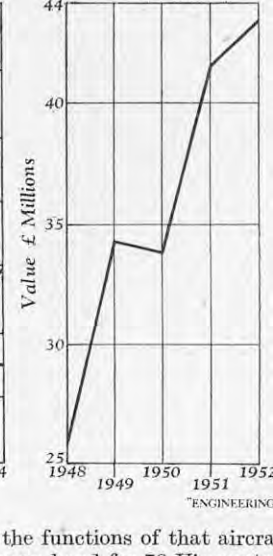


Fig. 6. EXPORTS OF AIRCRAFT, BY VALUE.



The Boeing Aircraft Company have in hand a "Project X," by which they hope to bring a jet air-liner quickly into service. A basic prototype has been designed, which is to be ready by the middle of 1956, when it is to be exhibited as a "sales demonstrator." It is thought that this can then be adapted to customers' requirements and be available for delivery within two years. As an air-liner, it should be capable of carrying a minimum of 75 passengers at a cruising speed of 580 miles an hour, but it can also be adapted as a military refuelling tanker or troop transport.

It is generally considered in the United Kingdom that the United States aircraft constructors have been over-optimistic in their time schedules. Seven years elapsed between the conception of the Constellation and its final production. The comparable period for the Comet I was five years and for the Comet III, virtually a new aircraft, it will be four years. The extent of the market which is at stake is considerable. There are about 1,000 main-line aircraft on the world routes; these have a life of six to eight years and cost over 500,000l. each to replace. In addition, on the shorter routes, there are about 2,000 medium-sized air-liners, which also have a life of six to eight years, and cost about 250,000l. each. During the next five to ten years, therefore, over 3,000 aircraft will have to be replaced at a cost of 1,000l. millions. This takes only replacement demand into account; air-liners will be required also, in increasing numbers, to cater for the rapidly expanding air traffic. To the aircraft constructors who capture this market will also fall a considerable business in spare parts and components. The orders in hand for British-built air-liners at the end of December (excluding spares) were valued at 75l. millions.

American viewpoints. Meanwhile, the United States authorities have indicated their willingness to consider the acceptance of specific British jet-engined aircraft on their individual merits. This ruling is of great importance, since Pan-American Airways have ordered three Comet III air-liners to be delivered late in 1956, and have a two-year option to buy seven more, for delivery in 1957.

The de Havilland Aircraft Company already have orders on hand for about 50 Comets, and disclosed recently that other orders were "under active consideration, many of them in an advanced stage of contract negotiation," for at least a hundred more. Some critics, impressed with the urgency of making the most of the present marketing opportunities, have thought that production of Comets has not been expanded rapidly enough. A statement by the de Havilland Company, issued in October, made it clear, however, that the rate of production has been considerably greater than might be justified by the volume of orders on hand. Increased production, beyond the scale of firm orders, entails a large commercial risk and also ties up resources which otherwise might be employed in introducing "the improved versions upon which Britain's technical lead in the future will depend." The pace at which new development is being carried out seems in itself to have caused some air-line operators to delay the placing of orders. Only 21 Comets of Series I are being built, since it was considered that operators would naturally choose to wait for the improved Series II, to carry 44 passengers, which would be available in 1954. Some operators, moreover, are confronted with the further problem of whether to buy the Series II or wait for the Series III, which will carry 58 to 78 passengers. The Series IV, which will follow, will

out cheaply many of the functions of that aircraft. There were firm orders on hand for 78 Viscounts in December, before the announcement of the B.E.A. order, and negotiations were well advanced over contracts for many more. Production has kept pace with the orders in hand, but extended delivery dates are inevitable as the result of the long cycle of production, though no orders have been lost on that account. Lord de L'Isle and Dudley said in February that "Vickers could increase production of the Viscount up to 100 a year—the highest production ever contemplated for a big civil air-liner, either in America or here," but "the cycle of production would still be 24 months." When, as planned, all Viscount production is transferred to the company's new factory at Hurn Airport, Hampshire, a very high rate of output should be achieved.

A third British jet-engined air-liner with a promising future is the turbo-propeller Bristol Britannia, which made its first flight in August, 1952. This aircraft, which can carry 104 tourist-class passengers across the Atlantic, has a still-air range of 4,000 miles and a cruising speed of 360 miles an hour. Operating costs for the most economic stage length of 2,500 miles will be about 8d. a ton-mile. The British Overseas Airways Corporation, who took the considerable commercial risk of ordering 26 Britannias "off the drawing board," intimated in November their intention to buy five freighter versions, which would cost about 41. millions. A number of potential users overseas are showing interest in the Britannia. The Canadian Government are said to be interested in a maritime reconnaissance version, and there is a possibility that the Britannia may be made in Montreal. The present production line can turn out only 18 aircraft a year, but the Bristol Aeroplane Company stated in December that they were considering plans for increasing production.



## STEAM TURBINE RESEARCH AND DEVELOPMENT.

As we noted briefly on page 339, *ante*, a one-day conference on Steam Turbine Research and Development was held on Friday, March 6, at the Institution of Mechanical Engineers, when seven papers were presented by Dr. T. W. F. Brown, Director of the Parsons and Marine Engineering Turbine Research and Development Association, and members of his technical staff. The morning and afternoon sessions were devoted to the presentation of the papers, and the evening session to a discussion on the whole series. Sir David Pye, F.R.S., President of the Institution of Mechanical Engineers, took the chair at the formal opening which preceded the first session and expressed the regret of the Council that, owing to illness, Sir Philip Johnson, the chairman of Pametrada, was unable to be present.

Sir David, continuing, said that when Dr. T. W. F. Brown, the Director of the Parsons and Marine Engineering Turbine Research and Development Association, had offered to the Institution a series of papers dealing with the research and development undertaken at the research station at Wallsend, the Council gladly accepted the offer, because they recognised that the existence of the station was of real value to the shipbuilding and marine-engineering industry. Dr. Brown and his staff had undoubtedly contributed in no small way towards ensuring that that great industry in Britain continued to maintain its leading position among the shipbuilding nations of the world. He welcomed the many visitors from other organisations who had accepted the invitation to join in the Conference and, in particular, those from Holland. The chairman for the morning session would be Mr. P. L. Jones, vice-president of the Institution, who had been connected intimately with steam turbines for the greater part of his life; and, in the afternoon, Dr. R. W. Bailey, vice-president of the Institution, would be in the chair.

Mr. P. L. Jones, M.C., B.Sc., then took the chair and invited Dr. Brown to present the first of the four papers in the programme for the morning session, on "Facilities for Full-Scale Testing of Marine Turbine Machinery."

### FULL-SCALE TESTING OF MARINE TURBINES.

In this paper, Dr. Brown described the inception, equipment, organisation and work of the Parsons and Marine Engineering Turbine Research and Development Association, more generally known as "Pametrada." The Association originated in 1944, when the shipbuilding and marine-engineering firms in Great Britain who were makers of marine turbines collaborated in the establishment of a turbine-testing and research station at Wallsend-on-Tyne. Subsequently, the organisation became a research association under the Department of Scientific and Industrial Research, while retaining complete autonomy in its own affairs. The station was designed to test turbine machinery developing up to 60,000 h.p. per shaft, and is equipped with a water brake to absorb this power at speeds from 160 to 300 r.p.m. The buildings were all constructed for their specific purposes, with access to the railway and also to the River Tyne, so that floating cranes can be used to place heavy machinery in position. The test-house was designed as an integral unit—"a concrete ship of cellular construction"—to reduce the specific ground loading to a minimum and to guard against subsidences which might have resulted from the presence of underground water. The main test-bed measures 83 ft. by 21 ft. 8 in., and carries a series of heavy iron beams, planed with great accuracy and set in concrete; the maximum deviation from truth in the whole plane of the test-bed is  $\pm 0.004$  in. The boiler house is built of standard troughing sections with flanges 6 in. deep, bolted together with tarred felt between, so that the whole boiler-house can be made airtight; it can withstand an internal pressure of 30 in. w.g. The construction of the building enables a complete boiler, landed on the quay by a Titan crane, to be drawn into place on greased skids through a temporary opening in the wall, which is then readily rebuilt to its former airtightness. Boilers can be used, therefore, which

are appropriate to the machinery under test, and have included units of as much as 200,000 lb. per hour evaporation. For the Association's own test rigs, there is a permanent boiler with a steam capacity of 40,000 lb. per hour at a pressure of 1,200 lb. per square inch, and another of about the same output, working at 250 lb. per square inch. Condenser cooling water is taken from the Tyne. Two steam turbines, of 4,000 h.p., are available for back-to-back tests of gearing, compressor tests, etc. The equipment includes laboratories for electronics, applied physics, chemistry, and metallurgy, and a workshop and instrument section. The staff numbers 260, of whom 65 are graduates.

### DEVELOPMENT OF MARINE STEAM-TURBINE DESIGN.

The second paper, on "The Development of Marine Steam-Turbine Design," was presented by Mr. H. G. Yates, M.A., the chief designer of the Parsons and Marine Engineering Turbine Research and Development Association.

Mr. Yates began his paper by tracing the development of steam-turbine designs at the Pametrada research station from its beginnings in 1944. From the outset, he said, certain principles were accepted as fundamental, namely, that reliability was a prime essential; that the turbine and its gearing should be considered jointly; that a high turbine efficiency should be aimed at, comparable with that usually achieved, in land power plants, only with units of the larger sizes; that turbines for mercantile service should be studied separately, without reference to the many other factors which influence a naval design; and that a successful design, intended for production in small numbers, must show a reasonable compromise between manufacturing costs and operating costs. Mr. Yates then proceeded to compare, in their principal features, a design of 1945, to develop about 7,000 shaft horsepower with steam at 450 lb. per square inch and 750 deg. F., with a corresponding design of 1953, to use steam at 850 deg. or 950 deg. F. The largest design yet produced, he mentioned, was for a set to develop more than 60,000 shaft horsepower on one shaft, and consisted of a single high-pressure turbine, to take the whole of the steam flow, and two double-flow low-pressure turbines in parallel; an arrangement which, he added, gave a marked saving in weight over a triple-expansion set. The smallest design prepared was for a twin-screw lake steamer of 400 shaft horsepower per shaft, with the turbines exhausting to a common condenser; a size and type of installation which was directly competitive with the Diesel engine, and which was preferred because it was desired to avoid the exhaust noise of a Diesel. Mr. Yates concluded by expressing the opinion that while, for many applications, the gas turbine would eventually supplant the steam turbine, that would not happen for many years; and that, meanwhile, the development of steam turbines would continue actively.

### MEASUREMENT OF SPECIFIC STEAM CONSUMPTION.

The third paper, on "The Measurement of Specific Steam Consumption," was presented by Mr. Michael H. Petty, B.A., a research engineer on the staff of Pametrada and leader of the Full-Scale Test Section of the organisation.

When, Mr. Petty said, the development of a specific type of prime mover reached the point where the law of diminishing returns began to operate, it became fundamentally important that the improvements resulting from small changes of design should be measured accurately. Such a period appeared to have been reached in the development of the marine steam turbine, and, in testing recent prototype units on shore, under ideal conditions, various methods had been used to measure the specific steam consumption. These he proceeded to describe, dealing in turn with the layout of the steam and feed systems and of the instrumentation, the trial procedure, the assessment of the required accuracies, the selection of instruments, and, in an appendix to the paper, with their calibration. To obtain a corrected specific steam consumption, in lb. per brake horsepower per hour, within an accuracy of  $\pm 0.5$  per cent., he showed that it would be necessary to measure the torque, in lb.-ft., and the revolutions per minute, to within  $\pm 0.18$  per cent.; the brake horsepower and the steam

flow, in lb. per hour, to within 0.25 per cent.; and the steam-pressure, steam-temperature and condenser-vacuum correction factors to within  $\pm 0.02$  per cent. These would give a measured specific steam consumption in lb. per brake horsepower per hour, and an overall correction factor, to within  $\pm 0.35$  per cent. If it were assumed that errors were proportional to  $\frac{1}{\sqrt{N}}$ , where  $N$  was the number

of measurements of any particular quantity, then, on average, the results of a trial based on four observation periods were twice as accurate as those of a trial based on one observation period; therefore, three consecutive observation periods were regarded as the absolute minimum, under steady conditions, for any trial. The observations for a trial were averaged, and then were corrected for gauge error from the calibration records, and for such errors as static-water head in pressure-gauge lines. The accuracy of  $\pm 0.05$  per cent. had been achieved in all cases except those at the lower end of the power range, where the measurement of exhaust pressure was outside the prescribed limits and the torque was too small to be determined with the desired accuracy on the available dynamometer, which was designed to test units up to 60,000 shaft horsepower.

### BACK-TO-BACK TESTING OF REDUCTION GEARS.

The morning session concluded with a paper on "Back-to-Back Testing of Marine Reduction Gears," by Dr. A. Cameron, chief chemist of Messrs. Thomas Swan and Company, Consett, and Mr. A. D. Newman, B.Sc., research engineer on the staff of Pametrada and leader of the Gearing, Bearings and Lubrication Section.

The system of testing described in the paper was that known as the "power-circulator" method, in which the power input from the turbine is transmitted to the pinion of a set of gearing, thence from the driven gearwheel to the corresponding gearwheel of a second set, and so to the pinion of the second set, which is in line with the pinion of the first set and coupled to it through a torque loader, by means of which a known torque can be applied to the system while running. The "circulating" torque may be measured either with the torque loader or by a torquemeter between the pinions and the wheels. The chief advantage of the method is that the external power supplied has to overcome only the losses in the system, so that the input torque gives the total losses in the two gearboxes. Tests carried out by this method showed the coefficient of friction for the gear teeth to be in the region of 0.047 for hobbled pinions of  $3\frac{1}{2}$  per cent. nickel steel, meshing with forged-steel hobbled wheels, and 0.03 for teeth that were case-hardened and ground. The bearing losses in a gearbox, which were from 65 to 85 per cent. of the total losses, could be analysed with reasonable accuracy from theory. Oil flow in the bearings could also be analysed and was found to consist of two components, one dependent upon inlet pressure and the second (the more important of the two) upon speed. A description of the Pametrada torque loader, designed by Mr. E. P. Peregrine, a former senior research engineer on the staff, was appended to the paper.

The conference then adjourned until the afternoon.

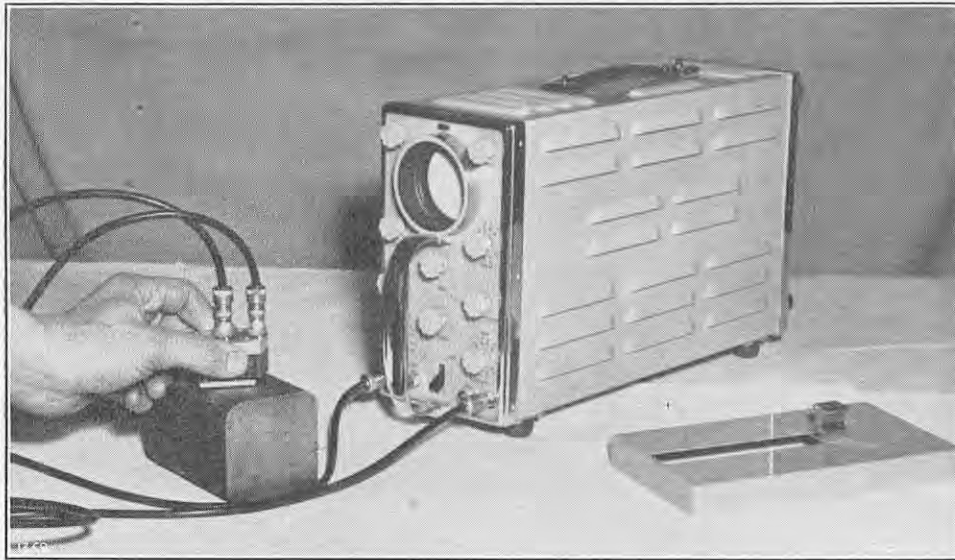
(To be continued.)

**MOBILE RECTIFIER FOR LOCOMOTIVE TESTING.**—The General Electric Co., Ltd., Kingsway, London, W.C.2, have built a mobile rectifier substation at the Glasgow works of the North British Locomotive Co., Ltd., to enable a direct-current supply at suitable voltage to be given to the 40 3,030-h.p. 3,000-volt locomotives which are now under construction for the South African Railways. The motors and control gear for these locomotives, which, like the other electrical equipment, are being supplied by the General Electric Co., are tested before dispatch to the engine builder, but the new substation will enable further tests to be carried out after these parts have been built into the locomotive. The substation is mounted on a road trailer and the rectifier, transformer and switchgear are housed in a water-tight sheet-steel cubicle. It is rated at 150 kW and receives three-phase power at 3.35 kV, an output voltage of between 0 and 4,000 volts being obtained by grid control and tapplings on the transformer.



## SUPERSONIC FLAW DETECTOR.

KELVIN AND HUGHES (INDUSTRIAL), LIMITED, LONDON.



### SUPERSONIC FLAW DETECTOR.

THE method of detecting cracks, holes, inclusions and other internal defects in steel and other metals and alloys by the reflection of high-frequency sound waves passed through the material was introduced in the early days of the recent World War and has been greatly extended during the war and subsequently, so that its use may now be regarded as well established. The principles involved are generally understood, but, as a reminder, it may be mentioned that oscillations set up by a piezo-electric crystal are applied to one end of, say, a steel bar and the reflections from the end of the bar, and from any intermediate flaw, are received by another crystal and shown in the form of peaks on the screen of a cathode-ray oscillograph. The position of the flaw can be determined by measuring on a scale the distance between the peak corresponding to the flaw and those caused by the ends of the bar.

As the principles employed are similar to those used in marine echo depth sounding and other supersonic work with which Messrs. Kelvin and Hughes, of Ilford, had had extensive experience, it was perhaps natural that they should be entrusted with the production of the early apparatus for flaw detection. Portable forms of apparatus were quickly produced and extensively employed during the war, since which time several improved models have been made available from time to time as a result of users' experience and the investigations of the firm's research staff. The latest form in which the apparatus has been produced is illustrated by the photograph reproduced on this page which shows the Mark 5 miniature flaw detector, specially designed for use in the internal inspection of welded pressure vessels although it has many other applications. The equipment has been made as light and compact as possible so that it can be passed through a manhole and operated by one man inside the vessel. The only external connection necessary is a lead to the alternating-current mains to provide a supply at 200 to 250 volts and 50 cycles. The complete circuit for supplying and controlling the operation of the cathode-ray tube is contained in the carrying case shown on the right in the illustration. The case measures 17 in. by 9 in. by 5 in. and on one end of it are the cathode-ray tube screen, the controls and a carrying handle. The total weight is under 30 lb., but the tube, valves and other components are mounted so that they can withstand without damage the rough usage to which the case is likely to be subjected in service.

One of the novel features of this apparatus is that the trace on the screen can be extended in length, by means of the controls, so that the trace only represents a small part of the total range which enables several closely-grouped flaws to be detected individually and also facilitates the measurement of

thickness when the apparatus is being used for that purpose. The movable components in which the transmitting and receiving crystals are mounted are known as "probes." Different types of these are available, some of which have a single crystal each for transmitting and receiving, respectively, so that two are required and must be applied separately to the test object. That being manipulated by an operator in the accompanying illustration, however, is a combined "transceiver" probe, which in certain applications of ultrasonic testing, is more convenient to use than two separate probes.

In this probe, a single transmitter crystal is mounted in the centre with a receiver crystal on each side of it set farther back from the working face. It will be clear that with this arrangement the combined directional characteristic in one plane is equivalent to that of a single crystal system, but in a plane at right angles to this the "beams" of the transmitting and receiving crystals overlap to some extent so as to give some of the advantages of a "split-beam" system with more accurate flaw location in a plane parallel to the testing surface. This is due to the lobe-shaped response of the combined probe which enables a sharper "maximum" to be obtained. Other advantages claimed for the combined probe are that it gives a considerably better performance on rough surfaces than is possible with a single crystal, and also facilitates the location of flaws or defects by the echo technique. The lightweight leads used for connecting the combined probe to the indicating instrument can be passed through a common sheath which further facilitates handling.

In supersonic flaw detection it is desirable to vary the operating frequency to suit the material being tested, and in the Mark 5 apparatus frequencies ranging from  $\frac{1}{2}$  to 5 megacycles per second can be obtained by means of the controls provided. The range represented by the full deflection of the time base can also be varied from 2 in. to 12 ft. An important point which will be appreciated by users of the apparatus is that the cathode-ray tube and all the valves employed are standard types which are readily obtainable when replacements become necessary. The apparatus is supplied by Kelvin and Hughes (Industrial), Ltd., 2, Caxton-street, Westminster, London, S.W.1.

ADHESIVES FOR AIRCRAFT CONSTRUCTION.—Dr. N. A. de Bruyne, of Aero Research, Ltd., Duxford, Cambridgeshire, held a reception for the Technical Press on Tuesday, March 17, in which he discussed his recent tour of the United States. Dr. de Bruyne restated the case for the use of adhesives in aircraft construction, quoting the Comet and Britannia airliners as pre-eminent examples where adhesives were used extensively, and he suggested that their use was a significant factor contributing to the lead held by the United Kingdom in jet aircraft. An article entitled "Redux" Adhesive Process for Metals" was published in *ENGINEERING*, vol. 171, page 144 (1951).

## MACHINING THE WILSON EPICYCLIC GEARBOX.

THE well-known Wilson epicyclic gearbox is made in two patterns and two gear ranges by Guy Motors, Limited, Fallings Park, Wolverhampton, for fitting to their commercial vehicles. It can be supplied either for mechanical operation by foot pedal, or for compressed-air operation from the braking-system reservoir. A gearbox of the air-operated type is shown in position on a vehicle chassis in Fig. 1, on page 364. Either of the two types of gearbox is available with four or five forward speeds and reverse, but the basic design is the same in all cases. The major components are common to the whole range, and it is only necessary to perform or omit certain machining operations in order to vary the type. This is exemplified by the gearbox shown in Fig. 1: the gearbox being, in this case, operated by compressed air, boring and facing of the boss seen in the left foreground, which carries the operating shaft, are omitted. Other parts are incorporated or omitted as required in the final assembly stage, and the choice of speed range is obtained in the same way.

The production of the gearbox requires the machining of numerous components in magnesium alloy and steel of various specifications, to precision limits, and in varying quantities. The total output of gearboxes—10 to 12 per week—precludes the possibility of using mass-production methods, and, to meet the requirements of the vehicle assembly line, flexibility in output is essential. The gearbox is therefore tooled for batch production on machine tools of orthodox design, and passes through the machine shop in company with a very wide range of other vehicle components. The size of each batch of parts is varied according to vehicle-building requirements, and it is always possible to reduce the production temporarily, or to increase it, by setting the machines up for other work, or by using extra machines for gearbox machining.

The principal components of the gearbox are either magnesium-alloy castings or steel drop-forgings, and machining is carried out with high-speed steel tools on the former, and tungsten-carbide tools on the latter. The usual precautions against fire are taken when machining magnesium alloy, but it has been found that, if high speeds and feeds are used, and the tools are kept in first-class condition, little or no trouble is experienced. Jigs and fixtures are provided for every machining operation, and they are so designed that, once a component is on a machine, the maximum amount of work is done at one setting.

The main box, a casting of magnesium alloy, illustrates the tooling and the machines used with components of this material. The castings are received in fully-fettled and dressed condition by the machine shop, and are marked out in the usual way for the first machining operation. This marking-out, which includes a dimensional check of the casting, is the only one that the component receives, all subsequent machining being carried out in jigs and fixtures locating from the first machined face. After marking out, the main joint face, which carries the bottom cover-plate, is machined on a Herbert No. 47V vertical milling machine, using fly cutters. The box next passes to an Archdale 4-ft. 6-in. radial drilling machine, where 39 holes are jig-drilled and tapped  $\frac{1}{4}$  in. Whitworth, and two holes are jig-drilled and reamed  $\frac{5}{16}$  in. diameter for dowels in the joint face. The dowels are used eventually to locate the bottom cover-plate when the box is assembled, and they are also used, in conjunction with the machined joint face, as location points in all subsequent machining. The next operation on the box casting is the machining of four vertical joint faces on a Cincinnati horizontal milling machine, with fly cutters. The side faces are finished, but the end faces are left  $\pm 0.005$  in. for cleaning up square with the bores in a subsequent boring operation. When joint-face machining on the batch of castings has been completed, they are inverted on the same machine, and a clearance slot is milled in the base of each one. A further joint face, which is at an angle of 15 deg. to the horizontal, and carries



## MACHINING THE WILSON EPICYCLIC GEARBOX.

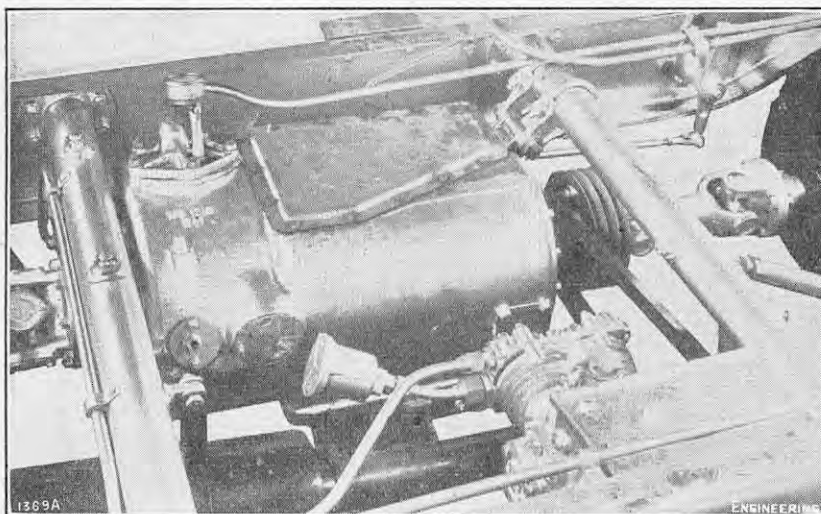


FIG. 1. AIR-OPERATED GEARBOX.

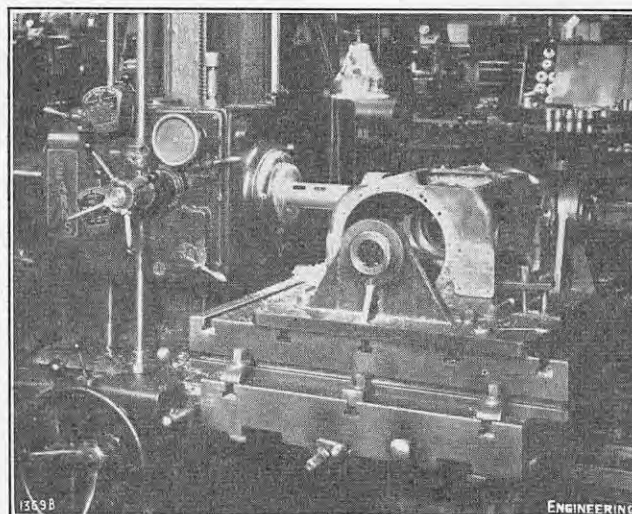


FIG. 2. BORING MAIN BOX ON KEARNS BORER.

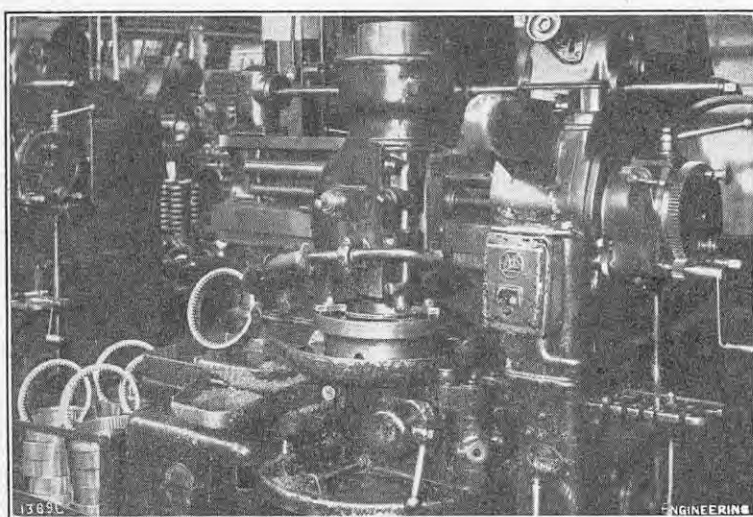


FIG. 3. SECOND-SPEED BRAKE DRUM ON FELLOWS GEAR SHAPER.

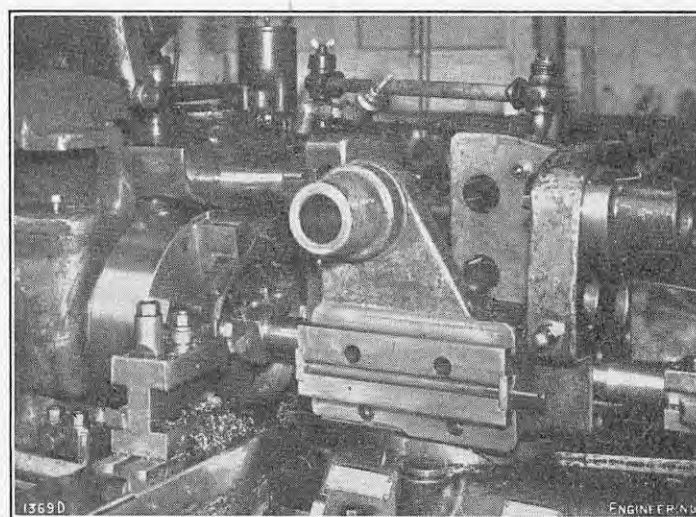


FIG. 4. BRAKE BAND ON HERBERT NO. 4 LATHE.

the air cylinder or the spring mounting used in mechanical operation, is next machined on a Herbert No. 47V vertical milling machine, with an angle fixture. The joint face in question is visible on the top of the gearbox in Fig. 1, which also shows the air cylinder in position.

The box then passes to a Kearns horizontal borer (Fig. 2, on this page) for the machining of all the main bores. Boring is carried out in two stages. All bores are first roughed out, except one in the centre of the box which carries a ball-race housing; this is finished to size, and the housing is pulled into position on the machine. The box is then removed and allowed to cool. When a batch has been rough-bored in this way, the same machine is used for the finishing of the bores, tungsten-carbide tools being substituted for the high-speed steel tools when working on the ball-race housing, which is of steel. The end faces are finished at this setting also, to ensure that they are square with the bores. A separate setting on the same machine is used to bore two holes which are at an angle to the main body of the box; one of these holes is the air-cylinder or spring-mounting hole, already mentioned, and the other is for the speedometer drive. The latter can be seen adjacent to the unmachined boss in Fig. 1.

The next operation is to drill and tap all the remaining screw or stud holes in the casting, which is done in a jig mounted on an Archdale 4 ft. 6 in. radial drilling machine. Only one machining operation remains, namely, the drilling of two  $\frac{1}{2}$ -in. holes in the body of the casting; this is also done on an Archdale radial machine. The two holes are each 8 in. long, and they are drilled at an angle, to meet to form an oil passage. Finally, the box is fitted with temporary covers and filled

with paraffin for a porosity test, before passing to the component stores. Other magnesium-alloy castings, such as the main cover-plate, which is used for mounting certain other components and has a number of machining operations done on it, are dealt with in a manner similar to that used on the main box.

The epicyclic-gear parts, which are of steel, vary somewhat according to the particular speed for which they are intended, but the operations performed on the second-speed brake drum are typical. Rough-boring and machining of one face are done on a Herbert No. 9B turret lathe. The component is then heat-treated, and shot-blasted to remove scale. It next passes to a Gisholt turret lathe, where it is held internally while the outside diameter, one face, and one of the gear diameters are finish-machined. A chamfer is also put on, ready for gear-cutting, while the component is in this machine. A second Gisholt lathe is used, with the component held externally, to finish the second face, counterbore the second gear diameter, and undercut between the two gear diameters. Both gear rings are then cut on a Fellows gear-shaper (Fig. 3). Ten oil slots are then milled on the side of the drum, and the component is ready for the final operation, that is, grooving on the outside diameter. Forty shallow annular "V" grooves are cut to increase the friction surface presented to the brake band. At one time, these grooves were cut with a single-point tool in a centre lathe, but they are now cut simultaneously. The drum is mounted on the spindle of a vertical hobbing machine, and rotated against a special milling cutter with staggered teeth. The operation, though carried out on a hobbing machine as a matter of convenience, is essentially one of milling.

The planet wheels, of which there are three to

each gear assembly, are made from drop forgings of 5 per cent. nickel case-hardening steel. They are first rough-turned as far as possible on the outside diameter on a Herbert No. 4 capstan lathe. At this setting, the drilling of the bore is performed, and the accessible face is machined. The blanks are then reversed in the chuck, the rough-turning of the outside diameter is completed, and the blank is faced approximately to length. Normalising and shot-blasting follow, and the blank is passed to a Herbert No. 4 capstan lathe for boring and reaming to within 0.010 in. of the finished diameter, the allowance being made for grinding. One side of the blank is chamfered, ready for gear-cutting, while it is on this machine. The blank is next mounted on an expanding adaptor on another Herbert No. 4 capstan lathe, and the outside diameter is finished, with a 0.010-in. allowance for grinding. The second chamfer is cut, and the radius for the tops of the teeth is put on while the component is on this machine. A small external grinder is then used to grind one face, and the blank passes to a Barber-Colman hobbing machine, where the teeth are cut. Allowance is made for grinding the teeth after hardening. The gear is then carburised and hardened to a Vickers diamond hardness figure of 680 minimum, and shot-blasted.

Several grinding operations follow. A medium external grinder is used to finish the tops of the teeth, and a Churchill internal grinder for finishing the bore to size. The gear is ground to length on a Snow vertical-spindle machine with a magnetic chuck. The last grinding operation, for tooth form, is done on an Orcutt gear-grinding machine with a hydraulic carriage traverse. Three gears are mounted at a time on the machine spindle



## MACHINING THE WILSON EPICYCLIC GEARBOX.

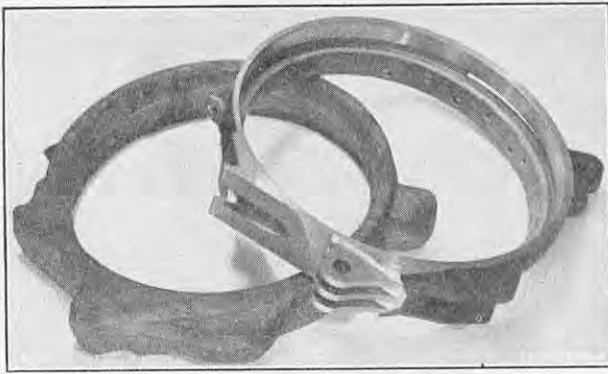


FIG. 5. BRAKE BAND.



FIG. 6. DRIVING SHAFT.

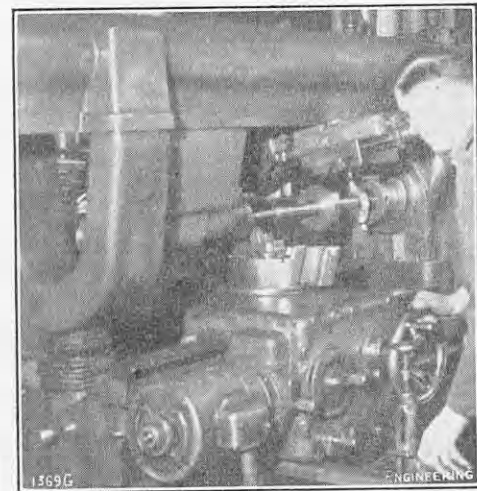


FIG. 7. HYDRO-COPYING DRIVING SHAFT.

and, when ground, are kept together as a set. The gears pass from the grinding operation to a Parkson gear-testing machine for complete inspection, and to a magnetic crack-detector. Finally, they are demagnetised before being sent to the stores.

The brake band is another drop forging, of  $3\frac{1}{2}$  per cent. nickel oil-hardening steel. Fig. 5, herewith, shows the forging and a band on which all machining operations have been performed, except splitting near the centralising lug, which can be seen in the foreground. This final operation is done after the lining material has been fitted. A Herbert No. 4 automatic lathe is used, with the component held in an air chuck, to rough out the two bores and to machine one face (Fig. 4). The band next passes to a centre lathe, where it is held internally, and the second face is finished to  $+0.006$  in. on the overall length. Both faces are then ground to the finished length on a Snow vertical-spindle grinding machine with a magnetic chuck. Finishing of both bores follows, with a special boring fixture on a Herbert No. 9 turret lathe, and at this setting the annular groove between the two bores is put in. The drilling of the  $\frac{1}{2}$ -in. hole in the centraliser lug, which is visible in Fig. 5, is then done on a vertical-spindle drilling machine. A series of milling operations follows, on a Cincinnati vertical milling machine, including the milling of part of the outside diameter of the brake band, for which purpose a rotary table is used. The band is then transferred to a Cincinnati horizontal milling machine, where six further milling operations are carried out.

The holes for the friction-lining rivets, 19 in number and  $\frac{11}{16}$  in. in diameter, are next jig-drilled and countersunk on a two-spindle or three-spindle Herbert vertical drilling machine, and, at the same time, a  $\frac{3}{8}$ -in. B.S.F. hole is drilled and tapped for the adjuster stop. The band now passes to the fitting shop, where the Ferodo friction linings are fitted and riveted in position. It is then returned to the machine shop, where the linings are skimmed to size in a centre lathe. Finally, a Cincinnati horizontal milling machine is used to put two saw cuts through the band near to the centraliser lug, and so to split it ready for assembly.

The driving shaft (Fig. 3) is made from a forging of 65-ton nickel-chromium steel. The first operation is to turn and centre both ends in a centre lathe. The forging then passes to a Fischer hydro-copying lathe for rough-turning all over. Guy Motors, Limited, installed one of the first two Fischer hydro-copying lathes to be imported into this country, and have used this type of machine for a variety of components. Until recently, the Fischer lathes used were of the type which copies the form of the component from a hardened and ground steel template. With this machine, a 45-deg. chamfer is formed at the roots of the flanges, and, where square flange roots were required, as in the driving shaft in question, a special overhead tool-box, which can be seen in Fig. 7, was used for flange facing and finishing. One of the latest Fischer hydro-copying lathes has now been installed. This machine (which is illustrated in Fig. 8, on page 368) is capable of working either from a template or from a finish-machined component; it is shown set up for the latter operation. The tool slide

and hydraulic-feed unit are set at an angle, and it is possible to produce square flange roots on this machine without using a top tool-box. The top tool-box, or in-feed attachment, is provided for the production of the few forms which cannot be copy-turned, and is only used occasionally. The Fischer lathe is said to be ideal for the production of components such as the drive shaft in question, but it has also been found economic to use the machine for many other components of much simpler form, and even for certain plain cylindrical turning operations, owing to the high rate of production which can be achieved.

Heat treatment and shot-blasting follow the rough-turning of the drive shaft, and there is provision for a press straightening operation if required. The component is then returned to the Fischer lathe, where it is finish-turned all over, leaving 0.010 in. to 0.012 in. on the diameters, and 0.003 in. to 0.004 in. on the faces, for grinding. An oil hole,  $\frac{1}{2}$  in. in diameter, is then drilled through the centre of the shaft on a Pollard two-spindle drilling machine, half the drilling being done from each end. A Barber-Colman hobbing machine is next used to hob the splines on each end of the shaft, and the component is passed to a medium radial drilling machine, where it is located in a jig, and the 12 holes in the flange are drilled. The drilling of 11 oil holes and one split-pin hole follows, and a Woodruff key slot is put in, on a horizontal milling machine. Two portions of the shaft, each about 1 in. long, are then hard chromium-plated, for working in phosphor-bronze bushes, and the final operation is to grind the shaft all over on a Churchill or Newall horizontal grinder.

Numerous other small components are machined by methods similar to those described, and require no further comment, but there are two machining operations which have not been mentioned, and which play a large part in the manufacture of some of the gearbox parts. These operations are milling with a dividing head on the machine table, and profiling. The former method is used to machine the selector camshaft, illustrated in Fig. 10, on page 368. This is a steel drop-forging, and, as will be seen from the illustration, it is only machined on the cams, the bearing surfaces at the ends, and the driving gear. The machining of the ends and the gear needs no comment. The flanges on which the cams are cut are first rough-turned on the outside diameter to ensure clearance on assembly, and the camshaft is then mounted between a centre and a dividing head on a Cincinnati vertical milling machine, as shown in Fig. 9, on page 368. The camshaft is located from the gear teeth, to ensure correct angular relationship of the teeth and the cam faces, and an end-milling cutter is used to machine away part of the flange to form one face of the cam. The camshaft is then rotated by means of the dividing head, and the second face of the cam is cut. The cam then consists of a double face, the included angle of the faces being 150 deg., and a backing which is the unmachined part of the original flange. The table of the machine is then traversed, and the machining operations are repeated on the next cam, and so the work proceeds until all the cams have been cut.

Profiling is used for several small components,

one of which, the operating strut (neutral), is shown in Fig. 11, on page 368. The machine used is an Asquith vertical-spindle profiling machine (Fig. 12, page 368), which has a follower working off a hardened and ground steel profile plate. The table motions are controlled by hand, through racks and pinions, and the slide carrying the machining head is adjustable vertically, so that the whole of a component edge, or part of it, can be profiled as required. Slots can be put in components, and a variety of complicated shapes can be machined without difficulty. This machine is used for all milling without difficulty, and for operations where the profile is not of simple geometric form.

Assembly of the gearbox is arranged to be as flexible as the manufacture of components. The latter, when machined, pass to a components store adjacent to the assembly shop, whence they are issued to the fitting benches, which adjoin the vehicle building line, as required. The work is arranged on a sub-assembly basis, groups of components being first sub-assembled on the bench and then built into the finished gearbox. The work of assembly is carried out mainly with hand tools of orthodox type, but power-driven nut-runners are also used. Complete assembly of any type of gearbox can be undertaken by one man, who is responsible for his own sub-assemblies, but if necessary the men can work in groups, several of them concentrating on sub-assemblies, while others attend to the final fitting up of the finished gearbox. Operation tests, under working conditions, are conducted on each gearbox before it is passed for fitting to a vehicle.

**SILICONES IN THE ELECTRICAL INDUSTRY.**—An exhibition of silicone materials of interest to the electrical industry has been held all this week on the premises of Midland Silicones, Ltd., 19, Upper Brook-street, London, W.1. The exhibition closes to-morrow, March 21. The principal insulation manufacturers have co-operated to display a full range of silicone-bonded materials, including glass cloth, fabric and asbestos laminated sheet; silicone-insulated cable and conductors; silicone-bonded mica plates, and other products. An interesting exhibit showed how the armature coils of the motor of a standard London Transport tube-train were insulated from earth with silicone-coated glass tape, it being emphasised that this material had proved of great value where the insulation was subjected to intense stresses as a result of vibration, the expansion and contraction of the iron and copper and the centrifugal force in the rotating parts. In declaring the exhibition open on March 16, Mr. J. C. Christopher-son, a director of Midland Silicones Ltd., mentioned that the firm, which was associated with Albright and Wilson Ltd., had been formed in 1950, and since then had continued to supply, on an increasing scale, British industry with silicones manufactured by the Dow Corning Corporation in the United States. This dependence on American supplies, however, would cease before long because a British plant of ample capacity had been erected, at a cost of 1,000,000/., at Barry, South Wales, by Albright and Wilson Ltd. By the middle of the present year, a full range of British-made silicones was expected to be available.



## NOTES FROM THE INDUSTRIAL CENTRES.

### SCOTLAND.

**SCOTTISH IRON AND STEEL OUTPUTS.**—The promising start to steel production in January this year was carried a stage further last month when the output of ingots and castings in Scotland was at an annual rate of 2,467,200 tons, the best performance since November, 1950, when it reached 2,590,700 tons. Production in January was equivalent to 2,287,300 tons a year, and in February, 1952, to 2,131,400 tons. Pig-iron production also rose in February to an annual rate of 877,100 tons compared with 862,500 tons in January. The corresponding annual equivalent in February last year was 879,500 tons.

**WATER-SUPPLY SHORTAGE.**—Local authorities are beginning to express concern about water supplies, because latterly the winter has been one of the driest for many years. If this is followed by a dry summer, several districts may be short. Mr. S. D. Canvin, the Glasgow water engineer, has said that, at this time of year, he likes to have at least 180 days' supply, but with daily consumption at just over 85,000,000 gallons, supplies are at present considerably short.

**DIESEL ENGINES FOR ROAD VANS.**—That the use of Diesel engines in vans could halve transport costs in retail distribution was stated by Mr. A. Prentice, chairman of the Scottish Co-operative Transport Association, at the annual meeting on March 10 in Glasgow. The Scottish co-operative movement, he continued, were now spending more than 800,000l. annually on liquid fuel. The adoption of the small Diesel could reduce the cost by 400,000l.

### CLEVELAND AND THE NORTHERN COUNTIES.

**PERMANENT WORKS EXHIBITION AT STOCKTON-ON-TEES.**—The Power-Gas Corporation, Stockton-on-Tees, have opened a permanent engineering exhibition at their works to give visitors an insight into their activities. The firm export goods to more than 20 different countries and frequently receive visitors from overseas. A large room has been fitted to accommodate the exhibition, which consists of diagrams, photographs and models of the firm's manufactures for the iron and steel, chemical, petroleum, gas and other industries. From a balcony adjoining the exhibition room, it is possible to see all the firm's premises.

**DELAYS AT MIDDLESBROUGH DOCKS.**—At the annual meeting of the River Tees Liner Agents' Association, at Middlesbrough, reference was made to the delay in the turn-round of ships. Mr. D. Povall, the retiring chairman, said that, at times, there were more ships than berths and more cargoes than men to handle them, but the Dock Labour Board's transfer arrangements were too inflexible to meet these peak demands. He expressed the hope that this year, the Tees Conservancy Commission would receive permission to proceed with their deep-water berths plan at Lackenby.

**PROPOSED GYPSIES GREEN MARSHALLING YARD.**—South Shields Town Council have referred to the Town Improvement Committee protests made by a deputation to the Council against the construction of a railway marshalling yard for the National Coal Board in the Gypsies Green area. The deputation pointed out that the proposed yard would depreciate the value of residential property in the district. The proposed yard had not been shown in the Corporation's development plan. The deputation contended that there was a suitable site for the yard two miles from the proposed site.

**NAVAL CONSTRUCTION WORK ON THE TYNE.**—A frigate ordered from Vickers-Armstrongs Ltd., Walker-on-Tyne, under the Admiralty's 1953-54 programme, is stated to be the first warship ordered on the Tyne since the war. At present, the only naval vessel being completed on the river is the aircraft carrier Albion, launched six years ago and expected to be completed this year. Palmers Hebburn Co., Ltd., are carrying out two important refits, namely, to the cruiser Mauritius, which has been at the yard for more than 12 months and will not be completed until about October, and to the destroyer Whirlwind, now being converted into an anti-submarine frigate. This job will be completed in June.

**INDUSTRIAL STEEL-PLATE NEEDS.**—Sir Mark Hodgson, chairman of the Northern Regional Board for Industry, suggested at Newcastle-on-Tyne that engineering firms should buy more steel plates from abroad. These foreign plates, he stated, had been dearer than

British steel, but prices were falling. Steel-plate production in this country totalled about 2,250,000 tons annually. Shipbuilding used 700,000 tons, the steel-tube industry 100,000 tons, and 200,000 tons were exported. Most of the remaining 1,250,000 tons went to the engineering industry. The shipbuilding industry was mainly interested in heavy plates, and most of an increased production of 150,000 tons of thin plates would go to the engineering industry.

**DEMOLITION OF OLD WALLSEND SHIPYARD OFFICE.**—Messrs. Swan, Hunter and Wigham Richardson, Ltd., Wallsend-on-Tyne, are to demolish an office building at their shipyard which is believed to be the last relic of the original shipyard of C. S. Swan & Co. The office is on the main road to the waterside through the shipyard. The road was formerly a public highway and was closed early in the present century. The office is being cleared in connection with a reconstruction programme now being carried out by the firm.

### LANCASHIRE AND SOUTH YORKSHIRE.

**NEED FOR STEELWORKS FOREMEN.**—Sheffield steel firms experience difficulty in persuading men to accept positions as foremen. The advantages formerly enjoyed by foremen as members of the staff are outstripped by the advantages in wages and conditions of employment which have been gained by the workmen. Mr. L. G. Darwent, the Sheffield representative of the National Union of Manufacturers, states that foremen frequently get less money, enjoy no more paid holiday than the men under them, and have no advantage in the assurance of regular work, as there is employment for all. Moreover, foremen often get no extra money for working overtime during the week.

**IMPROVING EXPORT PROSPECTS.**—Principals of Sheffield tool and cutlery firms, adversely affected by Australian import restrictions, have been making investigations on the spot, and are of the opinion that there will be a general improvement in trade with Australia towards the end of the year. Col. F. A. Neill, chairman and managing director of James Neill & Co. (Sheffield), Ltd., states that the "unbalance" caused by the quota system has left Australian importers understocked with some articles and overstocked with others. He believes, however, that when the arrears of unexecuted orders are overtaken as licences become available, a more even balance of imports will result.

**FACTORY FOR TUBULAR STEEL.**—Work has begun on a new factory at Kirkby, Liverpool, for Tubewrights Ltd., which will produce components for standard tubular structures. The site, which is 35 acres in extent, has been chosen partly for its convenient access to the docks, but partly also because of the availability of labour and the fact that Liverpool provides a good central point for sales for the British market. About 300 workpeople will be employed in the first instance. The building, which will be single-storey, will be about 360 ft. square. The tubular-steel frame, designed and made by the firm, will have a girder span of 120 ft. The main contractors are Taylor Woodrow Construction, Ltd.

**SHIPS OF RESERVE FLEET BERTHED AT BARROW.**—In pursuance of the policy announced last August, of laying-up ships of the Reserve Fleet in commercial harbours, the Admiralty have decided to berth some 20 or more frigates at Barrow-in-Furness. Already 48 ships of the Reserve Fleet are at Penarth, Cardiff, and West Hartlepool, and more are on their way. There, in a dehumidified state, they are in the care of ship-repairing firms. It is intended to lay up at Barrow a group of older-type frigates which were withdrawn from service immediately after the war. The care and maintenance of these vessels will be undertaken by civilian labour.

### THE MIDLANDS.

**LOSS OF ORDERS FOR MACHINE TOOLS.**—Sir Alfred Herbert, founder and chairman of Alfred Herbert, Ltd., Coventry, writing in the company's house magazine, says that, for the past two years, the firm have been losing orders because of their inability to meet the delivery requirements of overseas customers. Sir Alfred says that this is still the position, and that it is the result of the shortage of skilled labour, which makes it impossible to operate a full night-shift. He adds that German and Japanese competition is now severe, and that conditions in the American market, where the firm have been doing considerable business, are becoming difficult. The firm's employees, however, have little to fear on the question of redundancy, provided that they do their best to avoid it.

**SCRAP COLLECTION.**—The Midland Scrap Iron, Steel and Metals Association are planning to continue

the local scrap-collection drive for another year. It is considered that some of the sources of scrap—farms, domestic premises, and other non-industrial concerns—are almost exhausted, but arrangements will be made with local authorities to send collecting vehicles to the thickly-populated areas once more, and rural dumps will be set up as collecting centres for farm scrap. Among the possible industrial sources to be investigated are gasworks, which, it is believed, may be reasonably productive. The destination of the scrap produced in the Midlands is also receiving close attention. For some years, large quantities of Midland scrap have been sent to South Wales, Lincolnshire and the North-East Coast. There is a growing demand for larger quantities of scrap to be retained in the Midlands, where there are steelworks and foundries which can make good use of it.

**SUBURBAN PASSENGER TRANSPORT.**—Evidence is being collected by the Midland Branch of the Railway Development Association to demonstrate how inadequately the Midlands are served by the railways in the matter of passenger transport. The Branch already has sufficient data to enable it to claim that, of all the large centres in the British Isles, Birmingham has the worst suburban railway service. It is claimed that if the local services, for which the tracks exist, were developed with more enterprise, much would be done to reduce the road traffic jams which are now a daily part of Birmingham life.

**CENTENARY OF SCYTHE-MAKING FIRM.**—In 1853, Isaac Nash took over a scythe works at Belbroughton, Worcestershire, and so founded the present firm of Isaac Nash (Belbroughton), Ltd., which is now a part of Brades and Nash-Tyzack Industries, Ltd. For a century, the manufacture of scythes has been carried on at Belbroughton in the same way as when Nash took over the works, and scythes are still made there with the aid of water power. Nash acquired the business from a family named Waldron, who had owned the works since about 1613, and there are records of the trade having been carried on in Belbroughton at least as early as 1520.

**GLASS-TUBE PLANT RE-OPENED.**—The transfer of the fluorescent-lighting tube plant of Chance Brothers, Ltd. from Glasgow to Smethwick, Staffordshire, has now been completed, and the plant has been put into operation. The plant is at present producing about 3½ miles of tubing an hour, the equivalent of about one fluorescent tube a second, and is capable of a considerable increase in output if necessary.

**SHORT-TIME WORKING.**—A decline in the demand for iron products, particularly in the motor trade, has caused the malleable ironworks of Harrison & Co. (Lincoln), North Hykeham, to adopt a four-day instead of a five-day week. About 600 employees are affected. The short week affects all manual employees, but not the staff, and will continue until Easter, when the situation will be reviewed.

### SOUTH-WEST ENGLAND AND SOUTH WALES.

**SHIP-REPAIRING WORK AT PEMBROKE DOCK.**—A scheme for the development of the ship-repairing industry at Pembroke Dock has been submitted for Government approval by R. S. Hayes, Ltd. The firm are anxious to extend the dock facilities, to attract work to the port. Mr. R. S. Hayes, managing director of the firm, has said that the scheme was first investigated several years ago, when there was a proposal to enlarge the present dry dock. His firm took over Pembroke Dock about five years ago and were obliged then to take over 80 naval technicians. Since then employment has increased to 500 during busy periods. At present, it is 250. The extension is to enable the dock to accommodate large tankers.

**RHOOSE AERODROME.**—Work has begun on improving the aerodrome at Rhooose, near Barry, which is to be developed by the Ministry of Civil Aviation as the new airport for Cardiff and South Wales. Passenger accommodation is being increased and work has begun on providing aids for night flying. Rhooose, a former R.A.F. station, was inspected last January by the Parliamentary Secretary to the Ministry of Civil Aviation, Mr. J. D. Profumo. It is expected that the transfer from Cardiff (Pengam Moors) airport to Rhooose will be made about the end of this year.

**RESERVOIR FOR CARDIFF.**—At a Ministry of Housing and Local Government inquiry into Cardiff Corporation's proposal to construct a new 900,000-gallon reservoir at Blaentaf, in the Brecon Beacons, evidence was given of the city's need for further water storage. The scheme would involve the diversion of the Merthyr-Brecon road, which had been agreed to by the Ministry of Transport.



## NOTICES OF MEETINGS.

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

**INSTITUTION OF ELECTRICAL ENGINEERS.**—*Radio Section*: Monday, March 23, 5.30 p.m., Victoria-embankment, W.C.2. Debate: "That Broadcasting Hours Should be Drastically Curtailed." *North-Eastern Centre*: Monday, March 23, 6.15 p.m., Neville Hall, Newcastle-upon-Tyne. "Post-Graduate Activities in Electrical Engineering," by Mr. W. J. Gibbs and others. *North Midland Centre*: Tuesday, March 24, 6.30 p.m., Technical College, Great Horton-road, Bradford. Discussion on "Armature Windings," opened by Mr. E. M. Price and Mr. W. Lindley. *London Students' Section*: Tuesday, March 24, 7 p.m., Victoria-embankment, W.C.2. Address by the President, Colonel B. H. Leeson. *South Midland Centre*: Tuesday, March 24, 7.15 p.m., Works Institute, Hylton Road Power Station, Worcester. "Development and Design of Electrical Control Gear for Machine Tools," by Mr. A. R. H. Thorne. *Supply and Measurements Sections*: Wednesday, March 25, 5.30 p.m., Victoria-embankment, W.C.2. "Transformer-Analogue Network Analysers," by Mr. M. W. Humphrey Davies and Dr. G. R. Slemon. *Institution*: Thursday, March 26, 5.30 p.m., Victoria-embankment, W.C.2. "Studies of Telephone Traffic with the Aid of a Machine," by Mr. S. W. Broadhurst and Mr. A. T. Harmston. *Education Discussion Circle*: Friday, March 27, 6 p.m., Victoria-embankment, W.C.2. Discussion on "Special Features of Courses in Electrical Engineering in the Royal Navy," opened by Captain (L) L. S. Bennett.

**INSTITUTE OF METALS.**—Monday, March 23, 6 p.m., Royal Institution, Albemarle-street, W.1. Annual May Lecture. Tuesday, March 24, 10.30 a.m. and 2.30 p.m.; Wednesday, March 25, 9.30 a.m. and 2.30 p.m.; and Thursday, March 26, 10 a.m., Park Lane Hotel, Piccadilly, W.1. Annual Meeting. Wednesday, March 25, 8 p.m., 4, Grosvenor-gardens, S.W.1. Conversation and Exhibition. For programme, see page 127, *ante*.

**INSTITUTION OF PRODUCTION ENGINEERS.**—*Manchester Section*: Monday, March 23, College of Technology, Manchester. 6.30 p.m., Annual Meeting. 7.15 p.m., "Planning and Production Methods Used in the Construction of the de Havilland Comet," by Mr. H. Povey. *Western Section*: Wednesday, March 25, 7.15 p.m., Grand Hotel, Bristol. Annual Meeting and Film Display. *Shrewsbury Section*: Wednesday, March 25, 7.30 p.m., Technical College, Shrewsbury. "Productivity and the Machine Tool," by Mr. N. Stubbs. *South Wales Section*: Thursday, March 26, 6.45 p.m., South Wales Institute of Engineers, Park-place, Cardiff. "Industrial Economics," by Mr. C. T. Tragen. *London Section*: Thursday, March 26, Royal Empire Society, Northumberland-avenue, W.C.2. 6.45 p.m., Annual Meeting. 7 p.m., "Industrial Architecture," by Mr. H. V. Lobb. *Cornwall Section*: Thursday, March 26, 7.15 p.m., The School of Mines, Camborne. "A Broader Conception of Productivity and Its Measurement," by Mr. F. G. S. English.

**INSTITUTION OF BRITISH AGRICULTURAL ENGINEERS.**—Thesday, March 24, 2.15 p.m., Institution of Electrical Engineers, Victoria-embankment, W.C.2. "Hydraulics in Modern Tractors," by Mr. H. E. Ashfield.

**INSTITUTE OF PETROLEUM.**—Tuesday, March 24, 5.30 p.m., Manson House, 26, Portland-place, W.1. Papers on "The Examination of Used Lubricating Oils," by Dr. J. B. Matthews, Mr. J. H. T. Brook, Mr. H. C. Evans, Mr. J. Hughes and Dr. R. P. Taylor.

**CHADWICK TRUST.**—Tuesday, March 24, 5.30 p.m., University College London, Gower-street, W.1. "Public-Health Engineering: Research and Training," by Mr. H. R. Oakley.

**INSTITUTION OF CIVIL ENGINEERS.**—*Public Health Engineering Division*: Tuesday, March 24, 5.30 p.m., Great George-street, S.W.1. "Controlling Factors in the Choice of Sewage-Treatment Processes," by Mr. W. Fillingham Brown. *Midlands Association*: Wednesday, March 25, 7 p.m., Loughborough College, Loughborough. "The Removal and Reinstatement of Dover Train-Ferry Dock Gate," by Mr. H. W. Brinkworth. *Railway Division*: Thursday, March 26, 5.30 p.m., Great George-street, S.W.1. "Trend of Development in the Design and Equipment of Underground Railways," by Mr. D. H. Coombs and Mr. G. J. Willson. *Forks Association*: Friday, March 27, 7 p.m., Royal Victoria Station Hotel, Sheffield. (i) "The Lee-McCall System of Prestressed Concrete," by Mr. M. S. Wright; and (ii) "Some Applications of Soil Mechanics," by Mr. J. Holt.

**INSTITUTE OF MARINE ENGINEERS.**—Tuesday, March 24, 5.30 p.m., 85, Minories, E.C.3. Annual Meeting. Thursday, March 26, 7.15 p.m., Acton Technical College, W.3. "Construction of Steam Turbines," by Mr. J. Brown. Friday, March 27, 7 p.m., Secondary School, Conway-street, Birkenhead. "Photo-Elasticity," by Dr. J. Ward.

**INSTITUTE OF FUEL.**—Tuesday, March 24, 5.30 p.m., Institution of Mechanical Engineers, Storey's-gate, St.

James's Park, S.W.1. "Experience with Spreader Stokers," by Mr. T. H. Lindsay and Mr. P. Pilkington. *North-Western Section*: Thursday, March 26, Radiant House, Bold-street, Liverpool. 7 p.m., Annual Meeting of Liverpool Sub-Section. 7.15 p.m., Film Display arranged by Mr. H. P. Lupton.

**ILLUMINATING ENGINEERING SOCIETY.**—*Liverpool Centre*: Tuesday, March 24, 6 p.m., Offices of Mersey and North Wales Electricity Board, Whitechapel, Liverpool. 1. "Lighting in Shipyards," by Mr. J. S. McCulloch. *London*: Wednesday, March 25, 6 p.m., Lighting Service Bureau, 2, Savoy-hill, W.C.2. Various short papers by student members.

**INSTITUTION OF ENGINEERS AND SHIPBUILDERS IN SCOTLAND.**—Tuesday, March 24, 6.30 p.m., 39, Elmbank-crescent, Glasgow, C.2. "Fire Protection of Buildings," by Mr. N. Strother Smith.

**INSTITUTE OF ROAD TRANSPORT ENGINEERS.**—*North East of England Group*: Tuesday, March 24, 7 p.m., County Hotel, Newcastle-upon-Tyne. Various short papers.

**INSTITUTION OF WORKS MANAGERS.**—*Wolverhampton Branch*: Tuesday, March 24, 7 p.m., Star and Garter Royal Hotel, Wolverhampton. "The Place of the Foreman in the Management Structure," by Mr. John Ayres.

**ROYAL STATISTICAL SOCIETY.**—*Merseyside Industrial Applications Group*: Tuesday, March 24, 7 p.m., Radiant House, Bold-street, Liverpool. "The Control of Quality in the United States," by Mr. E. D. van Rest.

**BRITISH INSTITUTION OF RADIO ENGINEERS.**—*West Midlands Section*: Tuesday, March 24, 7.15 p.m., Technical College, Wulfruna-street, Wolverhampton. "Principles of Electronic Computing Machines," by Dr. B. V. Bowden.

**ASSOCIATION OF SUPERVISING ELECTRICAL ENGINEERS.**—*York Branch*: Tuesday, March 24, 7.30 p.m., Creamery Restaurant, Pavement, York. "Installation and Maintenance of Electric Motors," by Mr. R. Spence.

**INSTITUTION OF MECHANICAL ENGINEERS.**—*Eastern Branch*: Tuesday, March 24, 7.30 p.m., Great White Horse Hotel, Ipswich. "Rocket Propulsion," by Professor A. D. Baxter. *East Midlands Branch*: Tuesday, March 24, 7.30 p.m., Gas Showrooms, Upper Parliament-street, Nottingham. Joint Meeting with the *East Midlands Centre of the Institution of Electrical Engineers*. "Some Current Problems in the Field of Technical Education," by Dr. D. S. Anderson. *Southern Branch*: Wednesday, March 25, 6.30 p.m., Chamber of commerce, Commercial-road, Portsmouth. Joint Meeting with the *Southern Centre of the Institution of Electrical Engineers*. "Some Aspects of Generating-Station Construction," by Mr. C. W. A. Priest. *Institution*: Friday, March 27, 5.30 p.m., Storey's-gate, St. James's Park, S.W.1. Annual Meeting. **AUTOMOBILE DIVISION.**—*Western Centre*: Thursday, March 26, 6.45 p.m., Grand Hotel, Bristol. "Research and the Engineering Process, with Particular Reference to the Automobile Industry," by Dr. H. E. Merritt.

**ROYAL AERONAUTICAL SOCIETY.**—*Graduates' and Students' Section*: Wednesday, March 25, 7.30 p.m., 4, Hamilton-place, W.1. "Convertible Aircraft," by Mr. J. Shapiro. *Society*: Friday, March 27, 10 a.m. and 2.30 p.m., University College, London, Gower-street, W.C.1. All-Day Discussion on "Fatigue."

**ROYAL INSTITUTION.**—Thursday, March 26, 5.15 p.m., 21, Albemarle-street, W.1. "X-Ray Optics-IV," by Professor Sir Lawrence Bragg, F.R.S. Friday, March 27, 9 p.m., "Count Rumford and the Royal Institution," by Professor Sir Eric Rideal, F.R.S.

**INSTITUTION OF STRUCTURAL ENGINEERS.**—Thursday, March 26, 6 p.m., 11, Upper Belgrave-street, W.1. "A Simple Theory of Suspension Bridges," by Professor A. G. Pugsley.

**INSTITUTION OF ENGINEERING INSPECTION.**—*North-Western Branch*: Thursday, March 26, 7.30 p.m., Engineers' Club, Manchester. "A Rational System of Nomenclature in Ferrous Metallography," by Dr. P. Cranston.

**INSTITUTION OF NAVAL ARCHITECTS AND INSTITUTE OF MARINE ENGINEERS.**—Friday, March 27, 2.30 p.m., The "Wellington," Temple Stairs, Victoria-embankment, E.C.4. "The Insulation of a Refrigerated-Cargo Liner," by Mr. K. C. Hales and Mr. J. D. Farmer.

**MANCHESTER ASSOCIATION OF ENGINEERS.**—Friday, March 27, 6.45 p.m., Engineers' Club, Manchester. Annual Meeting. "Friction Between Solid Bodies," by Dr. R. Schürmann.

**JUNIOR INSTITUTION OF ENGINEERS.**—Friday, March 27, 7 p.m., Townsend House, Greycoat-place, S.W.1. "Copying Lathes," by Mr. K. J. Downes.

**INSTITUTE OF ECONOMIC ENGINEERING.**—Friday, March 27, 7 p.m., Engineers' Club, Manchester. "Time Measurement," by Mr. B. Davis.

**INSTITUTE OF WELDING.**—*East of Scotland Branch*: Friday, March 27, 7.30 p.m., 25, Charlotte-square, Edinburgh. "Jigs and Fixtures for Steel Fabrication," by Mr. H. H. Reeve.

## PERSONAL.

**ENGINEER REAR-ADMIRAL SIR SYDNEY FREW, K.B.E., C.B.**, has been appointed chief fuel engineer to the Ministry of Fuel and Power, Thames House South, Millbank, London, S.W.1, in succession to the late Mr. J. PRICE WALTERS. Sir Sydney has been fuel efficiency adviser to the Ministry since May, 1951.

**MAJOR-GENERAL COLIN BULLARD, C.B., C.B.E., B.Eng. (L'pool), M.I.Mech.E., M.I.E.E.**, Inspector of the Royal Electrical and Mechanical Engineers, has been appointed the first principal of the Royal Technical College of East Africa, now being built in Nairobi.

**MR. J. F. BICKERTON, B.Eng. (L'pool), M.I.C.E.**, who has been assistant district engineer, British Railways, Western Region, since 1949, has been appointed district engineer, Cardiff.

**MR. W. G. HALL**, chief draughtsman at the Elswick Works of Vickers-Armstrongs Ltd., Newcastle-upon-Tyne, since 1944, has been made assistant technical manager (gun mountings) of the firm at Newcastle.

**DR. F. H. LAST, B.Sc.**, has been appointed technical engineer (electrical) of the Eastern Generation Division of the British Electricity Authority.

**MR. E. C. SCOTT, B.Sc. (Eng.), A.M.I.E.E.**, for the past two years personal technical assistant to Sir John Hacking, deputy chairman (operation), British Electricity Authority, has been appointed system operation engineer in the Authority's North-Eastern Division, in succession to Mr. A. W. MITCHELL, who is retiring on March 31.

**MR. F. H. HARRIS, B.Sc. (Lond.), M.I.P.E.**, hitherto works manager to B.S.A. Tools Ltd., Birmingham, has been appointed group production adviser to Associated British Engineering Ltd.

**MR. W. L. HENDERSON, A.M.I.E.E.**, has resigned his position as assistant secretary to the Engineers' Guild Ltd., 78, Buckingham-gate, London, S.W.1, as from April 1, to take up a post in industry. The General Council of the Guild have appointed Mr. J. G. ORR, M.A. (Cantab.), barrister-at-law, to succeed Mr. Henderson.

**MR. A. S. DUNCAN, B.Sc.**, assistant general manager of the Doncaster Works of Crompton Parkinson Ltd., has been appointed general manager.

Following the acquisition of the manufacturing and selling rights of the TURBOMECA range of gas turbines, BLACKBURN AND GENERAL AIRCRAFT LTD., Brough, East Yorks., have made changes in the organisation of their Engine Division. GROUP-CAPTAIN H. J. WILSON, C.B.E., A.F.C., is to be sales manager (engines), with Mr. J. J. GADD as commercial sales manager (engines). Mr. F. R. BELL is to be chief designer (engines), with Mr. W. B. MATHISON as assistant chief designer, and Mr. E. MITCHELL is to be works manager (engines).

Following the retirement of Mr. T. W. EDWARDS, J.P., F.C.I.S., from the position of joint managing director of the Park Gate Iron and Steel Co. Ltd., Rotherham (noted on page 303, *ante*), Mr. C. H. T. WILLIAMS continues as managing director, with Mr. F. WOODFIELD as assistant managing director.

**MR. W. KEMP** has been appointed deputy chairman of the Hamworthy Engineering Co., Ltd., Poole, Dorset, and is succeeded as managing director by Mr. A. F. FERGUSON. **MR. JAMES HENDRY** has been appointed sales director, and **MR. R. G. PEACH**, technical director.

**MR. R. J. V. WHEELER** has been appointed secretary of Newton, Chambers & Co. Ltd., Thorncliffe Iron-works, Sheffield, in succession to Mr. A. W. GROGAN, who is retiring.

**MR. J. N. SMITH, A.M.I.C.E.**, of Leeds, and **MR. FRANK SUTCLIFFE, D.L.C.**, of Halifax, have been appointed to the Colonial Engineering Service, the former in Nyasaland and the latter to the East African Railways and Harbours Administration. **MR. G. H. MITCHELL, B.A., B.A.I.**, of Dublin, has been appointed to be a junior engineer on the Mombasa water-supply project.

**DR. HERBERT CHATLEY, M.I.C.E.**, has changed his address to 4, Grosvenor Villas, Claremont-road, Bath. (His telephone number remains Bath 4426.)

**THE WHARTON CRANE AND HOIST CO. LTD.**, Reddish, Stockport, are now represented throughout Scotland by FISHER BAXTER & Co., 140, West George-street, Glasgow, C.2.

**BRITISH INSULATED CABLES (AUSTRALIA) PTY. LTD.**, is the name of a new company registered in Victoria. The registered office is at 84-88, William-street, Melbourne, C.1, and there are branches in other Australian states. **SIR T. MALCOLM RITCHIE, M.I.E.Aust.**, is the first chairman.

**SIR ROBERT McALPINE & SONS LTD.**, 80, Park-lane, London, W.1, have formed a Canadian company to be known as **SIR ROBERT McALPINE & SONS (CANADA) LTD.**



# MACHINING THE WILSON EPICYCLIC GEARBOX.

(For Description, see Page 363.)

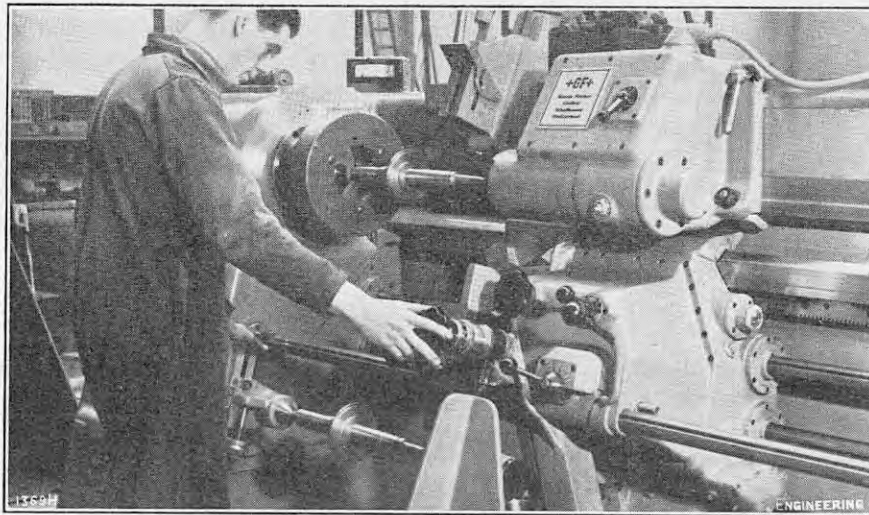


FIG. 8. TURNING SHAFT IN FISCHER COPYING LATHE.

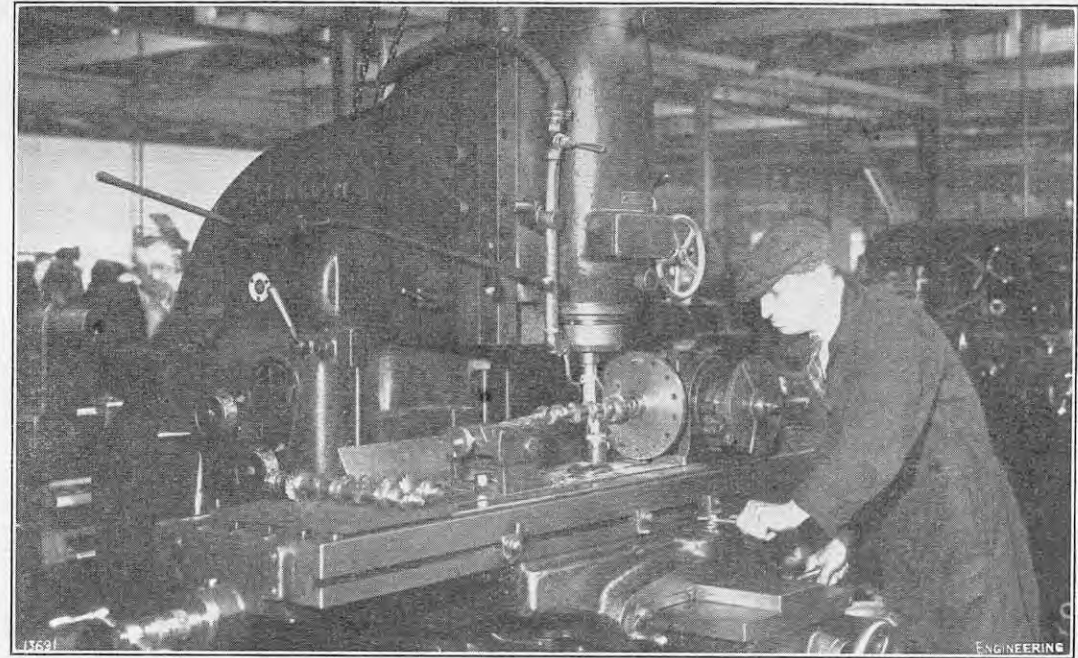


FIG. 9. CAMSHAFT ON VERTICAL MILLING MACHINE.

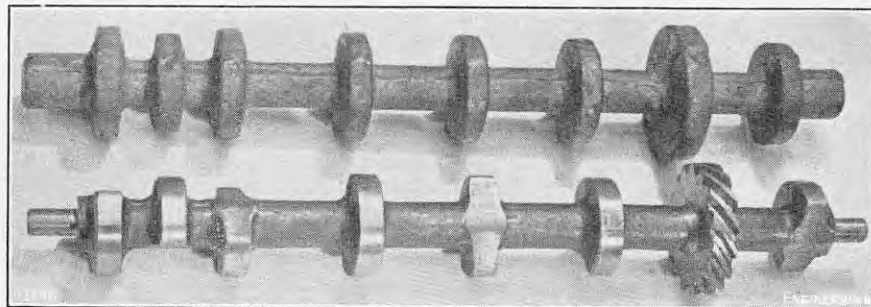


FIG. 10. SELECTOR CAMSHAFT.

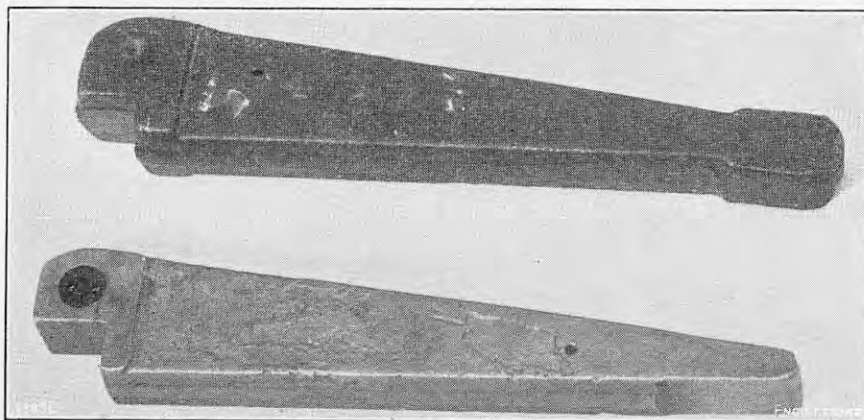


FIG. 11. OPERATING STRUT.

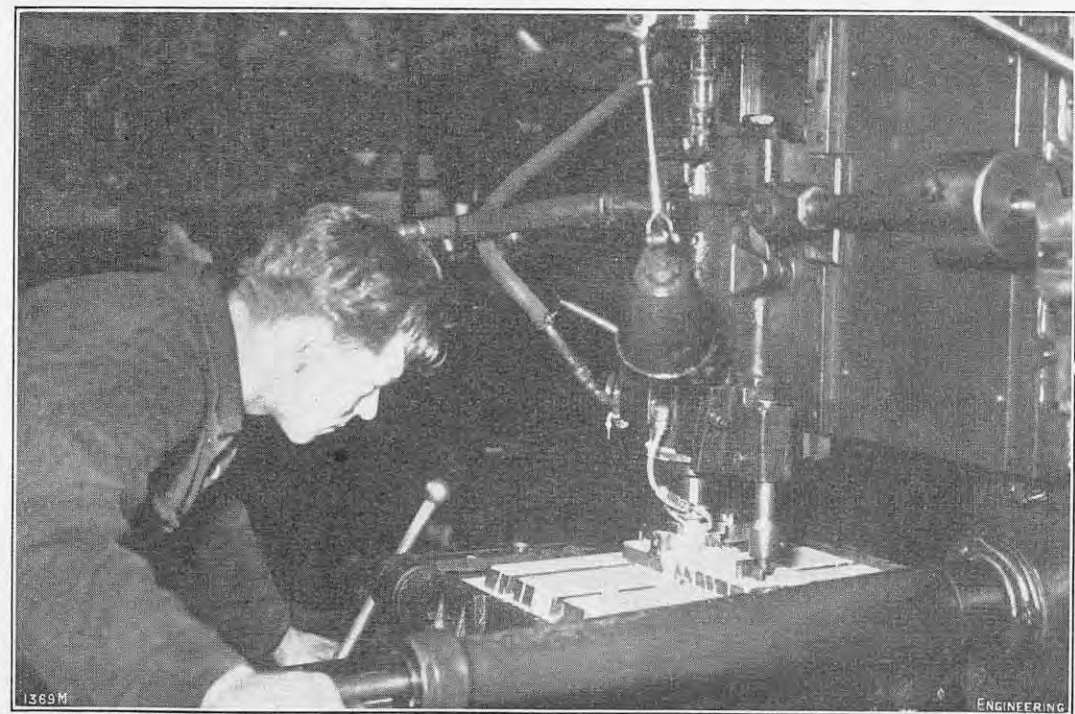


FIG. 12. PROFILING OPERATING STRUT.



## ENGINEERING

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

Registered at the General Post Office as a Newspaper.

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

## TIME FOR RECEIPT OF ADVERTISEMENTS.

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

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

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

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## ENGINEERING

FRIDAY, MARCH 20, 1953.

VOL. 175.

No. 4547.

THE DEVELOPMENT OF  
TURBINE RESEARCH.

WHEN some future historian comes to describe the progress of mechanical engineering in this country, he is likely to notice three phases in its development. In its earliest era, the advances were due to the individual efforts of certain outstanding men, of whom Watt, the two Stephenson, Fairbairn, Maudslay, Whitworth and Penn may be taken as typical. Very few of the early pioneers had more than a rudimentary education, their successes being due to their natural engineering talents, their training in practical craftsmanship, and their ability to learn from experience. By about the middle of the last century, the engineering industry was fairly established, and, as its founders passed away, their factories too often passed into the hands of less enterprising and able men, or were governed by boards of directors whose interests lay rather in continuing to manufacture some standard products than in the development of new and better kinds of machinery. Development is a costly and risky business, and to many commercially-minded industrialists it seemed wiser to "take the cash and let the credit go" by manufacturing any new kind of machine under licence from its originator, instead of endeavouring to maintain the spirit of leadership by which their firms had been built up.

Thus the second era began. The lack of enterprise in design became far too prevalent, and when, as was usually the case, the new machine was of foreign origin, the practice of working under licence unquestionably did some harm to British engineering prestige. Instances have come to our notice where buyers in the Dominions have refused to purchase certain machines from British manufacturers on the ground that the firms who originated the types would naturally be the best to deal with. The situation was probably at its worst round about

the beginning of the century, when enormous amounts of money were being spent by British firms in buying the rights to make various kinds of steam turbines, gas and oil engines, and even steam reciprocating engines, of Continental origin. Much of the money, indeed, was worse than wasted, for, in numerous cases, the designs were soon abandoned as unsatisfactory, and the types of machine concerned are now almost forgotten. Furthermore, when the outcome was more fortunate financially, the self-respect of the works was not enhanced, for the staff could never regard the adopted product with the same interest and pride as a design of their own firm would have commanded.

The evil effects of so much dependence on foreign designers, which was already becoming realised in many quarters, was brought home forcibly to industrialists during the first World War, when they were compelled to rely on native resources. The life and freedom of the nation being at stake, there was an unprecedented incentive not only to the devising of ever more efficient materials of warfare, but also to the provision by British engineers of everything needful for corresponding advances in industrial practice. The careful study of facts and problems, upon which engineering progress in any direction has always been based, became dignified by the name of "research," and under this title it was expected by the general public to be capable of giving almost magical results. From a too widespread disbelief in the benefits to be obtained from the scientific investigation of many problems, industrialists swung over to almost the opposite extreme, and every works with any pretensions to modernity aspired to have its own research department. The Government gave strong support to the research movement by establishing the Department of Scientific and Industrial Research, and by subsidising many schemes developed by manufacturers for co-operative research work in the interests of particular industries.

One feature of engineering research that has become apparent since its revival after the period of stagnation is its tendency to develop an existence of its own, rather than to serve merely as a means for the attainment of some practical objective. In the days of the pioneers, it was part and parcel of the business itself, and was carried out either by a head of the firm in person, or, at least, under his own direction. Watt had no research department at Soho, but conducted his experiments in a garret, and in practically every other case the prime mover in research was the founder of the firm himself, bent on developing his own ideas. With the advent of large-scale manufacturing on a repetition basis, research and development work could hardly be carried on without interference with the normal shop routine and, consequently, it had to be relegated to a special department with its own staff, apparatus and organisation.

This partial divorce from the manufacturing side was necessary, no doubt, from the business point of view, though it tended to make more difficult the maintenance of that unity of purpose and clear line of responsibility for results which it is so essential to preserve among a large and varied staff. An even greater strain may be imposed by removing the research work altogether from the factory, and expecting experienced draughtsmen and practical engineers to conform to the advice of a group of scientific workers whom they do not know and in whose opinions they may have little or no confidence. The position, indeed, would resemble that which sometimes arises in firms manufacturing to foreign designs, except that the latter could at least claim justification from some modicum of commercial performance. The fact remains, however, that progress nowadays often requires previous experimental work of a magnitude and cost that puts it out of the reach of the smaller undertakings.



Necessity, therefore, compels them to take advantage of outside facilities. Besides, it would be absurd for allied firms, engaged on similar work, each to maintain its own department for research useful to all.

The natural outcome of the situation has been the establishment of a number of research centres, each specialising in some particular kind of work, serviceable to the industries supporting the enterprise. The effective manner in which British ship-builders and marine-turbine makers have collaborated in the matter of research is made evident by the series of seven papers read last week before a Conference on Steam Turbine Research and Development, held at the Institution of Mechanical Engineers. In 1944, the firms concerned set up the organisation known as Pametrada (Parsons and Marine Engineering Turbine Research and Development Association) at Wallsend, almost on the site from which Parsons launched the first turbine-driven vessel, the Turbinia, 50 years before, and where his later experiments on propeller cavitation were made. The Turbinia's turbine developed a maximum of 960 h.p. at 2,400 r.p.m., whereas the Pametrada station is designed to test turbines developing up to 60,000 h.p. per shaft, and has a water-brake capable of absorbing this power at speeds from 160 to 300 r.p.m.

The equipment of the station, and some of the duties to which it has been applied, were described in the two papers presented to the Conference by Dr. T. W. F. Brown, M.I.Mech.E., the Research Director of Pametrada. The steam required is obtained from boilers of appropriate pressure and output, brought in for the purpose by a floating crane. Some of these boilers have had a capacity of more than 200,000 lb. of steam per hour. The permanent steam plant for the Association's own testing rigs includes a boiler supplying 40,000 lb. of steam per hour at 1,200 lb. per square inch, superheated to 1,050 deg. F. A separately-fired superheater enables the steam temperature to be raised to 1,200 deg. F. when required. An electrical power supply of 3,000 kVA is obtainable from the public mains, and an additional power for various kinds of test is available from other steam turbines ranging up to 4,000 shaft horse-power. One of these, developing 1,200 shaft horse-power with steam at 1,100 lb. pressure and 1,150 deg. F., has been installed to obtain information on the behaviour of austenitic castings, blading materials, valves, etc., under severe conditions. A 3,500 shaft horse-power experimental marine gas turbine, operating at 1,250 deg. F., has been running for several years, and work is actively proceeding with the object of securing data for the construction of a machine to work at 2,200 deg. F., because the gains to be realised would be so very great.

Since Pametrada was started, its work has steadily increased, and it now possesses the staff and equipment to help in the solution of any engineering or physical problem with which makers of turbine machinery may be confronted. In addition to carrying out tests of turbines and gearing up to the largest sizes, and investigating the detailed behaviour of component parts, the organisation applies the experience it acquires in the production of new and improved designs of machinery. Of its kind, the Pametrada station is so good that its Director can claim that, if the plant had to be built up again from the beginning, very few major changes would be made. It is doing excellent work, and may foreshadow a general trend in industry, though how far engineering firms can rely for progress on ready-made designs from outside sources, without losing their own powers of initiative and discouraging the inventive abilities of their own staffs, is a matter that has to be considered. The centralised research station, no matter how efficient, should always be regarded as the servant rather than the master of the firms in industry concerned.

## THE GENESIS OF DESIGN.

IN a Royal Institution discourse on April 20, 1951, on the subject of "Designing a Warship," Sir Charles Lillierap said "on receipt of his orders from the Board of Admiralty, in the form of Staff Requirements, the Naval Constructor investigates the possibility of meeting these requirements in what is known as the Sketch Design." He went on to say that this "first shot" was worked out in sufficient detail to indicate whether it was practicable or not. A procedure of this kind is probably followed by all designers, although, in the case of simple objectives, no doubt unconsciously. The "sketch design" of, say, a special cast-iron bracket may exist only in the draughtsman's mind, but, if he knows his business, as he proceeds to make a drawing of the bracket he will allow for the "requirements"; and such matters as adequate strength, accessibility of the fixing bolts, casting considerations and other relevant matters will be kept in mind. Probably, in a simple case of this kind, the immediately resulting design will be "practicable" and it will not be necessary to envisage more than one "sketch design," but in more complicated cases first drafts may be tentative and more than one approach may be necessary.

The design of a complicated piece of mechanism, such as a peat-burning gas turbine, involves many factors, some of which are imperfectly known, and even when a "sketch design" is adopted as a basis on which to work, many modifications will be made and steps retraced before a final working design emerges. It seems unlikely, however, that a designer will have any conscious image of the involved journey from preliminary sketch to final product; most people do not analyse their own mental processes. In a recent book,\* Mr. P. J. Wallace has traced the track leading from first notions to the completed article, but, although his analysis is interesting, and may be of some service to beginners, it is difficult to think that it will do anything to modify the proceedings of practised engineering designers. We trust it is not unkind to suggest that the logical relation between the series of steps which led up from a first sketch to the "spinning shaft" which he describes were possibly realised after the event rather than consciously followed as the design gradually developed.

The rigidity of the procedure which Mr. Wallace lays down is indicated by his statement that "for a successful design to be achieved, there is but one sequence of operations to be carried out and only that one, for no other will serve." The sequence specified is analyse; theorise; delineate; modify; and make a neat drawing. He adds that "the first step cannot be to make a neat drawing but to think." There is not likely to be any quarrel with this latter statement, but it seems doubtful if any competent designer separates, or could separate, his initial thoughts about some new project into analysis and theorising. Mr. Wallace certainly gives some explanation of what he means by these terms. Analysis is the consideration of the component parts and aspects of the problem presented by the projected design, and the possible conflicting relationships of these aspects. Theorising is considering how the various problems presented by the design might be solved. To delineate is, briefly, to make Sir Charles Lillierap's "sketch design."

The "spinning shaft" which serves as a text to illustrate Mr. Wallace's demonstration of the technique of design was a rig set up in connection with gas-turbine development. Its purpose was to investigate the behaviour of rotating discs and blades at speeds up to 75,000 r.p.m. and temperatures

up to 900 deg. C. The first step in the technique of design was to make a freehand sketch showing the "fundamentals." These were an electric motor driving a shaft carrying a disc and with a tachometer at the outboard end. Consideration showed that, at the speeds envisaged, it would be necessary to run the disc in a vacuum and the first rough sketch was accordingly succeeded by a second one in which the disc was enclosed by a casing with connection to an air pump. It is reasonable to assume that the design of this special rig was in the hands of a competent man and it is difficult to suppose that he would have found it necessary to fix his ideas by making sketches of a type which would, no doubt, be necessary if the rig was being described for the benefit of the average television audience.

Mr. Wallace then deals in a clear way with the various detail problems presented in working out an actual design. These include questions of a high-speed step-up gear, driving couplings and other matters. He emphasises that these initial studies are of use only for establishing the broad lines of the scheme; any of these particular items may have to be modified as a final design develops. He states that "the whole substance of mental development . . . can be reduced in the last analysis to the single process of separating details from masses" and goes on to point out that, for instance, the design of the step-up gear for this rig was a special problem which had to be studied independently once the conditions imposed by the general design had been determined; always, however, with the proviso that later modification might be necessary as the final design developed.

His description of the gradual evolution of a finished design, with its consideration of the interaction of the qualities of the various parts, is informative and interesting, but, at times, a determining influence, which Mr. Wallace does not mention, may act. It would appear that the design of the spinning shaft was worked out by a team. This is probably the usual practice with complicated articles; action from first to last by an individual is not common. Even with a team, however, the whole nature of a projected design may be modified by the effect of what is colloquially known as a "brain wave" occurring to one of the members of the team. Sudden inspirations of this kind are not subject to analysis.

In the course of one of his chapters, Mr. Wallace refers in appreciative terms to Miss Dorothy Sayers' *The Mind of the Maker*. That book is very far from being concerned with questions of mechanical design, but in a passage referring to literary composition it is pointed out that a character in a novel may "take command of the plot." He imposes his will on the author. Something of the same kind may happen when an entirely unexpected way of dealing with a problem occurs to a designer. The conditions with which he is concerned group themselves in a new way in his mind. He knows not how, but they take control of the situation and solve the problem presented in a new way. There is nothing esoteric about this. The mental capacity to reach the new conclusion existed in the designer's mind, but the catalytic action of previous musing and assembled data was necessary before the solution was reached. The goddess Minerva sprang ready-made from the head of Zeus—a fanciful illustration of the birth of an idea, but the claim made was exaggerated: Minerva is stated to have arrived fully-armed. The "brain waves" which may at times visit designers do not present conceptions fully worked out in detail. They do, however, furnish basic notions from which entirely new ways of dealing with problems may be worked out. They do not at once enable the "neat drawing," which constitutes the fifth stage in Mr. Wallace's sequence of operations, to be made, but they do tend to short-circuit the processes of analysing and theorising.

\* *The Technique of Design*, by P. J. Wallace. Sir Isaac Pitman and Sons, Ltd., Pitman House, Parkers' street, Kingsway, London, W.C.2. [Price 12s. net.]



## NOTES.

## THE INSTITUTION OF MECHANICAL ENGINEERS.

A REVIEW of the work carried out for the Steels for High Temperature Committee of the British Electrical and Allied Industries Research Association, between 1930 and 1952, was given by Mr. A. M. Sage, B.Sc., B.Sc.(Eng. Met.), in a paper entitled "Steels for Steam Power Plant" which he presented at a meeting of the Institution of Mechanical Engineers held in London on Friday, March 13. Such a review was, indeed, timely as a very extensive programme of work has been carried out, and is continuing, to develop steels able to meet the demands of increasing temperatures and pressures. The paper was based on Report J/T/52 of the Association. In a brief mention of future development, Mr. Sage said that, over the past 25 years, considerable increase in power-station efficiency had been obtained by increases in steam temperatures from 700 to 950 deg. F. and in steam pressures from 500 to 1,000 lb. per square inch. Further increases in steam temperatures and pressures were anticipated, and new steels having greater creep resistance at higher metal temperatures than those at present in use would be required. Although considerable data were available for steels used in the high-temperature components of aircraft gas-turbines, most of these creep data had been obtained from relatively short-time tests. Some of these steels were being considered for certain components in power stations, using steam at a temperature of about 1,050 deg. F., and one steel—the 18/12/1 austenitic steel—had been adopted for steam pipes and superheater tubes in two or three experimental stations in Britain. The 2½ per cent. chromium, 1 per cent. molybdenum ferritic steel developed in the United States and used in some high-temperature steam power plants, had been adopted for other development plants in Britain. Tests were now in hand to obtain design data on the basis of long-time creep tests carried out on specimens machined from both steam pipes and superheater tubes of each of these two steels. Similar tests were also in hand on specimens from steam pipes of molybdenum-vanadium steel which also was to be used for certain steam pipes in plants, operating under similar conditions, being made for export. The higher steam temperatures and processes would also give rise to higher temperatures and stresses in the bolts of the turbine casings. Alloy steels were being developed to meet these more severe conditions in casing bolts, and relaxation tests of the type described in the paper were in progress. At the high metal temperatures resulting from the use of steam at 1,050 deg. F. and at possibly higher temperatures in future, the development of steels having resistance to corrosion by superheated steam and to scaling in the flue-gas atmosphere became of equal importance to the development of steels resistant to creep. Considerable attention was, therefore, being given to the mechanism of corrosion and scaling of steels in contact with superheated steam and flue gases at these temperatures. The development of steels having the required creep, scaling and corrosion resistances at the temperatures being considered involved a number of fundamental problems concerning the mechanism of scaling and the relations between structure and creep properties, which were also being studied.

## UNITED STATES STEEL CORPORATION.

During the last four months of 1952, the steel-ingot production of the United States Steel Corporation stood at a record level. Nevertheless, as a result of protracted strikes in the spring and summer of the year, the total ingot production for 1952 was 29.4 million net tons, as compared with 34.3 million tons in 1951. Mr. B. F. Fairless, chairman of the board of directors, states in the firm's annual report for 1952, made public on March 18, that the steel output for 1952 was 85 per cent. of the rated capacity of the steelworks, against 101.3 per cent. in 1951. On January 1, 1953, the Corporation's annual ingot and steel-castings capacity was rated at 36.4 million net tons, this total representing 31 per cent. of the

reported capacity of the steel industry in the United States. The new Fairless Works, at Morrisville, Pennsylvania, began producing coke, pig iron and steel ingots on December 11, 1952. The construction of plant at these works for the production of slabs, blooms, billets, bars, sheets, tin-plate and pipes is progressing satisfactorily and, it is anticipated, will reach completion during the present year. A total of 45.4 million net tons of iron ore was extracted by the Corporation in the Great Lakes region in 1952, against 57.3 million net tons in 1951. Similarly, 26.6 million net tons of limestone and other fluxes were quarried in 1952, compared with 29.2 million net tons in 1951. As part of a long-range programme to ensure adequate supplies of mineral ores in the future, the firm is actively exploring and developing new sources of these materials at home and abroad. Among them, the Orinoco Mining Company is expediting the installation of iron-mining equipment at Cerro Bolivar, Venezuela, and shipments of iron ore are expected to commence early in 1954.

## COLLEGE OF AERONAUTICAL AND AUTOMOBILE ENGINEERING.

For the first time since the commencement of the second World War, the College of Aeronautical and Automobile Engineering, Chelsea, London, held a presentation ceremony for the award of the three College trophies on Wednesday, March 11. The trophies were presented by Lord Brabazon of Tara. Speaking of the opportunities awaiting students of the college, Lord Brabazon said that for a long time after the war the British motor-car industry had found easy markets, but that was no longer so. To-day, excellent cars were being produced on the Continent, and if Great Britain were to continue her exports, the design of British cars must be superior to those of her competitors. He did not consider that British automobile designers were sufficiently aware of overseas developments. In aeronautics, said Lord Brabazon, the past 40 years had shown unceasing development. The present period, as a result of the introduction of the jet engine, offered a particularly wide field of interest for the imaginative engineer. Although he did not consider that it would be worth while for the commercial aircraft to exceed speeds of 600 m.p.h. for at least the next 20 years, that was not true of military aircraft, in which superior technical performance was of far greater value than superior numbers. Already, the possibilities of ram-jets and rockets as power units for the short-range fighter aeroplane were introducing new problems in aircraft design. The helicopter also had many problems to be overcome. Although in many fields of aeronautical development Great Britain was taking a leading part, the United States had a far greater potential of skilled technologists, and strenuous efforts were therefore necessary if this country were to keep ahead. A sound technical education, he concluded, was an essential factor. The three trophies, awarded for the years 1940 to 1944, inclusive, 1952 and 1953, comprise the Mollison challenge trophy for general efficiency in aeronautical engineering, the Olley challenge trophy for practical ability in aeronautical engineering, and the Kathleen Drogheda challenge trophy for general efficiency in automobile engineering. The College of Aeronautical and Automobile Engineering, it may be recalled, was described on page 196 of our 173rd volume (1952). In addition to its automobile and aeronautical activities, which absorb respectively some 50 per cent. and 40 per cent. of the 400 students, an agricultural department was opened recently.

## RECOMMENDATIONS ON ROAD SAFETY.

A working party of the United Nations Economic Commission for Europe on the construction of road vehicles, which met from February 10 to 13, made a number of recommendations for promoting road safety, all of which stressed the need for a greater degree of international standardisation. The working party recommended periodical examination of vehicle lighting by state authorities or by private organisations, and compulsory use of marker lights on a vehicle or load which exceeds the maximum figure given in national regulations and on trailers which exceed the width of the tractor. These

marker lights should be placed within 16 in. of the outer edge, white being shown in the front and red at the rear. Governments have also been asked to introduce legislation for the compulsory fitting of rear lights and reflectors to bicycles and slow-moving vehicles. One of the recommendations which is not likely to meet with the approval of the British manufacturers, who believe it is a subject for the maker to decide, is the rated total weight of the vehicle on the ground. The recommendation, which suggests that the permissible maximum weight for a motor vehicle shall be determined by a competent authority in the country in which it is registered, and that the weight shall be compatible with the vehicle's technical characteristics, is to be submitted to governments for consideration. A system by which any breach of this principle can be prevented is also provided for in the draft. For economic and safety reasons a number of governments had also requested that the maximum weights be made the same in all countries. On the subject of brakes the working party agreed that, for the present, a large proportion of accidents could be avoided if regular periodic inspection of brakes was encouraged. It suggested that wind-screens should be made of a safety glass which would remain transparent after shock, and drew the attention of governments to the need for legislation making the approval of trailer couplings compulsory. The governments and organisations represented were Belgium, France, Italy, the Netherlands, Sweden, Switzerland, the United Kingdom and the United States of America (also representing the occupation zones of Western Germany), World Touring and Automobile Association, Permanent International Bureau of Motor Manufacturers, International Road Federation, International Organization for Standardization, and the International Road Transport Union.

## CANADIAN NICKEL.

During 1952, nearly 13½ million tons of ore, the highest output in its history, were raised by the International Nickel Company of Canada, Limited, Copper Cliff, Ontario, and the company's operations have furnished the "free world" with over 75 per cent. of its requirements of nickel. Considerable quantities of copper and platinum metals have also been made available. Deliveries of nickel in all forms, in 1952, amounted to 249,017,358 lb., compared with 243,865,030 lb. in 1951. Deliveries of copper totalled 234,323,432 lb. last year, against 236,954,595 lb. in 1951, and deliveries of platinum-group metals aggregated 287,135 oz., a decline of 88,000 oz. from the 1951 total. It is pointed out, however, in the company's annual report for 1952 which has recently appeared, that this decrease was caused principally by the "offering to the market of a considerable volume of palladium from other sources and does not reflect a reduction in the requirements of the trade." It is added that: "Deliveries of platinum itself are in pace with production capacity." As for a number of years past, there has been considerable expansion in the underground mining of nickel ores in the Sudbury Basin, Ontario. One new shaft was completed during 1952, two shaft sinkings reached their working depths, the deepening of a fourth shaft was continued, and shaft stations were excavated in a fifth shaft. In the producing mines, underground workings advanced by 132,435 ft., or approximately 25 miles, the length of the underground workings at the company's mines now totalling 325 miles. A considerable sum was expended during the year on exploration and prospecting for new sources of nickel, in Canada and in other parts of the world. Research and the consequent development work are also being undertaken. Thus, in 1952, the large-scale production of liquid sulphur dioxide, obtained as a by-product from the firm's oxygen "flash-smelting" of copper concentrates, was initiated by Canadian Industries, Limited, in a new plant built at Copper Cliff. The output of this chemical is expected to supply a substantial portion of the requirements of the sulphite-pulp industry in Ontario and Western Quebec. Research into the development of an economic process for treating nickel-bearing pyrrhotite for the recovery of both the nickel and a high-quality iron ore, is being



continued. It is concluded that the results of operations and activities have maintained the company in a strong position to continue to meet the conditions likely to arise in the coming years.

#### WEST OF SCOTLAND IRON AND STEEL INSTITUTE.

There were 448 names on the membership roll of the West of Scotland Iron and Steel Institute on September 30, 1952, as compared with 443 on the corresponding date in 1951. The honorary treasurer, Mr. P. W. Thomas, who is also the secretary, in his report which is to be presented this evening, March 20, at the annual general meeting of the Institute, states that the small increase in membership is welcome but is hardly sufficient. He adds that the present position may be summed up by stating that the growth of membership is not keeping pace with the rising technical standards of the Institute. In accordance with a resolution adopted at the last annual general meeting, the date of the end of the financial year has been altered from September 30 to August 31, and, consequently, the accounts to be submitted at the meeting are for 11 months. The revenue account, for the period October 1, 1951 to August 31, 1952, shows that the income was 1,257l. 18s. 8d., and the expenditure 1,261l. 9s. 2d., resulting in a deficit of 3l. 10s. 6d. This, Mr. Thomas states, is an indication of the precarious balance between income and expenditure which has existed for the past year or two.

### LETTERS TO THE EDITOR.

#### THE ENGINEERING OUTLOOK.

TO THE EDITOR OF ENGINEERING.

SIR,—We have noticed with particular interest Table IV, on page 235 of your issue for February 20, giving details of the United Kingdom exports of boilers and boiler-house plant.

Could you kindly advise us as to the basis on which the Tables are compiled? At first sight, it seems quite clear that the exports of vertical boilers are much more important than those of shell-type boilers, but we wonder whether we are right in congratulating ourselves on this. A large part of the production of shell-type boilers nowadays consists of "Economic" boilers and we wonder whether these are included with Lancashire or Cornish boilers, or if they form a large part of the unknown item, "Other Types of Boilers." Similarly, the figure for vertical boilers may have to be reduced if this includes very small low-pressure boilers, which really are quite another category.

"Other Boilers" needs elucidation. Are these cast-iron hot-water boilers, or do they include marine or locomotive boilers? In the latter category, locomotive-type boilers for stationary work should be separated from those used on railways. As they stand, the figures do not really tell us the types of boilers going overseas, and amplification would, we feel sure, interest everyone in the industry.

Yours faithfully,  
THE GRANTHAM BOILER & CRANK  
CO., LTD.  
J. L. Coltman, Managing Director.

Grantham,  
Lincolnshire.  
March 12, 1953.

[The *Trade and Navigation Accounts*, on which our Table was based, are compiled by H.M. Customs, who inform us that they are unable to state exactly what types of vertical boiler are included in the figures which we quoted. It seems clear, however, since the value of exports is so high, that the classification "Vertical Boilers" covers all vertical boilers, including low-pressure types. In the *Accounts*, "Economic" boilers are included under the heading of "Other Boilers." In the Export List, however, "Economic" boilers are given a separate classification; the figures for this type of boiler, separately, can be obtained from H.M. Customs on payment of a fee. The heading "Other Boilers" covers all boilers other than the water-tube, Lancashire and Cornish, and vertical types; but not cast-iron boilers for central heating, which are included in a separate Customs classification. The relevant heading in this case is "Radiators other than for use with gas and electricity, and boilers for

central heating, other than sectional boilers for steam." The total exports under this classification amounted, in 1952, to 2,626 tons and were valued at 237,000l.—Ed., E.]

#### UNIVERSITY GRADUATES IN INDUSTRY.

TO THE EDITOR OF ENGINEERING.

SIR,—The leading article in your issue of March 13, on page 337, *ante*, makes reference to certain figures, given by me in a recent lecture, which relate to the proportion of University students taking Arts courses and Pure Science courses, respectively. I would like to emphasise that these figures—as stated in that part of my lecture printed in *ENGINEERING* of February 27, page 283—refer to the 1950-51 session and are abstracted from a report published by H.M. Stationery Office in August, 1952. They are the latest figures I was able to obtain at the time the lecture was prepared, and it is to be expected that the figures for the present session will differ somewhat from them.

May I take this opportunity of expressing my agreement with the opinions expressed by Professor A. N. Black in his letter on page 340, *ante*? As I said in the lecture to which you have referred, it is a great pity that the public schools and the secondary grammar schools are so ill-informed about careers in applied science, and any move, from either side of the fence, to make relationships more intimate will be very much worth while. The results of a recent visit of a party of sixth-form schoolboys to the engineering department of this college encourage me to think that, once our schools realise what great opportunities exist for careers in engineering, we shall no longer have to deplore the fact that too large a proportion of our most promising young scientists enter the Pure Science departments of our universities.

Yours faithfully,

L. J. KASTNER,  
Professor of Engineering.

University College of Swansea,  
University of Wales.  
March 16, 1953.

### OBITUARY.

#### MR. CHARLES GORDON CURTIS.

WE regret to record the death on March 10 of Mr. Charles Gordon Curtis, who was responsible for the invention in the United States, about 1898, of the velocity-compounding type of steam turbine which bears his name. By a coincidence, this brief notice of his career is published simultaneously with a report on a recent steam-turbine conference held in London, and with our article on Count Rumford (1753-1814)—Mr. Curtis was awarded the Count Rumford gold and silver medals of the American Society of Arts and Sciences.

Charles Gordon Curtis was born on April 20, 1860, in Boston, Massachusetts, the son of George Ticknor Curtis. He studied to be a civil engineer at Columbia University, graduating from there in 1881 and being awarded the degree of Master of Science in 1907. He also studied law, at the New York Law School, gaining the degree of LL.B. in 1883. For eight years he practised as a patent lawyer, but subsequently entered commercial engineering. He was closely concerned with the C. and C. Electric Motor Company, who claimed to be the first firm in the United States to make electric motors and fans, and he founded the Curtis Electric Manufacturing Company and became its president. The steam turbine which he invented and developed combined the features of pressure and velocity staging and resulted in a machine that was smaller and cheaper than existing steam turbines, though with some loss of efficiency. He sold his rights in this invention to the General Electric Company, of America, who introduced turbines of their own design into the British, Japanese, German and United States navies. In this country the production of Curtis steam turbines was taken up by the British Thomson-Houston Company, and at the time an article was published in *ENGINEERING*, vol. 77, page 181 (1904), describing

the design and construction. The article acknowledged the fact that the idea of constructing an impulse turbine on the compound principle occurred to a number of engineers in different countries—particularly Curtis in the United States and Ferranti in this country. Among other inventions of Curtis was his scavenging system for two-stroke engines.

#### PROFESSOR R. G. H. CLEMENTS.

WE have to record also the death, on March 8, at Ilfracombe, of Professor R. G. H. Clements, a former occupant of the chair of highway engineering in the University of London. He was 72 years of age and had been living in retirement in Devon for some time.

Raymond George Herbert Clements was born on June 3, 1880, and received his general education in Edinburgh, where, subsequently, he attended the Heriot-Watt College. In 1896, he entered the Ordnance Survey office, remaining there until 1901. He then secured a post as assistant to the city architect of Edinburgh, afterwards becoming his chief engineering assistant. In 1908, he went to Brighton as deputy borough engineer, where he was engaged until, in 1914, he was sent to India in connection with the construction of war hospitals for Indian troops. He saw service with the Royal Engineers from 1916 to 1919, becoming a lieutenant-colonel and, eventually, having charge of some 3,000 bridges in the area administered by the Army of the Rhine. For his war service, he was awarded the Military Cross and was mentioned several times in dispatches.

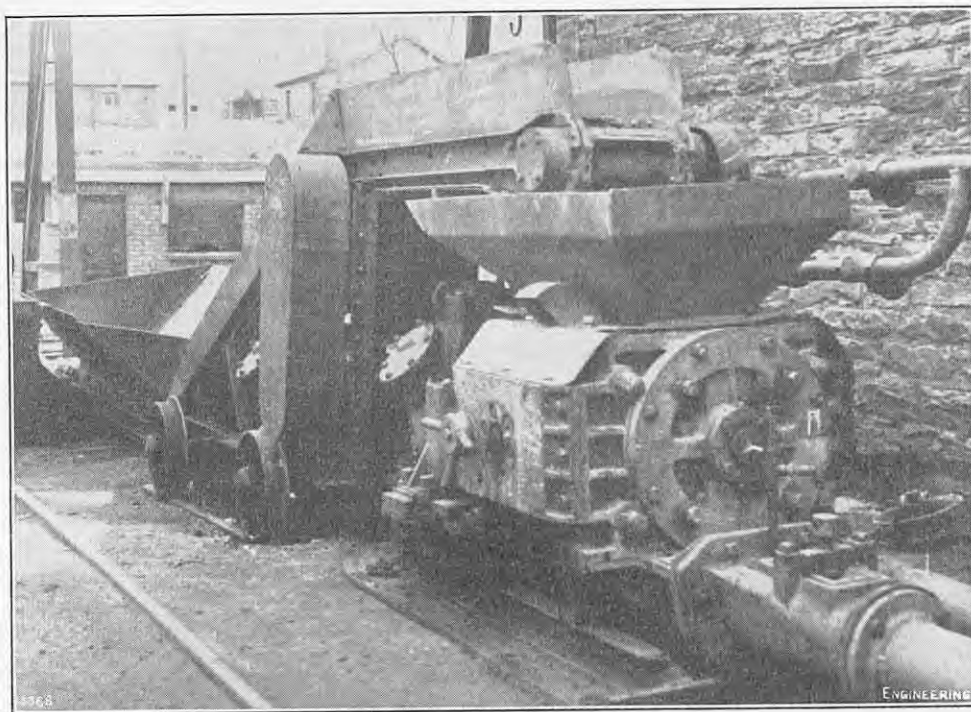
Returning to Brighton in 1919, Clements was appointed housing director to the borough council; but, in the following year, he joined the Ministry of Transport as assistant director in the Roads Department. In 1921, he was promoted to the office of Divisional Roads Engineer for the Eastern and Home Counties; a post which he held until 1924, when he established himself as a consultant on highways and bridges. Shortly afterwards, he was appointed Professor of Highway Engineering in the University of London, which position he held until his retirement. He was a member of the Institution of Civil Engineers, which he had joined as an associate member in 1908, and was also a Fellow of Imperial College, and of the Heriot-Watt College, Edinburgh.

#### MR. TRYGVE MOHN.

MR. TRYGVE MOHN, who died on February 26, was born on June 4, 1875, and educated in Oslo (then Christiania), Norway. After leaving the Cathedral School in 1891, he received his technical training in the Christiania Technical School, which he attended until 1895. He then began an apprenticeship with a local engineering firm, the Christiania Maskinverktsted, serving two years with them in their engine shops and on outside erection of machinery. In 1896, he went to Belgium, where he obtained a post as draughtsman with the Société John Cockerill, at Seraing; but, in the following year, he returned to his old firm, the Christiania Maskinverktsted, eventually becoming a partner. In 1898, he came to England, which henceforth was his home, starting in the drawing office of John Chadwick, Son and Clarke, of Manchester. He spent a year with them before transferring to the drawing office of Browett, Lindley and Company, whose chief draughtsman he became in 1903. This appointment lasted until 1905, when he went to Hick, Hargreaves and Company, Bolton; but in the same year he returned to Manchester as a draughtsman with the then British Westinghouse Company, Limited—now the Metropolitan-Vickers Electrical Company—where he was chief turbine draughtsman from 1906 to 1909. He left them in October of the latter year to become assistant manager with the National Gas Engine Company at Ashton-under-Lyne. By this time, he had been a naturalised British subject for three years. Eventually, he was appointed works manager in their large-engine department, retaining this position until he retired. He was a member of the Institution of Mechanical Engineers, to which he had been elected as an associate-member in 1907, being transferred to the class of member ten years later.



## POWER STOWING AT CROOKHILL COLLIERY.



## UNDERGROUND STOWING BY POWER.

UNTIL recently, it had not proved possible to mine a considerable quantity of a high quality coking coal at Crookhill Colliery, in the No. 6 Area of the Durham Division of the National Coal Board, for no other reason than that the coal lay at shallow depths and under property not owned by the Coal Board. The consequent danger of subsidence was aggravated by the existence of even shallower seams that had already been worked leaving pillars of coal standing to support the strata above. Pneumatic stowing appeared to offer a solution to the problem that would mitigate the possible subsidence and at the same time release about 11 million tons of valuable coal that was otherwise easily obtainable. This solution was limited, however, by the layout of the colliery, which, combined with the thinness of the seams, made it difficult to establish the necessary equipment underground. The alternative scheme of stowing from surface-installed plant has therefore been devised and is being tried at Crookhill as an experiment. The site chosen for the experiment is the 20-in. thick Brockwell seam, 50 yards below the surface, where a longwall panel, 90 yards long, is now being worked in conjunction with the over-ground stowing plant.

The material being used for stowing is discarded steel-works slag recovered from a nearby tip and transported by lorry and dumper to a stockpile located near to the crushing plant. From the stockpile the "discard" is carried up a 16-in. band conveyor to a hopper and live screen which has a capacity of 30 tons of slag per hour. Material that is suitable for stowing passes through the screen, which has a  $2\frac{1}{2}$ -in. mesh, and is then taken on a second band conveyor to a 20-ton hopper which serves the pneumatic stower; oversize material from the screen is transferred into a hopper above a crushing machine, then passes through the crusher and on to a return conveyor to be re-fed through the plant for re-screening. The crusher, which has been set to reduce the material to minus  $2\frac{1}{2}$  in., has a capacity of 25 tons per hour. A magnetic separator located in the crown pulley of the conveyor deflects metallic particles which might damage the delivery pipes, into a trap hopper and away from the live screen.

The stowing machine, which in normal practice would be installed near to the working face but which, for this experiment, is located above ground, is a standard "Bastower" made by Markham and Company, Limited, Chesterfield. This machine,

which is illustrated above, is driven through a fluid coupling by an electric motor and has a capacity of between 90 and 120 cubic yards per hour with air consumption of approximately 3,000 cub. ft. per minute. The overall dimensions of the Bastower are 10 ft.  $6\frac{1}{2}$  in. long by 3 ft. 4 in. high by 3 ft.  $2\frac{1}{2}$  in. wide; it is mounted on a fabricated steel frame, the underside of which forms skids, but wheels are provided in case they should be required. The Bastower consists of a steel casing with a reception hopper for the stowing material above the casing, and with an inlet connection from the compressed-air conduit and an outlet connection to the delivery pipe. Within the casing a pocketed rotor valve measures off the material and delivers it into the air stream without any undue leakage of the air. The air supply is obtained from a rotary-vane water-cooled compressor that has an output of 2,200 cub. ft. per minute at 30 lb. per square inch and which is driven by twin 120-h.p. electric motors; in keeping with standard N.C.B. practice, these two motors have been flame-proofed. Above ground, all the machinery, that is the crusher, the compressor and the stower as well as the electric motors, has been housed in three temporary buildings, framed in steel and clad with corrugated sheets.

From the Bastower, the stowing material is carried in a 5-in. diameter steel delivery pipe to the working face; this pipe is standard except that it has screwed spigot-and-socket joints in those sections that are located in the vertical boreholes. Two boreholes have been sunk and lined with 10-in. diameter steel tubes to house telephone-cable conduit as well as a 5-in. delivery pipe. The pipe bifurcates before entering the boreholes and runs in parallel in those sections so that work will not be completely interrupted by a blockage in one of the pipes. Where the pipe turns from the vertical drop through the borehole to run along the gallery, which is being cut on the level, an easy curve with a wide elbow has been incorporated in the lines. At the working face the delivery pipe is fitted with a right-angle connection and hardened-steel delivery nozzle for injecting the stowing material into the newly mined seam; the delivery nozzle has a quick-release connection so that additional lengths of pipe can be put into service as the work proceeds.

At the start of the working face, the pipe line is approximately 250 yards long, of which 30 yards is on the face, 50 yards in the boreholes and the remainder underground. It is expected that the delivery pipe will have a maximum length of 350 yards when the panel is finished. Despite a number of early troubles due to blockages, the experiment appears to be satisfactory and is likely to be repeated in similar conditions elsewhere.

## A POROUS THERMOPLASTIC MATERIAL.

PORVIC is the registered trade name of a microporous thermoplastic material developed and made by the Pritchett & Gold and E.P.S. Company, Limited, Dagenham Dock, Essex. It consists of porous unplasticised polyvinyl chloride and, in the case of the Porvic battery separator, is usually in the form of a sheet about 0.03 in. thick with narrow vertical ribs which make the overall thickness equal to the distance between the plates. In the past, wood has been used for making separators, but wood is subject to rapid breakdown in service and in the majority of cases failure of the separator has terminated the life of the battery. Porvic, however, is said to be unaffected by battery acid or by the chemical reactions occurring during charge and discharge. Therefore, batteries fitted with Porvic separators are freed from this source of failure, enabling the plates to give their full service life. It also makes closer assembly of the plates possible, which lowers the internal resistance of the battery and improves the performance. The separators now used are usually made in the form of an envelope which completely covers the plate, giving additional protection to its edges.

Porvic is of British origin, and the processes used to obtain its microporosity are patented throughout the world. The patent specification No. B.P. 565,022 shows that the porosity is obtained by mixing in the plastic material a uniformly-fine powder which is subsequently removed. A solvent is used for the plastic, to assist in the mixing of the ingredients and the fabricating of the final product. This solvent is later removed by the application of heat, leaving a brittle material comprising the plastic and pore-forming ingredient. Extraction of the pore-forming ingredient is by immersion in hot dilute sulphuric acid which leaves the plastic in a flexible and microporous form. Powdered maize starch is one of the pore-forming ingredients used, because its granule size is remarkably uniform and treatment with dilute sulphuric acid will turn it to sugar which can be readily diffused out, leaving a series of holes equivalent to the granule size.

The structure that is left consists of a system of spherical cells of uniform diameter, each having openings into neighbouring cells. In the standard-grade Porvic, the diameter of the spherical cells is approximately 0.015 mm., the openings into the adjacent cells are of the order of 0.001 mm., and the amount of free space or volume porosity is 85 per cent. As a porous medium, this grade is capable of holding back particles larger than 0.001 mm. diameter while allowing free passage of gases and liquids; this contrasts with other porous materials where there is often variation in pore size causing uneven distribution of flow and clogging by particles which penetrate the larger pores and become trapped within the structure. The uniform structure of the material makes it selective as to the size of particle it will pass and any particle too large will remain on the surface.

Its volume porosity, pore size, permeability and retention can be controlled and varied to suit a specific application. Experiment is being made at present to determine uses in filtration, aeration, electrolysis, and aerodynamic research. In the last field mentioned, it is being used to give an even distribution of glycol to the leading edge of the Bristol Freighter for de-icing purposes.

**"SUPERMARINE SWIFT" AIRCRAFT.**—Vickers-Armstrongs Limited, Vickers House, Broadway, London, S.W.1, have announced that the Supermarine Swift fighter aircraft, which is in production for the Royal Air Force and is due to enter squadron service this summer, has exceeded the speed of sound on several occasions. The Swift is expected to be the first British supersonic aircraft to go into service.

**ELECTRICITY SUPPLY IN SCOTLAND.**—The Secretary of State for Scotland (the Rt. Hon. J. Stuart) has approved a scheme for the erection of an overhead transmission system to connect the seven power stations of the Breadalbane project and the station of the Lawers project with the existing lines at Killin and Luib. Initially, some of the lines will be used to supply power for the construction of the works proposed under the Breadalbane project.



## COUNT VON RUMFORD, F.R.S. (1753-1814).

By ENGINEER CAPTAIN EDGAR C. SMITH,  
O.B.E., R.N. (Ret.).

IN the whole range of scientific biography, there are few more remarkable and romantic characters than Sir Benjamin Thompson, Count Rumford; neither is there any stranger story than that which tells how a young New England teacher became famous from Philadelphia to St. Petersburg, from Dublin to Vienna. It has been said that "the essence of genius is vitality, fecundity and versatility." Those characteristics Rumford possessed to the full, and it was not surprising that President Franklin Roosevelt should have placed him beside Thomas Jefferson and Benjamin Franklin as one of the three greatest minds America has produced.

In his day, Rumford played many parts, but through his whole career ran his devotion to scientific research and its application to practical affairs. He made experiments in gunnery and the explosive force of gunpowder, he studied problems in illumination, described methods of heating by steam, wrote on the management of fire and the economy of fuel, and devised new heating and cooking stoves. Foremost among his experiments were those on the generation of heat by friction during the boring of cannon, his observations on which gave him a place among the founders of the science of thermodynamics. His work touched many engineering problems. Next in importance to his purely scientific labours was his furtherance of schemes whereby science could be applied for the benefit of the working classes, the principal outcome of which was the founding of the world-famous Royal Institution of Great Britain, which has seen the labours of Young, Davy, Faraday, Tyndall, Dewar, Rayleigh, Bragg, Thomson, Rutherford, and others. From the laboratories of the Institution, the first of which was installed by Rumford himself, has come a long succession of great discoveries which have not only benefited mankind, but have led to the birth of some of our most important industries.

Born 200 years ago, on March 26, 1753, Rumford lived through the American Revolution, the French Revolution and the Napoleonic Wars, and his actions were influenced by all three. His boyhood was passed in the neighbourhood of Boston, Massachusetts, when the colonists were not only guarding their frontiers against French and Indians, but were withstanding the detested impositions of the Government. In the struggle for independence which ensued, it was perhaps more by circumstance than by conviction that he was found in the ranks of the Loyalists and so cut off from his early associates. When the struggle was over and the American Republic was recognised, being without

employment, he set out from England, like a crusader, to fight Muslims. A chance meeting and a chance conversation, however, completely altered his plans and, in the service of the Elector of Bavaria, though he remained a soldier, he found ample scope for his administrative abilities and his scientific inquiries in reforming the affairs of a State which, like the innumerable other German principalities, had not fully recovered from the devastation of the Thirty Years War of 1618-48. Having remodelled the Bavarian army, Rumford attacked the problem of mendicity in Munich and, at one swoop, removed the beggars from the streets. Bavaria benefited from his administration in a score of ways, from the making of cannon to the improvement of cattle.



COUNT RUMFORD, F.R.S.

Coming to London in 1795, he fell in with the founders of a society for helping the poor and of this he was made a life member. After spending parts of 1797 and 1798 again in Bavaria, he returned to London with his mind full of a scheme for an establishment for educating craftsmen, improving their ways of living, and for making science serve mankind. Called back to the Continent in 1802, he made Paris his headquarters and it was in the suburb of Auteuil that he died on August 14, 1814, at the age of 61. He had walked with princes and rulers, mixed with the learned and distinguished, and had been honoured by societies and cities; but, owing to the momentous events of the time, his passing scarcely stirred a ripple in the circles in which he had moved. To-day, however, the farmhouse in North Woburn, Massachusetts, in which he was born, is owned and maintained by the Rumford Historical Society; the periodic

awards of the Rumford Medals that he founded recall his work as a man of science; a professorship at Harvard University, bearing his name, was endowed by his bequest; a monument and statue remind the people of Munich of a great benefactor; his name is held in honour at the Royal Institution, and his tomb is maintained by his own countrymen.

The story of Rumford's life falls naturally into four periods, the first ending with the outbreak of the American rebellion, and the second with the conclusion of peace. The third shows him at the height of his powers, acting almost as a dictator, and the last gives a picture of a somewhat disillusioned, unhappy and lonely man. As a boy, though, through the early death of his father, the remarriage of his mother, and the absence of brothers or sisters, he missed something of normal home life, his development was perhaps stimulated by his being thrown much on his own resources. From school, he passed to the uncongenial work of an apprentice in shops at Salem and Boston, and then, from a Dr. Hay at Woburn, learned something of chemistry and medicine, and was free to walk to and from Harvard and listen to the science lectures of the famous John Winthrop (1714-79), F.R.S. Fairly well equipped for the position, in the winter and spring of 1771-72 he became a teacher in schools at Wilmington and Bradford, and in the summer he began to teach in a school in the small town of Concord, which then had a population of about 1,000. Now the capital of New Hampshire, Concord was first settled in 1725, but later was incorporated by the State of Massachusetts as the town of Rumford. Its incorporation as the town of Concord took place in 1765, but the old name of Rumford apparently lingered on. There are other Rumfords and Concords in New England, but the Rumford-Concord of 1772 is situated about 70 miles north-west of Boston. Foremost among the citizens of Concord in 1772 was the Rev. Timothy Walker, and it was to his widowed daughter, the well-to-do

Mrs. Rolfe, that Thompson was married, he being 19 and she 32 or 33. Of this union there was a daughter Sally, born in October, 1774, who later became her father's companion, was made a Countess in her own right, and after spending many years in London and Paris, returned to America and died there in 1852, at the age of 78, leaving money to found the Rolfe and Rumford Asylum for the Poor and Needy at Concord.

With his marriage, Thompson abandoned teaching and took up other pursuits. In 1773, he was given a commission as a major in the New Hampshire militia, an appointment which brought him more enemies than friends. Owing to the action of the Government of George III, the feelings of the colonists were becoming very embittered; in December, 1773, the 340 chests of tea had been pitched into Boston harbour; there was much talk of liberty and, unfortunately, not a little tyranny.



Thompson felt the full blast of this tyranny and was forced to leave his house in Concord. In December, 1774, he wrote to his father-in-law from Charlestown, near Boston, that "My persecution was determined on and my flight unavoidable"; and on August 14, 1775, from Woburn, he wrote "My enemies are indefatigable in their endeavour to distress me, and I find to my sorrow that they are but too successful. I have been driven from the camp by the clamours of the New Hampshire people, and am again threatened in this place." He had determined, he added, to seek peace and protection in foreign lands. This was a few months after the skirmish at Lexington and the battle of Bunker's Hill, with which the rebellion began. The details of Thompson's career at this time are not precisely known; but, obviously, New England was no place for him, and on October 13, 1775, a relation drove him southward to Narragansett Bay, where he was taken on board H.M. frigate *Scarborough* and conveyed to Boston. Five months later, when Boston was evacuated by the British, Thompson sailed for England, apparently in the same vessel as the defeated General Gage. He never saw Boston, Woburn, Concord or his wife again. His name was placed on the list of the proscribed and his property was confiscated.

Like other Loyalists, on his arrival in London Thompson was received cordially and was given employment in the office of Sir George Germain, afterwards Viscount Sackville (1716-85), the Secretary of State for the Colonies. His duties were probably not very onerous and he found opportunities to resume the experimenting which had occupied some of his boyhood days. This brought him into contact with Sir Joseph Banks (1743-1820), then about to begin his long presidency of the Royal Society. Banks and Germain both became Thompson's friends. In 1777, at Bath, Thompson studied the strength of materials; in 1778, at Germain's place in Sussex, he experimented with gunpowder and projectiles; and next year, after being made F.R.S., was able to increase his knowledge of gunnery by making a cruise in H.M.S. *Victory*, the flagship of Admiral Sir Charles Hardy. By 1780, plans were afoot for forming a regiment of American Dragoons to fight against the rebels and, as its commandant and with the rank of Lieutenant Colonel, Thompson recrossed the Atlantic and, with his force, saw some sporadic fighting in South Carolina. He was next sent to New York and Long Island, but with the surrender of Cornwallis at Yorktown, Virginia, in 1781, the war had practically ceased. After the signing of peace, Thompson returned to England. Documents preserved at the Royal Institution are eloquent of the public spirit shown by Thompson in gaining suitable recognition for his fellow Loyalists. He himself was given half pay, which he enjoyed during the rest of his life.

His experiences had evidently given Thompson a taste for a military life, and he was smitten with the quixotic idea of fighting for the Austrians against the Turks. He sailed from Dover to France in September, 1783, in the same vessel as the historian Gibbon, who, in a letter to Lord Sheffield, referred to his companion as "Mr. Secretary, Colonel, Admiral, Philosopher Thompson." Ten years later, Gibbon might have added the words "administrator and philanthropist." Travelling on horseback and in uniform, at Strasbourg Thompson fell in with Maximilian-Joseph, of Deux-Ponts (1756-1829), then a soldier in the French Service, but afterwards Elector and then the first King of Bavaria. Struck with Thompson's bearing, knowledge and enthusiasm, Maximilian invited him to visit his uncle, Charles-Theodore (1724-99), the ruling Elector. From Strasbourg, Thompson accordingly went to Munich, then to Vienna, Venice and the Tyrol, and back to Munich. In Charles-Theodore he found a man after his own heart, a lover of the arts and sciences, and one who ruled his subjects like a father. Offered high rank and position, Thompson returned to England to obtain the necessary permission to accept the offer, was knighted by King George III (who was also Elector of Hanover) and then took up his residence in the Bavarian capital. Well supported by his master, he reformed the Bavarian army, turning soldiers into citizens and citizens into soldiers, providing for the

troops better pay, clothing, food, training, work, education and recreation. He then turned to another problem. Germany at this time was divided into some hundreds of petty states with no national aspirations, and in which life was passed in a drowsy routine. Munich swarmed with beggars and so, on New Year's Day, 1790, Thompson rounded up over 2,000 of them, took their names and without any degree of harshness shepherded some into a great House of Industry. It was in connection with this masterly piece of philanthropy that Thompson made his investigation into the burning of fuel, the design of appliances, and the methods of cooking, all of which are recorded in his essays. In a booklet published by the Rumford Chemical Works, of Rumford, Rhode Island, great makers of baking powder, it is said that "not only was he the first to study diet . . . but also the first to conceive effective ovens, and roasters, and tea-kettles and boilers; to lay out efficient kitchens, to cure smoking chimneys, and to enquire into the processes of roasting, baking and boiling . . . He should be honoured to-day as the grand master of the great guild of chefs, the first and greatest scientist of the kitchen." For his outstanding service to the State the Elector Charles-Theodore, in 1791, secured for Thompson the rank of a Count of the Holy Roman Empire. Adopting the name of the little New Hampshire town, he became Count von Rumford.

(To be continued.)

## DEVELOPMENTS IN ELECTRICAL INSULATING MATERIALS.

A SYMPOSIUM on electrical insulating materials, organised by the Measurements Section of the Institution of Electrical Engineers, was held at Savoy-place, Victoria-embankment, London, on Monday, Tuesday and Wednesday, March 16, 17 and 18. In all, 32 papers were presented and the proceedings were organised in five sessions with the general titles of permittivity and dielectric losses in solids; permittivity and dielectric losses in liquids; electric strength and breakdown mechanisms; general properties and current problems; and classification, specification and testing. For the most part, the communications dealt with recent research and new developments in the science and practice of insulation, and should form a useful record of what is being done in this important branch of electrical work. It may be thought surprising that a conference on this subject has not been held at the Institution before. The ostensible reason is, however, that the responsibility for organising it did not clearly rest on any one section. Whether this is so or not it is obviously satisfactory that the omission has been repaired.

At the first meeting on Monday, March 16, the chair was taken by Dr. L. Hartshorn and an opening address was delivered by the President of the Institution (Colonel B. H. Leeson), who emphasised that it was desirable to prepare a balance sheet of progress (as was being done on this occasion) in an industry which was advancing so rapidly as that of electrical engineering. It was now essential to analyse the subject of insulation from the scientific point of view, to determine the behaviour of the available materials under normal conditions, their ability to withstand surges and lightning, and their durability under working conditions. Of these, the last was perhaps the most difficult, as it involved a study of the mechanism of breakdown and the discovery of some test which would not strain the material, but from the results of which its life could be calculated. Quality control was also a matter of importance, as this was not only a question of specifying conditions, but of utilising art in applying them.

### DIELECTRIC LOSSES IN SOLIDS.

The papers on permittivity and dielectric loss in solids were next reviewed by the rapporteur (Professor Willis Jackson), who said that Messrs. L. Hartshorn, J. V. Parry and E. Rushton's communication recorded the important contributions they had made to the technique of dielectric measurement, with emphasis on accuracy. Outstanding points

were the measurements made on silicones and the confirmation of the fact that the dielectric consequences of absorbed water depended markedly on the nature of the structure in which it was absorbed and on the form in which it existed in the structure. The paper by Mr. R. H. Norman also revealed the complexity of the problem of moisture absorption. The first paper, which overlapped that by Mr. A. Turney, also dealt with the extent to which Frohlich's theory governing the properties of dielectrics containing polar groups served to account for the main features in the behaviour of the materials studied.

The paper by Messrs. A. Fairweather and E. J. Frost dealt with a different mechanism. This was known as the Maxwell-Wagner and was associated with inhomogeneity of structure in the macroscopic sense, i.e., with dielectric systems composed of regions with different ratios of permittivity to conductivity. The authors had performed a remarkably successful quantitative analysis of the dielectric behaviour of granular semi-conducting aggregates. Mr. A. C. Lynch's paper dealt with an aspect of capacitor behaviour which had attained considerable importance in multi-channel radio equipment, namely, the possession of a substantially stable capacitance with respect to both temperature and duration of service, or of a reproducible temperature coefficient of capacitance which could be compensated by an inverse temperature coefficient in the associated inductance or resistance. The complexity of the problem was shown by the author's investigation of metallised-mica capacitors.

### LOSSES IN INSULATING MATERIALS.

The papers presented for discussion at this session included one on "The Dielectric Losses in Some Representative Insulating Materials," by Messrs. L. Hartshorn, J. V. Parry and E. Rushton. This covered a detailed study of work that had been carried out at the National Physical Laboratory on the permittivity and power factor of insulating materials over the whole range of conditions encountered in electrical practice, including frequencies from 10 cycles to 24,000 megacycles and temperatures from -35 deg. to +240 deg. C. The materials investigated fell into four groups: silicones and other silicon-oxygen structures, including mica and glass; non-polar plastics, including polystyrene, polyethylene, and polytetrafluoroethylene; pure synthetic resins of the phenol-formaldehyde and aniline-formaldehyde classes; and the polar plastic Kel F, a chlorinated derivative of the non-polar polytetrafluoroethylene. The objective was first to determine with precision the relevant properties of the most promising materials over the whole range of conditions likely to be significant in electrical practice and, second, to obtain such insight into the fundamental nature of the processes involved in dielectric behaviour and its relations to chemical structure and other controllable factors, as to enable existing materials to be used to the best advantage and the way pointed to better dielectrics.

Investigations into heat-hardened phenolic resins and thermoplastic materials of the same type emphasised the need for methods of measurement, applicable over the widest possible ranges of frequency and temperature, to one and the same sample of material. Such techniques were therefore developed concurrently with the investigation of the materials mentioned and were described in the paper. The main features of the dielectric behaviour of these groups were explained in terms of known features of their structures.

"The Dielectric Properties of Rubber" were dealt with in a paper by Mr. R. H. Norman, in which the results of the measurements of the power factor and relative permittivity of purified uncompounded natural rubber within the temperature range -50 to +40 deg. C. and within the frequency range 50 cycles to 1 megacycle were described. The conclusion was reached that the dielectric losses of purified rubber, when dried, were small and exhibited a broadened Debye type of characteristic superimposed on a constant background loss at low temperatures and an ionic or conduction-loss type of characteristic at room temperature and above. These losses were increased slightly by exposure to a moist atmosphere. The



dielectric losses of dry crude rubber were very similar to those of the purified material, which suggested that the impurities normally present in crude raw rubber did not of themselves contribute to the losses. In a moist atmosphere, however, the impurities absorbed sufficient moisture to raise the power factor to a marked extent. The sulphur cross-leakages in vulcanised rubber were responsible for higher power factors than those which occurred in raw rubber, the power factor maxima for a given type of compound being increased approximately linearly with the combined-sulphur content for compounds with low combined-sulphur. The relation, however, varied with the type of compound.

"The Dielectric Behaviour of Granular Semi-Conducting Aggregates with Special Reference to Some Magnesium Ferrites" was dealt with by Messrs. A. Fairweather and E. J. Frost, who pointed out that there were two kinds of granular semi-conducting aggregates: those for which the direct-current current/voltage characteristic was strongly non-linear (as in a metal rectifier or in a non-linear resistor of the bonded-aggregate type) and those for which it was not. The paper dealt primarily with aggregates of the second kind and with the properties of certain members of a family of semi-conducting ferrites derived from magnesium ferrite ( $MgFe_2O_4$ ) by replacement of the iron by aluminium in increasing amounts. Such aggregated granular semi-conductors might display high permittivity and dispersion effects, which varied with the temperature and voltage. This behaviour need not be characteristic of the granule material. It could be a consequence of its conductivity and of a particular kind of inhomogeneity of the aggregate arising from the contact structure of the intergranular boundaries. The bodies described might be regarded as abnormal dielectrics for several reasons, and perhaps especially because they could have dissipation factors exceeding unity. They might equally well be regarded as capacitive resistors. Their apparent properties were very dependent on the frequency. In fact, the intrinsic conductivity and permittivity, which, for the frequency range covered in the paper, were regarded as constant, might change slowly with the frequency.

#### CAPACITANCE VARIATIONS.

The "Variation of Capacitance with Temperature in Metallised-Mica Capacitors" was discussed by Mr. A. C. Lynch, who pointed out that capacitors, which must be physically small and reasonably cheap, but which would remain within, say,  $\pm 0.2$  per cent. of their original values for a period of years and at any temperature up to 70 deg. C., or even more, were often required in the frequency-controlling circuits of oscillators and in timing circuits. There were two readily available types of capacitor for work of this sort—those using ceramic material and those using metallised mica as a dielectric. The metal was usually, but not always, silver. The variations of capacitance could be classified into a cyclic charge which could be expressed as temperature coefficient in parts per million per degree Centigrade, and as a non-cyclic drift which might or might not be conveniently described by a single numerical value. The variations of capacitance with temperature might be due to the ordinary thermal expansion of the mica, irregular expansion and twisting caused by mechanical constraints, variations of the infinite-frequency permittivity and electrical effects associated with molecular relaxation processes. The magnitude of the first of these variations would account for a temperature coefficient of about  $\pm 10$ , while that due to the second might be expected to be larger, although of the same order. The third variation was apparently very small in mica. As a result of relaxation processes, however, the temperature coefficient of capacitance of a metallised-mica capacitor varied with the frequency and was therefore correlated with the power factor of the mica. The temperature coefficient of commercial capacitors ranged at least from  $-40$  to  $+100$  parts in a million per degree Centigrade at 1 kilocycle. It might be more negative by about 40 parts in a million per degree Centigrade at 1 megacycle. There was usually a non-cyclic variation as well, which might be about 0.1 per cent.

(To be continued.)

## LABOUR NOTES.

PENSIONS payable to retired railwaymen are to be increased, according to an announcement made by the Minister of Transport, Mr. A. T. Lennox-Boyd, in the House of Commons on Tuesday. Replying to an adjournment debate, on the inadequacy of certain railway pensions in the salaried grades, the Minister informed the House that the British Transport Commission had placed suggestions before him which, though modest, would help those who were most in need. It was proposed to introduce a scheme to grant supplementary amounts, on a graduated scale, to married men, and to single men with dependants, the value of whose retirement pensions was less than 140% per annum. The scheme would also include unmarried pensioners receiving less than 84% a year. In all, about six thousand persons would be affected and the benefits under the scheme would be paid, retrospectively, as from January 1 last. Although most of the Commission's employees are engaged on British Railways, it is understood that the new proposals will also apply to other sections of the Commission's service, including road transport.

The Ministry of Labour and National Service is sponsoring the introduction in this country of a two-reel black-and-white sound film entitled "Date of Birth." This film, which was produced by the National Film Board of Canada for the Canadian Department of Labour, draws attention to the economic and social problems associated with the provision of employment for older men and women. Although dealing with conditions in Canada, its applicability to Great Britain is emphasised in an introduction spoken by the Minister of Labour, Sir Walter Monckton, and added to the British version of the film. The aim of the film is to encourage employers, whenever it is practicable to do so, to remove age barriers when engaging new staff. Tribute is paid in the film to the dependability of older workpeople and attention is focused on the valuable contribution which such employees can make to industrial productivity.

In short sequences, the film depicts the tragedy of the employee who is unable to obtain a place in industry owing to the answer he has to give to the question "Date of birth?" Elderly men driving locomotives, navigating ships and performing other responsible jobs are portrayed, to show the unreality of using age as an index of a person's industrial value. The film runs for 18 minutes, and 16-mm. copies for non-theatrical showing may be obtained from the Central Film Library, Government Building, Bromyard-avenue, Acton, London, W.3, at a hire charge of 10s. for the first day and an additional fee of 2s. for each further day up to a maximum of six.

There was an increase by one point last month in the "all-items" figure of the interim index of retail prices. The Ministry of Labour and National Service announced on Wednesday that, on February 17, the index had reached a level of 139 for all items, as against a level of 138 on January 13. This was the first change in the index figure for four months and the first upward alteration since June, 1952. The increase was due, almost entirely, to the higher prices of vegetables during the four-weekly period ended February 17. The index figure declined by two points during August and September last and stood at a level of 133 in mid-February last year.

Shortages of steel in the shipbuilding industry were blamed for the redundancy which occurred at the shipyard of Messrs. Short Brothers, Limited, Pallion, Sunderland, during the past week. Over 130 men, equal to about one-fifth of the total number of employees at the yard, were served with redundancy notices last Tuesday. It was stated that a substantial part of the yard would have to be closed and that only a small amount of welding and riveting work would be undertaken at the firm's three shipbuilding berths, for the present.

Reference to the difficulties brought about by the lack of sufficient supplies of steel were made by Mr. J. H. Short, a director of Messrs. Short Brothers, at the launching of one of the firm's ships on Tuesday. He affirmed that the steel mills had failed to meet their obligations and that, during last year, the firm had received only about 60 per cent. of its steel requirements. The position this year was no less trying. During the first quarter of 1953, the firm was from 10 to 12 per cent. down on its allocation, while, for the coming three months, it had been possible to get the mills to accept orders for only 1,977 of the 3,000 tons of steel required. There had been assurances in Parliament that the shipbuilding industry was receiving more and more steel, but that, Mr. Short stated, was not the experience of his company. Unless the situation improved, it would be necessary to reduce still further the number of men employed at the yard.

There was an increase of short-time working in the Midlands during February, according to a report of the Ministry of Labour and National Service presented at a meeting of the Midland Regional Board for Industry on Tuesday. On February 16, there were 27,176 unemployed persons in the Midlands, compared with 25,701 on January 19, an increase of 1,475 in four weeks. The number of workpeople under-employed increased from 22,000 to 24,700 during the month of February. There was, however, some improvement in the motor-vehicle industry in the area. The report states that, taking the industry as a whole, and including persons engaged on the manufacture of parts and accessories, under-employment affected only 4,900 persons at the end of February, compared with 7,100 at the beginning of the month. Time lost in the industry averaged one day a week for each employee. In the motor-cycle industry, no employees were on short time, but, in the cycle industry, the working of short time doubled during last month.

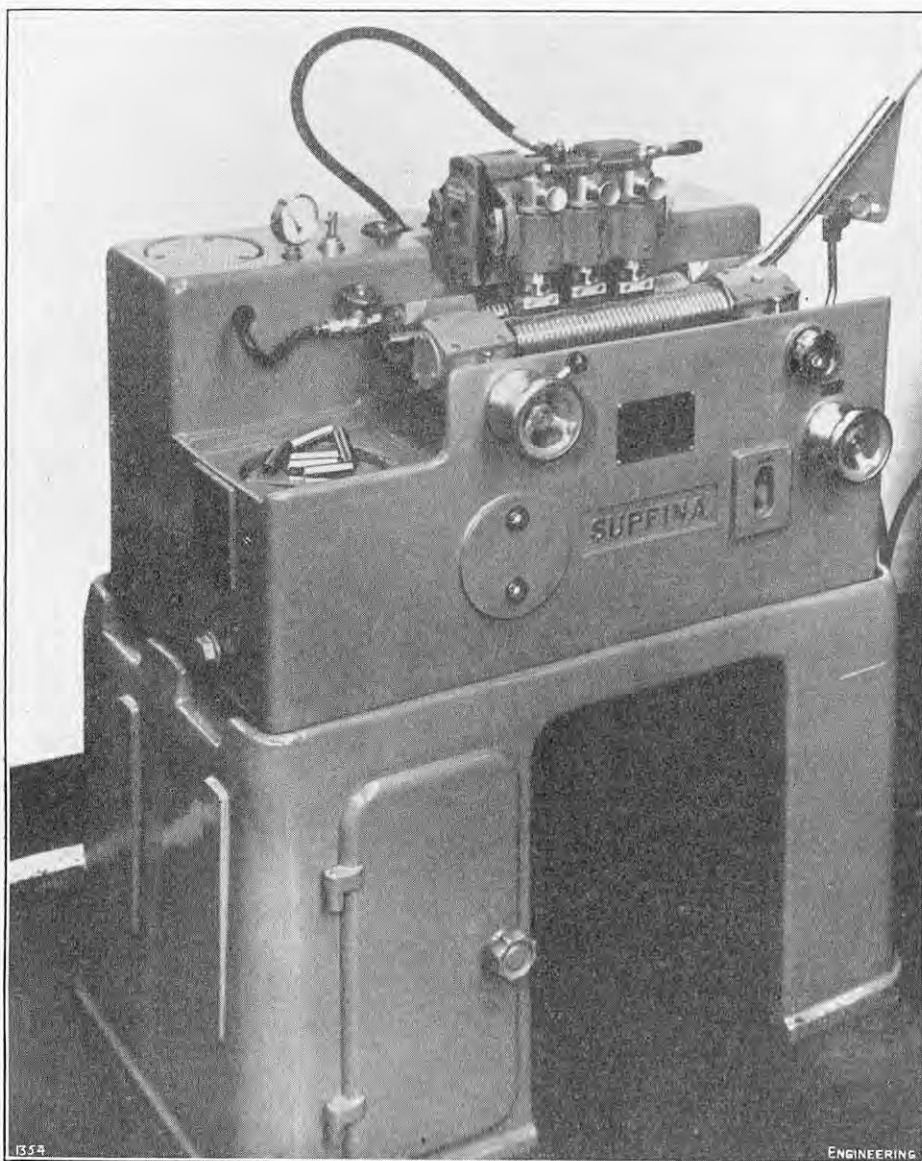
Some worsening of the position in respect to short-time working in the Midlands area has arisen recently owing to the strike of vehicle builders at the Longbridge works, Birmingham, of the Austin Motor Company, Limited. It was announced on Tuesday that more than two thousand persons employed at two Birmingham factories of Messrs. Joseph Lucas, Limited, would be placed on short-time work as from next Monday, owing to the strike at the Longbridge works. The firm produces electrical equipment for motor vehicles and only workpeople engaged on apparatus for Austin vehicles will be affected. Beginning on Monday, Messrs. Lucas will introduce a four-day working week at their factories. Although only some two thousand operatives may be affected at first, the number of persons on short time at these factories may increase rapidly, should the firm's stocks of equipment accumulate.

Several hundred employees of the Austin Motor Company are reported to have resumed work at Longbridge during the past few days, but the strike of the vehicle builders, introduced to secure the re-engagement of a former shop steward, is to continue. Mass meetings representing the 2,300 strikers, who belong to the National Union of Vehicle Builders, took place on Monday and Tuesday. The meeting on Monday was adjourned to hear a report from the union's executive, and those attending the meeting on Tuesday decided to hold a further meeting next Monday and to take no further action in the meantime.

At the meeting of the national executive committee of the N.U.V.B., which took place in Manchester on Monday, it was decided to approach the General Council of the Trades Union Congress, with a view to securing their intervention in the strike at Longbridge works. It was hoped, the union's general secretary stated, that the General Council would take the initiative and summon a meeting of officials of all the unions involved in the dispute, and that negotiations with the Austin Motor Company would result. The company stated on Wednesday that 7,276 persons were then idle, nearly one thousand less than on March 13.



## CENTRELESS LAPPING MACHINE.



## SUPER-FINISH CENTRELESS LAPPING MACHINE.

THE "Supfina" centreless lapping machine, illustrated herewith, is a recent addition to the range of machine tools distributed in this country by Charles Churchill and Company, Limited, Coventry-road, South Yardley, Birmingham, 25. It is made by Walther Hentzen A.G., of Remscheid, Germany. The machine is designed for the continuous centreless lapping of components which are fed by gravity from a feed chute to the work-support rollers, and it can also be used, when fitted with special rollers, to lap components with flanges. The machine operates on the super-finishing principle, the lapping stones being given a rapid oscillatory movement parallel with the axis of the components being lapped, while the components themselves are rotated. Two work-support rollers are provided, 2½ in. in diameter, and are rotated at speeds ranging from 50 to 750 revolutions per minute by a ½-h.p. electric motor, driving through an infinitely-variable gear of the P.I.V. type. The work-support rollers are adjustable in two directions; the centre distance can be varied to suit components of different diameters, and the angle of inclination to the horizontal can be adjusted to vary the feed rate. The rollers are carried on two shafts, and to adjust the centre distance it is only necessary to unlock the Allen-type screws holding the rollers on the shafts, slide the rollers to the position required, and re-lock the screws. The left-hand roller-carrying shaft is eccentrically mounted, and, by rotating it with the handwheel shown in the illustration, the rollers can be given an inclination to the horizontal. At zero inclina-

tion, no feed is imparted to the work; this setting is used when working on flanged components. The normal setting of the work-support rollers gives a feed to the component of 0.063 in. per revolution of the rollers, but this figure can be varied within limits, as required.

The lapping heads, three in number, are carried by a air-operated oscillating unit, taking air at 40 lb. to 70 lb. per square inch from the shop air line. The lapping heads are oscillated at 2,000 cycles per minute, and the stroke is infinitely variable between ½ mm. and 5 mm. Each lapping stone is kept in contact with the work by pneumatic pressure; the air cylinders can be seen in the illustration. The pressure on the stones is variable between 7 lb. and 28 lb.; it is usual to work with 14 lb. to 28 lb. for roughing and 7 lb. to 14 lb. for finishing. The pressure is shown on the gauge, which is visible in the illustration. The lapping unit is adjustable for height to enable work of different diameters to be accommodated. Each air cylinder is provided with a valve, operated by press-button, which lowers the stone into its working position or retracts it as required.

To set the machine, the work-support rollers are first adjusted to the correct centres, and locked. The pivot mountings of the lapping stones are then unlocked, a component is placed on the work-support rollers, and the stones are brought into contact with it by operating the air valves. The stone pivots are then locked while the air pressure is on, ensuring correct alignment of the stones with the component, and the stones are retracted by reversing the air pressure in the cylinders. A push-button starter is operated to set the work-support rollers in motion, and the oscillating lapping head

is started by means of an air valve. The components are placed in the feed chute, and, as the first one is fed under the first lapping stone, the air valve is tripped to bring the stone into contact with the work. This is repeated for the second and third stones, and the machine then operates without attention, so long as the feed chute is kept filled. A built-in pump supplies coolant through a perforated pipe, extending along the whole length of the rear work-support roller.

Typical "Talsurf" figures for the surface finish on a component lapped in the machine are: as ground, 4 to 7 micro-inches; after one pass, 1 to 1½ micro-inches; and after two passes, ½ to ¾ micro-inches. The lapping-head unit can be supplied independently of the complete machine, in forms suitable for mounting on the tool post of an ordinary centre lathe or on a grinding machine, if desired.

## ALUMINIUM-ALLOY ROOFS IN CORROSIVE ATMOSPHERES.

AN aluminium-alloy roof was erected in February, 1948, over the dry purification plant of the South Eastern Gas Board's works at Sevenoaks, Kent, to determine the suitability of this material in a corrosive atmosphere of this nature, and recently other aluminium-alloy roofs have been installed at Wandsworth and Guildford gasworks. The roof was built of standard structural sections with corrugated sheet covering supplied by the Northern Aluminium Company, Limited, Banbury, Oxfordshire. The alloys used were HE 10, B.S. 1476-1949 for the sections and NS 3, B.S. 1470-1948 for the sheet and both were installed without a protective coating.

In January, 1952, four years after the construction of the roof, specimens of the sheet and section were removed for metallurgical examination. The examination showed that pitting and corrosion had occurred on the structural member to a maximum depth of 0.0173 in. and mean depth of 0.0063 in. This was not considered to be serious, as the thickness of the section used was ½ in. on the flange and ⅜ in. on the web, and tensile tests made on the sample gave figures in excess of the minimum figures required by B.S. 1476. The sheet specimen, which was 0.028 in. thick when erected, had suffered pitting to a maximum depth of 0.0047 in. on the side exposed to the fumes. The outer face was not noticeably marked and tensile tests of the sheet gave results as satisfactory as those obtained from the section. The results indicate, it is claimed, that a roof of aluminium-alloy, if undisturbed and free from physical damage, would give 25 years of service under conditions where the air is sulphur-laden and polluted with products of combustion.

Aluminium-alloy, when subject to corrosive conditions, suffers pitting at points where the aluminium-oxide film is weakest and, as the film increases, there is generally less likelihood of new pits forming. After three or four years deterioration, it is thought that further pitting would be very slow. The initial cost of an aluminium-alloy roof is nearly twice as much as that of a similar roof using galvanised-steel sheet, with steel trusses and purlins, but a steel roof, when exposed to a highly corrosive atmosphere, would require painting about every two years, to prevent deterioration, whereas no covering is required for the aluminium-alloy. It is calculated, therefore, that the steel roof, which is considered to have a normal life span of 25 years, will probably have cost, with initial and upkeep charges, twice as much as the aluminium-alloy roof, at the end of the same period of time.

COMPOSITE PRESTRESSED-CONCRETE FRAME.—A rigid frame, comprising precast prestressed-concrete columns and beams, bonded at their junction by *in situ* concrete, has been erected at the Shell-Mex and B.P. oil installation at Dingle Bank, Liverpool. The frame forms a supporting structure for three elevated tanks, which, when full, will weigh nearly 150 tons, and all wind loads are taken by the columns acting as cantilevers about their bases. The precast-concrete members were designed and made by the Concrete Development Co., Ltd., Iwer, Buckinghamshire, and erected at site by Holland and Hannen and Cubitts, Ltd., Liverpool.



## SCALE IN SEA-WATER DISTILLING PLANTS.\*

By H. HILLIER, O.B.E., M.I.Mech.E.

(Continued from page 285.)

Fig. 6, on this page, shows the heat-transfer coefficients obtained with clean heating surfaces at various temperature differences and at evaporation temperatures of 160 deg. and 200 deg. F. These heat-transfer coefficients are greatly and progressively reduced as scale accumulates on the coils. A running period of about 200 hours was found necessary, to obtain scale formations of reasonably measurable thickness and character; to reduce the cost of the transport of the sea water, it was decided to use three coils only at various temperature differences. The fourth coil was left as an idle coil. For convenience in control, the coil-steam pressures were set and the temperature differences that resulted were accepted. The plant was operated continuously for five days a week. It was known that the calcium-sulphate scales could be avoided by operating with a sufficiently low brine density; so, to reduce the variables to be considered, most of the testing was carried out with a blow-down of about 100 per cent. of the made water, giving a brine concentration of 2.

### TESTING PROCEDURES AND SOME RESULTS.

The plant was run at each set of conditions for about 200 hours or more and the results were logged every four hours. The sea water and the evaporator brine were analysed at frequent intervals. At the end of a run, samples of the scales formed on the coils, the evaporator shell, and a deflector plate in the evaporator were analysed. After each run, the coils and evaporator shell were cleaned mechanically and with a solution of hydrochloric acid. In the early tests, the scale samples were taken at intervals along the length of each coil; but the sampling was limited to two places on each coil.

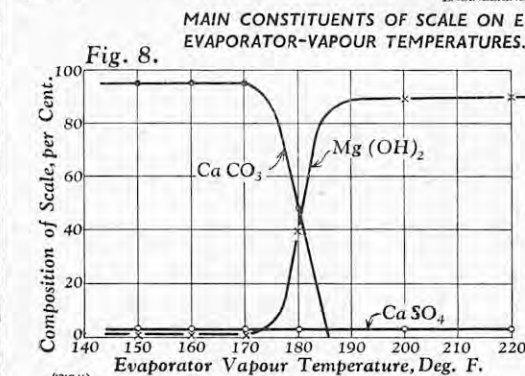
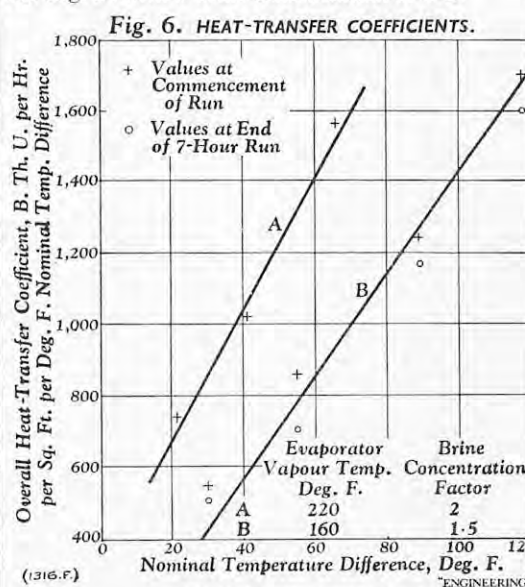
Fig. 7, plotted from a test at an evaporation temperature of 160 deg. F., shows how the heat-transfer coefficients fall as scale accumulates. The shell pressure was 4.74 lb. per square inch absolute; the brine-concentration factor, 2; duration of test, 220 hours. The week-end halt caused a slight discontinuity, but did not affect the general trends significantly.

The tests showed a definite pattern in the scale formation with evaporation temperature. A predominantly calcium-carbonate ( $\text{CaCO}_3$ ) scale occurred at evaporation temperatures of 150, 160, and 170 deg. F.; but there was an appearance of appreciable magnesium hydroxide ( $\text{Mg(OH)}_2$ ) at 170 deg. F. on the coil operating at the highest temperature-difference. At 180 deg. F., there was a transition phase in which coils 1 and 2 had a predominantly  $\text{Mg(OH)}_2$  scale. Coil 3, with the lowest temperature-difference, had a combined  $\text{CaCO}_3$ - $\text{Mg(OH)}_2$  scale; the unheated surfaces having a scale largely  $\text{CaCO}_3$ , with appreciable  $\text{Mg(OH)}_2$ . At evaporation temperatures of 200 and 220 deg. F., all the scales were mainly  $\text{Mg(OH)}_2$ ; but an appreciable proportion of calcium sulphate ( $\text{CaSO}_4$ ) appeared on the coil with the highest temperature-difference. The data showed that, starting from the low temperature, the scale formed is predominantly  $\text{CaCO}_3$ , which, as the evaporation temperature passes 170 deg. F., was replaced by a  $\text{Mg(OH)}_2$  scale. Figs. 8 and 9, herewith, show the incidence of the  $\text{CaCO}_3$  and  $\text{Mg(OH)}_2$  scales with evaporation temperature, and nominal temperature-differences of 22 deg. and 80 deg. F. respectively. The brine concentration factor is about 2. The curves show the amounts of  $\text{CaCO}_3$  and  $\text{Mg(OH)}_2$  as a percentage of the total scale present; in Fig. 9, the scale contains an appreciable percentage of  $\text{CaSO}_4$  at temperatures above 190 deg. F.

The general trends of the various scale formations were so marked that laboratory tests were made to obtain data on the factors controlling the precipitation of  $\text{CaCO}_3$  and  $\text{Mg(OH)}_2$  by progressively concen-

trating samples of sea water at different temperatures. Unfortunately, these tests gave widely varying results; but they showed that the precipitations of  $\text{CaCO}_3$  and  $\text{Mg(OH)}_2$  were on similar lines to the results in the large distilling plant. Fig. 10, opposite, shows the amounts of  $\text{CaCO}_3$  and  $\text{Mg(OH)}_2$  precipitated from sea water in the laboratory tests with a brine concentration of 2, at temperatures between 110 and 220 deg. F. It will be noted that there is a narrow range of temperature, of 180 to 190 deg. F., in which there is very little precipitation of either  $\text{CaCO}_3$  or  $\text{Mg(OH)}_2$ . In view of the widely varying results obtained from the laboratory tests, all further testing was carried out on the large distilling plant.

To determine the effect of a low brine concentration and low temperatures, tests were made at 140, 150, and 160 deg. F. with a brine concentration of 1.5. The scales formed were predominantly  $\text{CaCO}_3$ ; they were greater in thickness for a given operating time than for a brine concentration of 2 and the same evaporation temperatures. The comparative curves of scale formation, as measured in thickness per 100 hours' operation, are given in Fig. 11, opposite. A test was also made at 200 deg. F. with a brine concentration of 1.5.



### THE MECHANISM OF SCALE FORMATION.

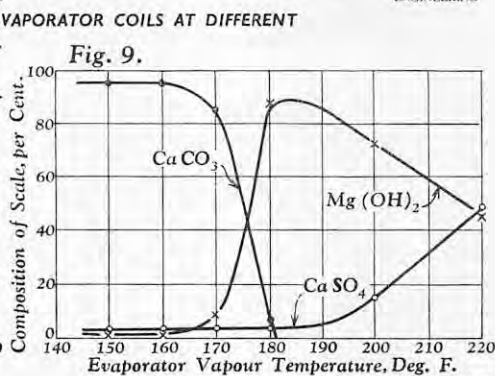
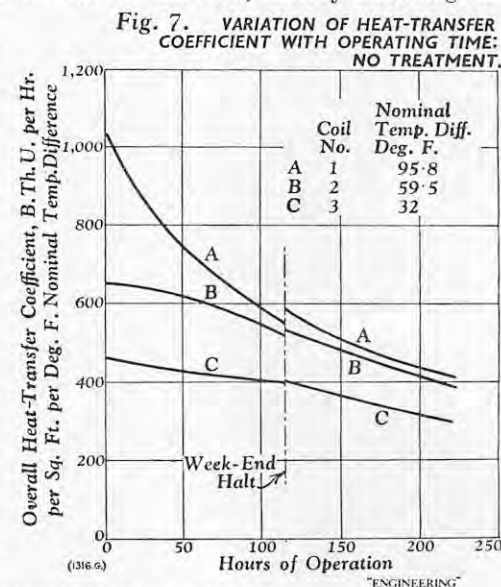
In our tests, scale was found on the evaporator heating surfaces and any other surface that was below the water line. Scale formation cannot, therefore, be attributed solely to evaporation. The rate of scale formation is, however, greater where heating and evaporation take place. The scale-forming elements are present in solution in ionic form and are also present in suspension within the brine, as compounds. There is probably a continual interchange between the ionic condition and the solid or compound condition of the scale-forming elements; but the amounts that can be present in the ionic state are limited by the temperature and concentration of the brine and, as the temperature and/or the concentration of the brine is increased, the amounts present in the ionic state are reduced and the amounts present in the compound state, either in the form of scale or in suspension in the brine, are increased.

The mechanism of scale formation is very complex; but it is suggested that it is due to electronic forces of attraction and cohesion, and that the rate of

scale growth is probably proportional to the degree of activity of the ions at the surface on which scale is being formed. It is probable that it is proportional to the number of impacts made by the scale-forming components on any given surface. In their compound state, they are electrically neutral; but in their ionic state they carry electrical charges, which provide the attractive and cohesive forces necessary for the adhesion of the ions to a surface.

Any surface is probably continually in a state of electrical dis-equilibrium, with a mixture of local positive and negative electrical charges; so that both negative and positive ions are liable to be adsorbed when they make contact with a surface in the liquid. This is a reversible process, in which the ions may go back into solution; but, where the necessary conditions exist, a balance of the ions will remain attached to a surface as scale. The build-up is probably ionic in character. In the same way, there may be a build-up of the same elements, in the compound state, in the liquid in suspension; if the density is carried sufficiently far, the solids in suspension may settle by gravity on any surface available.

Where heating takes place, the rate of movement of the ions is increased, thereby increasing the



number of impacts on a surface in a given time and resulting in an increased rate of scale growth. If the heating results in evaporation, then, as steam bubbles form, there is an increased concentration of scale-forming elements at the perimeter of contact of the steam bubbles with the heating surface. This increases the ionic activity in the adjacent liquid and gives rise to a further increase in the rate at which scale grows. The data given show a very appreciable scale formation on non-heated surfaces; but all the tests show that the greater the amount of heating and evaporation per unit area of surface, and the greater the concentration of the brine, the more rapid is the formation of scale.

In some circumstances, there is another way in which scale may form. In the operation of sea-water evaporators, it is usual to run with a controlled water-level at such a distance below the top of the heating surface that the ebullition level is just above the top of the heating surface. Sometimes this results in an intermittent coverage of the upper coils, which may then be subject to a different

\* Paper presented to the Institution of Mechanical Engineers at a meeting held in London on January 30, 1953. Abridged.

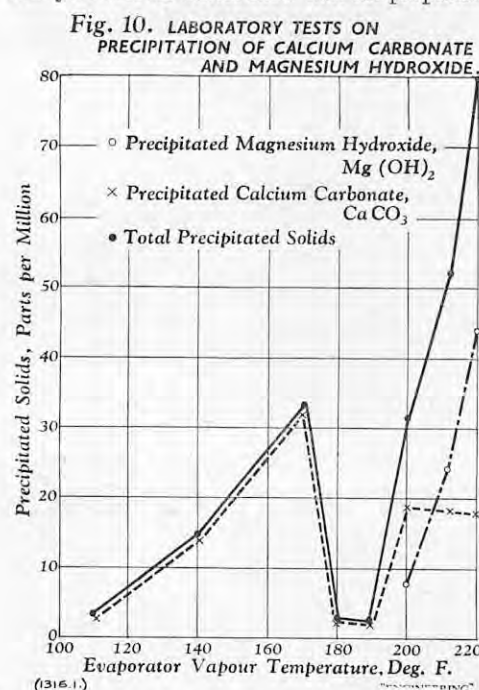


type of scale formation, caused by the total evaporation of some of the water splashed on to the heating surface, all the solids in that water being left as a deposit. This results in very heavy local concentrations of solid matter, which may contain appreciable quantities of sodium chloride; although the greater part of the sodium chloride is re-dissolved by the splashing action. This type of scale formation can be avoided by carrying a sufficiently high operating water level. The tests reported herein were run with the coils well submerged. Consideration of the data obtained to this point led to the conclusion that the carbonate ion,  $\text{CO}_3^{--}$ , was at the root of both the  $\text{CaCO}_3$  and  $\text{Mg(OH)}_2$  scales.

#### SEA-WATER SOLUBILITIES.

The soluble impurities found in sea water are mostly carried away from the land by water flowing to the sea. The bulk of such soluble solids is sodium chloride, which is extremely soluble. It is probable that the amount of sodium chloride in the sea has been slowly increasing over the ages. Sodium chloride need not be considered in the scale problem, because its precipitation point is not normally reached in sea-water distilling plants.

Analyses of river waters show that the proportions

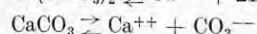
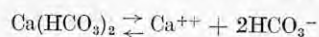


of carbonates and sulphates to chlorides in such waters are much greater than in sea water. The amounts of carbonates and sulphates in sea water are probably controlled largely by the biochemical processes of the organic life in the sea. It would appear, however, that, so far as bicarbonates and carbonates are concerned, the controlling factor is the equilibrium between the gases of the atmosphere and the gas content of the sea water; the surface sea water being in solution equilibrium with the gaseous carbon-dioxide ( $\text{CO}_2$ ) content of the air, with an average partial  $\text{CO}_2$  gas pressure of 0.0003 atmosphere.

Within the sea water, there is an equilibrium between the dissolved  $\text{CO}_2$  gas present and the combined carbonic acid,  $\text{H}_2\text{CO}_3$ . It has been calculated that, of the total carbonates in solution in the sea, about 96 per cent. are in the form of bicarbonates,  $(\text{HCO}_3)^-$ , and about 4 per cent. are in the form of carbonates,  $\text{CO}_3^{--}$ . Any change that tends to increase the concentration of the carbonate ions results in the precipitation of calcium carbonate.

#### REACTIONS IN THE EVAPORATOR.

The calcium bicarbonate and calcium carbonate present in sea water are almost completely ionised; thus



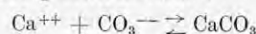
As the sea water is heated and evaporated, the partial  $\text{CO}_2$  gas-pressure within the water is reduced, resulting in the bicarbonate ions breaking up into carbonate ions, water, and gaseous carbon dioxide—

the carbon-dioxide gas leaving the water with the water vapour of evaporation, thus

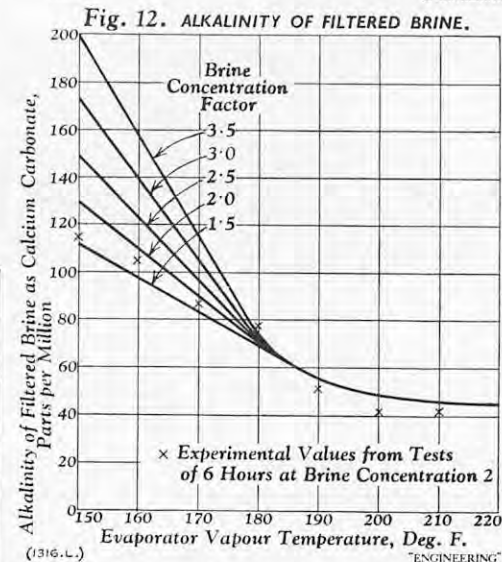
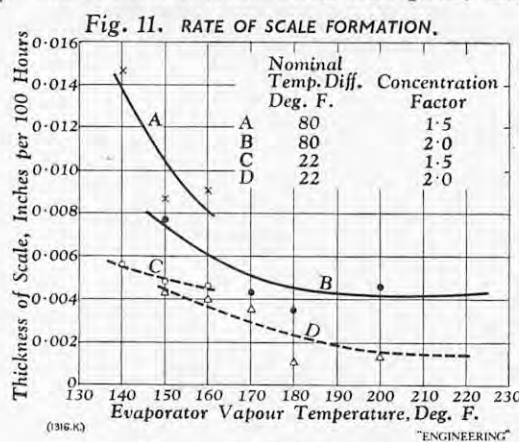


The conditions within an evaporator are in a state of dynamic equilibrium. A continuous supply of sea water is being fed into the evaporator, where it mixes with a concentrated brine that is being heated and evaporated. At the same time, there is a continuous outflow of concentrated brine from the evaporator. The concentration of the solids in the brine in the evaporator is determined by the relations between the rate at which sea water is fed into the evaporator, and the rate at which brine is withdrawn from the evaporator, and the rate at which solids are deposited as scale or sludge on the surfaces in the evaporator.

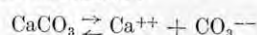
Heating and evaporation result in an increase in the concentration of the carbonate ions in a brine that is saturated with carbonate ions relative to calcium ions; with the result that some of the carbonate ions combine with calcium ions, and  $\text{CaCO}_3$  is precipitated as follows:



This is the first action which takes place; and



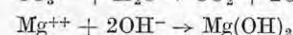
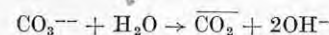
$\text{CaCO}_3$  can be held in suspension in the brine, and on the evaporator surfaces as scale, in equilibrium with its ions as follows:



The tests show that, in low-pressure evaporators, a predominantly  $\text{CaCO}_3$  scale is formed; and that, the greater the amount of sea water fed into the evaporator, the greater is the amount of scale formed. This is illustrated in Fig. 11, herewith, which shows that the use of a large blow-down increases scale formation.

While a  $\text{CaCO}_3$  scale is being experienced with evaporation temperatures of 140 to, say, 180 deg. F., another increasing reaction is taking place with increasing temperature, resulting ultimately in a  $\text{Mg(OH)}_2$  scale. As the evaporation temperature is increased, some of the carbonate ions,  $\text{CO}_3^{--}$ , break down; then, in conjunction with water, they give off carbon dioxide as a gas and give rise to the formation of hydroxyl ions. These combine with

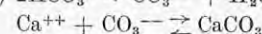
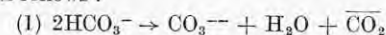
magnesium ions to form  $\text{Mg(OH)}_2$  as a precipitate; thus



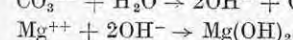
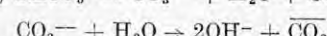
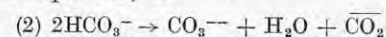
In all the tests carried out, the pH of the concentrated brine falls generally within the range of 8 to 9. The hydroxyl ions in solution, for pH values of 8 and 9, are, respectively, 0.017 and 0.17 lb. per million lb. of water. These are insignificant amounts; practically all the hydroxyl ions formed by the break-up of carbonate ions combine with magnesium ions to form  $\text{Mg(OH)}_2$ , in suspension in the brine or precipitated as a scale. From the practical point of view,  $\text{Mg(OH)}_2$  can be regarded as insoluble.

In the tests, the  $\text{Mg(OH)}_2$  formed increased with temperature and remained in suspension in the brine up to an evaporation temperature of about 180 deg. F. At about this temperature and above,  $\text{Mg(OH)}_2$  was precipitated as a scale on the evaporator surfaces; and, as  $\text{Mg(OH)}_2$  appeared in the scale, the proportion of  $\text{CaCO}_3$  in the scale fell until it disappeared altogether at the higher temperatures.

The bicarbonate ions in the sea water may provide one of two alternative forms of scale, the alternative results of the break-up of the bicarbonate ions being as follows:



giving calcium carbonate as a scale or precipitate in suspension; or



giving magnesium hydroxide as a scale or precipitate in suspension. In both cases, carbon dioxide is released as a gas.

The bicarbonate ion is responsible, therefore, for both the  $\text{CaCO}_3$  and the  $\text{Mg(OH)}_2$  scales. The incidence of the composition of the scales is dependent upon temperature, while the amount of scale at a given temperature increases with the amount of sea water supplied to the evaporator. Scale from sea-water evaporators in service operation sometimes shows a composition of appreciable amounts of  $\text{CaCO}_3$ ,  $\text{Mg(OH)}_2$ , and  $\text{CaSO}_4$ ; this has hitherto rather confused the problem.

Following the tests reported herein, scales from large sea-water evaporators have been carefully examined and the scale structure from some plants was found to be stratified, starting with a  $\text{CaCO}_3$  scale adjacent to the surface and followed by a  $\text{Mg(OH)}_2$  layer and an outer layer of  $\text{CaSO}_4$ . As the formation of scale accumulates, the local temperature conditions are changed by the resistance to heat flow set up by the scale. The resulting conditions successively give rise to the different scales.

The test data showed that only a part of the total amount of bicarbonate and carbonate ions fed into the evaporator go to scale formation. Some of the bicarbonate and carbonate ions, some of the  $\text{CaCO}_3$ , and some of the  $\text{Mg(OH)}_2$ , leave with the blow-down. A portion of some of the bicarbonate and carbonate ions leaves as carbon-dioxide gas. The balance remains in the scale. This balance is the amount of bicarbonates and carbonates that has to be dealt with, as a minimum, if scale formation is to be prevented; and it appeared to be reasonably small. The amount of  $\text{CaCO}_3$  and/or  $\text{Mg(OH)}_2$  in solution or suspension in the brine, and discharged with the brine, was now appreciated to be of importance.

The data obtained at 170 deg. F., brine concentration 2, were examined to ascertain the state and proportion of the scale-forming solids in the scale formed in the evaporator and in the blow-down. The calcium in the scale formed in the evaporator was estimated at about 9 lb., out of a total weight of feed-water of 76.3 tons fed into the evaporator during the run. The difference between the calcium fed into the evaporator and the calcium discharged with the blow-down was 9.4 lb. The difference in magnesium was estimated from the scale analyses to be 0.15 lb.



Summarised, the total  $\text{Ca}^{++}$  in the scale = 0.123 lb. per ton of sea water and the total  $\text{Mg}^{++}$  in the scale = 0.002 lb. per ton of sea water, of an alkalinity of 115 lb. per million lb. of water (p.p.m.), expressed as  $\text{CaCO}_3$ , in the sea water; 41 p.p.m., or 36 per cent., was removed as scale, or as  $\text{CaCO}_3$  in suspension; 43 p.p.m., or 37 per cent., was removed in solution; 31 p.p.m., or 27 per cent., was decomposed, resulting in  $\text{CO}_2$  as a gas and  $\text{Mg}(\text{OH})_2$  as scale or in suspension.

At this point, it was decided to obtain data on the amount of the alkalinity carried in solution in the brine. Tests were run at a given evaporation temperature, feeding with sea water and boiling the brine at a constant level, so that the concentration slowly increased to 3.5. No blow-down was used, and each test occupied between five and eight hours. The brine was sampled as the concentration increased. The alkalinity was generally as shown in Fig. 12, on page 379; but it should be emphasised that the curves indicate trends only, because the actual results had a wide scatter. The tests indicated that, up to about 170 deg. F., the alkalinity varied with concentration; but at higher temperatures the alkalinity appeared to be independent of the concentration and fell slightly with increasing temperature. The tests were not truly representative of evaporator operating conditions, because there was no blow-down, and it is possible that the length of time to obtain completion of reactions may be a significant factor. Nevertheless, the curves are of interest in showing the general trend and giving a rough indication of numerical significance.

#### DISTRIBUTION OF CARBONATE ALKALINITY.

Sea water contains about 140 p.p.m. of bicarbonate and carbonate ions: 115 p.p.m. alkalinity in terms of  $\text{CaCO}_3$ . This alkalinity may take different forms in the evaporator: (a) some of the alkalinity remains in solution and leaves in the blow-down; (b) a part of the alkalinity may be precipitated as  $\text{CaCO}_3$  in suspension in the brine, and leave with the blow-down; (c) some of the alkalinity may lead to the formation of  $\text{CaCO}_3$  as scale on the evaporator surfaces; (d) some of the alkalinity leads to the formation of  $\text{Mg}(\text{OH})_2$  as a precipitate, which leaves in suspension in the blow-down; (e) when the formation of  $\text{Mg}(\text{OH})_2$  reaches a sufficient concentration, some of it forms a  $\text{Mg}(\text{OH})_2$  scale on the evaporator surfaces. The proportions of this distribution of the alkalinity are of interest because the portions (a), (b) and (d) do not form scale.

Tests were carried out at constant evaporator-vapour temperatures of 160 deg. and 200 deg. F., with different brine concentrations. The alkalinity in the sea water was 117 p.p.m. as  $\text{CaCO}_3$ . From a brine concentration of 2.7 upwards, there was a slightly increasing amount of  $\text{CaCO}_3$  in suspension. The remainder of the alkalinity was deposited as a  $\text{CaCO}_3$  scale. The amount of scale formation experienced with different brine concentrations increases with the amount of sea water supplied to the evaporator, and is greater with a lower brine concentration than with a high brine concentration. No advantage, therefore, was obtained in using a large blow-down.

(To be continued.)

**BRITISH PRODUCTIVITY COUNCIL.**—As already announced in our columns, the chairman and deputy chairman of the British Productivity Council are, respectively, Sir Peter Bennett and Sir Lincoln Evans. The Council, it will be recalled, are the successors to the United Kingdom Section of the Anglo-American Council on Productivity, and their offices are at 21, Tothill-street, London, S.W.1. The other members of the Council are: Sir Cuthbert Clegg, Mr. Charles Connell, Sir Greville Maginess, Mr. A. G. Stewart and Mr. K. J. Burton representing the British Employers' Confederation; Sir Harry Pilkington, Sir Ewart Smith, Sir James Turner and Sir Norman Kipping representing the Federation of British Industries; Mr. J. A. Birch, Mr. J. Crawford, Mr. Arthur Deakin, Sir William Lawther, Mr. Andrew Naesmith, Mr. Jack Tanner, Mr. Tom Williamson and Sir Vincent Tewson representing the Trades Union Congress; Mr. Harry Yates representing the Association of British Chambers of Commerce; Mr. F. T. Jackson representing the National Union of Manufacturers; and Sir John Benstead, Lord Citrine, and Sir Hubert Houldsworth representing the nationalised industries.

## STANDARD WAGONS FOR BRITISH RAILWAYS.

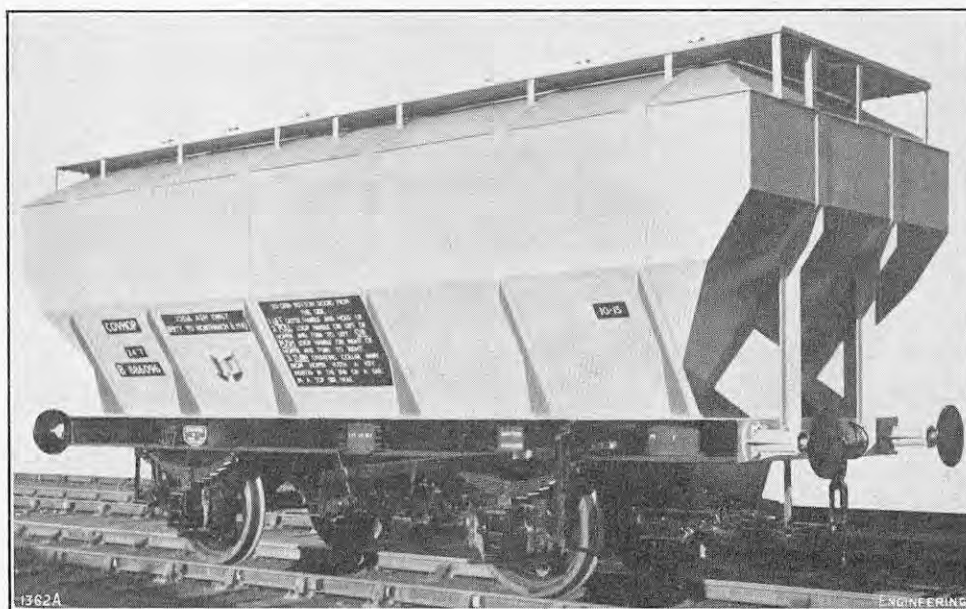


FIG. 1. 24-TON COVERED HOPPER WAGON.

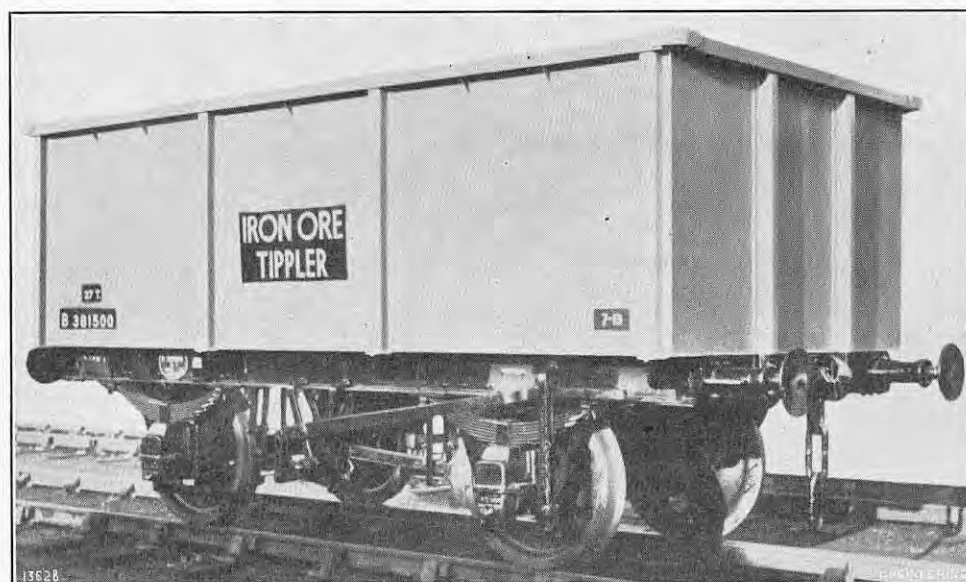


FIG. 2. 27-TON IRON-ORE WAGON.

### IRON-ORE AND COVERED HOPPER WAGONS FOR BRITISH RAILWAYS.

Two further standard wagons which have been introduced on British Railways are of the maximum permissible gross weight which can be carried on four wheels. They are a 24-ton covered hopper wagon or van, for bulk chemicals, and a 27-ton iron-ore wagon, illustrated in Figs. 1 and 2. The designs have been prepared at Derby to the specifications of Mr. R. A. Riddles, C.B.E., M.I.Mech.E., the member of the Railway Executive for mechanical and electrical engineering.

The 24-ton covered hopper wagon is for the bulk conveyance of chemicals such as soda ash, sodium tripolyphosphate or catalysts, and has a tare weight of 10.65 tons and a capacity of 1,241 cub. ft. The total gross weight is rated at 35 tons. A partition of  $\frac{1}{2}$ -in. plate divides the body into two compartments, with completely flush surfaces. Each hopper can be discharged by gravity through two horizontally sliding doors on the longitudinal centre line of the wagon. The body takes full advantage of the loading gauge and the wagon has been designed to obtain the maximum capacity allowed by the total gross load. The wheelbase is 10 ft. 6 in. and the wagon will negotiate a curve of 1-chain radius. For soda ash and sodium tripolyphosphate, a coupling of a quickly-detachable

vibrator is welded to the sides of the hoppers to assist unloading. Two double-hinged filling doors, 6 ft. 11 in. long and 2 ft. 5 in. wide, are provided in the roof and are fitted with rubber weather seals and secured by screwed eyebolts. A roof vent is used, with or without a valve, according to the traffic, and a cat-walk provides ready access to the doors. The discharging doors each measure 1 ft. 4 $\frac{1}{4}$  in. longitudinally and 1 ft. 11 $\frac{3}{8}$  in. laterally, and are opened and closed by a rack and pinion, operated from either side of the wagon by a removable handle. The doors can be sealed with wire seals.

The length of the vehicle is 24 ft. 6 in. over the buffers and 23 ft. 0 $\frac{3}{4}$  in. inside the body. The height overall is 12 ft. 2 $\frac{3}{8}$  in. and the inside width of the body is 8 ft. 7 in. The underframe is of special design to accommodate the hoppers. It is of all-welded construction and has standard buffing and drawgear, with three-link couplings. The wheel diameter is 3 ft. 1 $\frac{1}{2}$  in. and the axles have 10 in. by 5 in. journals, running in fabricated steel axleboxes. The body is also welded,  $\frac{1}{8}$ -in. mild-steel plates being used for the roof and sides, and  $\frac{1}{4}$ -in. plates for the ends and hoppers.

The 27-ton iron-ore wagon has been constructed for discharging by tipplers, and has no doors. The body is of  $\frac{1}{8}$ -in. high-tensile low-alloy steel or  $\frac{1}{4}$ -in. mild steel and has a capacity of 648 cub. ft. The tare weight is 7.65 tons, the length over the



## STEEL INGOTS FOR SEAMLESS TUBE MAKING.

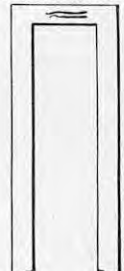
Fig. 3.  
NORMAL TYPE  
OF INGOT.Fig. 4  
INGOT AFTER  
PRE-PIERCING.

Fig. 5. AFTER ELONGATING.

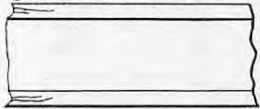
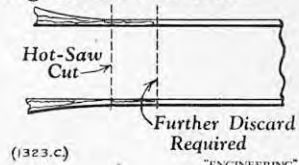


Fig. 6. AFTER ROLLING.



(1323.C)

"ENGINEERING"

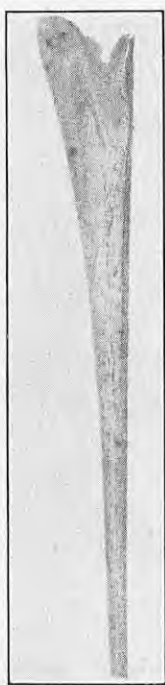
FIG. 7. SULPHUR  
PRINT OF DISCARD.Fig. 8.  
HOT-TOP TYPE  
OF INGOT.Fig. 9.  
INGOT AFTER  
PRE-PIERCING.

Fig. 10. AFTER ELONGATING.

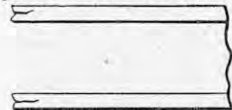
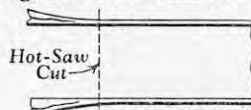


Fig. 11. AFTER ROLLING.



(1323.E)

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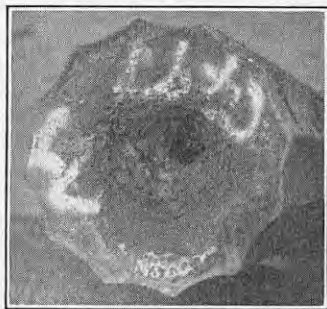
FIG. 12. SULPHUR  
PRINT OF DISCARD.

FIG. 13. OPEN-TOP INGOT.

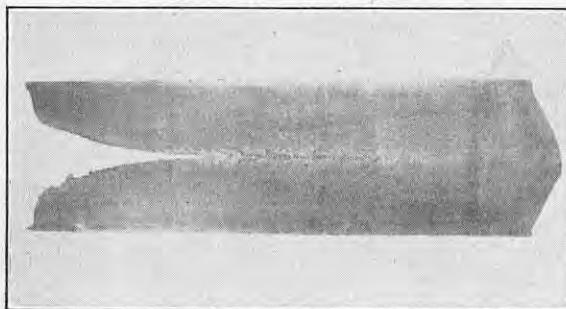
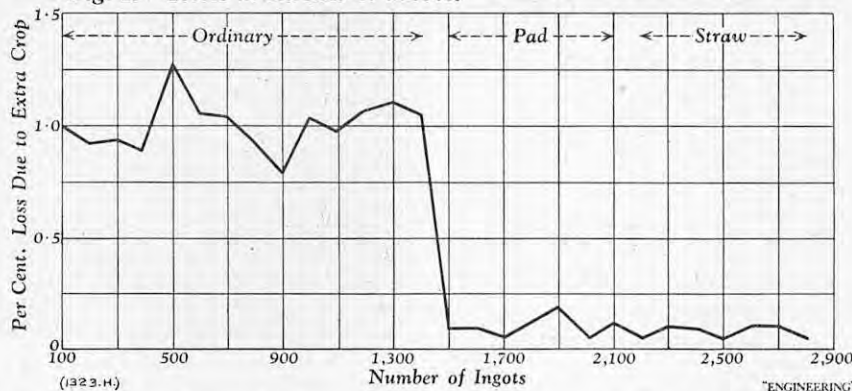


FIG. 14. SECTION OF OPEN-TOP INGOT.

Fig. 15. LOSSES IN BATCHES OF INGOTS.



(1323.H)

"ENGINEERING"

buffers is 19 ft. 6 in., and the wheelbase is 9 ft. Two designs of underframe are used—either riveted or welded construction—the main members being rolled steel channels 9 in. by 3½ in. The body has a flush interior and is strengthened by pressed-steel side and end stanchions, the former stiffened to withstand the loaded contact with tippler beams. The wheels are 3 ft. 1½ in. in diameter and the axles have 10 in. by 5 in. journals running in cast-iron axleboxes. The brake gear has four blocks, two being actuated from each side by a system of levers which give a mechanical advantage of 30 to 1.

**ELECTRICITY SUPPLY IN QUEENSLAND.**—The fifteenth annual report of the State Electricity Commission of Queensland shows that, during 1951, 795 million kWh were sold, compared with 664 million kWh in the previous year, an increase of 131 million kWh, or 19.7 per cent. In the south-east of the state good progress was made with the construction of two major

power stations at Bulimba and Tennyson, while two 10-MVA emergency plants were purchased to assist in temporarily meeting the demand. In all, 44.5 MW of generating plant has been commissioned since July 1, 1951, and schemes for building small standard power stations for supplying isolated communities of 250 to 1,000 people are making good progress.

**MODELS FOR SOUTH AFRICA.**—One of the largest orders ever placed in this country for models of transport equipment was completed last year by member firms of the Model Engineering Trade Association of Great Britain. The models included railway locomotives, rolling stock and permanent way, as well as models of horse-drawn vehicles, used in South Africa during the past 300 years. They were for the Van Riebeeck Tercentenary Exhibition held in Cape Town last year, for which the M.E.T.A. were responsible for 95 per cent. of the model work. The Association, of which Mr. George Dow is President, have published a booklet with over 60 illustrations of this notable work. The address of the secretary is 156, Camden High-street, London, N.W.1.

## THE CASTING OF INGOTS FOR SEAMLESS TUBE MAKING.\*

By G. BOWMAN.

(Concluded from page 287.)

## CAVITATION.

WHEN considering the freezing of a killed-steel ingot, the effect of the inevitable pipe cavity is borne in mind. Invariably the shape, depth and accompanying segregate are taken into account when the amount of discard from the rolled product is being estimated. In the normal cogging practice, the extent to which the cavity and segregate exist in the bloom determines the amount to be discarded at the shears. Thus, every attempt is made to minimise the dimensions of the pipe cavity, particularly the depth within the ingot. For this reason, hot topping is practised extensively and in a large variety of ways, many of them comprising specific designs of refractory tops for moulds.

In the rotary-forge practice the pipe cavity is also an important factor. In casting ingots for this method of rolling it is impossible to use the refractory hot-topping system owing to the varying ingot lengths which are necessary in casting for tube orders. Moreover, the approach to the cavity problem is slightly different. The length of cavity is not so important for this purpose as it is in the case of the cogging mill, but the cross-sectional area is important. For normal cogging, there is no mechanical method for compressing the length of the cavity and the cross-sectional area is relatively unimportant. For rotary forging, the cavity can be compressed adequately, provided the cross-sectional area is small enough to be covered entirely by the piercing punch. This is illustrated in Figs. 3 to 6, herewith. Fig. 3 shows a killed ingot teemed normally and having the usual top bridge and one secondary bridge across the pipe cavity. Fig. 4 illustrates the result of the pre-piercing operation, showing the compression of the cavity, with two lines of segregate indicating the new position of the cavity bridges. Fig. 5 shows the result of the next operation which elongates the piece and, of course, the lines of segregate, which do not weld. Fig. 6 shows the finished tube, in which two points are indicated by dotted lines. These are the normal hot-saw cut, and the further discard required to remove the segregate. The point at which the normal saw-cut is made is determined purely by tube-making practice. The thick-walled end of the tube shown in Fig. 6 is called the "bell end." This has to be discarded and the normal cut is made so that only the thickened portion is removed. The normal type of ingot frequently gives rise to unsoundness beyond this point as shown diagrammatically in Fig. 6 and in the sulphur print Fig. 7. When this occurs, a further discard is necessary.

In considering how this loss could be avoided, it was thought that if the bridges, particularly the thick top bridge, could be eliminated, any unsoundness would be concentrated still nearer the end of the pre-pierced ingot, shown in Fig. 4, and so have less tendency to spread along the tube. This suggested that some form of hot topping was the possible remedy, and experiments were made with various materials ranging from anti-piping compound to circular pads made from different substances. The most efficient method to give an open cavity was found to be a circular pad made by compressing the residue from the effluent from paper works. These pads were made in hydraulically-operated dies, dried in ovens at controlled humidity, and dropped into the moulds before teeming commenced. Trials using these pads gave the desired reduction in crop loss, and Figs. 8 to 11, herewith, repeat the diagrams in Figs. 3 to 6, but illustrate the effect of the open cavity. In this case, the heavy segregate at the base of the cavity is compressed to the end of the ingot after pre-piercing. Thus, in cutting at the hot saw, the segregate is

\* Paper, entitled "Some Practical Notes on Casting of Ingots for Seamless Tubemaking," read before the West of Scotland Iron and Steel Institute, at Glasgow, on Friday, February 20, 1953. Abridged.



removed completely, as illustrated by the sulphur print in Fig. 12, on page 381.

During the course of these experiments, it was found that the quality of the raw material for making the pads varied considerably, and, consequently, the mechanical strength and drying properties were variable. Moreover, it was found that the pad absorbed moisture during storage, and the generation of gases from this source during teeming was undesirable. A second effect of this moisture absorption was the tendency for the pads to disintegrate during teeming and for pieces to become embedded in the ingot. While these disadvantages were not serious enough to rule out the possible use of pads on a production scale, the search for other materials was continued. One possible substance was straw, the use of which was referred to in an article in the American journal *Blast Furnace and Steel Plant*, of December, 1951. Preliminary experiments using a few pounds of straw packed loosely into the moulds, prior to teeming, gave promising results, but it was found advisable also to place loosely-fitting steel plates over the moulds in order to retard the burning of the straw. The straw began to burn immediately the molten metal entered the mould, and the heat generated in this way appeared to be sufficient to keep the top surface of the metal molten during teeming and for a short time afterwards. The burnt residue from the straw acted as an insulator and assisted in this direction so that the fluid steel could sink back to form the contraction cavity and produce an open-topped ingot as shown in Figs. 13 and 14, on page 381.

A large-scale trial was carried out to compare ingots cast in the normal way, with ingots cast with pads, and others cast with straw. As might be expected, the use of straw on this larger scale revealed several difficulties, such as ignition of the straw by sparks prior to the commencement of teeming. Consequently, all the ingots obtained were not as perfect as the examples which have been shown. Nevertheless, the large majority were substantially open topped and considered suitable for the trial. These ingots were rolled in mixed batches and a careful check was made on all additional cropping which was required after the normal tube "bell end" had been removed. These additional cuts were measured and converted to a percentage of the ingot weight. This can be considered as a scrap loss which might otherwise have been good tube. The losses on each batch of ingots in the different categories is shown in Fig. 15, in page 381. It will be seen that the open-topped ingots, either from pads or straw, resulted in a saving of approximately 1 per cent., which is appreciable under present-day conditions.

#### CRUSTING.

Reference was made earlier to a major cause of defects which was associated with teeming speed. This is frequently referred to as "crusting" and consists of deoxidation products and eroded refractory rising to the surface of the metal, oxides resulting from oxidation of the exposed top surface and frozen steel. Anyone who has had experience in uphill casting will have seen this and know how it tends to migrate towards the mould wall and how, occasionally, it can be trapped in the rising metal. This crust or skull gradually increases in size as the metal is rising, so that the greatest danger of entrapment is near the top of the ingot. It will be appreciated that a piece of this trapped in an ingot must give rise to a comparatively serious defect in the final product. Such defects in cold ingots are not too obvious and may easily be missed. They are, however, associated with a slight lap which, although apparent on the ingot surface, does not look like a serious defect; an example of this is shown in Fig. 16, on this page. Ingot inspectors must suspect all laps and examine these further with the use of an oxy-acetylene torch. The lap shown in Fig. 16 is shown again in Fig. 17 after torch de-surfacing. It will be seen that the defect is then quite obvious. Such defects are frequently of sufficient depth to necessitate scrapping the complete ingot.

Higher teeming speeds have always been a counter to this source of trouble, both by reducing the time available for the crust to form and by tend-

## STEEL INGOTS FOR SEAMLESS TUBE MAKING.

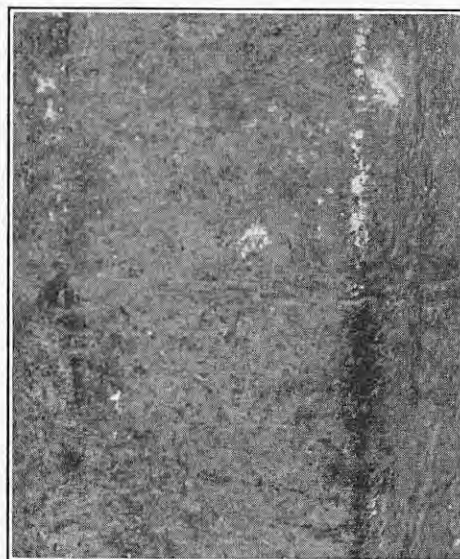


FIG. 16. LAP ON INGOT SURFACE.

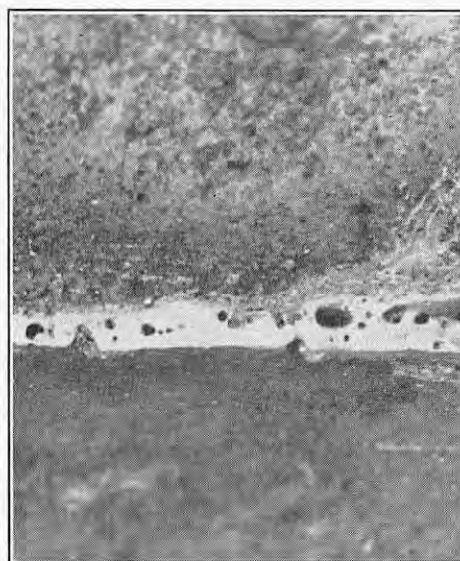


FIG. 18. SUB-CUTANEOUS BLOW HOLES.

Fig. 20. FALSE BOTTOM PLATE.

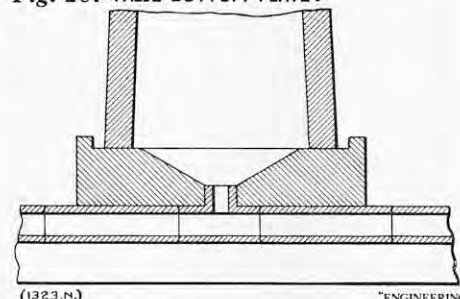


FIG. 17. LAP AFTER TREATMENT WITH OXY-ACETYLENE TORCH.

Fig. 19. NORMAL RISER HOLE.

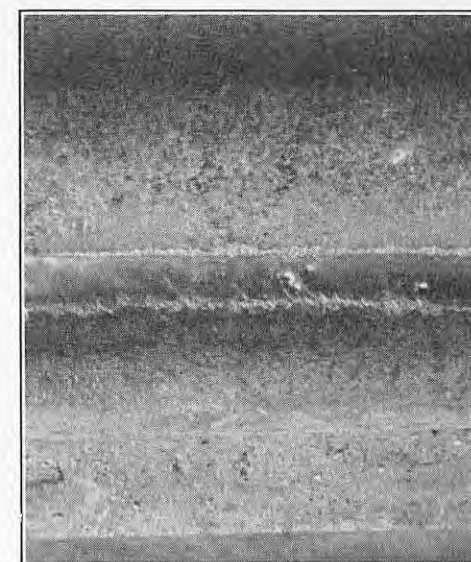
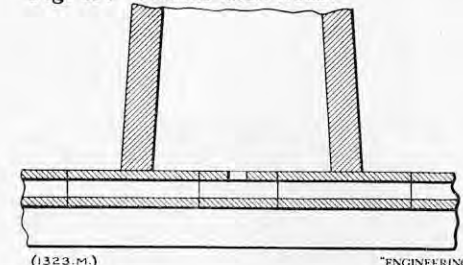


FIG. 21. POROSITY IN BODY OF INGOT.

ing to keep it away from the mould wall. Unfortunately, the maximum teeming speed permissible without serious danger of cracking is not high enough to eliminate this defect. Nevertheless, the incidence is substantially reduced by using the highest teeming speeds which can be permitted. Another factor which is helpful in this direction is the use of a good mould coating. The gas evolved from the coating at the mould/steel interface tends to keep the crust away from the mould wall although it does not in any way inhibit its formation.

Obviously, the complete answer is to prevent the formation of such crusts, and, with this object in view, casting was carried out with the tops of the moulds closed except for a small vent hole. The intention was to reduce the heat loss from the top surface and maintain a reducing atmosphere within the mould. It was felt that if this could be done to a sufficient extent, the formation of both frozen metal and oxide would be prevented. Results

showed that, while there was an improvement, this cure was only effective to a limited extent. Now, the reason why this subject has been bracketed with cavitation is that the use of straw and a plate over the mould has also proved the most effective cure for crusting. A great many ingots cast by this method have been de-surfaced to a depth of 1 in. by machining, and the number of entrapped crusts found has been negligible. It must be emphasised that what has been said here regarding the use of straw has been based on experimental work, although some of the trials involved large numbers of ingots. It may be that in full-scale production unforeseen difficulties would arise.

#### POROSITY.

Porosity can and does occur occasionally in killed-steel ingots which have been teemed uphill. The blow holes are sub-cutaneous and consequently cannot be detected or studied by examination of



the as-cast ingots. The following three methods have been used to expose and study porosity. (1) Longitudinal sections have been cut and examined, but this only revealed a very restricted area of ingot skin, and did not justify the excessive amount of machining involved. (2) Ingots have been de-surfaced in a lathe, and if this is done in small steps it is quite an effective method of examination, particularly for round ingots; examination of fluted ingots by this method is not so successful. (3) Oxy-acetylene torches have been used to de-surface ingots, and this method is quite effective, but is more suitable for exposing sample areas than for examination of a complete ingot surface. Methods (2) and (3) have been used extensively to expose and study porosity. Fortunately, or unfortunately, depending on whether the interest is in production or investigation, blow holes are not present in all ingots, and very large numbers have had to be examined in order to obtain a reasonable amount of evidence.

In the course of this work, two distinct types of blow hole were identified on numerous occasions. Although sub-cutaneous, both types were near enough to the surface to be removed by either methods (2) or (3) or to be exposed by scaling during reheating. Fig. 18, opposite, shows the first type which was sometimes found at the bottom corner of an ingot. The shape and distribution of these holes will be noted and, although it cannot be ascertained from the photograph, they were completely free from contamination of any kind. When these holes or cavities were found in ingot sections which had been etched and sulphur printed, it was noticed that they were always located where the chilling appeared to have been most severe as judged by the thickness of the chilled layer.

The first metal gushes into the mould with a fountain effect and splashes into the bottom corners where it freezes very rapidly due to the combined effect of the mould and the bottom plate. It will be seen from the normal type of entry by riser hole, shown in Fig. 19, opposite, that the metal first chilled in these corners is not likely to be reheated by molten metal subsequently entering the mould. It was therefore concluded that such holes might be a series of small contraction cavities resulting from the rapid chilling. It is not unusual for the first surge of metal entering a mould to go mainly towards one side, and this might well account for the holes being associated with the thickest chill. On this assumption, a new false bottom plate was designed with the object of avoiding such holes; this is shown in Fig. 20, opposite, from which it will be seen that this was introduced between the main bottom plate and the mould. The intention was that the first surge of metal should be confined in the conical portion so that any rapid chilling which took place would be counteracted by the further metal entering the mould; also that a pool would be formed in the cone, and that the metal would flow slowly and smoothly from this into the bottom corners. This arrangement also ensured perfect centring of the mould over the inlet, thus reducing the danger of uneven distribution of the molten steel. A large number of ingots were made with this set-up, and the results were very much as expected. Ingots cast in this way showed very much less tendency to have unsound areas at the bottom corners. It is felt that even better results might have been obtained had the diameter at the base of the cone coincided with the diameter at the bottom of the mould.

The other type of porosity encountered occurred in patches on the body of the ingot and mainly in the upper half. An example of this type is shown in Fig. 21, opposite. Each hole contained a small bead of slaggy material of the following approximate composition:—

|                        | Per cent. |
|------------------------|-----------|
| Silica ... ..          | 41.0      |
| Alumina ... ..         | 9.0       |
| Ferric oxide ... ..    | 8.0       |
| Manganous oxide ... .. | 41.0      |

This type of porosity was found mainly on one side of the ingot and again was associated with the thickest portion of the chill layer. It has been established that variation in the thickness of the

chill and the incidence of this porosity is aggravated by an off-centre inlet to the mould, the thick chill being on the side farthest from the inlet.

In looking for a possible source of the slaggy material occurring in these holes, it was found that, after use, the mould surface had small globules adhering to the surface. The analysis of this material was:—

|                        | Per cent. |
|------------------------|-----------|
| Silica ... ..          | 15.2      |
| Alumina ... ..         | 8.5       |
| Ferric oxide ... ..    | 64.4      |
| Manganous oxide ... .. | 11.2      |

These globules may be the result of erosion from the runner bricks and/or ladle lining, deposited on the mould surface during filling. Subsequent ingots from such a mould have thus two sources of pick-up of this material; that is, erosion by the current teeming and pick-up from an improperly cleaned mould. When this material is trapped by solidifying metal the  $\text{FeO} + \text{C}$  reaction takes place, leaving the residual alumino-manganese silicates in the form of a bead. If the mould is cleaned and coated efficiently, there is a distinct decrease in the deposition of these globules on the surface and also a reduction in the pick-up by the metal. To minimise the second type of porosity it is essential to clean and coat the moulds properly, to centralise the moulds over the riser holes properly, and to keep the metal as fluid as possible during teeming to ensure the rising of slaggy material to the top of the ingot.

## HYDRAULIC BRAKE AND CLUTCH CONTROL FOR MOTOR VEHICLES.

A TWIN master-cylinder unit for hydraulic control of the brake and clutch on motor cars has been made by the Lockheed Hydraulic Brake Company, Limited, Leamington Spa, Warwickshire. It was developed to provide a flexible connection between the clutch mechanism and the pedal and to replace the present type of mechanical linkage, which is thought to be responsible for the vibration and "judder" that occurs when starting. This mechanical linkage is also said to be responsible for transmitting engine vibration to the bodywork of the vehicle and producing drumming of the light-gauge steel panels used in modern designs.

The clutch-control cylinder is identical in principle with the brake cylinder used in the Lockheed hydraulic-brake system. In the new unit, the clutch cylinder shares the same body as the brake master cylinder, which is therefore a twin-bore unit. Each cylinder has a separate fluid tank and the tanks share a common filler, thus achieving simplicity and cheapness of design. The outlet from the clutch-control cylinder is connected by a flexible pipe to a slave cylinder which operates the clutch-withdrawal lever. The clutch and brake-pedal pivots are brought close together by this unit, making it necessary for the shanks to be curved to provide sufficient space between the pedal tread-plates.

Depression of the pedal pushes the small piston into the master cylinder driving fluid along the flexible pipe into the slave cylinder; this forces the clutch-operating piston forward and disengages the clutch-plate. The hydraulic system is enclosed and self-lubricating and friction is less than with the system of mechanical linkages, which permits the use of a lighter clutch-pedal shank and pivot mechanism. It is said that the success of this unit is ensured as it follows closely on other well-established hydraulic systems.

**ELECTRICITY-SUPPLY STATISTICS.**—Figures issued by the British Electricity Authority show that 56,845 million kWh were generated during the year ending January 31, 1953, an increase of 3.3 per cent. over the output for the previous 12 months. The monthly output for January, 1953, was 6.0 per cent. greater than that for January, 1952, when the necessary corrections had been made for the weather and the number of working days. The total electricity sent out by the Area Boards during January, 1953, was 6,045 million kWh, compared with 5,796 million in January, 1952, an increase of 4.3 per cent. The increase in the "mainly industrial areas" was 1.6 per cent. and in the "mainly non-industrial areas" 8.5 per cent.

## NOTES ON NEW BOOKS.

### *Solutions of Problems in Strength of Materials.*

By S. A. URRY, B.Sc. (Eng.). Sir Isaac Pitman and Sons, Ltd., Parker-street, Kingsway, London, W.C.2. [Price 20s. 0d.]

THIS book is intended for students who are preparing for an examination in Strength of Materials and it covers the syllabuses for the Higher National Certificate in Mechanical Engineering and the examinations for the various professional institutions. In addition, the book should prove of use to degree students, particularly those taking the B.Sc. (Engineering) of the University of London. Each chapter comprises a summary of essential formulae related to a particular topic, followed by worked examples in which these formulae are derived and applied; each chapter is then completed by a set of practice examples with answers and, where necessary, explanatory notes. To a conscientious student this book should prove a useful adjunct to a set of lecture notes or to a formal text-book.

### *Coal-Tar Fuels.*

Edited by J. S. SACH. The Association of Tar Distillers, 9, Harley-street, London, W.1. [Price 21s. 0d. net.]

THIS book has been compiled by the Tar-Fuels Technical Sub-Committee of the Association of Tar Distillers, and brings together in a compact volume a general technical review of the subject. The range of fuels discussed extends from creosotes, which are normally liquid at ordinary temperatures, to hard pitch. The introductory chapter gives a brief survey of the industry, together with a concise account of the methods of making of the various fuels. Another chapter has been devoted to the physical properties of the fuels, and particular mention is made of viscosity which is given, for a particular fuel, in absolute units (Stokes), so that the information is in a convenient form for engineering calculations. Coal-tar fuels played an important part in the war effort and, in no small way, temporarily replaced imported petroleum fuels; the production of these fuels continues in the United Kingdom at the rate of approximately two million tons of crude coal tar each year, nearly the whole of which is distilled for the more refined products. The greater part of the book is concerned with applications for which these fuels are particularly suitable.

### *Steam Power Stations.*

By Dr. GUSTAF A. GAFFERT. Fourth edition. McGraw-Hill Book Company, Incorporated, 330, West 42nd-street, New York 18, U.S.A. [Price 8 dols.]; and McGraw-Hill Publishing Company, Limited, 95, Farringdon-street, London, E.C.4. [Price 68s.]

ENGINEERS who are interested in central-station work would have far to go to find a book more compendiously informative than the present treatise, which has now been brought up to date in a fourth edition. Except for the description of a few high-pressure boilers of European design, it is concerned with American practice, on which the author, as a partner in the consulting firm of Sargent and Lundy, writes with authority. It can be commended both to students and to engineers holding responsible positions. The former will gain useful knowledge of the design and construction of every kind of non-electrical plant from boilers and turbines (the latter mostly of the General Electric Company's type) with all their auxiliary apparatus, to coal and ash-handling machinery, piping, duct work, and other details of power-station equipment, besides information on heat transfer, feed-water treatment, fuels and combustion. The short chapter on reciprocating engines, however, seems too reminiscent of the power-station practice of half a century ago to deserve a place in a book of this kind, in company with steam turbines now standardised in sizes up to 100,000 kW capacity, working with steam pressures up to 1,450 lb. per square inch and temperatures up to 1,000 deg. F. For more mature readers whose interests lie mainly in the field of



power-station economies, there are chapters on steam-station costs; load curves and plant location; selection of prime movers and steam generating equipment; heat cycles; and on station design generally, including many facts about the electrical position in the United States. Among the technical developments that have yet no counterpart in this country may be mentioned the mercury-steam plants, of which six have now been built, the latest, with an output of 40 MW, having now been in operation for a year, with a heat consumption of 9,400 B.Th.U. per kilowatt-hour when burning coal. There is also an increasing number of "outdoor" stations, in which the boilers and turbo-generators are of weatherproof design, and operate in the open air. Drawings of two outdoor stations, the larger having two generators of 60 MW each, are reproduced.

#### *The Growth and Activities of the British Electrical and Allied Manufacturers Association.*

British Electrical and Allied Manufacturers Association, 36, Kingsway, London, W.C.2.

THE second edition of the *Beama Catalogue*, which was published towards the end of last year, contained an informative account of the history and constitution of the British Electrical and Allied Manufacturers' Association, then celebrating its jubilee. This account, together with sections on present-day activities and overseas trade, has now been reprinted in the form of a booklet, thus providing an interesting description of co-operation in what has grown to be one of the leading British manufacturing industries. It is hardly necessary to describe the activities of "Beama" in detail, but the contents of this publication indicate clearly how the fundamental policy of increasing in every possible way the unity and efficiency, and therefore the prestige and advancement, of the industry has been and still is being carried out. As is rightly said, the ultimate test of an industry and its organisation is the service it renders to its constituents, to its customers, to the public and the nation. The success of Beama in these directions has been amply demonstrated.

#### *Electricity Tariff Handbook.*

Compiled for the *Electrical Review* with the assistance of V. A. H. CLEMENTS. *Electrical Review Publications*, Limited, Stamford-street, London, S.E. [Price 7s. 6d. net.]

THIS reference book, which has been compiled with the advice and assistance of the assistant commercial manager of the British Electricity Authority, gives full details of the standard tariffs enforced by the Area Boards in England, Scotland and Wales. The various classes—domestic, commercial, industrial, farm and miscellaneous—are shown separately and a tabular summary of each class is provided for ease of reference. The Central Authority's bulk supply tariff is also shown, and other information given includes the names and addresses of the chief officials of the Area Boards, definitions of official terms and classifications, and tables of electricity sales and revenue for 1951-52. All these details, besides being valuable for purposes of reference, indicate the extent to which the obligations laid on the Boards by the Electricity Act, 1947, to standardise tariffs has been carried out. This task has naturally been protracted, but it is evident that good progress is being made.

UNIVERSAL CIRCLE-CUTTING MACHINE.—For cutting rings and discs up to 11½ in. in diameter in materials such as glass, paper, cork, felt, rubber, etc., Harman's Engineering Co., Yelland, Barnstaple, North Devonshire, have introduced a universal circle-cutting machine. It consists of a baize-covered turntable mounted on a cast base. An overhead bar carries a cutter head which can be locked at any radius from the centre of the table, and also a removable centre head for locating and clamping the material, when necessary. Interchangeable cutters, including a glass-cutter, are provided. The material to be cut is placed on the turntable, and clamped in position by screwing down the clamping spindle in the centre head. Having set the cutter head to the required radius, the cutter is depressed on to the material with the finger, and the turntable is rotated by hand. The overhead bar can be removed to leave the turntable unobstructed for paint-spraying, welding, etc.

### 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.

**Hacksaw Blades.**—A new specification, B.S. No. 1919, covers hacksaw blades. It represents the fruit of co-operation between the Institution and the British Hacksaw Makers' Association and has the further advantage, for many sections of industry, that its provisions, for the ranges of sizes, teeth and dimensions, are identical with those accepted by American and Canadian manufacturers through agreements between trade organisations. The specification presents a simple series of types and sizes, and safeguards the quality and cutting properties of the blades. Both hand blades and those used by machines are included. [Price 3s. 6d., postage included.]

**Jig Bushes.**—A revision of B.S. No. 1098, originally prepared in 1943 as a war-emergency measure and relating only to drilling-jig bushes, has now been issued. It now covers bushes to be fitted to jigs for the purpose of guiding twist drills or reamers. Four types are specified, namely, press-fit bushes, which may be either headed or headless; renewable bushes of the fixed type; renewable bushes of the slip type; and liners which may be either headed or headless. The specification is primarily dimensional. [Price 3s., postage included.]

**Temporary Prevention of Corrosion.**—A revision of the war-time section 3 of B.S. No. 1133, the "Packaging Code," has recently been issued. It is now designated section 6 of B.S. No. 1133, and in its pages, temporary corrosion preventives for protecting engineering equipment during transportation are described in detail. Moreover, the essential preliminary conditions are catered for by an extensive section on cleaning and a short section on drying. The publication has been carefully prepared in order that it may serve the dual purpose of a readable hand-book on the subject and a reference book. It is intended to meet the needs of technical persons, but has been prepared also with the ordinary packer, as a reader, in mind. [Price 10s. 6d., postage included.]

### LAUNCHES AND TRIAL TRIPS.

M.S. "LONDON SPLENDOR."—Single-screw oil tanker, built by the Furness Shipbuilding Co., Ltd., Haverton Hill, County Durham, for the London and Overseas Freighters, Ltd., London. Fifth vessel for these owners. Main dimensions: 560 ft. between perpendiculars by 80 ft. by 42 ft. 3 in. to upper deck; deadweight capacity, 24,600 tons on a summer draught of 32 ft. 3½ in.; oil-carrying capacity, 23,516 tons. Wallsend-Doxford six-cylinder single-acting two-stroke oil engine, developing 6,600 b.h.p. at 116 r.p.m., constructed by the Wallsend Slipway and Engineering Co., Ltd., Wallsend-on-Tyne. Speed, 14 knots. Trial trip, January 27.

M.S. "MERCHANT BARON."—Single-screw oil tanker, built by the Furness Shipbuilding Co., Ltd., Haverton Hill, County Durham, for the Drake Shipping Co., Ltd. (Managers: Lykiardopulo & Co., Ltd.), London, E.C.3. Main dimensions: 525 ft. between perpendiculars by 71 ft. by 39 ft. 3 in.; deadweight capacity, about 18,025 tons on a draught of about 30 ft. 5½ in.; oil-carrying capacity, about 17,250 tons. N.E.M.-Doxford six-cylinder two-stroke opposed-piston oil engine, developing 6,800 b.h.p. at 119 r.p.m., constructed by the North Eastern Marine Engineering Co. (1938), Ltd., Wallsend-on-Tyne. Speed, 15 knots. Launch, January 29.

S.S. "ROMERAL."—Single-screw ore-carrying vessel, built and engined by William Gray & Co., Ltd., West Hartlepool, for the Compañía Sud-Americana de Vapores, Valparaíso, Chile. Second vessel of two. Main dimensions: 415 ft. between perpendiculars by 57 ft. 6 in. by 34 ft. to upper deck; deadweight capacity, 9,465 tons on a draught of 25 ft. 9½ in. Triple-expansion steam engine and two forced-draught oil-fired boilers, developing 1,835 i.h.p. at 69.5 r.p.m., constructed at the builders' Central Marine Engine Works. Service speed, 10½ knots. Trial trip, February 4.

M.S. "GLENMOOR."—Single-screw cargo vessel, built and engined by R. and W. Hawthorn, Leslie & Co., Ltd., Hebburn-on-Tyne, County Durham, for the Moor Line Ltd. (Managers: Walter Runciman & Co., Ltd.), Newcastle-upon-Tyne, 1. Main dimensions: 423 ft. between perpendiculars by 58 ft. by 29 ft. to upper deck; deadweight capacity, about 9,350 tons on a draught of 25 ft. 8½ in.; gross tonnage, 5,850. Hawthorn-Doxford four-cylinder oil engine, developing 3,300 b.h.p. at 108 r.p.m. in service. Speed, about 13 knots. Trial trip, February 17.

### BOOKS RECEIVED.

*Aerodynamics of Propulsion.* By DR. DIETRICH KÜCHEMANN and DR. JOHANNA WEBER. McGraw-Hill Publishing Company, Limited, 95, Farringdon-street, London, E.C.4. [Price 64s. 6d.]

*University of Illinois. Engineering Experiment Station. Bulletin Series No. 400. Almost Sinusoidal Oscillations in Nonlinear Systems. Part II: Synchronisation.* By PROFESSOR JOHANNES S. SCHAFFNER. [Price 25 cents.] No. 401. *Comparative Performance of a Warm-Air Ceiling Panel System and a Convection System.* By PROFESSOR ROBERT W. ROOSE and others. [Price 80 cents.] No. 402. *A Study of the Practical Efficiency under Static Loading of Riveted Joints Connecting Plates.* By PROFESSOR WILBUR M. WILSON, PROFESSOR WILLIAM H. MUNSE, and M. A. CAYCI. [Price 75 cents.] The Director, Engineering Experiment Station, University of Illinois, Urbana, Illinois, U.S.A.

*The Measurement of Particle Size in Very Fine Powders.* By DR. H. E. ROSE. Four Lectures Delivered at King's College, London. Constable and Company, Limited, 10, Orange-street, London, W.C.2. [Price 9s. net.]

*Ministry of Transport. Tramway Accidents. Report on the Collision which Occurred on 4th September, 1952, between Two Trams at Oakwood, Leeds.* H.M. Stationery Office, Kingsway, London, W.C.2. [Price 2s. net.]

### TRADE PUBLICATIONS.

*Rubber Goods.*—The Milestone Rubber Co. Ltd., 167, St. John's-hill, Battersea, London, S.W.11, have issued a trade price list of their general domestic and industrial rubber goods.

*Aluminium Paste Pigments.*—We have received from the Northern Aluminium Co., Ltd., Bush House, Aldwych, London, W.C.2, an illustrated technical publication entitled "Noral Alpaste," describing the manufacture, characteristics and applications of Alpaste paints and printing inks. Three grades of Alpaste are available, a standard grade for paint, a fine grade for the preparation of silver ink, and an extra-fine grade for printing, which is, however, less resistant to atmospheric corrosion than the other two grades.

*Sectional Belt Conveyor.*—British Jeffrey-Diamond, Ltd., Stannard Works, Wakefield, Yorkshire, have issued an illustrated leaflet describing their 52-B sectional belt conveyor, which is made in three widths for belts 26 in., 30 in., and 36 in. wide, and which can be supplied with a 30-h.p. or 60-h.p. motor. The speed range is from 175 to 420 ft. per minute.

*Breathing Apparatus.*—We have received from Siebe, Gorman & Co. Ltd., Tolworth, Surbiton, Surrey, an illustrated brochure describing the several types of self-contained oxygen or compressed-air breathing apparatus that they make; notes on the selection and use of such appliances are included in the brochure.

*Temperature-Control Apparatus.*—Sunvic Controls Ltd., 132, Long-acre, London, W.C.2, have sent us a pamphlet describing switches, regulators, thermostats, relays and thermometers for use in laboratories and industries.

*Flameproof Air-Break Circuit-Breakers.*—The flameproof air-break circuit-breaker, which is made by them for currents of 200 amperes at voltages up to 650 volts alternating current, is described in a leaflet received from the Belmos Co. Ltd., Belshill, Lanarkshire.

*Hydro-Electric Plant in New Zealand.*—A pamphlet received from the English Electric Co. Ltd., Marconi House, 336, Strand, London, W.C.2, describes the 35,000-h.p. hydro-electric station at Tekapo, New Zealand, for which they supplied the plant and equipment.

*Electric Water Heaters.*—A catalogue dealing with their electrode water heaters has been received from G.W.B. Electric Furnaces Ltd., Dibdale Works, Dudley, Worcestershire. Automatically-controlled patterns are made with loadings up to 1,000 kW and hand-operated types with loadings up to 3,100 kW.

*Control of Spreader Stokers.*—Details of their automatic control system, for use with "spreader" stokers are given in a leaflet issued by Bailey Meters and Controls, Ltd., Progress Way, Croydon, Surrey.

*Selenium Rectifiers.*—The dimensions and weights of their SenTerCel spindle-mounted rectifier stacks, together with the coding system used to describe them are given in detail in a booklet received from Standard Telephones and Cables, Ltd., Aldwych, London, W.C.2.

*Unit Construction for Line Transmission Equipment.*—A bulletin issued by Automatic Telephone and Electric Co., Ltd., Strowger Works, Liverpool, 7, describes and illustrates the application of their unit construction system to the design and manufacture of line transmission equipment for telephone and other communication systems.

*Aerodynamic Dust Collector.*—A catalogue giving details of dust collectors and information on methods of measuring dust-particle size has been published by Musgrave & Co., Ltd., St. Ann's Works, Belfast, Northern Ireland.