DEVELOPMENT OF A 750-KW GAS TURBINE FOR INDUSTRIAL USE.

SEVERAL industrial gas turbines made by Ruston and Hornsby, Limited, Lincoln, will go into service this year in England and the Middle East. They will be of the Mark TA design, developed during the past three years from the firm's original 750-kW gas turbine, and will be "batch produced" at the Lincoln works. The significance of this information lies in the fact that "users rarely like to be the first to use a new design . . . on the other hand, very few users like to be the last"—to quote from a Letter to the Editor which appeared in our issue of February 20. The work that Ruston and Hornsby, Limited, have carried out in the gas-turbine field since the war has now well justified itself, technically and commercially.

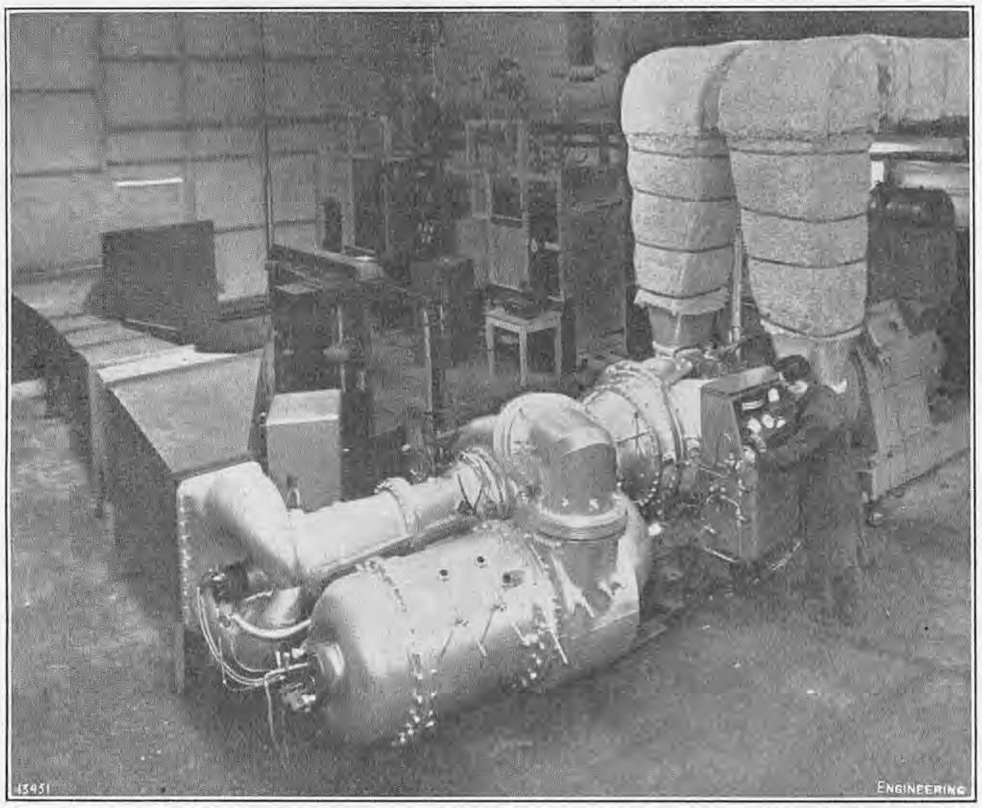


FIG. 1. RUSTON "TA" GAS TURBINE.

The first production Mark TA units include three for the Air Ministry, one with a heat exchanger and two without. They will be coupled to 3·3-kV 50-cycle alternators and will burn any distillate fuel oil. The turbine and alternator will be mounted on a combined base and arranged to break into three separate components, each with rollers for wheeling into an aircraft and flying to a site. The Kuwait Oil Company, Limited, have ordered a TA gas turbine without heat exchanger, with a tropical rating of 900 brake horse-power and arranged to burn natural gas. It will be coupled to a multi-stage pump for pumping crude oil from the Kuwait gathering centre to the coast, where the oil is loaded on tankers. Another TA turbine, with heat exchanger and a 440-volt 50-cycle alternator, is to be supplied to the Admiralty for research work on the combustion of residual fuel oil. The Crittall Manufacturing Company, Limited, have ordered a TA machine without heat exchanger, but exhausting into a waste-heat boiler, the output of which will be used for process work and space heating. It will be coupled to an 11-kV alternator, and, by means of auxiliary oil burners in the boiler, heat requirements in excess of the turbine output will be met during the winter. A by-pass duct in the turbine exhaust will enable the turbine and boiler to be used independently of each other. A seventh TA turbine, the destination of which is not yet disclosed, has a heat exchanger and is coupled to an 11-kV alternator, and its exhaust gases are ducted to a waste-heat boiler. The turbine burns coal-tar fuel and produces power and process heat, control of the heat output being achieved by fitting a heat exchanger. As the heat required from the boiler is reduced, larger quantities of the turbine exhaust are passed through the heat exchanger, the outlet from which is also ducted to the boiler, so maintaining a high overall efficiency even though the heating load is reduced.

These current applications are typical of the duties for which the TA turbine has been developed. It can be used for base-load generation or as a standby unit, and it is particularly suitable for waste-heat recovery applications. Its light weight and the fact that it can be used without heavy foundations enhance its value for many applications, especially overseas, and, of course, being a gas turbine, it requires no cooling water, and its versatility is correspondingly extended. It is also very quick starting from cold and the range of fuels it will burn is likely to be extended in the future. When running with a heat exchanger, the TA turbine is rated at 750 kW, but in the non-recuperative form its maximum rating is 1,000 kW. The principal features of the design include a single combustion chamber (the original Ruston machine had twin combustion chambers*), novel and extensive cooling arrangements, and an elbow combustion chamber in which the turbulence due to the right angle improves combustion.

The TA gas turbine is illustrated in Fig. 1, herewith, in its non-recuperative form, and a longitudinal section of it is given in Fig. 4, on Plate VII. In designing it attention has been paid to ease of maintenance, economy and batch production, as the thermodynamic performance of the prototype machine proved so satisfactory that no major changes were required. Structurally, it consists of two self-contained units; the gas generator (or charging set), consisting of the compressor and compressor turbine; and the power turbine and gearbox unit. Each of these units is completely "vertebrate"—the rotors and stators of the compressor and turbines being located, relatively to each other, by short internal structural paths and not through the bedplate. Normal installations can, therefore, be completed very rapidly, and in portable applications no damage can arise if the plant is supported unevenly. The standard gearbox has been arranged to provide different output speeds, including 1,500 and 1,800 r.p.m., suitable respectively for 50-cycle and 60-cycle alternators, and a direct drive from the turbine can also be provided at 6,000 r.p.m.—a speed suitable for rotary air or gas compressors.

* See ENGINEERING, vol. 169, page 85 (1950).

RESEARCH LEADING TO MARK TA DESIGN.

The most fruitful source of data for the design was the experience gained with the orginal 750-kW gas turbine, which has completed over 3,000 hours' running on a variety of fuels. The earlier part of this testing has already been reported, in "Operating Experience with a 750-kW Gas Turbine," a paper by G. B. R. Feilden, M.A., M.I.Mech.E., presented to the Diesel Engine Users Association on March 15, 1951. Subsequent experience included a 700-hour non-stop run, and tests in which the twin combustion chambers originally fitted were replaced by a single Ruston elbow combustion chamber. Concurrently with the engine tests, a programme of rig tests was carried out on a number of aerodynamic and mechanical features intended for use in the TA machine. One of the prime considerations in the design of the ducts was to enable these to be phased round radially to suit a wide variety of installations. This involved some changes to the structural design and a modified compressor inlet duct was tested aerodynamically. The single combustion chamber necessitated a single outlet duct from the compressor and a single entry duct to the high-pressure turbine. Both of these were model-tested (Fig. 2, on page 322, shows the model for the compressor-turbine inlet duct) and a redesigned power turbine outlet duct, arranged to give free access to the gearbox without removal, was also developed.

The compressor and turbine blade sections were tested in a large-scale cascade in a slow-speed wind tunnel to determine the deflection and loss over a range of incidence. A model turbine blade has been made for measuring the chordwise variation in pressure on the upper and lower surfaces. This will permit the development of "breakaway" to be studied. The modes and frequencies of vibration of the TA compressor and turbine blades have been investigated using a crystal vibrator. A number of fuel pumps have been rig-tested for periods up to 500 hours, in addition to longer running tests on the engines, because the duty required is somewhat different from those for which commercially available pumps have been designed. Testing is now in hand on boiler oils. The first TA engine has completed its initial test series and an endurance test will shortly begin. The efficiency has proved to be better than was assumed in the design.

COMBUSTION.

Design and development work on elbow combustion chambers commenced in 1945. Fig. 3, on page 322, shows the latest chamber to be built, which is suitable for a TA engine. This design takes advantage of the fact that many industrial gas-turbine layouts have at least one right-angled bend between the compressor exit and the turbine inlet, particularly when a heat exchanger is fitted, and this bend produces a pressure loss, due to turbulence, which might well be controlled and utilised to assist combustion. The entry is rectangular in cross-section, and a supply of air is taken off for primary combustion. This air is distributed evenly through an annular throat formed between the thistle-shaped bowl and the conical diffuser, thus producing a ring vortex as shown. The location of the burner minimises the amount of heat it picks up, and also gives good access. The fuel spray is arranged so that its path is in the opposite direction to that of the incoming air in order to give high scrubbing velocity and good mixing. Combustion is initiated in the primary bowl and proceeds in the diffuser.

The dilution air is deflected into left-hand and right-hand vortices (one of which is shown in Fig. 3) by a centrally-placed adjustable cut-water in the remaining portion of the rectangular entry. These vortices ensure gradual dilution without chilling, since the centrifugal tendency is to throw the cold air on to the flame-tube wall, thus giving a measure of internal cooling. However, the inter-action of the two opposing vortices gradually reduces the strength of the centrifugal field until it finally breaks down into large-scale turbulence and gives good mixing, a good outlet-temperature distribution and little residual swirl. Originally, for atmospheric testing and also for pressure testing on small-scale models, no outer casing was fitted. Such a construction would be satisfactory for small engines, but for larger chambers a pressure-carrying casing of mild steel was incorporated, and some of the air was allowed to pass through the annular space between the two casings at relatively low velocity to act as insulation. In the heat-exchanger engines this air is likely to reach temperatures of 750 deg. F. before admission, and so a lagging-filled metal box has been fitted inside the pressure casing. This serves the dual purpose of being a radiation shield and an insulator, so reducing the heat flow to the outside.

The combustion chamber has been developed to operate on a variety of boiler oils, including the Admiralty reference fuels "Mothball" and "Tarmac," which it will burn satisfactorily. Later development work has centred on the case of an engine where no heat exchanger is fitted and the combustion-chamber inlet temperature is that of the compressor exit. Satisfactory combustion can be obtained under these conditions, with minor adjustments to the various settings. However, the problems of using boiler oils in gas turbines do not centre around the combustion chamber.

More recently work has been devoted to the combustion of other fuels, and tests have shown that relatively pure methane produces little difficulty apart from the fact that the stability limits obtainable in practice are not as wide as with liquid fuels in heterogeneous dispersion. Other tests have been carried out on a gas containing 24 to 27 per cent. carbon monoxide, 2 per cent. hydrogen, and the remainder incombustible, giving a calorific value of about 85 to 95 B.Th.U.'s per cubic foot, and these have shown that such a gas can be burnt satisfactorily in a combustion chamber of the elbow type, though the burner arrangements have to be amended appreciably owing to the greater volume of fuel gas. Dual-fuel operation is possible with this combustion system. Investigations are being carried out on various types of air-blast and air-assisted burners, the latter incorporating a fairly normal fuel swirler in addition to the air blast. It is hoped in this way to extend the range of fuel flows over which satisfactory atomisation can be obtained without using a high pressure, which is of particular importance when coal-tar fuels have to be pumped.

A major item of long-term research in hand at the present time is an investigation, on the original 750-kW machine, into the problems of burning boiler oils. Tests have been carried out to determine the rates of corrosion and deposition experienced by the highest temperature blading, and work has lately turned to the use of additives to inhibit either corrosion or deposition, or both. The co-operation of Government research establishments and of various private firms has been of great assistance. The programme envisaged is fairly long and no results can be made available at present, but tests now being carried out are intended to check the

750-KW INDUSTRIAL GAS TURBINE.

RUSTON & HORNSBY, LTD., LINCOLN.

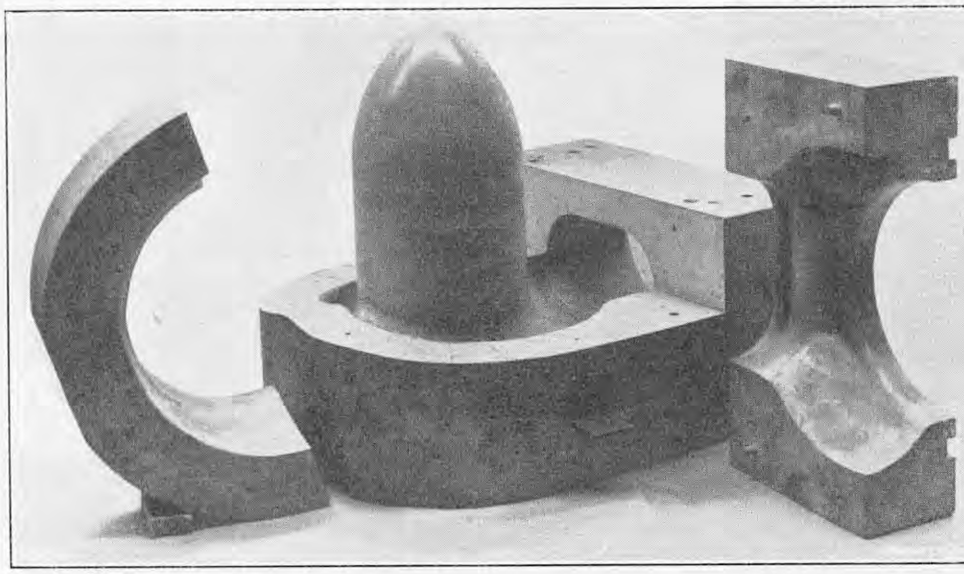
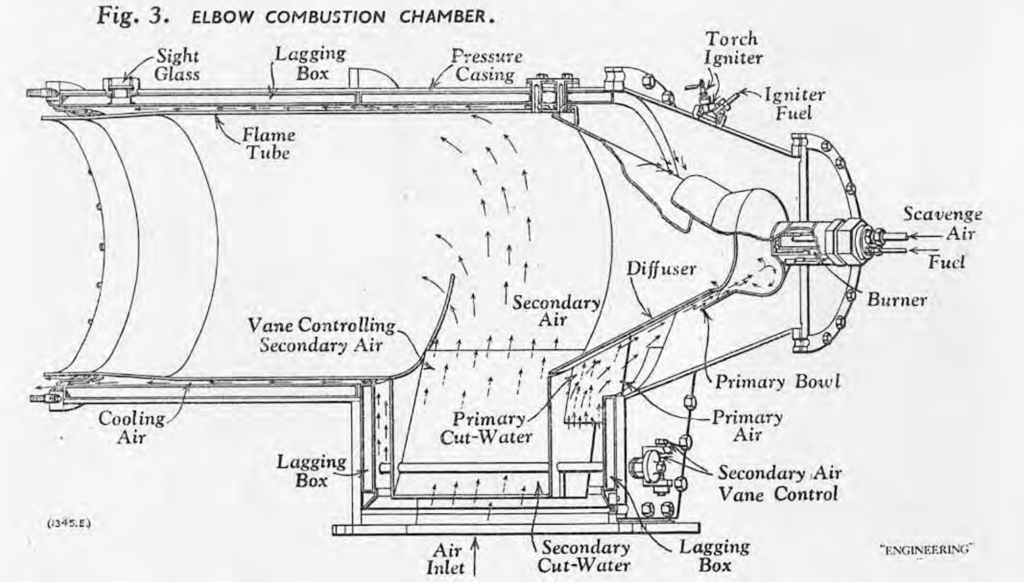


FIG. 2. TEST MODEL OF COMPRESSOR-TURBINE INLET DUCT.

Fig. 3. ELBOW COMBUSTION CHAMBER.



results of laboratory experiments and solve the practical difficulties of full-scale operation. A turbine rig is being built to run on water instead of air in order to reduce the power required. This rig is intended to be used in connection with future designs of turbine blading and it is hoped that the three-dimensional nature of the flow will give complementary data to those already obtained on the wind-tunnel cascade tests. Work is also being carried out on cooled turbines, including the use of sweat-cooled metal walls. In addition, a slip-ring unit is being used to measure the temperatures of turbine discs and blades on an engine under power.

THE MARK TA GAS TURBINE.

The Mark TA is the first gas turbine to be put into series production by Ruston and Hornsby, Limited. The first two machines have been completed and subsequent units are in an advanced stage of construction.

An analysis of the requirements which had led to inquiries for Ruston gas turbines showed that, to be able to standardise the main turbine components, it must be possible to operate both with and without a heat exchanger, and also to assemble the main ducts at inlet and exit from the compressor and turbines facing in any direction. These requirements have been successfully attained; it is possible to phase the ducts round the centre line in steps of 15 deg. On the original turbine, the twin combustion chambers showed a tendency to instability between the outlet temperatures of the two chambers. To avoid this difficulty, and to simplify the design, a single combustion chamber has been adopted.

It will be seen from Fig. 4 that the only connection between the gas-generator section of the plant and the output turbine unit is a short annular gas duct. One end of this duct is rigidly bolted to the power-turbine stator, while at the other end a piston-ring joint allows for axial and radial expansion. The gas generator is positively located by a double pin joint at the turbine end, and the front of the compressor is supported by a resilient plate which accommodates the small axial expansion of the unit relative to its under-bed. Fig. 1 shows the arrangement applicable to those sites where the turbine is required to be installed entirely above ground level. It will be seen that the combustion chamber is mounted alongside the compressor casing —a layout which provides excellent accessibility for all components. A small cubicle on the under-bed contains the turbine starting and running controls and all instruments for checking the operation of the plant in service. For the TA design, a new type of exhaust duct was developed, based on the results of a series of model tests. In this duct, a satisfactory combination has been achieved of low pressure loss with a duct shape which leaves the casing of the reduction gear fully accessible. The

750-KW GAS TURBINE

RUSTON & HORNS

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Fig. 4.

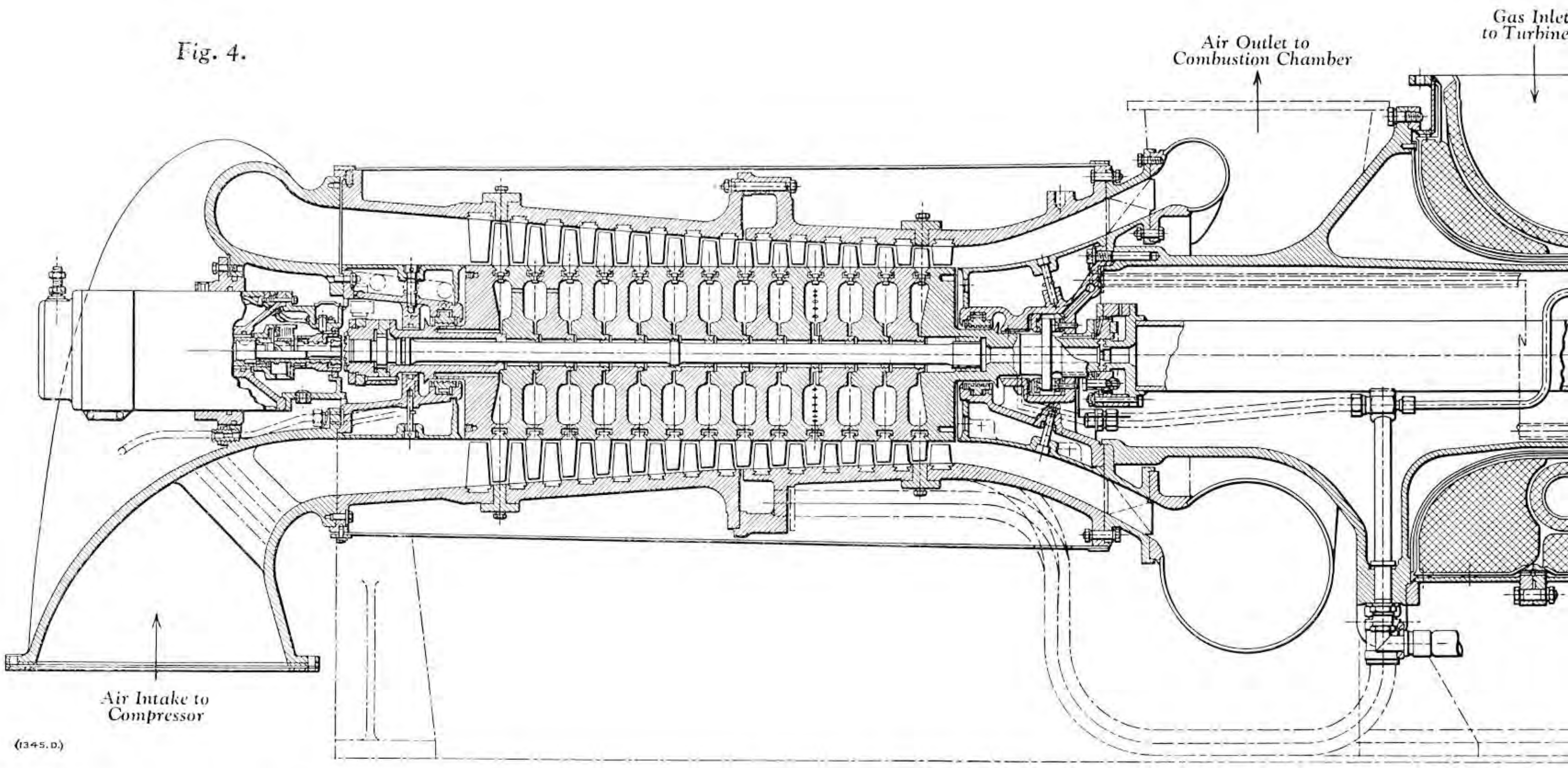

Fig. 5. Inner Lining of Louvre-Wall Combustion Chamber.

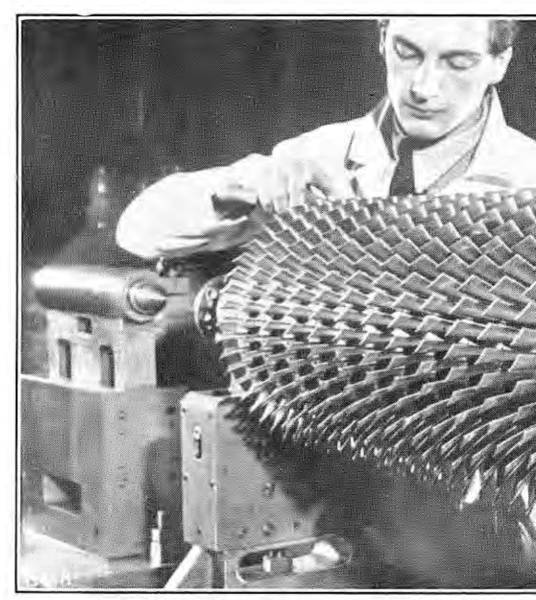

Fig. 6. De-Burring Bl

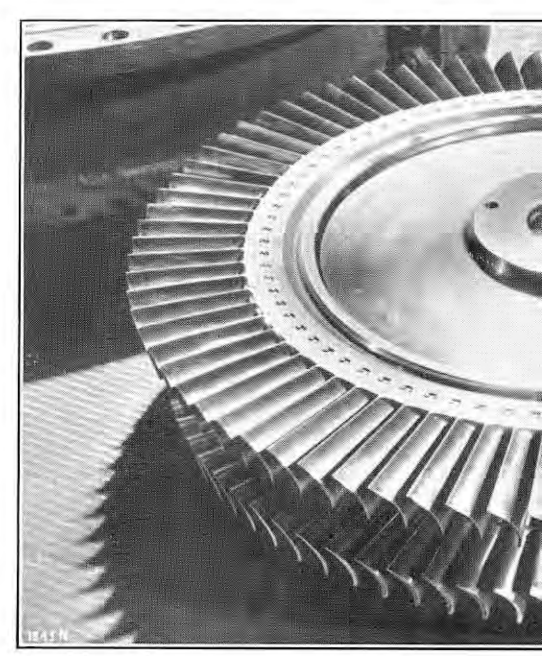

Fig. 7. Rotor o

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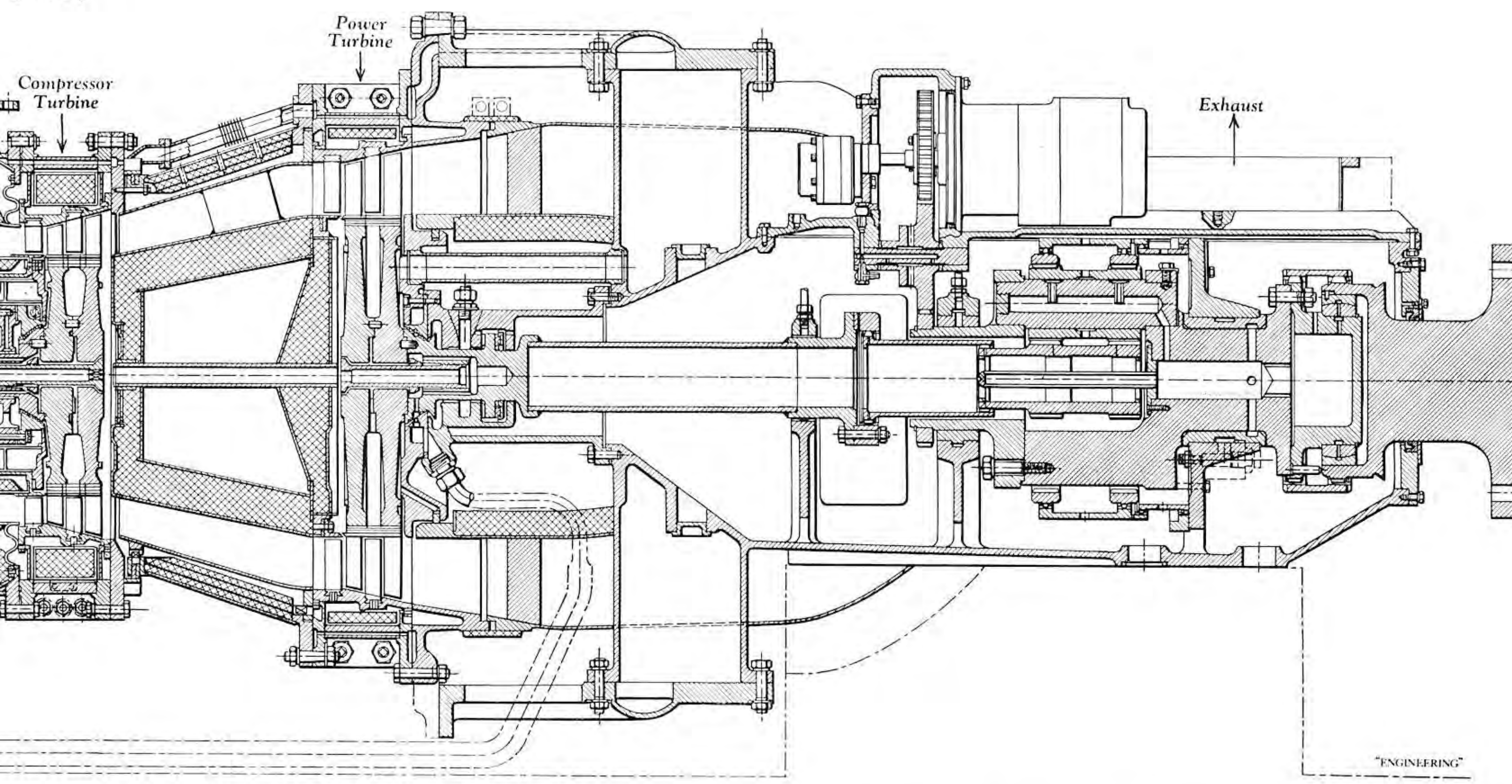

S OF COMPRESSOR ROTOR.

RESSOR TURBINE.

FIG. 8. POWER TURBINE; TOP-HALF STATOR CASING REMOVED.

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complete gear train may be removed for inspection through the opening at the top of the gear casing without disturbing the turbine, ducting or driven machinery.

The 13-stage axial-flow compressor is identical in aerodynamic design and in its basic mechanical construction to that fitted on the original Ruston gas turbine. The compressor rotor is shown in Fig. 6, on Plate VII. Detailed improvements have been made in the air-inlet casing, which is now in the form of a single-piece casting which can be phased round to any of 24 positions as already explained. By lifting the top half of the compressor stator casing, the blading and bearings are exposed, and the compressor rotor can be lifted for inspection without disconnecting any ducting. At the front end of the compressor rotor, "saw-tooth" dogs have been provided for the engagement of the starter motor. Where battery starting is employed, the motor is mounted directly on the end of the compressor inlet casing, as shown in Fig. 4, and a similar arrangement can be adopted for compressed-air starting. For starting from a 400-volt alternating-current system, an identical drive arrangement is used, but the motor, being more bulky, is mounted on the turbine under-base, and transmits its power to the compressor shaft by a duplex chain running in an oil bath. At the delivery end of the compressor, a curved diffuser passage has been used, from which the air is collected in a spiral duct. Spanning the entry to this duct, a number of turning vanes have been fitted.

As the single combustion chamber is an external part of the turbine, it is a simple matter to change it to suit different operating requirements. The first TA turbines are each fitted with a Shell louvre-wall combustion chamber (the inner lining of which is shown in Fig. 5, on Plate VII), but the Ruston elbow combustion chamber is being fitted to a number of subsequent units. With the Shell combustion chamber, a reverse-flow arrangement has been adopted: the burning gases flow in the opposite direction to that of the incoming air from the compressor. This reduces the external ducting to a minimum and leaves the atomisers in an accessible position at the end of the combustion chamber. By using a new design of burner mounting, it is possible to change the burners while the plant is under load. Both the Shell and Ruston combustion chambers are suitable for operating with or without a heat exchanger, and are satisfactory for a wide range of fuels from natural gas to heavy boiler fuels.

Each turbine is secured to its shaft by a high-tensile steel bolt having a conical head recessed into the disc profile. This construction removes all excrescences and permits the use of a single-piece connecting duct between the turbines, which can quickly be slid out of position after the top half of the power-turbine stator has been removed. The discs in both turbines are machined from a high-chromium ferritic steel, and all turbine blades are machined from Nimonic 80A bar. The rotor blades are secured by fir-tree serrations, the form of which is identical for both the compressor and the power turbines, except that one additional serration is used to carry the load of the larger blades used in the power turbine. The rotors of the compressor turbine and the power turbine are shown in Figs. 7 and 8, on Plate VII.

COOLING SYSTEM.

The cooling arrangements, particularly for the turbine stator, which were adopted in the first Ruston gas turbine were novel, and proved to have important advantages in operation, not the least of which is that it is possible to start the turbine and place it on load regularly in a very short time, without any damage being sustained by the rotors, or distortions developing in the stators. In the Mark TA, even more extensive use has been made of the principles applied to the original machine; all parts of the machine between the combustion chamber and the final exhaust are now made in a double-skin cooled construction. Cooling air is bled from the compressor at three points. A low-pressure flow from the annulus opposite the eighth-stage rotor blades is the principal feed, supplying air for cooling the high-pressure turbine inlet casing and both turbine stators, as well as for cooling the power-turbine rotor. The feeds for these points are shown in chain-dotted lines in Fig. 4. In addition, a small high-pressure air feed is led by a straight internal pipe from the compressor outlet to the front face of the high-pressure turbine disc. This flow escapes over the turbine blade roots and, by forming a boundary layer of cold air round the periphery, substantially reduces the rate of heat transfer into the turbine discs. A further cooling-air feed taken from the eleventh-stage rotor blades passes down the compressor rotor and through the hollow cardan shaft which connects this to its turbine. Here, it divides into two flows, one of which passes between the turbine discs and escapes over the roots of the second-stage rotor blades, thus reinforcing the boundary layer of cold air provided by the high-pressure feed just mentioned. The remainder of the air passing down the turbine shaft flows through the hollow turbine-securing bolt and provides a cooling blanket over the rear face of the high-pressure turbine.

By using three separate air feeds from different stages in the compressor, as described, the lowest pressure necessary to circulate the cooling air is used in each case, thus resulting in the minimum loss of power. Some of the power expended in compressing the cooling air which passes through the higher pressure feeds is recovered when the air expands through the subsequent stages of the turbines.

REDUCTION GEAR.

As in the original Ruston gas turbine, an epicyclic reduction gear is used, the internal components of which have been designed and made by W. H. Allen, Sons and Company, Limited, Bedford. The drive is taken from the power turbine through a welded tubular shaft and a flexible muff coupling to a hardened and ground double-helical sun-wheel, which is fully floating. Three hardened and ground planet gears mesh with the sun-wheel and with two flexibly-mounted annuli. As a result of this arrangement, which is due to Mr. W. K. Stoechicht, perfect load-sharing is assured between the three planet gears and between the two helices. The planet assembly of the gear is mounted on two white-metal lined bearings. At the output end of the gear, a bearing of massive proportions has been provided; it has sufficient area to support half the weight of the heaviest driven machinery to which the turbine is ever likely to be connected. Normally, when the driven machinery is a generator, a single pedestal bearing only is required, which is placed on the side remote from the turbine. To prevent any bending moment due to inaccurate lining-up between the two bearings in the reduction gear and this pedestal bearing, a lubricated flexible coupling is included as a standard feature; its construction is shown at the right-hand end of Fig. 4. In those cases where the driven machine has two bearings, the flexible coupling just mentioned is retained, and a further coupling is fitted adjacent to the driven machinery, thus providing a fully-floating cardan shaft.

The turbine auxiliaries, comprising lubricating-oil pump, fuel pump, governor, emergency overspeed governor, tachometer and hours counter, are driven from the front extremity of the planet assembly by the spur-gear train shown in Fig. 4. In cases where the output speed is 1,500 r.p.m. or 1,800 r.p.m., this train has a ratio of 1 : 1, so that the auxiliaries run at the same speed as the driven machinery. Where direct drive at 6,000 r.p.m. is required, a single-helical reduction train of 4 : 1 ratio is mounted on the standard idler gear, thus providing a drive at 1,500 r.p.m. for the auxiliaries, and avoiding the need for any change in their design. The design of the reduction gear makes it readily accessible, and the whole of the running gear can be lifted out of the casing without disturbing the driven machinery or the output turbine, by simply removing the top cover and disconnecting the input and output flexible couplings.

CONTROL SYSTEM.

For standby or portable plants, speed and ease of starting are important, and a control unit has therefore been designed which can be made fully automatic for these applications, or manually controlled for installations where automatic starting is not required. This starting control brings the turbine from rest up to its running speed, after which the speed or load is under the control of the turbine governor. Owing to the variety of fuels for which the turbine is already being supplied, the construction of the control unit and governor is such that, by substituting relatively few parts, either unit can be adapted to handle any of these fuels. Since the main fuel and lubricating-oil pumps are mechanically driven from the gearbox, auxiliary electrical pumps are required for starting. For most portable applications, starting power is provided by batteries supplying the main starter motor, the auxiliary pump motor and the combustion-chamber spark igniter; for permanent installations, however, alternating current is usually available, and suitable motors can be substituted without any change in the control unit.

The control unit consists of a fuel control section and an electrical switching section, both of which are actuated simultaneously either by a handwheel or, in the case of automatic units, by a constant-speed motor. Basically, the fuel section is an adjustable relief valve, the spring of which is compressed by a plunger actuated by the turbine lubricating oil. In its movement, this plunger successively uncovers ports leading to the igniter and the main burner, supplying fuel to these points at the appropriate stages of the starting cycle. No movement of the plunger can take place until the lubricating-oil pressure has reached 10 lb. per square inch, thus providing a safeguard against failure of the lubricating-oil system. Should such a failure occur while the turbine is running, springs return the plunger to its initial position, where it actuates a contact which switches on the motor driving the auxiliary lubricating-oil pump, thus ensuring a supply of lubricant to the bearings while the rotors run down to rest. The speed governor is of the centrifugal type and operates through a hydraulic servo mechanism, which varies the pressure of fuel, whether liquid or gaseous, supplied to the combustion chamber. The speed-load characteristic of the governor can be adjusted from isochronous control, which is often preferred where the set is running as an isolated unit, to the droop characteristic which is appropriate where a number of power units are operating in parallel. This adjustment is made by a screw on the governor body, even while the turbine is under load.

As in the starting control, the governor fuel control is spring-biassed so as to be inoperative when the lubricating-oil pressure falls below 10 lb. per square inch. If a slight reduction from its normal value of 20 lb. per square inch occurs in the lubricating-oil pressure, the governor is arranged so that it is impossible to obtain the maximum fuel throughput corresponding to full load, though the set will operate normally at lower loads, unless a further fall of lubricating-oil pressure takes place. Thus, as a result of these safeguards, ample warning is given if any defect is developing in the lubricating system, and effective protection is provided against accidental damage to the turbine bearings or reduction gear from this cause.

ELECTRIC-TRACTION BRAKING.—II.*

By T. F. Wall, D.Sc., M.I.E.E.

The energy involved in braking a train running on a level track is characterised by the fact that the retardation due to braking is obtained by the expenditure of a relatively small amount of energy during a short period of time, that is to say, by means of energy transformation at high power. In the case of braking a train on an incline, the characteristic feature is the transformation of a large amount of energy during a comparatively lengthy period, that is to say, by means of energy transformation at low power.

Numerical Examples.—An express train on a level track, and of the total weight of 750 metric tons, is required to slow down from an initial speed of 120 km. per hour by a retardation of 0·7 metre per second², and it is required to find what the initial expenditure of power will be. The procedure is as follows:

750 metric tons† $= 750 \times 10^3$ kg., and, for convenience, this will be denoted by m. 120 km. per hour $= \dfrac{120 \times 10^3}{3{,}600} = 33{\cdot}3$ metres per second, and, for convenience, this will be denoted by v.

The stored kinetic energy is therefore,

$$\tfrac{1}{2}\, m\, v^2 \text{ joules} = \tfrac{1}{2}\, \frac{m\, v^2}{3{\cdot}6 \times 10^6} \text{ kWh.},$$

and, if the given numerical values for m and v are inserted, it is found that,

$$\tfrac{1}{2} \times \frac{750 \times 10^3 \times 33{\cdot}3^2}{3{\cdot}6 \times 10^6} = 116 \text{ kWh.}$$

The retarding force is,

$$\frac{(750 \times 10^6) \text{ gm.} \times (70 \text{ cm. per sec.}^2)}{981} \text{ gm.},$$

that is,

$$53{,}500 \text{ kg.} = 53{\cdot}5 \text{ metric-tons.}$$

The initial expenditure of energy will then be

$$53{\cdot}5 \times 10^3 \times 33{\cdot}3 \text{ kg. m. per sec.},$$

and, since 1 kW is equal 102 kg. m. per second, the initial expenditure of energy will be 17,500 kW. If the rail-track friction and windage are taken into account, this result will be reduced to about 16,300 kW.

It will now be assumed that the train specified in the previous example is running down an incline at a constant speed of 60 km. per hour and that the gradient is 25 per 1,000. If the incline is 10 km. in length, it is required to find the braking power.

From the given data and the diagram Fig. 4, it is known that,

$$\sin \alpha = \frac{h}{l} = 0{\cdot}025$$

so that

$$h = 0{\cdot}025\, l = 0{\cdot}025 \times 10^3 \text{ metres};$$

that is $h = 250$ metres.

The potential energy of the train when it is at the head of the incline is

$$750 \times 10^3 \times 250 = 187{\cdot}5 \times 10^6 \text{ kg. m.},$$

and since 1 kg. m. $= 9{\cdot}81$ joules, the initial potential-energy of the train is $187{\cdot}5 \times 9{\cdot}81 \times 10^6$ joules, that is, $1{,}820 \times 10^6$ joules or, noting that one kWh $= 3{\cdot}6 \times 10^6$ joules, it follows that, the potential energy of the train will be 511 kWh; or if the rail-track friction and windage are taken into account, the available potential energy will be about 410 kWh.

The time required for the train to reach the end of the incline will be,

$$t = \frac{10 \text{ km.}}{\left(\dfrac{60}{3{,}600}\right) \text{ km. per sec.}} = 600 \text{ sec.}$$

The required uniform braking action throughout the descent of the incline, will therefore be

$$\frac{dv}{dt} = \frac{410 \times 3{,}600 \text{ kW sec.}}{600 \text{ sec.}} = 2{,}460 \text{ kW.}$$

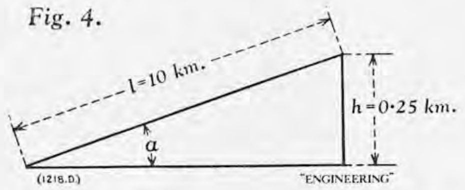
Some idea of the large amount of energy involved in such braking operations can be obtained from the following data.

The type of railway operation for which the greatest amounts of braking energy are involved, is that of a suburban railway system in which high speeds are attained associated with frequent braking. Thus, in the case of the Berlin Suburban Railway, the data for 1937 showed that the braking energy expended was 121×10^6 kWh, and this amount corresponds to 13,800 kW continuously in operation throughout the whole year or, expressed in terms of coal consumption, this energy corresponds to the utilisation of 87,000 tons of coal per annum. Thus, if 1 kg. of coal has a heat value of 5,600 kilogram-calories, the above stated amount of energy expenditure, viz., is equal to

$$\frac{121 \times 10^6 \times 860}{5{,}600} \text{ kg.},$$

or 18,600 tons of coal.

Fig. 4.



If the coal had a heat-value of only 1,200 kg.-calories per kilogramme, the wastage of coal corresponding to the braking operation would be

$$\frac{5{,}600}{1{,}200} \times 18{,}600 = 87{,}000 \text{ tons per annum.}$$

These data will be sufficient to show the practical importance of the braking problem in railway operation.

In general, the energy involved in braking can be expressed by the following equation:

$$\text{Energy U} = \left[\tfrac{1}{2}\, \frac{G \times (1 + p) \times 10^3 \times v^2}{9{\cdot}81} - w\, G\, l\right] \text{ metre-kg.}, \quad (2)$$

where v m. per second is the speed at the start of the braking period, w kg. per ton weight of train is the retarding force of wind and rail-friction (in practice, the value of w is from 4 to 6 kg. per ton), p is the percentage addition to take account of the kinetic energy of the rotating parts, l km. is the distance over which the braking-action takes place, and G metric tons is the mass of the train.

The fundamental equation which defines the retarding force when braking takes place on a level track is:

Retarding force $Q_{\text{kg.m.}}$

$$= \frac{10^{-3}\, (G \times 10^6) \times \begin{pmatrix}\text{Retardation,} \\ \text{cm. per sec.}^2\end{pmatrix}}{981},$$

or, when expressed in metres per second²,

$$Q_{\text{kg.m.}} = \frac{10^{-3} \times 10^2 \times 10^6 \begin{pmatrix}G \times \text{Retardation,} \\ \text{m. per sec.}^2\end{pmatrix}}{981},$$

For convenience, writing b for the retardation in metres per second,²

$$Q_{\text{kg.m.}} = \frac{G \times 10^3 \times b}{9{\cdot}81}, \quad . \ (3)$$

and the retardation force due to rail friction and windage as given above, viz.,

$$(w \times G) \text{ kg.}, \quad . \ . \ (4)$$

Then the retarding force which must be provided by the braking appliance will be the difference between expressions (3) and (4), viz.,

$$\frac{G \times 10^3 \times b}{9{\cdot}81} - w\, G. \quad . \ (5)$$

When the rail friction and windage are taken into account, therefore, the applied retarding force must be:

$$G\left(1 - \frac{9{\cdot}81\, w}{10^3\, b}\right)\frac{10^3 b}{9{\cdot}81} \text{ kg.} \quad (6)$$

A comparison between expressions (3) and (6) shows that when rail friction and windage are taken into account, the "equivalent mass" may be written

$$G\left(1 - \frac{9{\cdot}81}{10^3\, b}\, w\right) 10^3 \text{kg.} \quad . \ (7)$$

Taking into account the effect of the energy of the rotating masses as defined by the factor p, then expression (7) must be modified as follows, for the total equivalent mass of the train,

$$\left[10^3\, G\, (1 + p) - \frac{9{\cdot}81\, w\, G}{10^3\, b}\right]. \quad . \ (8)$$

When the train is moving at v m. per second, the kinetic energy will be given by the expression

$$U = \tfrac{1}{2} \times \text{equivalent mass in kg.} \times v^2 \text{ joules.}$$

that is, kinetic energy U

$$= \tfrac{1}{2}\left[G\, (1 + p)\, 10^3 - \frac{9{\cdot}81\, w\, G}{b}\right] v^2 \text{ joules.} \quad (9)$$

For some purposes, it is more convenient to rewrite expression (9) in equivalent, but more convenient forms, thus:

$$U = \tfrac{1}{2}\left[(1 + p) - \frac{9{\cdot}81\, w}{b \times 10^3}\right] \times 10^3\, v^2$$

joules per ton-weight of train, (9*a*)

or

$$U = \tfrac{1}{2}\left[(1 + p) - \frac{9{\cdot}81\, w}{b \times 10^3}\right] V^2 \times \frac{1}{46{\cdot}7}$$

watt-hours per ton, (9*b*)

where V is in km. per hour.

A still more convenient form, for some purposes, is:

$$U = \left[\ 10{\cdot}7 \times (1 + p) - 0{\cdot}105\frac{w}{b}\right]$$

$\times\ 10^{-3}\ V^2$ watt-hours per ton,

where p is the percentage addition to take account of the moment of inertia of the rotating parts of the train; V km. per hour is the speed of the train; w kg. per ton is the weight of the train and takes account of the rail and windage friction; and b metres per second² is the retardation.

* Part I appeared on page 244, *ante*.

† One metric ton = 1,000 kg. = 2,200 lb.

Standard Fused Plugs and Sockets.—D.S. Plugs, Ltd., Ordsal Electrical Works, Manchester, 5, have introduced a fused plug which complies with British Standard Specification No. 1363. Like the earlier pattern made by the firm, it incorporates a fused pin, which in this case is arranged so that the fuse can be changed without interfering with the wiring. The terminals are removable for easy wiring and fuses with ratings of 3, 7 or 13 amperes can be supplied.

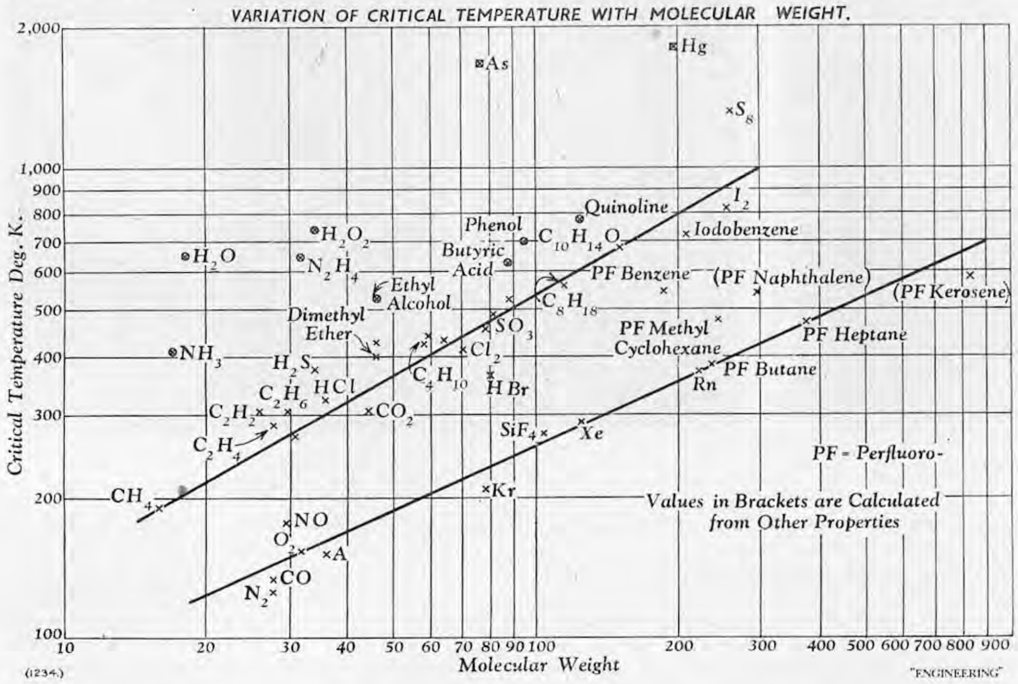
Films on Blast-Furnace Operation.—Three short sound films on blast-furnace operation, made for the Training Department of the British Iron and Steel Federation, Windsor House, 46, Victoria-street, London, S.W.1, were shown in London recently. They are the first of a projected series of instructional films on the main processes of iron and steel manufacture, and deal with the materials entering the blast furnace the production of pig iron, and the main products of the blast furnace. The films are intended to cover the subjects of the iron and steel operatives' course of the City and Guilds Institute. They are to be used in class-rooms, in conjunction with wall charts, film-strips, lecture notes and other visual aids prepared by the Federation. The films are well suited to the purpose of instructing youths, entering the industry, in the general principles of pig-iron manufacture, and the judicious use of animated explanatory diagrams greatly enhances the value of the films as educational media. The films are obtainable, on loan, on application to the area training officers of the Federation, the names and addresses of whom may be obtained from the manager of the Training Department, at the address given above. Both 35-mm. and 16-mm. films are available.

HIGH-TEMPERATURE VAPOUR CYCLES FOR HEAT ENGINES.

By J. F. ALCOCK, M.A., M.I.Mech.E., and E. J. MACNAIR, M.A.

A VAPOUR cycle has many advantages over a gas-turbine cycle; in particular, the lower negative work of the cycle, and hence the lesser effect of component inefficiencies, and also the much greater heat-transfer coefficients to and from boiling liquid and condensing vapour, leading to reduction in irreversible heat losses and heat-exchanger sizes. In practice, however, the thermal efficiency of a steam engine is relatively low because of the limited maximum temperature imposed by the low critical temperature, 374 deg. C., and the excessive pressure prevailing at this temperature (3,310 lb. per square inch). This temperature is, of course, considerably lower than the maximum temperature in a gas-turbine cycle, which is only limited by the temperature which can be tolerated by the metallic components, with or without cooling. Any superheating of the steam merely superimposes a "gas" phase and is irrelevant to the vapour cycle as such.

VARIATION OF CRITICAL TEMPERATURE WITH MOLECULAR WEIGHT.



From time to time proposals have been made to get the best of both worlds by compounding the simple steam cycle with one or more vapour cycles in cascade, using high-boiling working fluids. The fluids proposed have all suffered from practical disadvantages, such as inflammability, toxicity, and high cost, the last two objections applying, in particular, to the only fluid of this type which has actually been used in a heat-engine cycle, that is mercury. Thus, although the potential gains in performance are considerable, no material was available which could be accepted for such purposes as marine propulsion.

The recent rapid developments, particularly in the United States, in the chemistry of the fully-fluorinated hydrocarbons, has opened up a new field. A large class of compounds is now becoming known, characterised by an "inert gas" electronic structure of the molecule, and possessing a very high degree of thermal and chemical stability. It was natural to inquire whether a safe high-temperature working fluid might not be found among these compounds; however, on examining the physical properties of a number of fluorocarbons it was found that they all tended to have critical temperatures lower than that of water. The question therefore arises whether the existence of the ideal high-temperature working fluid is physically possible.

The main requirements for this hypothetical substance may be briefly defined: (a) its critical temperature should be appreciably higher than that of water, and its critical pressure lower; (b) it should be intrinsically stable, non-inflammable, and inert to constructional materials, air and water over the full temperature range of the cycle; (c) it should be non-toxic; (d) it should approximate to an ideal gas. The change in entropy of the saturated vapour between boiler and condenser pressures should be small, to avoid excess of wetness or superheat; (e) its melting point should be below room temperature.

The properties of known materials may then be examined in the light of these requirements. The accompanying diagram shows the variation of critical temperature with molecular weight for a wide variety of materials. It will be seen that most substances fall roughly about a straight line on the log-log plot, with the exception of three classes: (a) inert gases and perfluorocarbons, which fall about another straight line, nearly parallel to the first but considerably lower in temperature; (b) metals (mercury and arsenic) the critical temperatures of which are extremely high for a given molecular weight; and (c) associated liquids with hydrogen bonding between the molecules (H_2O, H_2O_2, NH_3, N_2H_4, alcohols, phenol, aniline, etc.), which fall between the "normal" compounds and the metals.

One class of high boiling compound for which critical temperature data are not available is the silicones. By taking critical temperature as being approximately equal to boiling point $\times \frac{1}{0 \cdot 65}$ (an empirically established relation), compounds with critical temperatures in the range 700-800 deg. K. have molecular weights of 250-450; in fact, they fall rather below the "normal" line on the diagram.

The diagram demonstrates the elevating effect on critical temperature of high intermolecular forces, whether hydrogen bonds or metallic free electrons, and the converse effect of the low attractive forces between molecules with an "inert-gas" electronic structure. This "inert-gas" structure ensures lack of chemical reactivity. For intrinsic stability the bond strengths within the molecule must be high; unfortunately, no single bond energy greater than 150 k.-cals. (600 B.T.U.) is known, and in complex molecules there are usually weak links of considerably lower energy. At temperatures around 500 deg. C. the probability of the molecule absorbing activation energy of this order cannot be neglected, and real stability cannot be guaranteed except in monatomic vapours. Ideal gas properties are also most nearly approached by vapours with the minimum number of atoms in the molecule, and low intermolecular forces. Toxicity is not simply related to structure, except that completely non-reactive "inert gas" structures can be assumed to be non-toxic. Many metal vapours appear to be toxic.

To summarise: (a) hydrogen-bonded structures give high critical temperatures (see diagram), but they are inherently "acid" in the widest sense, i.e., are liable to yield hydrogen ions which will attack metal in the presence of moisture. They are far from perfect gases. No unknown substance better than water in this class is likely to be found; (b) metals have the necessary high critical temperature and yield thermodynamically ideal monatomic vapours. They are stable, but not inherently unreactive, the low-melting alkali metals being particularly susceptible to attack by air and water. Mercury is the only common metal with a sub-atmospheric melting point; toxicity is its main drawback; (c) the perfluorocarbons give a very high degree of chemical inertness, but there is a possibility of carbon-carbon bonds cracking at high temperatures. By extrapolation from the diagram it would appear that a molecular weight of well over 1,000, and hence a very complex molecule, would be necessary to achieve a critical temperature appreciably higher than that of steam.

In conclusion, it appears that there is little chance of selecting an ideal, inert, non-toxic, high-boiling working fluid. Mercury is still the nearest approach to the ideal, apart from its toxicity, and otherwise there is no fluid which shows a marked all-round improvement over steam.

This subject was reviewed originally on behalf of the Admiralty, by whose permission it is published; but the opinions expressed are the authors' own.

ECONOMIES ON BRITISH RAILWAYS.

THE savings in working expenses (including maintenance) due largely to unified management since the British railways were nationalised in 1948 are stated to be 16,000,000*l*. a year. The number of wagon types has been reduced from 480 to 90. The latter figure may seem to contradict the figure of "not more than 150" given in an article on British Railways' wagons and containers which appeared on page 221, *ante*. The explanation is that there are to be 90 main types of wagons, but as some of these will be built with a few minor variations —with or without vacuum brakes, sheet supporters, etc.—there will be a gross total of not more than 150. Some types will consist of only a few special-purpose wagons. There has been an increase in the average locomotive mileage between failures from 15,845 in 1949 to 32,183 to-day. The net operating stock of locomotives fell from 20,445 on December 31, 1947, to 18,849 at the end of 1951. The railway workshops are now used on a national basis, facilitating large-scale production on more economic lines. The number of wagons out of service for repairs have been halved since 1947, and freight trains are now routed without regard to the former railway company boundaries. Locomotive coal consumption was 2·58 lb. per mile less in 1951 than in 1947, and although nearly 10,000,000 more steam-engine miles were run in 1951, the consumption of locomotive coal decreased by 285,000 tons compared with that in 1947. Other economies arise from the inter-regional working of locomotives and crews; the closing of many goods depots, motive-power depots, etc.; a reduction in the number of district officers—48 out of a total of 271; the fewer locomotive types (being reduced from 400 to 12); the design of engines and carriages to give maximum availability; the use of flat-bottom rails; and the elimination of 7,300 printed forms.

275-KV POST INSULATOR.

STEATITE AND PORCELAIN PRODUCTS, LTD., STOURPORT, WORCESTERSHIRE.

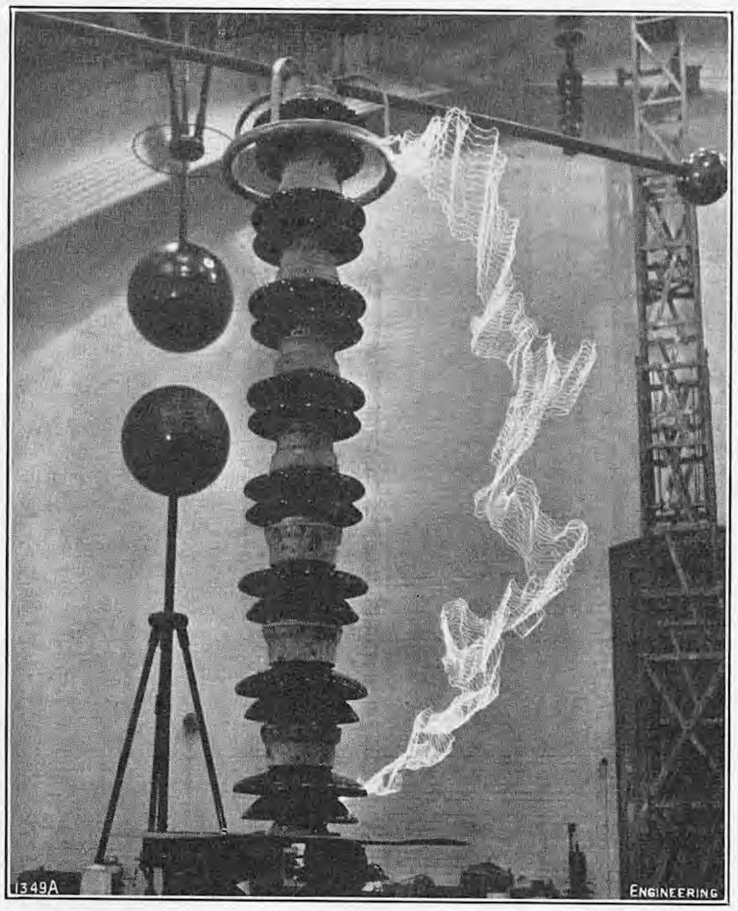


FIG. 1. INSULATOR FLASH-OVER AT 705 KV.

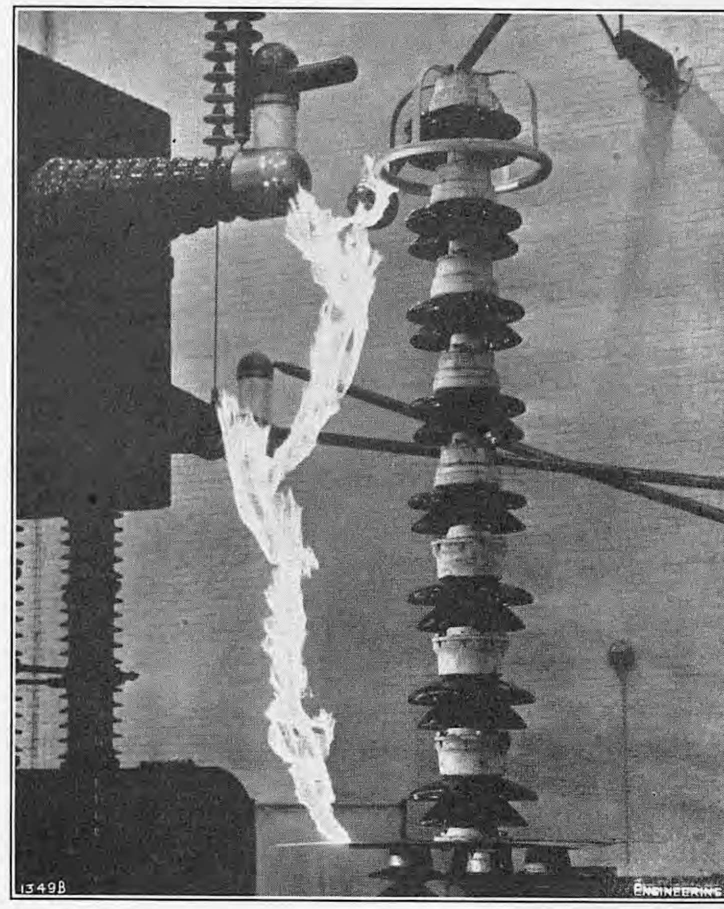


FIG. 2. TESTING TRANSFORMER.

275-KV POST INSULATORS.

THE accompanying illustrations show one of a number of post insulators which are being manufactured by Messrs. Steatite and Porcelain Products, Limited, Stourport, Worcestershire, for use on the new 275-kV network of the British Electricity Authority. They will be employed as supports for isolating switches and 'bus-bars, and each consists of eight units, the total height being 9 ft. 8 in. They have been designed so as to ensure trouble-free operation in fog and smoke and to have a minimum cantilever strength of 2,000 lb. To obtain this strength, three of the units are of heavier construction than the other five. Tests on three posts gave an average cantilever strength of 2,160 lb. In a few positions, underhung posts are to be used. These will be made up of eight units, all of which will, however, be of smaller sizes. These units were specified to have a cantilever strength of 1,200 lb., but during tests an average figure of 1,550 lb. was obtained.

Since the 275-kV network is to be "effectively" earthed, a comparatively low insulation resistance was specified. The insulators were not, however, designed down to this level, and during the type tests a considerable margin was found to exist between the specified and actual flashover values, in spite of the fact that deep grading rings were fitted to avoid corona and thus interfere with television. Actually, with the grading rings in position, the insulators were successfully subjected to the specified impulse withstand voltage of 1,050 kV. The dry flashover voltage on the main post insulators was 702 kV, compared with the 580 kV specified, and on the underhung insulators it was 756 kV. Without the grading rings the dry flashover voltage would have been about 850 kV. The specified wet withstand voltage was 460 kV, which was complied with on test, as was the corona-test voltage of 191 kV. The wet flashover voltage on the main post insulators was 614 kV, compared with the specified figure of 520 kV, and on the underhung insulators 563 kV compared with the same figure. The values for the dry and wet flashover voltages in each case are the average of the measurements on three posts.

While the type tests were in progress, sample temperature-cycle, cantilever, tensile, torsional and electrical fracture tests were also carried out in accordance with the British Electricity Authority's specification. Much of the apparatus required for this purpose at the company's high-voltage laboratory had to be specially constructed because of the size and strength of the insulators. A post is also on test at the insulator-testing laboratory of the British Electricity Authority, where its performance under conditions of heavy industrial pollution is being studied.

"NOVOSTON" ALLOY FOR SHIPS' PROPELLERS.

As a result of research work carried out since the war, J. Stone and Company (Charlton), Limited, 1A, Cockspur-street, London, S.W.1, have evolved a new alloy for ships' propellers. This material, known as Novoston, is a copper-base alloy containing manganese, aluminium and nickel, the presence of a large proportion of manganese making the alloy completely different from the usual nickel-aluminium bronzes. The material is stated to be capable of producing uniformly sound castings, having smooth and accurate finish and a regular and fine grain size, even in thick sections. This, of course, results in less variation in mechanical properties in a single casting. Some physical and mechanical properties of the alloy, compared with Messrs. Stone's propeller bronze, are given in the Table; they refer to separately-cast test bars in all instances, and average figures are quoted. It is claimed that the considerably higher ultimate and fatigue strength of the new alloy enable the blade scantlings to be reduced appreciably without detriment to the factor of safety. The reduced scantlings naturally result in a lower propeller weight and this is further enhanced by the fact that the new material has a lower specific gravity than ordinary propeller bronze. Moreover, this reduced specific gravity has the effect of lowering the centrifugal force of a rotating propeller. As a result, a Novoston propeller has a weight about 12 per cent. less than that of an ordinary bronze propeller with a consequent reduction in the moment of inertia.

Material.	0·15 per cent. Proof Stress.	Ultimate Tensile Strength.	Elongation.	Fatigue Stress.*	Specific Gravity.
	Tons per sq. in.	Tons per sq. in.	Per cent. on 2 in.	Tons per sq. in.	
Novoston Bronze	19	41	22	11	7·5
"Propeller" Bronze	16	32	20	6·5	8·3

* 20 × 10^6 reversals in salt spray.

The new alloy is more expensive per ton than propeller bronze, but the lower specific gravity and permissible reduction in blade scantlings, to some extent balance this, so that a Novoston propeller costs little more than one of the ordinary bronze alloy. From the aspect of ease of repair, the new alloy is claimed to possess excellent qualities. Ingots of Novoston can be used readily for repairs by the method of "burning on." It is also stated that the new alloy can be welded without difficulty and that, despite its toughness, it possesses good ductility and can be subjected to a fair amount of straightening. The alloy has been tested at sea in the form of a 13-ton propeller fitted to a 7,500-h.p. motorship in which it is stated to be "performing its functions admirably in every way." By the co-operation of shipowners, Novoston propellers are to be fitted to ships engaged in a wide variety of routes, including Far Eastern and North Atlantic cargo lines, Middle East oil tanker routes, Mediterranean services, trawlers serving in northern waters, West African coastal and river services, and North Sea collier routes. It is also to be tried by the Admiralty.

POST-WAR PROBLEMS IN ENGINEERING EDUCATION.*

By PROFESSOR L. J. KASTNER, M.A., M.I.Mech.E.

(*Concluded from page* 317.)

PROBLEMS OF SYLLABUS AND STAFFING.

I PROPOSE now to discuss in more detail certain difficulties which I have already touched upon. The first difficulty I should like to deal with is the problem of drawing up a syllabus of studies which will give, if conscientiously pursued, an adequate knowledge of fundamentals. The student, on entering the university, should be well grounded in pure and applied mathematics, in physics and in chemistry (though the latter of these subjects is not of the same basic importance as the others); and he should then receive in the early part of his university career a thorough training in what I would term the "primary" engineering subjects, namely, strength of materials, applied electricity, heat engines and hydraulics, together with adequate practice in mechanical drawing and a little surveying, after which some specialisation may be permitted, dependent on his special interests, and leading to an honours degree at the end of three years. Mathematics should not be neglected, and should certainly be studied up to the end of the second year of a three-year course. A decision as to whether a student is of pass degree or honours degree calibre should be made as early as is just and fair; and, where practicable, pass and honours courses should be separate and distinct. A multiplicity of special courses should be avoided at all costs, and an undergraduate syllabus should be ruthlessly pruned of excess descriptive matter in the realisation that what matters here is a proper understanding of engineering science, which cannot be gained without much hard slogging at problems with a distinct mathematical flavour. A great deal of importance should be attached to courses in engineering design, and these courses should keep close touch with practice; but it should be realised that an adequate knowledge of the technology of a subject can only be obtained as a result of experience in industry. It is no part of the duty of a university to attempt to impart detailed information of a technological character, though a student can always learn, and should learn, by individual effort, much about the technology of that branch of engineering which he favours.

Unfortunately, the need for a concentration on basic subjects is not always appreciated by the type of engineer who has "come up the hard way" and who sometimes seems to expect a young graduate to know as much, if not more, about technical matters than he himself has been able to assimilate after many years of experience. Once implanted in an individual, this attitude seems impossible to eradicate, but I am glad to say that it seems to be becoming increasingly rare and soon, I hope, it will be altogether extinct.

In considering the syllabus for an engineering degree course, a place should be left for some instruction in economics and industrial organisation. I do not believe that these subjects should be treated quite so seriously as the more basic ones, but rather that they should be looked upon as a kind of savoury, to be partaken of towards the end of other and heavier courses, and probably not earlier than a student's last year. Though the lecturer may be treated to a certain amount of banter by students accustomed to more solid fare, he will quickly find that a great deal of notice is taken of what he has to say, more especially by those students who have had no industrial experience. There is everything to be said in favour of a young graduate knowing something about wages and profits, company organisation, trade unionism, etc., and even an elementary course on such subjects may kindle an early interest in the executive and managerial side of industry; which is a very good thing, because far too many men who have done well in their honours school examinations find it difficult to look beyond the research laboratory or the design office.

It has been rightly said that engineers should not be narrow men, and the university, even in the three crowded years of an undergraduate course, should do something to make students aware of the great currents in modern thinking and of the developments—social, philosophical, religious and scientific—which have sprung from the thoughts of great men. At the University College of Swansea, a series of general lectures on these topics is given during the first two terms of every academic year. In a further effort to broaden the education of our undergraduates, they are asked to write a number of essays in their first year, these essays being read before a tutor, who endeavours to give advice regarding clarity of expression, style, arrangement of subject matter, and so on. I feel that the course of general lectures referred to above, taken together with practice in essay-writing, should do something to make applied science undergraduates realise the importance of the spoken and written word, and should help them to take an interest, as every educated man should, in the problems and achievements of modern civilisation.

Practice in public speaking, which I have referred to earlier, is a very useful exercise for the young engineer, and a flourishing university engineering society, where he can learn to deliver a short paper which will be subject to the good-natured criticism of his classmates, has much to commend it, particularly if it is supported by the occasional presence of senior engineers. Students who accept the positions of officers of such a society are taking on a somewhat thankless task, but the experience they will gain is often invaluable in developing the right kind of self-confidence in dealing with others. Senior engineers, who willingly give to student societies their time and the wisdom born of long experience, receive no concrete reward, but they have the satisfaction of knowing that they are helping on the next generation in their profession, and the knowledge that their kindness is invariably warmly appreciated.

THE RECRUITMENT OF TEACHING STAFF.

One of the most pressing problems with which university departments of engineering are faced is the problem of recruitment of academic staff. In the applied sciences, it is highly desirable that a teacher should have had a period of first-hand experience in industry (using this term in its widest sense) and this is likely to mean that a man will have reached the late twenties, taking into account his present liability to two years of National Service, before he is qualified for a junior post. Such posts are not highly paid, and there is often the utmost difficulty in obtaining the services of the right kind of man for a particular vacancy.

Certainly, an academic career, especially in science, does not in these post-war days offer the prospect of a leisured life in a quiet backwater, whatever may have been the situation 25 years ago; and it involves many sacrifices which only the man who is really keen on his job is prepared to make. When there is competition for the services of a valuable man, the universities ought not to be in the position of being compelled to stand by a salary scale in some respects notably inferior to that likely to be offered by industry.

Even if teaching staffs are of the highest quality, however, how can we make certain that a steady stream of the right kind of young men will flow into the engineering departments of our universities? In a country like ours, renowned for many generations for its engineering skill, and which has produced, I think, more great engineers than any other, there will always be men who will be attracted by our profession; but will there be enough to meet our future needs? As I have said, I believe that, at the present time, too many of the best boys from the senior science forms of our schools choose to study pure science at the university. There are probably several reasons to account for this, but I think that there is one of special importance—this being that nearly all science masters at schools have been trained in pure science and have almost no knowledge of, and often little interest in, engineering. In view of the importance of applied science in maintaining and improving our standard of living, it is imperative that our schools should tackle the task of informing themselves of the opportunities offered for a career in the various branches of engineering and the other technologies.

It is quite certain that the British engineering industry must, in the future, meet and overcome the sternest competition from abroad. As its leaders, whether in the technical or in the executive branches, it must have men who will look beyond the immediate advantage; who will prefer long-term gains to ephemeral profits; who will think, as it were, strategically rather than tactically. Such men are few in any community, but our post-war educational system will ensure that most of them will obtain a university education. I believe it is vital that a larger share of them should obtain this education in applied science.

Without doubt, the subjects I have been discussing bristle with unsolved problems; without doubt, our young engineering graduates have many shortcomings; without doubt, our engineering degree courses leave much to be desired; certainly, the armour of a professor of engineering is full of chinks through which a persistent critic can score many shrewd thrusts. I suppose that these things are inevitable, to some extent, where we are concerned with an organisation or a system of which the end products are men and not things. Even in a small engineering school, it is not possible to give each student that measure of individual attention which might turn him—assuming him to have adequate native ability—into that cool-headed, clear-thinking, logical, sensible and well-informed individual, with a real ardour for his subject, who is the ideal after which we strive. But never in this country has so much thought been given to engineering education as at the present time; never have there been so many reports, memoranda, lectures, discussions and letters to the Press. In the long run, all this will have its effect and I believe that the results will be good; in the meantime, what is wanted is a concentrated attack on two major weaknesses, namely, the attitude of the schools towards a university training in applied science and the difficulty faced by the universities in attracting the right kind of man to an academic career in engineering.

Let us agree that, whatever improvements are made in our systems of engineering education, a deep and wide gulf will always yawn between the newly fledged graduate and the qualified engineer. Nothing can fill this gulf save experience; but there are times when the gulf must be bridged by tolerance and tact and understanding, to make profitable contact possible between a senior colleague and a junior one. It is on these occasions, I think, that the true quality of the education of an engineer emerges, no matter whether that education has been obtained mainly in a university or wholly on the workshop floor. The most important expression of this quality may consist of nothing more than a knowledge of when to hold one's peace when provoked by the injustice of a superior or the impertinence of a subordinate; that is to say, to maintain an equable and philosophical attitude in the face of the stupidities and inconsistencies of others—and of oneself. The engineer who constantly keeps before him the thought that men are often unequal to the stresses and strains of life, and cannot always be expected to carry out their duties with the precision of well-oiled machinery has, I suggest, a priceless asset. Do not expect the education of engineers ever to become a precision job.

* Address delivered on January 26, 1953, to the South Wales and Monmouthshire Association of the Institution of Civil Engineers. Abridged.

LUBRICATION OF BALL AND ROLLER BEARINGS.—The Hoffmann Manufacturing Company, Limited, Chelmsford, Essex, have published a booklet entitled *The Lubrication of Ball and Roller Bearings*, which describes the objects of lubrication and the advantages of using grease or oil, and gives reasons for selecting different grades of either. Vegetable oils are unsuitable because they may become rancid, with detrimental results to the bearing, and a graph shows the maximum speeds suitable for standard journal bearings using lime soap and soda soap greases. Information on the design of bearing housings for grease and oil lubrication is provided, and in the latter case, methods of applying the lubrication are dealt with. Mention is made of some of the oil seals that can be used; a labyrinth-type seal is recommended for use at high speeds. The booklet also contains a number of diagrams illustrating the features of design that are mentioned.

THE ENGINEERING OUTLOOK.

VII.—THE MOTOR-VEHICLE INDUSTRY.

THE motor industry had a difficult year in 1952. Shortages of raw materials retarded production in the early months of the year, drastic import cuts in Australia in March virtually closed the largest export market, and competition sharpened in foreign markets. The difficulty of disposing of some of the cars diverted to the home market (together with uncertainty about purchase tax) necessitated price reductions for many of the more expensive models. Towards the end of the year, there were reports of dismissals and short-time working in various parts of the industry, and a threatened strike at the Morris works was averted by a compromise reducing the number to be discharged. At the works of the Austin Motor Company, labour trouble has arisen recently over the reinstatement of dismissed men.

The statistics for the year do not reveal any serious deterioration in the industry's position. Production was only slightly lower than in 1951, amounting to 448,000 cars, against 476,000, and 242,000 commercial vehicles, against 258,000. Moreover, this fall can be attributed in part to the steel shortage: production in the second half of the year was slightly higher than in the second half of 1951. Compared, however, with the record production of 1950, or with the industry's estimated capacity of one million units, the production in the last two quarters of 1952, when raw material supplies were adequate, does show signs of diminution; the production of cars in the second half of 1952 was 15 per cent. lower than in the same period of 1950. Production trends are illustrated in Figs. 1 to 10, on pages 329 and 330.

Exports in 1952 fell more severely than production, the number of both cars and commercial vehicles exported being about 10 per cent. lower than in 1951, as can be seen from Tables I and II, herewith, which are taken from the *Trade and Navigation Accounts*. These figures, however, conceal the extent of the fall in the second half of the year: exports in the first six months of 1952 were higher than in the same period of 1951. The largest single market for cars in 1952 was the United States, which took 31,000, compared with 20,000 in each of the two previous years. Australia took 30,000, most of them at the beginning of the year, compared with 58,000 in 1951. Exports of motor-vehicle chassis, which go principally to Australia, were nearly halved.

The number of commercial vehicles exported was only slightly lower in 1952, and their value was considerably higher than in 1951. This was due to the increased export of goods vehicles and 'buses; the fall in exports was confined to the delivery vans and dual-purpose vehicles. The markets for commercial vehicles are widely dispersed; nearly a quarter of the total in 1952 went to the unspecified "other foreign countries." Australia remained the largest single market, but took only half as many vehicles as in 1951.

The home market benefited substantially from the fall in car exports. Production for the home market in 1952 amounted to 173,000 cars, compared with 109,000 in the previous year. This was considerably more than was intended at the beginning of the year, when the Government aimed at restricting the home market quota to 60,000 cars. In June, this fixed quota was replaced by a percentage: the industry was to export 80 per cent. of its production, which meant that the home market would receive approximately 90,000 cars. By the end of September, this figure had already been reached, and the industry was exporting only 50 to 60 per cent. of its output. Despite this, the industry's steel allocation was increased in the fourth quarter, and the Minister of Supply admitted that the 80 per cent. export target had been virtually abandoned.

The division of output between the home and export markets is becoming an increasingly important question for British motor manufacturers. Traditionally, a thriving motor industry is based on a flourishing home market, which can make a more than proportionate contribution to overhead costs, as was the practice in countries which were large exporters of motor vehicles before the war. Cars can then be sold in the export markets at a lower *ex*-works price, which compensates for the costs of transport and import duties. In Britain, since the war, the position has been reversed; the home market has been deliberately starved so that the greatest possible volume of exports could be achieved. In the sellers' market of a few years ago, the industry was able to sell the bulk of its output abroad at prices which covered a full share of overhead costs. To-day, however, competition abroad is much keener, and price is often a deciding factor. The British industry, exporting so high a proportion of its output, is at a serious disadvantage in competition with the French, German and Italian industries, which export only 20 per cent., 30 per cent., and 26 per cent., respectively, of their output.

PROSPECTS IN THE HOME MARKET.

The increased flow of new cars to the home market brings to the fore the question of the level of the home demand for cars, which, in the earlier post-war years, was a rather academic consideration. The long waiting-lists ($1\frac{1}{4}$ million at the beginning of 1952) built up since the war give no guide to the real demand; apart from an obvious duplication of orders, prices are now much higher than at the time of ordering, owing largely to the doubling of the purchase tax. Dealers have already found themselves with some of the more expensive new cars left on their hands by the cancellation of orders. Sales resistance has caused reductions in the prices of the more expensive models; the Humber Super Snipe was reduced by 335*l*. (though this car was due to be replaced by a new model), and the Jowett Javelin and Jupiter were reduced by about 40*l*. The first move to cut prices was made by the Ford Motor Company, who reduced all their home market prices by 5 per cent. when making a 10 per cent. cut in export prices.

Prices of secondhand cars fell sharply during 1952, and, for the first time since the war, the prices of many secondhand models fell below their list prices. The scope for speculation in cars was thus reduced and it was possible to withdraw many of the more expensive models from the covenant scheme. The covenant period was reduced from two years to one year, and the declaration form, introduced in May, 1952, was abolished. Gradually more and more cars were withdrawn from the scheme, and the covenant was finally abolished in January, 1953.

Opinion in the industry is divided on the deterrent effect of the purchase tax on the demand for new cars. Mr. L. P. Lord, chairman of the British Motor Corporation, demanded the removal or reduction of the tax to save the industry from imminent unemployment. Sir William Rootes has deprecated pessimism about either home or export sales; the Rootes Group are still working on home orders placed in 1947 and 1948. He agreed, however, that "there is no longer any justification for retaining as an anti-inflationary measure the present purchase tax on motor cars and commercial vehicles." The present rate of $66\frac{2}{3}$ per cent. adds 176*l*. to the price of the cheapest model, and must be a serious deterrent to the private buyer. At the same time, it does not have such a serious effect on the sale of cars for business purposes, which are estimated to

TABLE I.—UNITED KINGDOM: EXPORTS OF NEW CARS AND CHASSIS.

—	Number.			Value (£1,000).		
	1950.	1951.	1952.	1950.	1951.	1952.
Complete Cars:						
Union of South Africa	19,313	22,591	18,236	4,493	6,031	5,329
India	10,137	11,740	6,438	2,633	3,260	2,013
Malaya	5,909	13,594	10,830	1,871	4,956	4,104
Ceylon	2,516	4,639	4,411	729	1,547	1,601
Australia	76,245	58,335	30,534	28,218	23,016	11,942
New Zealand	16,381	29,652	26,017	4,539	10,518	9,277
Canada	76,193	27,391	21,330	21,495	8,423	7,517
Irish Republic	8,148	11,546	10,119	2,034	2,905	2,633
Finland	609	1,840	6,122	239	754	2,626
Sweden	23,567	16,302	13,763	7,350	5,522	4,746
Denmark	3,478	2,438	4,560	1,020	812	1,660
Netherlands	9,486	7,654	7,373	2,619	2,358	2,490
Belgium	12,955	11,149	13,422	3,810	3,624	4,641
United States of America	19,994	19,807	31,287	6,068	7,407	13,310
Brazil	7,176	9,209	7,710	2,362	3,609	3,303
Other countries	51,202	61,106	63,597	17,991	23,425	26,721
Total	343,309	308,993	275,749	107,471	108,167	103,913
Chassis:						
Australia	45,943	48,976	26,499	7,275	8,425	5,231
Other British countries	4,059	6,115	3,843	818	1,400	959
Foreign countries	4,812	4,523	3,741	1,001	1,128	1,182
Total	54,814	59,614	34,083	9,094	10,953	7,372
Total, Complete Cars and Chassis	398,123	368,607	309,832	116,565	119,120	111,285

TABLE II.—UNITED KINGDOM: EXPORTS OF NEW COMMERCIAL VEHICLES AND CHASSIS.

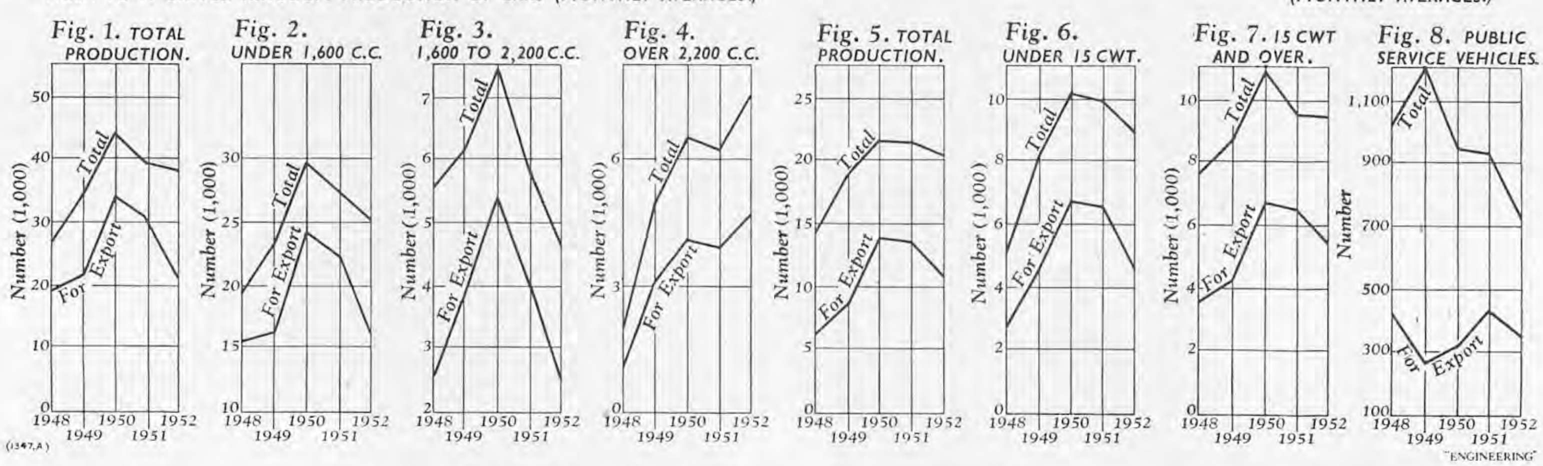
—	Number.			Value (£1,000).		
	1950.	1951.	1952.	1950.	1951.	1952.
Complete Vehicles:						
British West Africa	1,488	1,670	2,023	816	942	1,519
British East Africa	2,707	3,259	2,404	1,138	1,429	1,348
Malaya	1,232	2,374	2,517	468	1,016	1,261
Australia	20,774	14,251	7,046	6,725	4,999	2,890
New Zealand	1,624	3,916	3,904	451	1,362	1,719
Irish Republic	1,196	3,919	2,618	360	940	735
Denmark	949	1,049	2,114	255	331	611
Belgium	3,907	2,232	2,751	1,085	751	909
Brazil	3,461	3,517	2,281	1,406	1,442	1,080
Other countries	36,439	31,536	34,514	14,652	16,368	20,848
Total	73,777	67,723	62,172	27,356	29,580	32,920
Chassis:						
British West Africa	4,741	2,763	5,550	2,067	1,469	3,446
Union of South Africa	2,691	4,179	4,598	1,644	2,584	4,017
British East Africa	2,184	2,058	2,342	1,163	1,323	1,661
Australia	27,889	21,986	10,700	11,759	10,917	5,532
New Zealand	4,565	5,902	4,896	1,633	2,396	2,354
Finland	911	2,526	2,731	434	1,450	1,663
Denmark	1,526	1,856	5,440	621	819	2,749
Belgium	2,701	1,795	3,084	1,191	987	2,284
Turkey	1,949	2,274	4,179	982	1,321	3,057
Other countries	21,483	24,031	22,781	12,831	16,381	18,284
Total	70,640	69,370	66,301	34,325	39,647	45,047
Total, Complete Vehicles and Chassis	144,417	137,093	128,473	61,681	69,227	77,967

account for 90 per cent. of home sales. The Daimler Company, in announcing a temporary reduction in price, equivalent to a halving of the purchase tax, have taken a bold step to overcome the pre-Budget uncertainty about the tax, and, incidentally, should discover how serious a deterrent the tax is.

Whatever the merits of Mr. Lord's case for a reduction in purchase tax, the timing of his demand was unfortunate. Having raised the question of purchase tax four months before the Budget, the industry can scarcely complain about the uncertainty which, in large measure, they themselves have created. Possibly they were hoping to obtain an immediate modification of the tax, as the textile, glass and leather industries had done earlier in the year. Certainly, the industry has a good case for some relief, as the motoring public pays a very heavy petrol tax as well as the purchase tax on new cars. From a national point of view, the case is less strong; the industry's main purpose must be to export as many cars as possible, and it may be, as *The Economist* suggests, that the present level of purchase tax is a valuable means of "encouraging" the industry to make the maximum effort in the export market. This is rather severe, perhaps, in view of the industry's admirable post-war export record; moreover, as Mr. Lord pointed out, half of the export markets are administratively controlled, and no amount of "encouragement" would increase their export quotas.

FIGS. 1 TO 4: UNITED KINGDOM PRODUCTION OF CARS (MONTHLY AVERAGES.)

FIGS. 5 TO 8: UNITED KINGDOM PRODUCTION OF COMMERCIAL VEHICLES (MONTHLY AVERAGES.)



The alternative argument against reduction of the tax is that, if the motor industry cannot increase its exports, the unemployed capacity, labour and material should be diverted to more successful exporting industries. It is doubtful if this argument carries any weight at all; it is difficult to see what the industry's surplus capacity could be switched to, especially as the re-armament programme has been reduced and the aircraft industry (according to the de Havilland Aeroplane Company) is already producing slightly ahead of the world demand. It is significant that, because of an adjustment in the aircraft programme, the Standard Motor Company have suspended the construction of a 1½*l.* million factory outside Liverpool, to which their spare-parts organisation was to have been transferred to provide space for the production of jet aero-engines at Coventry. The sheet steel consumed in the manufacture of cars is no longer in short supply, and, rather than allow part of the industry's capacity and labour to become unemployed, the Government should allow home demand to find its own level by removing the tax, or, at least, reducing it.

The level of the home demand for cars freed of purchase tax, or with a considerably reduced tax, must be a matter for conjecture. American manufacturers receive a detailed and reliable indication of their future home demand from the sample "Survey of Consumer Finances" carried out annually by the University of Michigan in co-operation with the Federal Reserve Board. Unfortunately, there is as yet no comparable information about the British market. Replacement requirements should sustain the home demand for some considerable time to come, as most of the cars on the roads are still of pre-war construction. Of the 2·38 million cars in use at the end of 1951, 1·6 millions were pre-war models at least 12 to 15 years old. Before the war, the average life of a car was eight years, after which it was uneconomic to repair. The 420,000 new cars released to the home market between 1948 and 1951 did not, for the most part, replace existing cars, because the number of cars in use rose by 405,000 over the same period. A further 173,000 cars were supplied to the home market in 1952; probably a higher proportion of these replaced pre-war cars.

The potential replacement demand for cars in the United Kingdom is therefore enormous; to replace all the pre-war cars now in use would absorb the whole of the industry's production for three to four years. Obviously, a substantial proportion of this demand will not be realised, because the present-day prices of new cars are prohibitive in relation to present-day incomes. Much will depend on events in the secondhand market. In the earlier post-war years, the buyer of a new car was able to exchange his old car at a price which covered a substantial proportion of the cost of a new one. To-day the position is very different, because there is a much wider gap between the values of new and secondhand cars. When new cars become more plentiful, dealers' chances of re-selling many of the pre-war cars which will be offered to them will be rather slender. The fall in secondhand prices which resulted in 1952 from the stricter monetary policy, and the improved supply of new cars to the home market, will make the new cars more difficult to sell. The industry must look to an enlargement of the motoring public to sustain the demand for old cars; a strong secondhand market would then encourage many owners to buy new cars on a part-exchange basis. There are, doubtless, many people in this country who would like to own a car, no matter how old, but running costs are likely to be the main obstacle. Petrol tax alone at 2*s.* 6*d.* per gallon costs 1*d.* per mile at 30 miles per gallon, and the annual licence has gone up from 10*l.* to 12*l.* 10*s.* 0*d.* from January, 1953, while repairs to pre-war cars are bound to be an increasingly expensive item.

Business demand should be a sustaining feature in the home market. One estimate puts the proportion of cars used for business and professional purposes at 80 per cent.; according to another, already quoted, business purchases account for 90 per cent. of sales. The proportion will probably not be so high as the supply of cars improves, because cases of essential business need have been given priority in the allocations of the post-war cars. Nevertheless, the business demand is likely to remain strong for a number of reasons. The return of the sellers' market has compelled many companies to extend their sales staffs, most of whom will have to be equipped with cars. Though profits in industry are falling and conditions are becoming more difficult generally, business buyers can still be expected to take up a substantial proportion of the new cars available to the home market.

For both business and private buyers, however, price will be a vital factor, and this is closely linked with the size and type of car. The question facing the motor industry, in both home and export markets, is, "How large a vehicle can the largest possible number of customers afford?" Immediately after the war, opinion in the industry favoured a car seating up to six people, but of smaller power and weight than the standard American car. Recently, the emphasis has been more on the small cars; the Morris Minor has been a very successful model, particularly since the installation of the Austin overhead-valve engine; the Austin Seven is now in full production; and the Standard Motor Company also have a new small car in preparation. That this is the type of car preferred by the British motorist is obvious from the waiting lists and the secondhand prices, but it is possible that an even smaller and cheaper car, such as the 2-h.p. Citroen, which provides only the barest minimum of the essentials of motoring, might appeal to a wider market, both at home and abroad.

EXPORT ACHIEVEMENTS IN NORTH AMERICA.

Despite the changes which took place in 1952, exports still account for the major proportion of the United Kingdom's output of cars, and, in the country's present economic conditions, constitute the principal justification of the post-war expansion of the industry. Although the total exports in 1952 were 10 per cent. lower than in 1951 and 20 per cent. lower than in 1950, they were better distributed in that exports to the United States were increased by more than 50 per cent. The post-war expansion of British car exports has been assisted by two favourable circumstances, namely, the accumulated demand for vehicles, which has now been overcome, and the dollar shortage, which still hampers American exporters in many countries. The success of the British manufacturers in the United States market augurs well for future competition with the Americans in third markets, though, admittedly, British exports affect only a small proportion of the home market of the United States.

The British manufacturers have succeeded in demonstrating to at least a section of the United States market the advantages of the small British saloon car as compared with the standard American sedan. The first and most important is the lower price—equivalent to the price of a year-old American model—and the lower operating cost. The British cars are also more manœuvrable—an important advantage in dense American traffic—and more easily parked. Naturally, the British cars appeal mainly to the lower-income groups, though there is also scope for them as second family cars. Moreover the prestige and popularity of the British cars are increasing, and sales and service organisations are now reasonably well established.

British sports cars have also been very successful in the United States, to such an extent that American manufacturers are designing new models to capture a larger share of the market. The most successful British sports cars are the M.G. and the Jaguar. Sales of Jaguars in the United States in 1952 are estimated at 10 million dols., and orders for delivery in 1953 amount to 20 million dols., representing about 5,000 cars. The Jaguar sells in the United States for about 4,000 dols., while the M.G. Midget costs about 1,800 dols., and appeals to a rather different type of sports-car enthusiast. Between these two prices there is probably a good market for the new Austin-Healey sports car, which comprises an Austin A.90 engine and the light Healey combined chassis and body, and will sell in the United States for about 3,000 dols. The Austin Motor Company have also arranged to manufacture, in conjunction with Messrs. Fisher and Ludlow, Limited, a small sports car specially designed for the American market by the Nash-Kelvinator Corporation. The Austin Company will provide the A.40 engine and the chassis and will carry out the assembly; Messrs. Fisher and Ludlow are to make the body. The Nash firm are already producing in small quantities the Nash-Healey, a two-seater sports car with a Nash engine and Healey body, selling at 5,000 dols.

On the whole, however, the American manufacturers are designing sports cars for prestige and publicity rather than for immediate profits, as the sports-car market is not large enough for mass production in the American style. The cars they are designing are unlikely to detract from the popularity of the British cars; the ratio of weight to horse-power is too high, the steering is inadequate, and too much is sacrificed to comfort to suit the genuine sports-car enthusiast, for whom performance is the overriding factor.

There seems to be no reason why the present level of British exports in the United States should not be maintained or increased. According to Sir William Rootes, the prospects for 1953 are exceptionally encouraging. Competition from European manufacturers in the United States is negligible, though the German Volkswagen has been making headway in Canada. Provided that the British manufacturers continue to consult the requirements of their American customers (by such means as the recent provision of an automatic gearbox in the Rolls-Royce, Bentley and Jaguar), the price and quality of their products, and the prestige they have won, should enable them to reach the target set them by a United States automobile manufacturer—the doubling of their trade in that country.

EXPORT PROSPECTS

Valuable though this success in the Unitea States market is, both to the industry and to the country, the export picture as a whole is less promising, as can be seen from Tables III and IV, herewith. To prevent redundancy and a fall in output, the industry must at least maintain the 1952 level of exports. In this task they face three main obstacles, namely, the increasing competition of the Continental manufacturers, the limitation of exports by administrative measures, and the growing practice of assembly abroad, frequently leading to manufacture abroad.

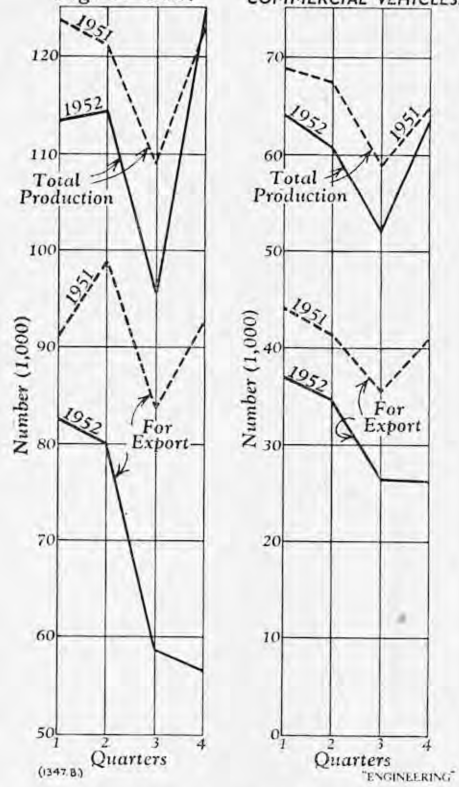
Continental competition is most severe in the important small-car class, where the German Volkswagen and the French Renault offer certain advantages over the corresponding British vehicles. Both these models are produced at a rate of 2,000 a week, higher than the output of any single British model. At the moment, there is little to choose in price between the British and Continental cars; all were reduced during 1952, the Renault 4-h.p. car coming down from 450*l*. to 400*l*. The enormous domestic demand for the Volkswagen enables the manufacturers to vary their export prices considerably to meet changed conditions. The attraction of the Volkswagen is its performance and sturdiness, which, together with its low running costs, outweigh for many European motorists the minor defects in appearance, convenience and noise. The Volkswagen is very popular in Holland, Switzerland and other European markets; the demand in Sweden cannot be fully met. About 1,000 a year are being sold in Japan, an assembly plant has been established in Brazil, and assembly in Canada is planned. French production of cars and commercial vehicles exceeded half a million units in 1952 for the first time, but exports fell, those to foreign countries being 30 per cent. lower than in the previous year.

TABLE III.—*United Kingdom: Exports of Cars, by Types.*

—	Number.		Value (£1,000).	
	1951.	1952.	1951.	1952.
Complete Cars, Assembled:				
Not exceeding 1,000 c.c.	31,198	25,608	8,497	7,659
Exceeding 1,000 c.c., but not 1,600 c.c. ..	136,664	123,208	45,941	44,746
Exceeding 1,600 c.c., but not 2,200 c.c. ..	37,200	20,306	16,998	10,479
Exceeding 2,200 c.c., but not 2,800 c.c. ..	20,363	23,001	9,903	10,808
Exceeding 2,800 c.c., but not 3,500 c.c. ..	5,093	8,268	4,028	6,930
Exceeding 3,500 c.c. ..	3,674	1,712	3,610	2,178
Unassembled:				
Not exceeding 1,000 c.c.	9,843	10,906	2,035	2,493
Exceeding 1,000 c.c., but not 1,600 c.c. ..	50,323	41,969	12,730	11,770
Exceeding 1,600 c.c., but not 2,200 c.c. ..	5,139	3,494	1,779	1,282
Exceeding 2,200 c.c., but not 2,800 c.c. ..	9,284	17,203	2,546	5,526
Exceeding 2,800 c.c., but not 3,500 c.c. ..	20	22	14	17
Exceeding 3,500 c.c. ..	192	52	87	25
Total, complete cars	308,993	275,749	108,167	103,913
Chassis:				
Not exceeding 1,000 c.c.	1,520	1,000	233	168
Exceeding 1,000 c.c., but not 1,600 c.c. ..	43,256	20,754	7,547	4,253
Exceeding 1,600 c.c., but not 2,200 c.c. ..	9,707	4,736	2,166	1,162
Exceeding 2,200 c.c., but not 2,800 c.c. ..	4,898	7,057	875	1,484
Exceeding 2,800 c.c. ..	233	536	132	305
Total chassis ..	59,614	34,083	10,953	7,372
Grand Total ..	368,607	309,832	119,120	111,285

FIGS. 9 AND 10: UNITED KINGDOM PRODUCTION OF VEHICLES.

Fig. 9. CARS. Fig. 10. COMMERCIAL VEHICLES.



Australia is the outstanding example of a market restricted by Government measures. Imports of motor-car bodies and assembled chassis were cut by 80 per cent. and motor-car engines by 40 per cent. in March, 1952. Since then, as the Australian balance of payments improved, there have been some modifications in the regulations, and further concessions are possible. Nevertheless, the import cuts "signalled the end of the Australian honeymoon," as Sir John Black put it, and he expected that the restrictions would encourage British manufacturers to open factories in Australia. This was confirmed in August, when the formation of a new company, Standard Products, Limited, was announced; the company, with a capital of £A.5 millions, was to undertake the assembly and progressive manufacture of Standard and Triumph cars.

Holdens, the General Motors subsidiary in Australia, are planning an expansion of their manufacturing and assembly facilities, estimated to cost £A.11 millions. By the end of 1953, the output of Holden sedan cars and utility vehicles is expected to reach a daily rate of 200 units, compared with 155 at present. The export of Australian cars to Malaya, the Philippines and other Asian markets is envisaged. Holdens' have demonstrated the advantages to be derived from the production of a car which has been modified to suit local conditions, while remaining in principle a foreign design. With the Standard Motor Company following suit, the need for imports of cars from the United Kingdom will be further reduced, and the British industry cannot expect a return to the 1951 level of exports when the import restrictions are removed. This is recognised by the industry, and the British Motor Corporation and the Rootes Group are also planning to develop from assembly to manufacture in Australia.

Exports to the other main Commonwealth markets, Canada, New Zealand and South Africa, were fairly well maintained in 1952. In the second half of the year, the demand in Canada revived with the easing of credit restrictions, the full benefit of which should be felt in 1953. In South Africa, the assembly of Austin cars is expected to begin next June, after the completion of a new 1*l*. million factory at Blackheath, near Cape Town. The cars to be assembled there include the Austin Seven, and the factory may later assemble Morris cars, including the Minor. In Japan, an agreement has been reached between the Nissan Motor Company and the Austin Motor Company for the assembly of about 2,000 cars a year. An assembly plant is now being constructed in Yokohama and is expected to begin operations in April.

The export of cars "C.K.D." (completely knocked down) is something of a necessary evil for the British motor industry. It is a relatively expensive method of production, and it involves numerous administrative difficulties. Nevertheless, the industry has had to adopt overseas assembly to prevent the complete loss of the markets concerned; as Sir John Black writes, "it is better to earn money from capital investment overseas and to send parts of cars, rather than to send no cars at all." The Austin Motor Company state that C.K.D. markets accounted for about 30 per cent. of their exports in 1952, and are expected to account for a further 8 per cent. in 1953. The one advantage of overseas assembly is that it provides a certain measure of stability in the demand for unassembled parts; overseas Governments are unlikely to create unemployment in their assembly plants by refusing import licences for parts. Eventually, however, overseas assembly will be followed by overseas manufacture, with a consequent reduction in the demand for British cars.

It is obvious that costs are becoming an increasingly important factor, and the British industry suffers from several disadvantages. According to

TABLE IV.—*United Kingdom: Exports of Commercial Vehicles, by Type.*

—	Number.		Value (£1,000).	
	1951.	1952.	1951.	1952.
Complete Vehicles:				
Delivery vans and dual-purpose vehicles (utilities)	62,497	54,252	21,334	20,394
Coaches and omnibuses—				
Single-deck	884	1,295	3,452	5,089
Double-deck	15	34	63	148
Tractors (other than track-laying and agricultural tractors) ..	509	805	511	900
Goods vehicles—				
Exceeding 3 tons unladen weight:				
With Diesel and similar engines ..	623	837	1,327	1,812
Other..	635	1,102	622	1,170
Not exceeding 3 tons unladen weight ..	1,985	3,253	1,162	2,360
Other descriptions ..	575	594	1,109	1,038
Total	67,723	62,172	29,580	32,920
Chassis:				
Of electric trolley 'buses	48	52	121	137
Of coaches and omnibuses—				
Single-deck	3,072	3,506	3,923	4,754
Double-deck	229	105	447	208
Of goods vehicles—				
Assembled with Diesel and similar engines..	4,551	4,877	5,498	6,763
Other	14,976	15,284	7,154	8,545
Unassembled, with Diesel and similar engines	6,340	7,126	6,815	7,978
Other	40,110	35,322	15,664	16,630
Of other descriptions ..	44	29	25	28
Total	69,370	66,301	39,647	45,045
Grand Total ..	137,093	128,473	69,227	77,967

MECHANISED CARRIAGE CLEANING AND MAINTENANCE DEPOT.

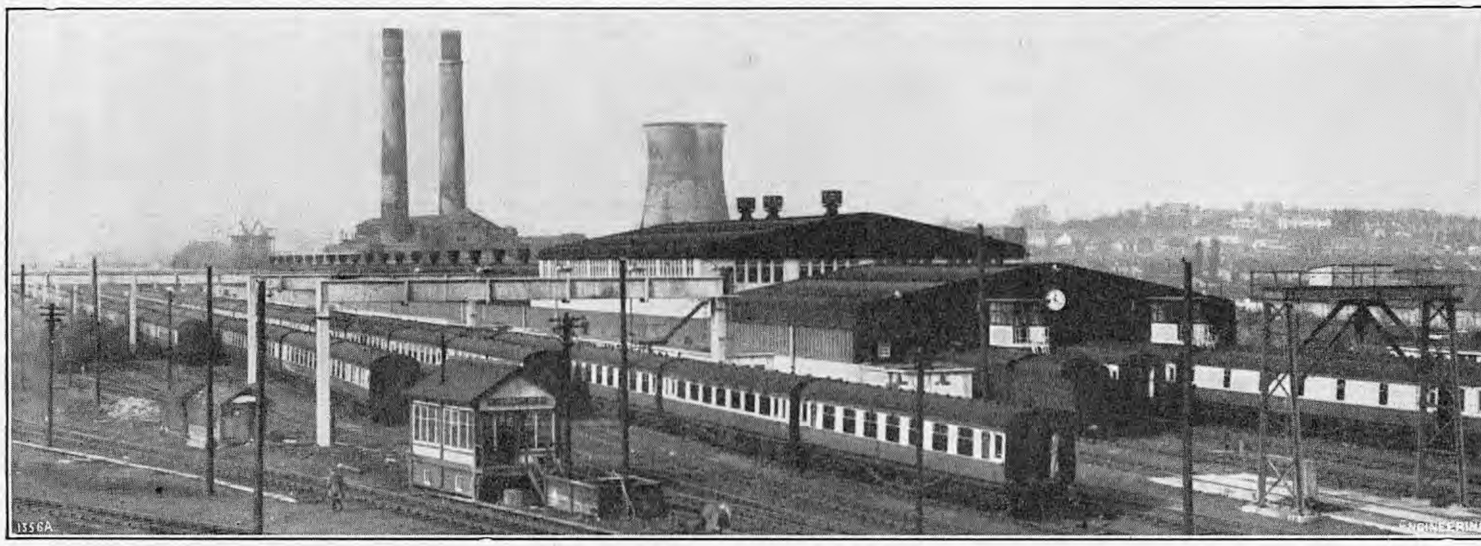


FIG. 1. GENERAL VIEW OF DEPOT.

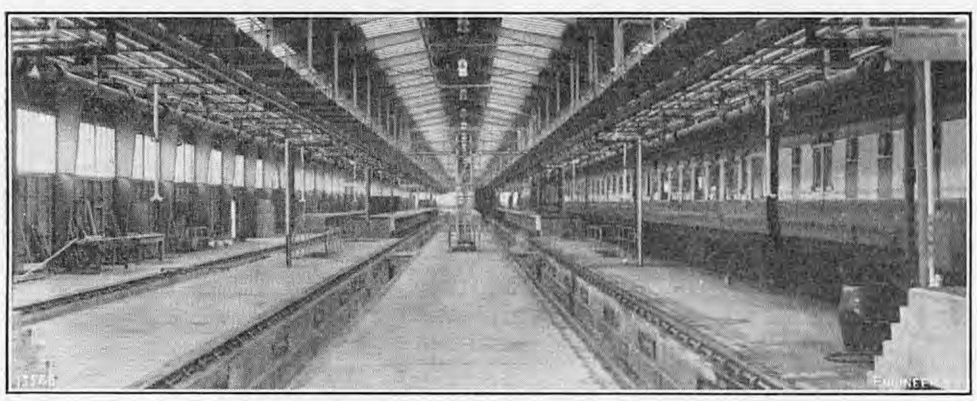


FIG. 2. INTERIOR OF CLEANING AND MAINTENANCE SHED.

Sir John Black, "the secret of low costs can be summed up in one word, volume," and the British industry is operating at only 70 per cent. of its capacity at the moment. The high export proportion is a double disadvantage; as conditions in the export markets become more difficult, the volume of production tends to fall, and, unlike their competitors, the British manufacturers cannot look to home sales to absorb the major proportion of overhead costs. Steps already taken to cut costs and simplify production have involved the dismissal of 800 employees by the Austin Company and 500 by the Morris firm, indicating, perhaps, the existence of concealed unemployment when the post-war shortage of steel limited output.

The multiplicity of models produced by the British motor industry has long been considered the main obstacle to reduction of costs and prices. The new electrically-controlled assembly system at the Austin plant at Longbridge appears to provide the answer to this problem, as it combines the advantages of mass production and complete flexibility. The present production consists of the A.40 and the A.70, which may be made up in a number of variants—left-hand or right-hand drive, for instance. The operation is controlled by Hollerith punched cards, on which the details of the model to be assembled are punched. The system is believed to be the most advanced in the world, and is to be extended later to the sub-assemblies.

COMMERCIAL VEHICLES.

The makers of commercial vehicles are even more dependent on exports than are the manufacturers of passenger cars. About the same proportion of output (50 to 75 per cent.) is being exported, but the home market is already receiving the same supplies as before the war, when it absorbed the total output of the industry. Since the war, a new class of commercial vehicle has been evolved, designed specifically to operate under conditions wholly different from those in this country.

In 1952, the exports of commercial vehicles and chassis were well maintained, despite the halving of exports to Australia by the import restrictions. Australia was still the largest single market, taking nearly twice as much as any other market—an indication of the wide dispersion of British exports. The comparative ease with which exports were diverted from Australia to the smaller markets suggests that these had been neglected in earlier years, and it is likely that they will soon reach saturation point. Exports of the lighter commercial vehicles fell in 1952, mainly owing to import restrictions in Europe, but this fall was offset by increased exports of goods vehicles and 'buses. Both Vauxhall Motors and the Rootes Group switched their production from lighter vehicles to 7-ton trucks, owing to the declining demand. This has increased the competition in the markets for heavy vehicles, though the mass-produced commercial vehicles of the motor manufacturers do not compete directly with the special-purpose vehicles built by firms such as Leyland Motors, and Associated Commercial Vehicles, Limited.

In the home market, there are signs that the demand for public-service vehicles is drying up. The post-war replacement of 'bus and coach fleets has been carried out, and there seems to be little new demand to take its place. Credit restrictions and higher fuel costs, together with restrictions on spending by local authorities, appear to be responsible for the decline in demand. The home demand for goods vehicles has been depressed by the uncertainty about the future of the road-haulage industry. A few of the larger companies have substantial re-armament orders to keep them occupied, but, in general, the commercial-vehicle industry cannot look to the home market to take up the slack if exports fall.

CARRIAGE CLEANING AND MAINTENANCE DEPOT.

THE new carriage cleaning and maintenance depot at Willesden, which is exceptionally well equipped with mechanical and electrical plant, should lead to a marked improvement in the cleanliness of London Midland Region long-distance trains working from the Euston terminus. The standard of carriage maintenance will also rise since the system and facilities provided for inspection and maintenance are in advance of anything existing on British Railways. In addition, by concentrating the preparation, marshalling and stabling of coaches for the long-distance Euston trains at the new depot—instead of having, until now, these facilities dispersed at several places—congestion on the main line between Euston and Willesden will be relieved, and trains of coaches coming out of, and being returned to, traffic will be worked more easily. This improvement will react favourably on the punctuality and orderliness of traffic in the area.

The maintenance shed itself is shown in Fig. 1, on this page; in the background is Stonebridge Park power station, from which steam supplies for the shed are to be drawn. Trains of coaches are first passed through mechanical washing plants which span a line in the open on the far side of the shed (Fig. 1). They are then delivered by a locomotive to one of four roads in the shed. Thereafter they are moved through the shed by winch-operated "mules." A train is shown on one of the four roads in Fig. 2. Each road is divided into four stages, at which the following work is progressively carried out: examination of the interior, exterior and underneath to determine the maintenance required, together with initial cleaning internally; exterior cleaning and interior maintenance; interior cleaning and exterior maintenance; and equipping sleeping cars with linen, and final inspection. Each stage takes four coaches, i.e., each road accommodates a 16-coach train. A train entering the shed enters, initially, only as far as the first four coaches, which come to rest in the first stage. The train is moved a stage length about every 20 minutes or so. When the first four coaches have been completed, the last four have still to pass through the second, third and fourth stages. Thus, the cleaning and maintenance of a train takes about $2\frac{1}{2}$ or 3 hours.

Empty coaching stock from Euston is first passed over a concreted section of track 480 ft. long, which is provided with drains so that the lavatories can be flushed. A chemical cleaning solution is applied to the sides of the carriages by the plant shown in Fig. 4, on page 336, the train being hauled through at about 3 miles an hour by a steam locomotive. A few yards in advance of the "solutioning" plant, fresh water is sprayed on to the sides of the vehicles to damp and cool the sides in hot weather and to seal small cracks, etc., in the paint with water and so prevent the ingress of cleaning solution. The solutioning plant consists of a steel framework spanning the track and supporting 16 pivoted brush arms, shown in the retracted position in Fig. 4. They are swung inwards by compressed air as soon as the engine has passed through the plant and the first carriage is about to enter. At the outer end of each arm there is an adjustable steel hood which supports a freely-rotating drum, carrying ten brush heads. Each arm is actuated by compressed air, at a pressure of 25 lb. per square inch, acting on a motor-car piston $2\frac{1}{2}$ in. in diameter. The piston works in an open-ended cylinder, and the arm is retracted by a counterbalance weight on release of the air pressure. The cleaning solution is contained in a 1,000-gallon sump built of acid-proof brickwork between the rails. It is pumped to the plant by a " Mono " pump with a capacity of 5 gallons per minute. There is a small feed tank to each brush head. The two upper tanks on each side of the machine are fed directly from the pump, and the overflow from these tanks is fed into the tanks below in cascade until the residual overflow from the lowest tank discharges into a spill-way leading to the sump.

Ten minutes after the solution has been applied, the train is passed through the washing machine shown in Fig. 3, on page 336, at about 3 miles an hour, to remove all cleaning solution and dirt. There are two washing machines in tandem, of a much improved design compared with existing machines. The steel frame on each side of the track supports four vertical flail rotors. Each rotor is driven at 50 r.p.m. Between the two machines there is a pump and attendant's house which contains two recirculating pumps, two fresh-water pumps, and a " Mono " sump-drainage pump.

The main shed is 1,120 ft. long and 77 ft. 8 in. wide, excluding stores, offices and amenities. Each of the four roads has normal-depth pits for 860 ft. and shallow pits for the remainder. All pits are of mass concrete construction, with drainage and fluorescent lighting. The shed floor is at rail level except where there are cleaning platforms and decks above the haulage mules. The shed is a single-span rigid steel frame of welded construction. A laundry for dealing with sleeping-car linen, etc., is housed on an upper floor which extends the full width of the shed for a length of 160 ft. Five subways with stairways leading to the pits, floor and decks enable the staff to move freely when trains are in motion.

Eight mules, one of which is shown in Fig. 5, on page 336, are provided, two for each road. The mules of each pair of adjacent roads work along the opposite sides of a T-section deck. Safety of the staff is ensured by means of a system of colour-light signals, and control keys which are carried by the staff. Each mule runs on upper and lower rails, supported and guided by horizontal and vertical rollers. A hinged arm, which can be raised and lowered by a 1-h.p. motor, is fitted with four cantilever leaf springs which embrace the buffer heads of two adjacent coaches. The haulage rope is connected to the mule through a bridle mounted in guides; this bridle can be moved longitudinally up to 3 ft. in relation to the mule carriage to enable an attendant to line up the arm with the buffers. A rotary exhauster is provided for coupling to the vacuum brakes.

The winch gear has been designed to move and bring to rest trains of 500 tons. Each winch consists of a 120-h.p. motor driving two drums, one for each of two adjacent roads. The motor drives each drum through two scoop-tube fluid couplings and two sets of gearing. One set of gearing and the coupling drives the winch forward, whereas the other reverses the mule or, if a train connected to the mule is in motion, it applies a braking effort to stop the train smoothly.

All shed roads are provided with the following services: vacuum cleaning, cold water, hot water and oil gas. These are arranged at floor level; in the pits, steam and vacuum-testing points are provided. Overhead, there are the pipes shown in Fig. 6, on page 336, for steam testing, vacuum testing, vacuum cleaning, gas, hot and cold water, electrical services and communications. The Sturtevant vacuum-cleaning installation comprises a multi-stage turbo-exhauster driven by a 15-h.p. motor, together with a dust separator, suction main, branches, etc. Loudspeaker equipment is provided in the shed and yard. A high standard of lighting is provided in the yard by lights supported on prestressed-concrete gantries. The total length of the marshalling and stabling sidings, excluding running loops and roads through the shed, is 8,680 yards, providing accommodation for 434 coaches. The whole scheme cost over 750,000*l*.

LOW-TEMPERATURE TEST CHAMBER.

ALFRED J. AMSLER & COMPANY, SCHAFFHOUSE, SWITZERLAND.

(*For Description, see Opposite Page.*)

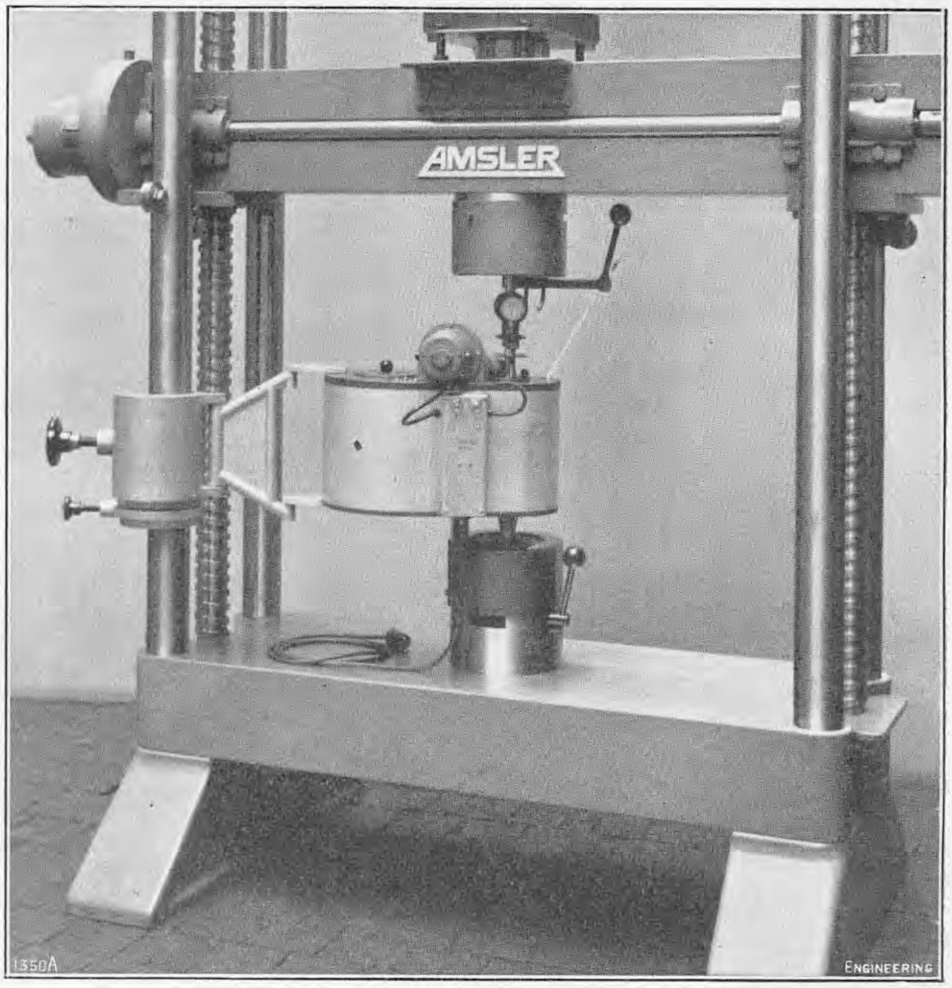
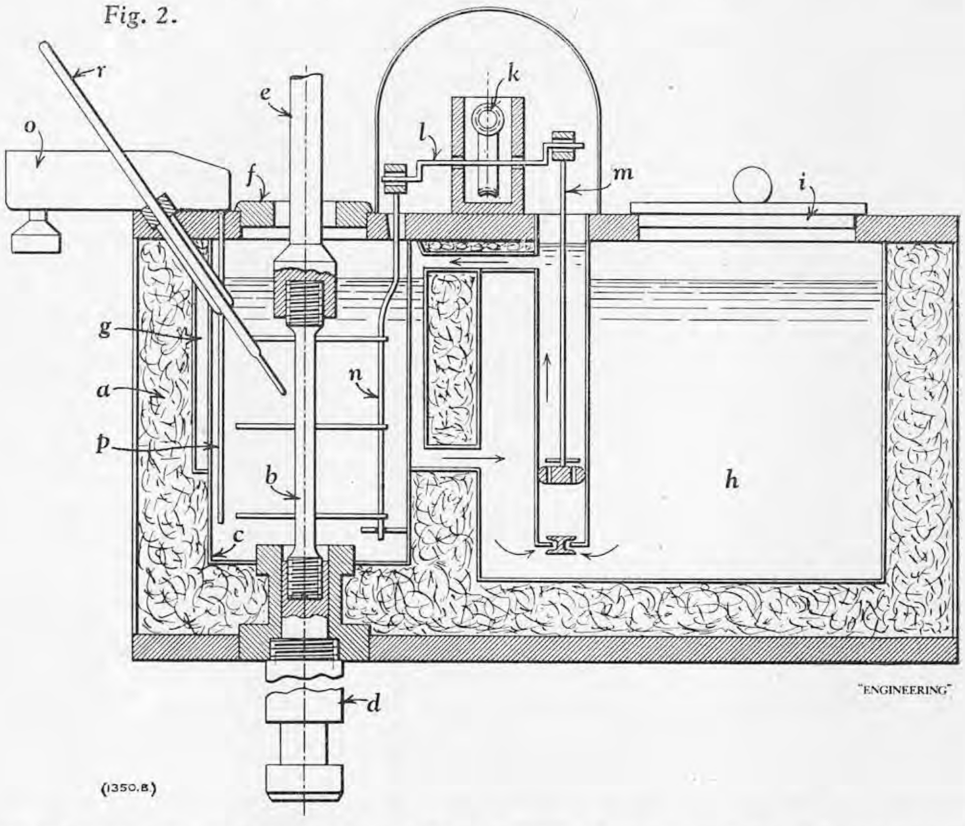


FIG. 1. CHAMBER ON TENSILE-TESTING MACHINE.

Fig. 2.



LOW-TEMPERATURE TEST CHAMBER.

ALFRED J. AMSLER AND COMPANY, SCHAFFHOUSE, SWITZERLAND.

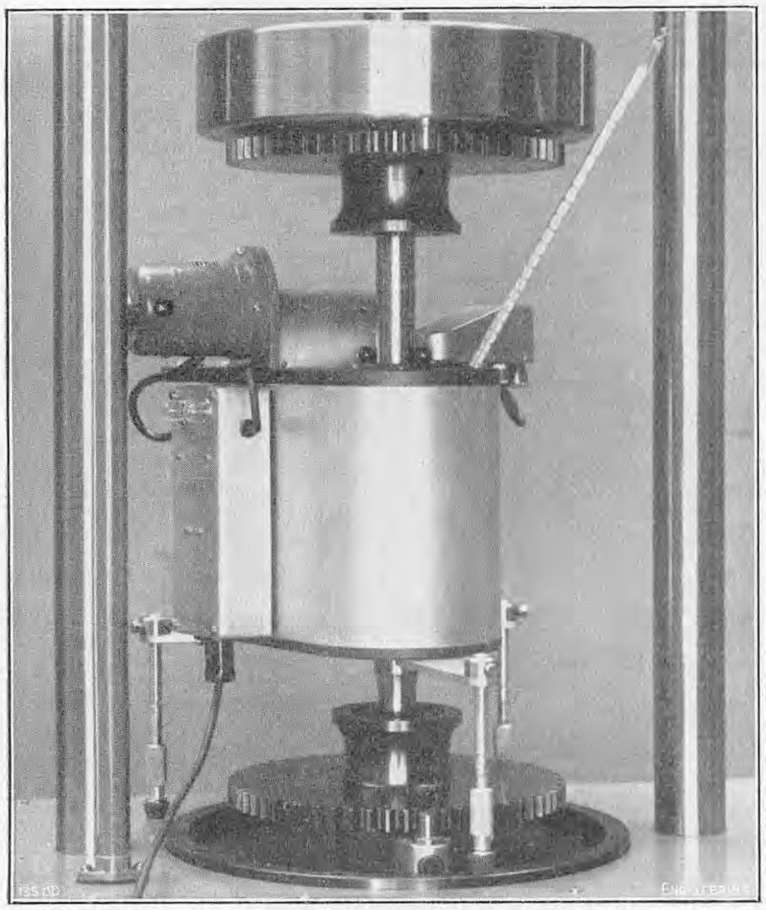


FIG. 3. CHAMBER USED WITH HIGH-FREQUENCY VIBROPHORE.

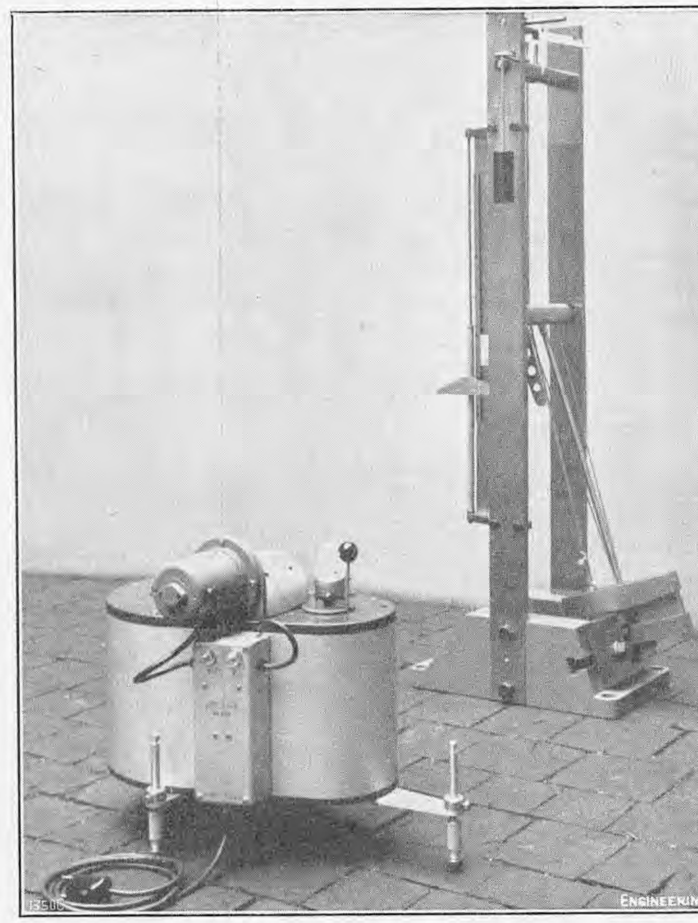


FIG. 4. COOLING IMPACT-TEST SPECIMENS.

LOW-TEMPERATURE TEST CHAMBER.

THE present stage in the development of internal-combustion engines, gas turbines, jet engines, chemical plant, etc., could not have been reached without intimate knowledge of the high-temperature properties of the materials used. With high-altitude flying and work under Arctic conditions, low-temperature tests are gaining almost equal importance. Hitherto, most mechanical tests of materials at low temperatures have been carried out either in a rather primitive way or by using elaborate scientific equipment. The low-temperature chamber illustrated in Figs. 1 and 2, opposite, and Figs. 3 and 4, on this page, makes tensile, compression, fatigue, hardness or impact tests at sub-zero temperatures almost as easy to carry out as tests at room temperature. Test temperatures can be chosen within a wide range and maintained constant with high precision by means of an automatic control. No special experience is needed to use the apparatus, and no gas cylinders, valves, tubes, etc., need be connected, as the unit is entirely self-contained.

The working principle of the low-temperature chamber, arranged for tensile tests, is shown in Fig. 2. Within a well-insulated plastic and sheet metal box *a*, the specimen *b* is contained in a closed well *c*. This specimen, which has threaded ends, is screwed into the bottom adaptor *d* and the top adaptor *e*. The bottom adaptor is screwed directly into the box *a*, and the top adaptor protrudes from the well *c* through the lid *f*. Part of the well *c* is surrounded by the cooling channel *g*, communicating with the main coolant container *h*, which is filled through the opening covered by the lid *i*. A small electric motor (not shown in the diagram) drives, by means of a worm gear *k* and the crankshaft *l*, a circulating pump *m* and a stirring device *n*. The motor is switched on and off by a bi-metallic temperature controller *o*, the feeler *p* of which is immersed in the well *c*. A glass thermometer *r* is used to measure the temperature in the well.

With the specimen and the adaptors in place, the well *c* is filled with a transfer medium, a liquid with a freezing point below the test temperature, and the container *h* and the channel *g* are filled with the coolant. The range of temperature for which the chamber can be used extends from room temperature to − 196 deg. C., the boiling point of liquid nitrogen. Liquid nitrogen is used as a coolant from − 30 deg. C. down to − 196 deg. C., but it is simpler to use solid carbon dioxide in a low-freezing liquid for temperatures from 10 deg. C. to − 60 deg. C., or ice-water from room temperature to about 5 deg. C. The motor is switched on and the pump *m* then causes the coolant to circulate between the container *h* and the channel *g*, while the stirrer *n* agitates the liquid in the well, to facilitate the exchange of heat between the specimen and the coolant. When the glass thermometer, which has a range of + 30 to − 200 deg. C., indicates that the test temperature is reached, the bi-metallic thermostat *o* is set and takes over the control of the motor. Whenever the specimen temperature rises above the set value, the motor is switched on and the excess heat is carried away by the coolant until the fall of temperature, sensed by the feeler *p*, is sufficient to switch the motor off again.

The temperature measurement is accurate to within ± 1 deg. C., and the test temperature can be maintained constant to less than ± 2 deg. C. The soaking time for the lowest temperature is about one hour, and for higher temperatures, proportionally less. The coolant-container holds about 4·4 lb. of ice or solid carbon dioxide, or about 0·88 gallon of liquid nitrogen. Once the stationary condition has been reached at a chosen temperature, the coolant consumption is about 0·5 lb. of ice, about 1·1 lb. of carbon dioxide or about 0·7 gallon of liquid nitrogen per hour at − 100 deg. C. specimen temperature. As a transfer medium, down to about − 165 deg. C., petroleum ether has been successfully used.

Fig. 1 shows the low-temperature test-chamber built into a tensile testing machine. The whole chamber is suspended from, and pivots on, an arm which is clamped to one of the machine columns. Above the chamber can be seen the dial gauges of a special extensometer, which is clamped directly on to the gauge length of the specimen. The dial gauges have divisions of 0·0004 in., but, for high-precision elasticity measurements, they can be provided with knife edges with mirrors, permitting readings to 0·00004 in. The extensometer is so designed that thermal contraction is compensated for, and thus only effective changes of the gauge length are indicated. For assembly of the specimen, adaptors and extensometer, the chamber can be readily swung out of the machine. The maximum permissible load for tensile tests is 17,000 lb.

In Fig. 3, the chamber is shown built into a high-frequency vibrophore for fatigue tests at speeds up to 300 cycles per second. Instead of the suspension arm, the chamber is supported by three rubber-tipped legs, screwed into a supporting frame. The maximum permissible load amplitude is 8,800 lb., which can be applied anywhere between 8,800 lb. tension or compression (e.g., between + 6,000 lb. and − 2,800 lb.). The chamber can also be used as an independent cooling unit for impact-test specimens, placed near the impact tester, as shown in Fig. 4. The specimens are placed in a wire-mesh basket with a handle which can be seen protruding from the chamber. With the impact-tester cocked, the extraction and placing of the specimen can be effected so speedily that the temperature-rise of the specimen is negligible. If need be, the chamber temperature can be set lower than the desired test temperature to compensate for the temperature rise during transfer.

Hardness tests can either be made in a similar manner, or, if the design of the hardness tester permits it, the anvil, specimen and punch can be arranged to work in the testing well. The complete chamber is about 16 in. long, 15 in. wide and 12 in. high. The dry weight of the test-chamber, which is made by Alfred J. Amsler and Company, Schaffhouse, Switzerland, is about 22 lb.

NOTES FROM THE INDUSTRIAL CENTRES.

SCOTLAND.

NATIONAL COAL BOARD AND EXPORTS.—A warning that this year was probably the last chance for the United Kingdom to establish a foothold in many of the coal-export markets was given by Sir Hubert Houldsworth, chairman of the National Coal Board. when addressing the Scottish branch of the National Association of Colliery Managers, in Glasgow, on March 4. It was hoped and intended to increase coal exports this year; the limitation of opportunity was the lack of coal production.

COAL OUTPUT.—Coal production in Scotland in the last week of February, the first in which the increased wages for day-wage men came into operation, totalled 493,000 tons, the best performance this year. The number of pits working the extra Saturday shift was 163, one of the highest figures for many weeks. In the preceding week, 479,500 tons were mined.

THE REAR DOORS OF THE "PRINCESS VICTORIA."—Mr. Edward Denny, chairman of William Denny & Bros., Ltd., Dumbarton, builders of the cross-channel ship, Princess Victoria, said at a launch on March 3 that some of the statements made in public in regard to the sinking of the vessel "have been singularly ill-advised." He referred, *inter alia*, to a reported statement by a Member of Parliament implying that the design of the doors at the rear of the ship was defective or unsatisfactory. Mr. Denny pointed out that the safety requirements of the Ministry of Transport must be met in such matters.

THE LATE MR. BENJAMIN BUTTERS.—We regret to record the death, in Glasgow, on March 6, of Mr. Benjamin Butters, managing director of Butters Bros & Co., Ltd., Glasgow, the largest firm of derrick-crane makers in this country, with whom he had been associated for 62 years. Mr. Butters was born on April 30, 1876, the eldest son of Michael Butters, who had founded the business in 1867, and he was therefore in his 77th year. He and his brother, James, helped to build up the business in its early years but James died comparatively young. Benjamin then became principal and was responsible for the growth of the firm, extending its range to include shipyard tower cranes in addition to the Scotch derricks which had been the first interest. Mr. Butters was chairman of the Derrick Crane Makers' Association until he retired from this position about two months ago.

CLEVELAND AND THE NORTHERN COUNTIES.

GROWING PRODUCTION IN THE NORTH.—In a report to the Northern Regional Board for Industry, Newcastle-upon-Tyne, Captain J. R. S. Haines, regional Admiralty officer, said that a further improvement in the steel position was likely. While the shortage was still noticeable, allocations, on the whole, were being met. With the increased allocations recently announced, and the prospects of increased steel production, the outlook should improve further. In marine engineering a shortage of boiler plates was still holding up work. The consumption of cement in the northern counties had risen from 494,000 tons in 1949 to 600,000 tons last year, and, in 1953, it would be about 631,000 tons. The Board of Trade Controller reported that, although there had been few inquiries for factories from firms outside the area during the past two months, many existing firms were expanding. Nineteen industrial-development certificates had been issued during December and January, covering more than 469,000 sq. ft. of space. These were expected to provide work for another 739 men and 240 women.

C. A. PARSONS & CO.'S RESEARCH DEPARTMENT.—A large research and design building erected by C. A. Parsons & Co., Ltd., Heaton, Newcastle-upon-Tyne, will be completed in April. This marks another stage in a large-scale development plan, costing 4,000,000*l*. carried out by Messrs. Parsons since the conclusion of the war. The building covers 185,000 sq. ft. of floor space.

PRODUCTION ENGINEERS AND AIRCRAFT INDUSTRY.—The lack of trained production engineers for the aircraft industry was referred to by Mr. J. E. Fogg, Sunderland manager for the Bristol Aeroplane Co., Ltd., addressing a meeting of Sunderland Rotary Club on February 26. He stated that Britain was not training enough technicians to compete in a possible market worth 100,000,000*l*. annually, excluding military requirements and smaller charter companies. Of 50 colleges providing training of this kind in Britain, there was only one in the North-East, at Gateshead. According to the present rate of training, it would not be until 1962 that there would be one technician to 300 operatives. Britain had the finest aircraft engines in the world, but was not making them fast enough.

INCREASED OUTPUT AT PNEUMATIC-TOOL WORKS.—Since the pneumatic-tool works of Armstrong Whitworth & Co., Ltd., Gateshead, were taken over by United States interests, two years ago, the works output has increased by 70 per cent. Mr. R. G. Faverty, the firm's American managing director, said that this had not been achieved entirely by United States methods, but by convincing the employees that by working hard they were not working themselves out of a job. The works were still short of capstan-lathe operators, drillers, grinders, turners and millers.

PROPOSED AMALGAMATION OF CHEMICAL FIRMS.—At the annual general meeting of the Eaglescliffe Chemical Co., Ltd., Eaglescliffe, County Durham, on April 8, a proposal will be made to shareholders to amalgamate the firm with the Scottish chemical firm of John and James White, Ltd. The directors of both firms believe that a merger would result in a more efficient working of the companies' plants, with consequent economies in costs and the better utilisation of capital for development of processes.

LANCASHIRE AND SOUTH YORKSHIRE.

RECORD STEEL OUTPUT.—The open-hearth melting shop at the Stocksbridge works of Samuel Fox & Co., Ltd., Sheffield, has achieved a steel output record of 4,392 tons in one week.

BUYERS BECOME SELLERS.—Sheffield manufacturers of hacksaws and other tools complain that demands for their products are being further reduced by the action of large firms, ordinarily buyers, who are selling their accumulated stocks to reduce the amount of dead capital which these goods represent. The action is regarded as unfortunate, as these sales are often at rates below the market price.

A HOLIDAY CONCESSION.—The North-Eastern Divisional Coal Board have acceded to the application of the men at two Doncaster district pits, Hatfield Main and Thorne, to take the two weeks of their annual holiday together this year. Other pits in the area are taking two separate weeks—one in July and the other in September. The area board originally asked the Hatfield and Thorne miners, for safety and administrative reasons, to fall into line with the rest of the area pits.

TRAINING SALESMEN.—Mr. C. E. Holmstrom, managing director of Firth-Vickers Stainless Steels, Ltd., Sheffield, has expressed regret to the Sheffield branch of the Incorporated Sales Managers' Association that there was no university course, in this country, dealing with selling and the study of distribution. He welcomed the decision of the University of Sheffield to consider courses on business studies.

THE MIDLANDS.

LESS WORK FOR IRON FOUNDRIES.—Because of lack of orders, a number of Derbyshire foundry operatives have been put on short time, and others given notice to terminate their employment. At the Park Foundry, Belper, about 100 men are working a four-day week, and Qualcast, Ltd., have dismissed about 30 employees. At Ley's Malleable Castings Co., Ltd., Derby, it is understood, about 50 have been given notices. Because of cancelled orders it has been decided to suspend men in the foundry at the works of Marshall, Sons & Co., Ltd., Gainsborough, and put others on a four-day week. It is understood that it will be possible to find many of the men work in other departments which are on overtime.

PROGRESS AT BLITHFIELD RESERVOIR.—The new Blithfield reservoir, near Abbot's Bromley, Staffordshire, which is being constructed for the South Staffordshire Waterworks Company, is nearly completed. A dam 3,000 ft. long has been built across the shallow valley of the river Blythe, and a new embankment has been constructed across the reservoir site to carry the main road from Uttoxeter to Rugeley. The reservoir will hold more than 4,000 million gallons of water, which will be piped to the company's purification plant at Seedy Mill, near Lichfield, and used to augment supplies to south Staffordshire.

TRADES EXHIBITION.—The Brierley Hill (Staffordshire) Manufacturers' and Traders' Association have decided to hold an exhibition of local industrial products in the town during the week beginning June 1. The exhibition will be on the lines of the one held in May, 1950, when 50 local firms displayed their products. Iron and steel, chain cables and anchors, ships' tackle, refractory products, and general engineering are leading products of the district.

GIRLING, LIMITED.—Girling, Ltd., King's-road, Tyseley, Birmingham, 11, makers of vehicle and aircraft braking systems, celebrated the 21st anniversary of the foundation of the company at the end of February. The company originally developed out of the old cycle and motor-cycle firm of New Hudson, Ltd., but it is now a subsidiary of Joseph Lucas, Ltd.

LARGER AIRCRAFT TO USE BIRMINGHAM AIRPORT.—The Ministry of Civil Aviation have lifted the ban which prevented regular operation by four-engined aircraft from Elmdon airport, Birmingham. Until recently, the largest aircraft using the airport regularly have been Dakotas, but last year the Ministry agreed to a limited use of the facilities by Wayfarers. It will now be possible for Skymasters, carrying 44 or 50 passengers, to operate on regular routes between Manchester, Birmingham and Paris, and, for the first time, Paris will be brought within two hours flying time of Birmingham.

INQUIRY INTO REDUNDANCY.—The Midland Federation of Trades Councils have decided to hold a conference at Digbeth Institute, Birmingham, 5, on April 25, to discuss redundancy and under-employment. The conference will be of a non-political nature, concerned with fact-finding, and it is hoped that out of the discussion will come a clear picture of the position in the Midlands, and some concrete suggestions for remedies.

UNDERGROUND FIRE.—Workmen of the borough of Rowley Regis, Staffordshire, have been engaged for the past three months in an effort to seal off an underground fire which is buring at the back of a housing estate. The estate was built on old colliery workings, and there has been a fire under part of the land since August, 1952. In recent months it has become sufficiently active to require extensive trenching in an endeavour to prevent it from spreading to the houses. Trenches 8 ft. deep are being dug and filled with sand, to isolate the fire. Quantities of usable coal are being uncovered—a relic of the days when Black Country collieries had no sale for small coal.

SOUTH-WEST ENGLAND AND SOUTH WALES.

EXTENSIONS AT EBBW VALE STEELWORKS.—Increased development plans in the cold rolling-mill section of the Ebbw Vale steelworks, involving a new five-stand and other mills, together with all ancillary equipment, had been finally approved, Mr. G. A. Young, general manager of the Ebbw Vale Works of Richard Thomas and Baldwins Ltd., announced at the annual dinner of the Ebbw Vale No. 2 branch of the British Iron, Steel and Kindred Trades Association. The 3,000,000*l*. developments on the coke ovens, open-hearth and blast furnaces would be completed towards the autumn of next year, and the whole scheme in 2½ to 3 years.

TIN-PLATE POSITION IN WEST WALES.—Following the debate in the House of Lords on the tin-plate position in West Wales, where ten works have been closed recently, the Lloyd Committee, set up last month to deal with the industrial development of this area, met in Cardiff under the chairmanship of Lord Lloyd, Under-Secretary for Welsh Affairs. They discussed the problem which arises out of redundancy in the tin-plate industry. In the House of Lords debate, Lord Lloyd said that the present was regarded as a temporary setback and there was every hope that, in a comparatively short time, the industry's expectations of even fuller order books would be fulfilled. The ten works closed down employed 2,300 men, and, of these, 900 had been re-absorbed in the tin-plate industry, while 350 had been found alternative employment. Of the remainder, a considerable number were of pensionable age or unfit for further work, but nearly 400 were still unemployed.

ROAD COMMUNICATIONS FOR SOUTH WALES.—The need for better road communications for South Wales has been urged again during the past week by the East Wales district committee of the Welsh Board for Industry and by Mr. C. T. Brunner, President of the Institute of Transport. Mr. Brunner told members of the South Wales and Monmouthshire section of the Institute that although a capital investment of about 300,000,000*l*. had been made in Welsh industry since the war, virtually nothing had been done in connection with the vital links it needed with the rest of the country. South Wales suffered badly from lack of road connections and inferior rail services.

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.—*Measurements Section:* Monday, March 16, 5.30 p.m.; Tuesday, March 17, 2.30 p.m. and 5.30 p.m.; and Wednesday, March 18, 2.30 p.m. and 5.30 p.m., Victoria-embankment, W.C.2. Symposium on "Electrical Insulating Materials" (see page 243, *ante*). *Mersey Centre:* Monday, March 16, 6.30 p.m., Town Hall, Chester. "Radio Telemetering," by Mr. E. D. Whitehead and Mr. J. Walsh. *Utilization Section:* Thursday, March 19, 5.30 p.m., Victoria-embankment, W.C.2. Discussion on "Economies in Wiring Practice."

INSTITUTION OF THE RUBBER INDUSTRY.—*Merseyside Section:* Monday, March 16, 7 p.m., Electricity Showrooms, Whitechapel, Liverpool. "Engineering for a New Product," by Mr. D. C. Crabbe. *Scottish Section:* Tuesday, March 17, 7.30 p.m., 25, Charlotte-square, Edinburgh. "New Developments in Sponge and Cellular Products," by Mr. W. R. Pryer and Dr. J. T. Watts.

INSTITUTION OF PRODUCTION ENGINEERS.—*North-Eastern Section:* Monday, March 16, 7 p.m., Neville Hall, Newcastle-upon-Tyne. "Arc Welding as an Aid to Production," by Mr. D. G. Sinfield. *Derby Section:* Monday, March 16, 7 p.m., College of Art, Green-lane, Derby. Annual Meeting and Film Display. *Southern Section:* Tuesday, March 17, 7 p.m., Municipal College Annexe, Anglesea-road, Portsmouth. "Production-Engineering Research, with Special Reference to Metal Cutting," by Mr. K. J. B. Wolfe. *Birmingham Section:* Wednesday, March 18, 7 p.m., James Watt Memorial Institute, Birmingham. Annual Meeting. *Glasgow Section:* Thursday, March 19, 7.30 p.m., 39, Elmbank-crescent, Glasgow. "Increased Productivity by the Use of Compressed Air," by Mr. C. Willcox.

ASSOCIATION OF SUPERVISING ELECTRICAL ENGINEERS.—*Central London Branch:* Monday, March 16, 7.10 p.m., St. Ermin's Hotel, Caxton-street, S.W.1. "Automobile Electric Equipment," by Mr. W. Cooke. *Association:* Tuesday, March 17, 6.30 p.m., Lighting Service Bureau, 2, Savoy-hill, W.C.2. "Applications of Electricity to Oil Refineries," by Mr. S. York.

INSTITUTION OF WORKS MANAGERS.—*Preston Branch:* Monday, March 16, 7.30 p.m., Starkie House, Starkie-street, Preston. "Some Legal Aspects of Management," by Mr. L. Walsh.

SHEFFIELD SOCIETY OF ENGINEERS AND METALLURGISTS.—Monday, March 16, 7.30 p.m., The University, St. George's-square, Sheffield. "New Die-Block Plant at Walter Somers, Ltd., Birmingham," by Mr. F. J. Somers.

INSTITUTION OF CIVIL ENGINEERS.—Tuesday, March 17, 5.30 p.m., Great George-street, S.W.1. (i) "Special Features of the Affric Hydro-Electric Scheme, Scotland," by Mr. C. M. Roberts; and (ii) "Scale-Model Experiments on High-Head Siphons and Vortex Chambers Connected Thereto," by Dr. W. Eastwood, Dr. G. A. Taylor and Professor Jack Allen.

INSTITUTE OF REFRIGERATION.—Tuesday, March 17, 5.30 p.m., Institution of Mechanical Engineers, Storey's-gate, St. James's Park, S.W.1. "Influence of Mass Manufacture on Machine Design," by Mr. R. R. Poole.

CHEMICAL ENGINEERING GROUP.—Tuesday, March 17, 5.30 p.m., Geological Society's Apartments, Burlington House, Piccadilly, W.1. "Objectivity in the Design of Sulphuric-Acid Plants," by Mr. Stanley Robson.

INSTITUTE OF FUEL.—*Midland Section:* Tuesday, March 17, 6 p.m., James Watt Memorial Institute, Birmingham. "Progress in Underground Gasification," by Mr. C. A. Masterman. *East Midland Section:* Friday, March 20, 7.15 p.m., Loughborough College, Loughborough. Joint Meeting with *East Midlands Branch* of the INSTITUTION OF HEATING AND VENTILATING ENGINEERS. "Heat Pump," by Mr. P. E. Montagnon.

INSTITUTION OF STRUCTURAL ENGINEERS.—*Wales and Monmouthshire Branch:* Tuesday, March 17, 6.30 p.m., South Wales Institute of Engineers, Park-place, Cardiff. "Tubular Structures," by Mr. J. R. M. McEwen. *Scottish Branch:* Wednesday, March 18, 6 p.m., Royal Technical College, Glasgow. "Tension Members in Engineering Structures," by Mr. H. Nelson. *Yorkshire Branch:* Wednesday, March 18, 6.30 p.m., The University, Leeds. "Report on the Papers Given on Concrete Shell Roofs in London, July, 1952," by Mr. H. E. Manning.

INSTITUTE OF METALS.—*South Wales Section:* Tuesday, March 17, 6.30 p.m., University College, Singleton Park, Swansea. Annual Meeting and Film Display.

INSTITUTION OF HEATING AND VENTILATING ENGINEERS.—*Liverpool Branch:* Tuesday, March 17, 6.30 p.m., Radiant House, Bold-street, Liverpool. "Centrifugal Pumps," by Mr. N. Youatt and Mr. G. O. Stevenson. *North-East Coast Branch:* Tuesday, March 17, 6.30 p.m., Neville Hall, Newcastle-upon-Tyne. "Steam Trap Types: Their Application and Limitations," by Mr. B. Pheasant.

INSTITUTE OF BRITISH FOUNDRYMEN.—*East Anglian Section:* Tuesday, March 17, 7 p.m., Public Library, Ipswich. "'C' Shell Moulding Process," by Mr. J. Fallows. *Slough Section:* Tuesday, March 17, 7.30 p.m., Messrs. High Duty Alloys, Ltd., Slough. "Flow of Metal," by Mr. R. W. Ruddle. *Southampton Section:* Wednesday, March 18, 7 p.m., Southampton Technical College, Southampton. "Manufacture of Chill and Grain Rolls," by Mr. L. H. Grainger.

SHEFFIELD METALLURGICAL ASSOCIATION.—Tuesday, March 17, 7 p.m., Grand Hotel, Sheffield. "Intergranular Corrosion of 18/8 Cr.Ni.-type Stainless Steels," by Mr. R. Butcher.

ROYAL SOCIETY OF ARTS.—Wednesday, March 18, 2.30 p.m., John Adam-street, W.C.2. "The Contemporary Role of Industrial Standards," by Mr. H. A. R. Binney.

ROYAL SANITARY INSTITUTE.—Wednesday, March 18, 2.30 p.m., 90, Buckingham Palace-road, S.W.1. "Timber Preservation," by Mr. H. A. Cox.

INSTITUTION OF LOCOMOTIVE ENGINEERS.—Wednesday, March 18, 5.30 p.m., Institution of Mechanical Engineers, Storey's-gate, St. James's Park, S.W.1. Annual Meeting. "Organisation and Control of Locomotive Repairs on British Railways," by Mr. R. C. Bond.

INSTITUTION OF SANITARY ENGINEERS.—Wednesday, March 18, 6 p.m., Caxton Hall, S.W.1. "Public Health Engineering in Britain and America," by Mr. Peter C. G. Isaac.

WOMEN'S ENGINEERING SOCIETY.—*Manchester Branch:* Wednesday, March 18, 6.30 p.m., Engineers' Club, Manchester. "Permali," by Mr. T. H. Ison.

INCORPORATED PLANT ENGINEERS.—*Kent Branch:* Wednesday, March 18, 7 p.m., Bull Inn, Rochester. "Fluid Flow," by Mr. R. F. Walters. *Western Branch:* Wednesday, March 18, 7.15 p.m., Grand Hotel, Bristol. Annual Meeting. "Aspects of Metallurgy in Plant Engineering," by Mr. J. Hinde.

INSTITUTION OF ENGINEERING INSPECTION.—*North-East Coast Branch:* Wednesday, March 18, 7.30 p.m., 8, Oxford-street, Newcastle-upon-Tyne. "Radiography," by Mr. A. Gottfeld.

INSTITUTE OF ROAD TRANSPORT ENGINEERS.—*North-West Centre:* Wednesday, March 18, 7.30 p.m., Victoria Hotel, Wigan. Various short papers. *Institute:* Thursday, March 19, 6.30 p.m., Royal Society of Arts, John Adam-street, W.C.2. "Vehicle Maintenance," by Mr. J. H. Vincent. *Yorkshire Centre:* Thursday, March 19, 7.30 p.m., Hotel Metropole, Leeds. "Automotive Fuels," by Commander B. H. J. Thomas.

INSTITUTE OF WELDING.—*Wolverhampton Branch:* Wednesday, March 18, 7.30 p.m., Victoria Hotel, Wolverhampton. "Review of Technical Works at the B.W.R.A.," by Dr. A. A. Wells.

ROYAL INSTITUTION.—Thursday, March 19, 5.15 p.m., 21, Albemarle-street, W.1. "X-Ray Optics.—III," by Professor Sir Lawrence Bragg, F.R.S. Friday, March 20, 9 p.m., "Size and Shape of Big Molecules," by Professor H. W. Melville, F.R.S.

ROYAL AERONAUTICAL SOCIETY.—Thursday, March 19, 6 p.m., Institution of Mechanical Engineers, Storey's-gate, St. James's Park, S.W.1. Louis Bleriot Lecture on "Making Commercial Aircraft Pay," by General Guy du Merle.

INSTITUTION OF MECHANICAL ENGINEERS.—*North-Western Branch:* Thursday, March 19, 6.45 p.m., Engineers' Club, Manchester. "Use of Heavy Fuels for Diesel Engines," by Mr. J. R. P. Smith. *Scottish Branch:* Thursday, March 19, 7.30 p.m., Royal Technical College, Glasgow. Repetition of Presidential Address by Sir David Pye, F.R.S. *Institution:* Friday, March 20, 5.30 p.m., Storey's-gate, St. James's Park, S.W.1. (i) "A Room Temperature Photo-Elastic Technique for Three-Dimensional Problems," by Dr. J. H. Lamble and Dr. S. E. A. Bayoumi; and (ii) "Use of Gelatin Models in Structural Analysis," by Mr. J. D. C. Crisp. AUTOMOBILE DIVISION.—*Scottish Centre:* Monday, March 16, 7.30 p.m., 39, Elmbank-crescent, Glasgow. "Research and the Engineering Process," by Dr. H. E. Merritt. *North-Eastern Centre:* Wednesday, March 18, 7.30 p.m., The University, Leeds. Address by Professor W. A. Tuplin.

NORTH-EAST COAST INSTITUTION OF ENGINEERS AND SHIPBUILDERS.—Friday, March 20, 6.15 p.m., Literary and Philosophical Society's Hall, Newcastle-upon-Tyne. "Development and Maintenance of Post-War Naval Machinery," by Commander (E) A. F. Smith.

JUNIOR INSTITUTION OF ENGINEERS.—Friday, March 20, 7 p.m., Townsend House, Greycoat-place, S.W.1. "The Aether," by Mr. J. Heywood.

NORTH-EAST METALLURGICAL SOCIETY.—Friday, March 20, 7.15 p.m., Cleveland Scientific and Technical Institution, Middlesbrough. "Role of Metallurgy in Atomic Energy," by Dr. H. M. Finniston.

PERSONAL.

MR. W. O. GARDINER, late of Cammell Laird & Co., Ltd., has joined the staff of the Caledon Shipbuilding and Engineering Co. Ltd., Caledon Shipyard, Dundee, as general manager of the marine-engineering department. MR. W. J. STEWART is remaining with the Caledon Co. as technical manager of the marine-engineering department.

MR. L. W. D. SHARP, M.A. (Cantab.), A.M.I.E.E., has been appointed chief engineer, components division, Plessey Co., Ltd., Ilford, Essex.

MR. GUNNAR POPPE, O.B.E., M.A., has been appointed general manager and director of James Beresford and Son Ltd. (a subsidiary company of Cornercroft Ltd.), Stork Works, Marston Green, Birmingham, 33.

MR. A. M. LEIPER, general manager of Fawcett, Preston & Co., Ltd., Bromborough, Cheshire, since June, 1952, has been elected a director.

MR. G. P. CLAY has been appointed chief engineer of the Metals Division of Imperial Chemical Industries Ltd. In 1951 he was appointed assistant to MR. J. T. SMITH, whom he now succeeds.

MR. J. V. DANIEL has been appointed a joint managing director of Crompton Parkinson Ltd., Crompton House, Aldwych, London, W.C.2. MR. J. B. SCOTT, D.F.C., Assoc.I.E.E., an executive director and at present assistant sales director (home), becomes a sales director. MR. C. F. DICKSON, O.B.E., will remain a sales director until June 30, after which he will continue to serve as a member of the board. MR. D. E. GRAHAM, Assoc.I.E.E., M.I.Ex., the general sales manager, overseas division, has been appointed an executive director.

MR. F. L. NOBES joined the board of the Carborundum Co., Ltd., Trafford Park, Manchester, 17, on January 7. MR. S. G. BLAKE became a director emeritus on the same date. MR. N. V. CRABTREE has been made manager of the coated-abrasives division of the company.

MR. H. F. JUDD has been appointed general manager and a special director of Ioco Ltd., Netherton Works, Anniesland, Glasgow, W.3.

MR. H. S. CARTER, B.Eng. (Liv.), has been made sales manager, heating and welding department, Metropolitan-Vickers Electrical Co., Ltd., Trafford Park, Manchester, 17.

MR. G. J. BENNINGTON DAVIES, B.Sc., has been transferred from the Home Counties' territory of Acheson Colloids Ltd., to the head office, 18, Pall Mall, London, S.W.1, to undertake wider duties. MR. A. S. HUKIN is taking over the Home Counties territory and is operating from 18, Hill Rise, Richmond, Surrey. MR. A. D. WRIGHT, B.Sc., has joined the export section of the sales department.

MR. E. S. PEARSON, secretary of Clarkson (Engineers) Ltd., Nuneaton, has been appointed to the board of directors following the resignation of MR. G. F. COLE. MR. C. E. MIDDLEMISS, sales manager, will be in complete charge of all home sales in future.

MR. W. H. HAMBROOK, F.R.Ae.S., sales controller, Short Bros. and Harland Ltd., Belfast, has been made technical manager and the post of sales controller has been abolished. MR. MARK HOWARD, formerly contracts manager, has been appointed sales and contracts manager.

MR. DONALD SUTHERLAND, A.M.I.C.E., of Inverness; MR. J. W. BLOWS, A.M.I.Mun.E., of Harlow, Essex; MR. ROBERT SCRIMGEOUR, G.M.I.Mech.E., of Dundee; MR. RAYMOND COOK, B.Sc., of Southampton; and MR. P. H. STEWART, B.A., B.A.I., of Dublin, have been appointed to the Colonial Engineering Service in Malaya.

A. C. FARNELL LTD., 15, Park-place, Leeds, 1, have been appointed exclusive agents in the West Riding of Yorkshire for very high frequency radio equipment manufactured by Marconi's Wireless Telegraph Co. Ltd., Chelmsford, Essex.

WOLF ELECTRIC TOOLS LTD., have opened a new office and service depot at 405, York-road, Leeds, 9, to replace the previous service depot at 2, Park-square, Leeds. The new depot is under the direction of MR. D. S. POWELL.

SMALL AND PARKES LTD., Hendham Vale Works, Manchester, 9, announce that the address of their Birmingham depot is no longer 54, Lancaster-street, but is now 216, Moseley-street, Birmingham, 12. (Telephone: Midland 4659.)

The sales divisions of R. H. WINDSOR, LTD. have been transferred from Royal London House, Finsbury-square, London, E.C.2, to the head office and works at Leatherhead-road, Chessington, Surrey. (Telephone (new number): Epsom 5631.)

LEYLAND BELGIUM S.A., agents for LEYLAND MOTORS LTD. in Belgium, have changed their address from 32, Rue Auguste Lambiotte to 64, Rue de la Loi, Brussels.

MECHANISED CARRIAGE CLEANING AND MAINTENANCE DEPOT, WILLESDEN.

(*For Description, see Page* 331.)

FIG. 3. CARRIAGES PASSING THROUGH WASHING PLANT.

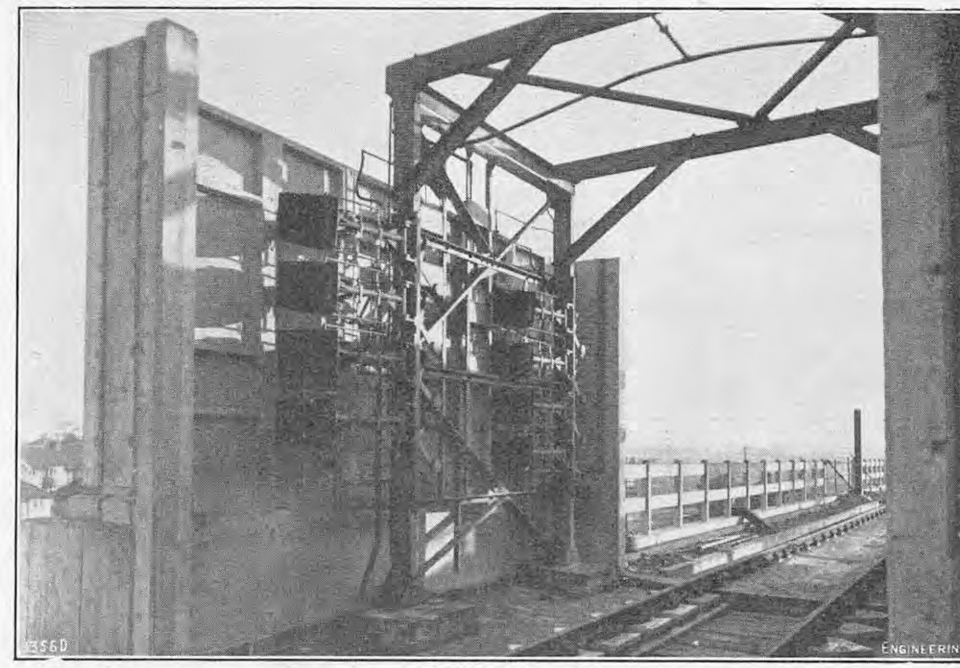


FIG. 4. PLANT FOR APPLYING WASHING SOLUTION.

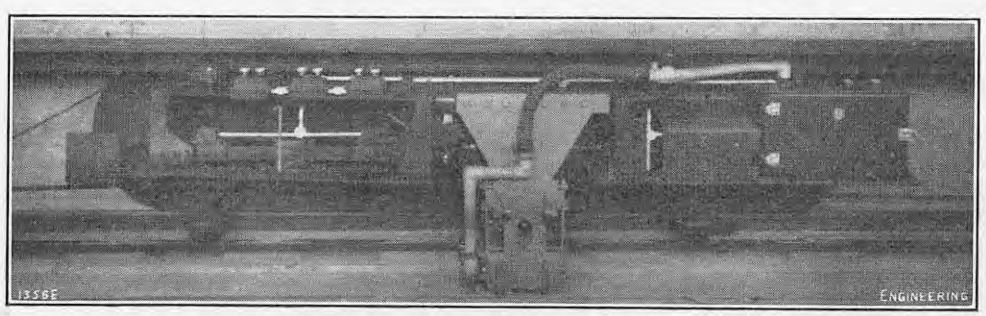


FIG. 5. WINCH-OPERATED "MULE."

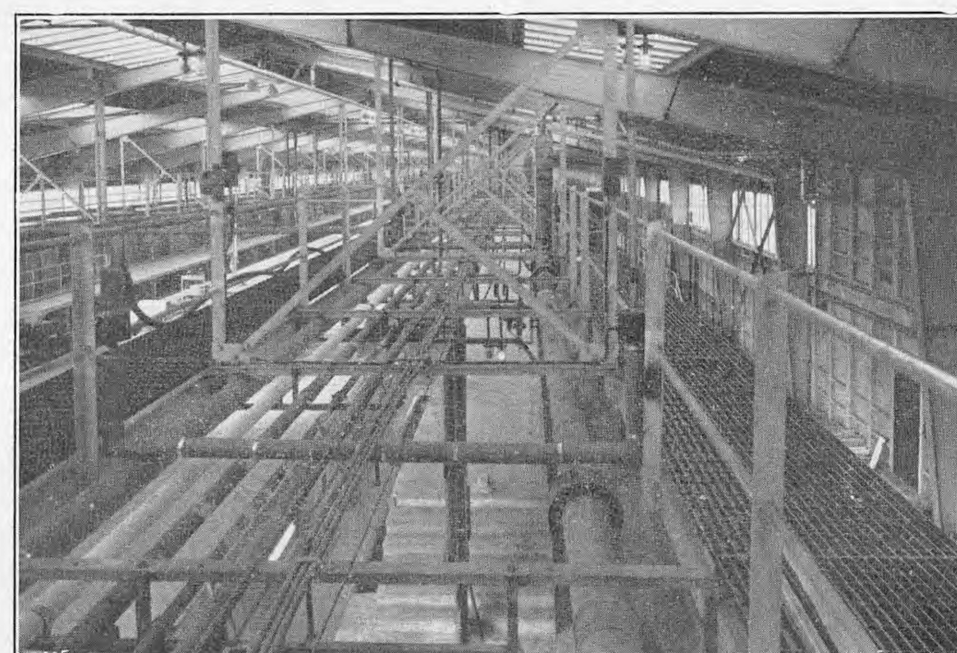


FIG. 6. VIEW FROM SHED GALLERY, SHOWING SERVICE MAINS.

ENGINEERING

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ENGINEERING

FRIDAY, MARCH 13, 1953.

VOL. 175. No. 4546.

UNIVERSITY GRADUATES IN INDUSTRY.

IT might be suggested that all that can usefully be said or written about the subject of this article has long since been said and written. Apparently, however, the Federation of British Industries would not agree with this view, as they have just published a further report* on the question of university education and its relation to industrial requirements. The conference with which the report deals was the eighth of its type. The first was held in 1949 and was followed by regional conferences in Oxford, Bristol, London, Birmingham, Leeds and Nottingham; the proceedings at the latter of these were reviewed and commented on in a leading article on page 178, *ante*. The purpose of the latest conference, at Ashorne Hill, was to review progress made since 1949 and to consider what could be done to foster closer relationship between the universities and industry.

Probably no one will be hopeful enough to expect that any generally-agreed conclusions have been come to as a result of the many papers presented and the many discussions held. This latest report still records widely differing opinions, but it does contain a "preface and summary" of "the main points made in the papers or which emerged from the discussions." It was compiled by representatives of the three main parties concerned in the organisation of these conferences. The Federation of British Industries was represented by the Director-General, Sir Norman Kipping; the universities, by Dr. C. R. Morris, Vice-Chancellor of the University of Leeds; and industry by Mr. D. R. O. Thomas, of the United Steel Company, Limited.

The first point made in the summary is that industry must attract a larger proportion of those possessing high intellectual ability and of those combining average ability with good personal qualities. One way to encourage this was for industry to publish well-written literature explaining its purposes and attractions. This literature should be designed "to stimulate the imagination of boys and young men," but how an important proportion of the 43·1 per cent. of university students who now take an arts course can be induced to read it is not mentioned. The figure of 43·1 per cent. was given by Professor L. J. Kastner, as reported on page 283 of our issue of last week. No doubt, well-designed literature might be of service, but propaganda might be more effective if it was directed at the schoolmasters rather than the boys. Apart from the classical tradition of some schools, the "modern" sides of many are not much concerned with industry. Interest is directed to mathematics or pure science, with the result that, according to Professor Kastner, 20·1 per cent. of undergraduates are studying this latter subject as compared with 12·4 per cent. for technology. Mr. B. L. Hallward, Vice-Chancellor of the University of Nottingham, throws part of the blame on the open-scholarship system at Oxford and Cambridge, and possibly London.

Another matter mentioned in the summary is that "the increase in the university population has not led to a corresponding increase in the number of men obtaining first-class honours degrees." This was referred to by more than one speaker and Lord Hives, at the Nottingham conference, said that there were not enough first-class men. One possible explanation of this state of affairs might be that an adequate number of first-class men are not being born, but apparently the sociologists would not agree with this cheerless conclusion. Professor P. M. S. Blackett, in one of the discussions, quoted figures in which the population was split up into income groups. These showed that the mean intelligence quotient increased with income, but that, as the lower-income groups were much larger than the higher, the total number of individuals of superior ability was larger in the lower-income groups. Of people with an I.Q. of 135, which represented first-class honours standard, and who constituted some 1 per cent. of the total population, about 800 were found in the lowest income group compared with 550 in the highest. A statement roughly corresponding to that implied in Professor Blackett's figures was made in the report on *Scientific Man and Power*, published in 1946. The report stated that "about 5 per cent. of the whole population show, on test, an intelligence as great as the upper half of the students, who amount to 1 per cent. of the population." Since, as Dr. Eric Ashby, Vice-Chancellor of the Queen's University, Belfast, pointed out, "it is becoming positively difficult for a reasonably bright boy . . . to avoid going to a university," it is reasonable to ask why this talented lower-income group majority is not producing more first-class honours men. Mere engineers may be permitted to wonder if this reservoir of talent really exists, and whether psychologists and sociologists are not inclined to draw sweeping conclusion from very slender evidence.

Whatever the facts may be, it would appear that no sphere of activity is getting as many first-class men as is desirable. This is apparently the case even with the Civil Service, which is traditionally the aim of most of the best brains from Oxford and Cambridge. One of the papers was read by Sir John Maud, Permanent Secretary of the Ministry

* *Report of the Universities and Industry Conference organised by the Federation of British Industries and the Committee of Vice-Chancellors and Principals of the Universities of the United Kingdom and held at Ashorne Hill, Leamington Spa, Warwickshire, 24-26 October, 1952.* The Federation of British Industries, 21, Tothill-street, London, S.W.1. [Price 5*s.*]

of Fuel and Power, who said, "I am quite sure that we in the Civil Service ought to have a larger proportion of first-rate university graduates." He also said, however, that he would do everything he could "to persuade the marginal first-rater to go into industry or trade rather than into the Civil Service." This statement, from a leading civil servant, was good-natured, but the officials of the Civil Service now have so much influence on practically every type of activity that the country simply cannot afford that it should be run by second-class brains. Sir Robert Wood, in some final reflections on the conference, expressed a fear that this country, "which was for so long protected by its wooden walls, might, in the end, be destroyed by its wooden heads."

Much of the time of the conference was devoted to the question of the arts graduate in industry, and there was much discussion about universities providing tuition in management, both for arts and science men. Dr. Ashby, on this subject, said that "if one analysed management, one came to the conclusion that there was no such subject." It was not a technology and the universities were opposed to teaching it because it was not codified. Management was an art and the only way of teaching an art was by apprenticeship. There is much in this, and it became evident in the course of the discussion that many non-engineering firms are now operating graduate-training schemes in which recruits are given experience in a variety of departments. The system is not necessarily copied from, but it is in essence of the same type as, the graduate-apprentice schemes which have been operated for many years by most of the large engineering firms.

The engineering industry has long since worked out a satisfactory method of utilising engineering graduates and to a large extent it has found that satisfactory managerial ability is to be found in the ranks of technical men. It has no special interest in the question of arts graduates in industry. Its concern is rather how the proportion of science students in universities can be increased. It is not a question only of first-class honours men. Frequently, reports of research organisations and technical services record that work is hampered, or has to be abandoned, because of shortage of staff. Men of I.Q. 135 are certainly required, but many of less ability are needed, and an increase in the number of science undergraduates improves the chances of the emergence of men of ability above the average.

The purpose of the various regional conferences which have been held was to interest local industry in the work of the universities and, conversely, to interest the universities in industry and to show that it could offer promising careers to graduates. Dr. Ashby said that "to-day the universities were filled with students who did not know what they wanted to do." Some, if they could be caught in time, might be influenced to aim at an industrial career by the atmosphere created by such conferences. Another way to induce a more industrial outlook in the universities would be for industry, as a definite policy, to attempt to encourage members of university staffs, not only professors, to take an active part in industrial activity, possibly as consultants on special points. Although it is clearly desirable to influence undergraduates, it might be even better to influence schoolboys. Fortunately, in this country, the Australian system is not in operation. There, according to Dr. Ashby, a boy of 17 has to decide whether to go to a university or enter the Civil Service. As the universities can now accommodate any young person who can pass matriculation, the Civil Service finds itself "left to choose from a reservoir of boys not intelligent enough to get into a university." Possibly more might be directed to an engineering career if that industry attempted to get in touch with schoolmasters as well as university lecturers.

FACTORS OF SAFETY.

THE term "factor of safety" is both concise and expressive, but, unless it is specifically qualified and related to a particular context, it may well be not only meaningless, but misleading. In engineering literature, the explanatory qualifications are either specifically defined, or are indirectly implied by the circumstances in which the term appears. To the man in the street, however, it has a plain, simple and direct meaning. Supposing, for example, that a man buys a rope to bear his own weight, and he is told that the factor of safety is five on a weight of 16 stone, he would have a perfectly reasonable expectation that it would take a load of half a ton to break the rope. But now let him purchase a shackle or hook to hold the end of the rope. He wants it to have the same breaking strength as the rope, but he will run into trouble if he should ask for a factor of safety; what he wants now is not a factor of safety, but a "load factor," and the engineers' factor of safety may have a much lower value than five.

There are, indeed, many interpretations of the term "factor of safety." Constructional steelwork engineers commonly use it as the ratio of ultimate tensile strength, as proved in testing machines, to an arbitrary design stress at working load, which is calculated by conventional rules based on the simplest possible mathematical images of the very complex physical phenomena involved in the action of loading a structure. In this sense, the so-called factor of safety is of the order of three or four. Constructional engineers working with concrete, plain, reinforced or pre-stressed, have other interpretations of the term. On the other hand, armament designers work to a simple code, but a very different one, taking the ratio of the yield stress or proof stress to the design stress at the working load; in this case, due to the redistribution of stress in a thick cylinder, when the elastic stress on the inner surface has been exceeded under the pressure of the burning propellant confined by the inertia of the projectile, the "factor of safety" in a gun tube may well be less than unity.

The uninstructed layman, therefore, when he chances to hear that factors of safety less than unity are customary in one branch of engineering design, may well ask why the same rule cannot be applied in another. When he has not received the simple explanation to which he is entitled, he may be pardoned for jumping to a false conclusion. Mr. G. A. Gardner, O.B.E., in the first of the two 1953 Cantor lectures at the Royal Society of Arts, to which we referred on page 275, *ante*, explicitly stated that laymen—and laymen in high places—were telling engineers that they built too strongly, and that they should not design structures which would actually carry three or four times the loads they were intended to carry. Hitherto, engineers have dismissed such observations as ill-informed or even ignorant comment; but in this they have themselves been at fault, because laymen are often more intelligent than some of the specialists they employ. The profession should be grateful, therefore, to Mr. Gardner for having stooped from his technical eminence to give a simple exposition of the matter, giving engineers the opportunity to consider putting their own house in order.

Begging this question for the moment, the fact remains that there are different standards of safety-factor in different fields of engineering practice. Engineers aim to produce, and almost invariably succeed in producing, a solution in which the risk of failure is reasonably related to the duty to be performed, the endurance required, the onse-c quences of collapse, and the cost of perfection. To take a simple illustration, the vehicle designer will set himself very different standards according to whether he is producing a racing car or a public-service passenger coach; and, even in the design of the racing car, the safety-factors on steering and brake controls will be far higher than on the details of engine, gearbox and transmission, since the results of failure would be so much more catastrophic in the former components than the latter. Similarly, a passenger lift must be designed to higher factors, and subjected to more rigorous inspection, than a contractor's erection tackle. By and large, engineers produce machines, ships or structures with safety-factors which are inherently reasonable. The engineer's work is neither over-strong nor cut too near the bone, for, in the one case, there would be no need for engineering insurance, and, in the other, the premiums would be prohibitively high.

This is the overall picture, using the insurance market as a statistical barometer, but that is not to say that there are no fields of design in which factors could be more finely adjusted and some economies effected. Theoretically, if, for the sake of argument, we exclude "the wonderful one-hoss shay," there is no engineering structure which could not be refined, improved and lightened, if the designer had nothing else to do and if he knew precisely the loads for which he had to design. Sir Benjamin Baker, for example, complained that he had been forced to make the Forth Bridge much heavier than was necessary to meet the rolling-stock standards and prospects of the eighteen-nineties, because the conservatively obdurate assessors of the Board of Trade insisted on higher factors of safety (as distinct from load factors or safety factors) than were technically necessary, in his professional judgment as the most experienced and competent constructional engineer of his generation. We have good cause to-day to be grateful for the refusal of those assessors to give way to Baker's instinct for engineering elegance, since they forced him to provide, albeit unwittingly, a substantial reserve for the future. Just as the bridge designer never knows precisely the loads to which his bridge may one day be subjected, so the designer of a roof or a tall building has no real knowledge of the loads, in snow or wind, that his work may be called on to endure. In practice, of course, design loads are based on conventional rules or fairly closely known requirements, and that is the starting point for the consideration of a load-factor. Given an approved system of design, the engineer can, if required, work to a tight load-factor or safety-factor; but, the finer the margin, the higher the design cost, and, unless there is considerable repetition of the unit or sub-unit, it will not be financially economical to match a specification with the closest precision.

The final answer, however, to the plaint that engineers build too strongly, is that failures are not entirely unknown. In relation to the volume of work carried out, they are remarkably few; but if anyone were to compile a comprehensive catalogue of failures, the layman would be asking the engineer to take fewer risks. Tay, Quebec, and Tacoma are well-remembered names in the literature of bridge construction, but these are only the high spots of catastrophe. Never a year goes by but some roof comes down under snow, or a footbridge under an unusual press of passengers. In one field of construction, however, collapse is extremely rare. The Ministry of Works has long had a fine record of designing and sponsoring works that stand "from war to war, and reign to reign," and it may well be that their engineers' ideas on safety-factors are a little more conservative than those of a speculative contractor, fighting for a contract, or of a progressive consulting engineer or architect, trying to introduce novelties in design. This is reasonable enough; and if the official side are rightly putting safety first, the independent professional engineers should not take umbrage when a Government department issues a pamphlet advocating economy in constructional materials—provided always that the Service engineers are prepared to practise what they preach.

NOTES.

STEAM TURBINE RESEARCH AND DEVELOPMENT.

A ONE-DAY Conference on "Steam Turbine Research and Development" was held at the Institution of Mechanical Engineers, Storey's-gate, London, S.W.1, on Friday last, March 6, when seven papers were presented by Dr. T. W. F. Brown (research director of "Pametrada"—the Parsons and Marine Turbine Research and Development Association) and members of his staff. Two of the papers were read by Dr. Brown himself, on "Facilities for Full-Scale Testing of Marine Turbine Machinery" and on "The Application of Research to Marine Turbine Development." The other papers were on "The Development of a Marine Steam Turbine Design," by Mr. H. G. Yates, M.A.; "The Measurement of Specific Steam Consumption," by Mr. Michael A. Petty, B.A.; "Back-to-Back Testing of Marine Reduction Gears," by Dr. A. Cameron and Mr. A. D. Newman, B.Sc.; "Some Reflections on the Thermal Distortion of Turbine Casings," by Mr. Basil J. Terrell, M.B.E., B.Sc. (Eng.); and "The Determination of Natural Resonances in Mechanical Systems," by Dr. O. P. T. Kantorowicz. The Conference was opened by Sir David Pye, C.B., F.R.S., President of the Institution of Mechanical Engineers, who spoke of the value of the work done by Pametrada at their research station at Wallsend-on-Tyne in the development of naval and mercantile marine propelling machinery. He considered that Dr. Brown and his staff had contributed materially towards ensuring that the British steam-turbine industry continued to hold a leading position among the shipbuilding nations of the world. Mr. P. L. Jones, B.Sc., then took the chair for the first session, during which four papers were presented. For the second session, in the afternoon, Dr. R. W. Bailey, F.R.S., occupied the chair, while the remaining three papers were read. After an interval for tea, the third and final session was devoted to a discussion of the seven papers together. It is announced that written contributions to the discussion will be accepted by the secretary of the Institution of Mechanical Engineers until May 6.

GROWING GRASS IN SEWAGE SLUDGE ON ASH DUMPS.

An article by Mr. W. J. Rees and Mr. A. D. Skelding in the current issue of *Agriculture* (which is published monthly by the Ministry of Agriculture) describes the result of a two-year attempt to produce a grass ley on the ash dumps at Hams Hall power station. These dumps now occupy an area of about 40 acres, which is raised about 40 ft. above the original ground level, and consist of waste from pulverised fuel, which does not quickly become colonised by weeds. Being composed of very fine particles it also gives rise to clouds of dust on drying. The establishment of ley was therefore undertaken to stabilise the ash, to reclaim areas of otherwise useless material for agriculture and to camouflage their drab appearance. An area of about 1½ acres of the ash heap was levelled with bulldozers, divided into 15-yd. by 6-yd. plots and spread with either domestic or industrial sewage sludge—another waste material—to a depth of either 3 in. or 12 in., an additional 3 in. of waste subsoil sometimes being placed on top. After being allowed to weather, these plots were dressed with National Compound Fertiliser No. 1 at the rate of 2 cwt. per acre. No lime was, however, necessary since the ash itself was decidedly alkaline. A mixture of Italian rye grass, cocksfoot, red fescue and white clover was sown at the end of May, 1951, and a good growth had appeared on many of the plots by early July. The plots were subsequently cut five times and the harvests weighed, the results showing that much higher yields were obtained with domestic sludge. Productive capacity was also found to be greatly increased by the addition of small amounts of soil. Italian rye grass was by far the most vigorous component of the leys, but all the others, with the exception of the fescue, produced yields. A few species of weeds were found and there was a varying amount of bare ground. On the deepest domestic-sludge plots the roots penetrated as much as 2 in. into the ash. The results of the two seasons observations led the authors to conclude that the application of sewage sludge may prove to be an effective expedient for establishing grass on derelict areas produced by industrial spoil. The cause of the comparative failure of industrial sludge is, however, still a matter for conjecture. Soil, even of poor quality, is a useful expedient to alleviate dust and produce grass when sludge is not available.

THE INSTITUTE OF MARINE ENGINEERS.

After examining the distribution of the membership of the Institute of Marine Engineers, the Council have decided to give greater service to the members residing outside London, and the feeling is that this could best be accomplished through the medium of local sections of the Institute. Local sections, indeed, have been operating for some years in Cardiff and Swansea, and these have now been amalgamated to form a South Wales section. Its sphere of operation has been extended to include the whole of the southern half of Wales, and the honorary secretary is Mr. W. Patton, 17, Muirton-road, Cardiff. Similarly, the existing local section at Kingston-upon-Hull has been extended to cover the southern portion of Yorkshire, and also northern Lincolnshire. The honorary secretary is Dr. B. Pugh, 362, Chanterlands-avenue, Kingston-upon-Hull. In January, a Merseyside and North-Western section was formed, based on Liverpool, its honorary secretary being Mr. G. H. Cornish, c/o Messrs. Alfred Holt and Company, India Buildings, Liverpool, 2. Two well-attended meetings have so far been held by this section. Last month the foundations for a further section, covering the West Midlands and based on Birmingham, were laid. The honorary secretary of this section is Mr. T. J. Strand, Barn Close, Lilbourne, near Rugby, Warwickshire. Overseas, in addition to the Sydney local section, which has been operating successfully for some years, another section has been formed in Australia, at Melbourne, and one in India, at Calcutta. The honorary secretaries of these three sections are: Engineering Captain G. I. D. Hutcheson, R.A.N. (retd.), Cockatoo Island Dockyard, Sydney, Australia; Mr. R. D. Stabb, c/o Lloyd's Register of Shipping, 483, Collins-street, Melbourne, C.1, Victoria, Australia; and Mr. Y. Arakie, 6, Pretoria-street, Calcutta, India. It is expected that the sections will meet a distinct need. Local members are invited to communicate with their honorary secretary directly.

NEED FOR A BRITISH STANDARD FOR TIN-PLATE.

For some years past there has been a growing desire for the publication of a British Standard specification for tin-plate, and, as a result of discussions which took place at the outbreak of the war, a draft specification was prepared. The shortage of tin-plate and other factors, however, made the general issue of the specification undesirable, but the question was again discussed on the return of peace, in 1945. At that time, the tin-plate industry had just commenced a reorganisation which would take some time to complete and, consequently, it was decided to defer action. The reorganisation of the industry, however, is now well advanced; moreover, the general need for a specification was recently expressed by means of formal requests from the Ministry of Supply and the British Tin Box Manufacturers Federation, that the discussions deferred in 1945 be opened once again. In consequence of this, a conference was held under the aegis of the British Standards Institution on February 17. The conference was attended by representatives of the British Tin Box Manufacturers Federation, the Ministry of Supply, the Board of Trade, the British Iron and Steel Federation, and the Tin-plate Conference, the last-mentioned body representing the tin-plate producers. In addition, there were present representatives from the British Closure Manufacturers Association, the Association of Steel Drum Manufacturers, the British Toy Manufacturers Association, the oil companies and other organisations concerned with the use and manufacture of tin-plate. Mr. John Ryan, the chairman of the Institution, presided at the conference, during which the users stressed the importance of reducing the wastage resulting from faulty material and the need for greater accuracies in manufacture. The tin-box manufacturers emphasised particularly the need for increased manufacturing speeds and improvement in accuracy of product in order to meet the requirements for increases in canning speeds. It was argued that these increases and improvements could be obtained only by the supply of satisfactory tin-plate. The representatives of the tin-plate industry pointed out that, although the reorganisation of the industry had made considerable advances, it was not yet complete. The conference decided, however, that the machinery for the preparation of a British Standard should be set in motion without delay.

EASTERN MARKETS FOR BRITISH ENGINEERING PRODUCTS.

The important part which is now being played in the country's export trade by the engineering industry is universally acknowledged. An examination of future prospects, however, provides no reason for complacency, and the British Council for the Promotion of International Trade, 15, Hanover-square, London, W.1, has, therefore, done well to devote a special study to the markets that should be available in China, Russia and Eastern Europe. In a pamphlet recently issued on this subject the long-term outlook for the export of vehicles, machinery and equipment is surveyed against the background of the dollar gap and the present declines in sales and new orders; and it is concluded that serious consideration must be given to potential markets in the countries mentioned. A number of schemes now under construction in China are described. These include extensions of the railway system and the building of flood-control, irrigation and hydro-electric schemes, all of which represent a large potential market for British equipment of many kinds. In Russia, too, considerable expansion of the country's railway and road systems is taking place, while shipbuilding and ship-repairing yards are being enlarged. In endeavouring to obtain a share of this work, Great Britain has the advantage that the quality of its engineering products is fully appreciated, especially in China. Nevertheless, the approach to the problems involved is not so realistic as that of some competitors. In addition, it is claimed that a main obstacle is the present basis for licensing engineering exports, the regulations regarding which are being so interpreted by the Board of Trade that trade in engineering goods (not only those of a "strategic" character) between the United Kingdom and China and Russia is virtually prohibited. The result is that not only are other Western countries obtaining orders, but industrial development in the customer countries is being accelerated.

EXPORT OF ELECTRIC POWER FROM YUGOSLAVIA.

A group of representatives drawn from Austria, Italy, the western zones of Germany, and Yugoslavia has been appointed by the United Nations Economic Commission for Europe to study the possibilities of exporting electricity from Yugoslavia to the other three countries. Four committees will be appointed to study the economic, technical, financial and legal aspects of the problem, and the rapporteurs of these bodies will form a co-ordination committee under the chairmanship of a member of the secretariat, on which representatives of France and Switzerland will also sit. The results of the work of these committees will be submitted to the Commission's group on exports of Yugoslav electricity, which will hold its next meeting in Geneva in June. A study of this subject, which was prepared by the secretariat and published last September, showed that the potential hydro-electric resources of Yugoslavia are equivalent to an annual output of 50,000 million kWh, of which only 3 per cent. have been developed. On the other hand, the hydro-electric resources of Austria, Italy and Western Germany are much less and have been much more fully exploited.

LETTERS TO THE EDITOR.

MARINE CONDENSER TUBES.

To the Editor of Engineering.

Sir,—I have noted with much interest the letter in your issue of March 6, on page 308, *ante*, from Mr. John Davidson of Messrs. G. and J. Weir, Limited, commenting on the "Notes on the Improvement of Steam Turbine Machinery for Merchant Ships," issued by the Admiralty, following the speech of the Engineer-in-Chief of the Fleet, Engineer Vice-Admiral the Hon. Sir Denis Maxwell, at Liverpool last November.

Sir Denis's recommendation to change from the existing practice of using ¾-in. diameter aluminium-brass tubes with water speeds of 4 ft. per second to the naval practice of cupro-nickel tubes with water speeds of 7 ft. per second, implies that this increase in water speed renders aluminium-brass an unsuitable condenser-tube material. I doubt whether Sir Denis meant to imply this, but I feel it should be made clear that there is ample evidence that aluminium-brass is as satisfactory at 7 ft. per second as at 4 ft. per second—indeed, in some cases, it may be more so, since at 7 ft. per second harmful deposits are more likely to be dislodged.

It is important, therefore, that designers proposing to increase water speeds in condensers should not assume that, in consequence, a change in tube material is necessary. Mr. Davidson's letter makes it clear that there must be considerable experience of the use of aluminium-brass with water speeds of 7 ft. per second; and this material has also been used on a large scale in naval vessels, in condensers and heat exchangers where the water speeds are 7 ft. per second or more.

Occasionally, corrosion of aluminium-brass condenser tubes occurs, usually due to the action of polluted waters from certain harbours and estuaries. This type of attack is known also in certain land power stations, but it is not dependent on water speed within the limits under consideration. Where, therefore, satisfactory service has been given by aluminium-brass at 4 ft. per second, there is no occasion to fear trouble due to increasing water speeds up to 7 ft. per second. On the contrary, there would be some advantage in this change, particularly if the condenser is not allowed to stand idle in port, full of water, for long periods.

Tubes of 70/30 cupro-nickel, conforming to the Admiralty specification for this material, are, in general, probably rather more resistant to polluted waters than aluminium-brass; but, unless there is known to be some peculiar and abnormal water condition to contend with, there is no point in preferring the more expensive cupro-nickel to aluminium-brass with water speeds in condensers up to 7 ft. per second or, probably, even to 10 ft. per second. Such use of cupro-nickel results in a large increase in cost, and in the demand for nickel, which is still difficult to obtain in the quantities required.

Yours faithfully,
G. L. Bailey,
Director, British Non-Ferrous Metals Research Association.
Euston-street, London, N.W.1.
March 9, 1953.

THE UNIVERSITIES AND INDUSTRY.

To the Editor of Engineering.

Sir,—I should like to refer to the letter from Professor J. A. L. Matheson, on page 244, *ante*. I agree with him that too many of the most promising schoolboys apply to the pure science faculties of the universities and not enough to the engineering faculties. One very strong reason is undoubtedly that masters tend to encourage the students to continue along the line in which they have shown ability, rather than to branch off into what is, to the masters, the unfamiliar study of engineering. What they do not realise is that many of these students will enter industrial life with a background less sound than if they had taken the plunge earlier.

If we are to obtain the largest possible flow of engineering graduates, with the personal qualities for which industry looks to the universities, it is essential to encourage the schools to put their best students into engineering. Anything which firms can do, perhaps through their educational or personnel officers, to make known in schools the opportunities and advantages to be obtained by taking an engineering course at the university will be most helpful. We have already, at this university, some evidence that activity of this kind in the schools by industrialists has led to an increase in the number of applications from candidates of good quality to enter the engineering faculty. Although Professor Matheson specifically mentions the grammar schools, my own feeling is that the need is even greater in the public schools.

On one point only would I dissent from Professor Matheson. He suggests that professors are competing for students by offering a conditional acceptance before the General Certificate results are available. I can assure him that this is done for reasons other than a spirit of competition. To postpone any decision on applications until late in August, when the results are published, would lead to great administrative difficulties, and it is not fair on the students.

Yours faithfully,
A. N. Black,
Professor of Mechanical Engineering.
University of Southampton,
February 25, 1953.

OBITUARY.

MR. STERRY B. FREEMAN, C.B.E.

It is with much regret that we record the death of Mr. Sterry B. Freeman, C.B.E., which occurred at his home in Heswall, Cheshire, on March 6. Mr. Freeman, who was 77 years of age, had been living in retirement since 1944, when he relinquished the position of chief superintendent engineer to the Blue Funnel Line (Alfred Holt and Company).

Sterry Baines Freeman was born in Great Crosby, Liverpool, on November 9, 1875, and received his general education at the Merchant Taylors' School, Crosby, and at the Gymnasium at Lüneberg, Hanover. His apprenticeship to engineering was served from 1891 to 1896 with Messrs. Higginson and Company, Liverpool, an old-established firm who, incidentally, constructed the first steam steering gear, for the steamer Great Eastern. Concurrently, he attended the Bootle technical school in the evenings. In 1898, he went to Scott's Shipbuilding and Engineering Company, Greenock, as a draughtsman, but returned to the Mersey in the following year, to serve in a similar capacity with Laird Brothers, Birkenhead. He was there only a short time, however, before going to sea in various cargo and tanker lines, including ships of the Blue Funnel Line. He obtained a first-class Board of Trade certificate in 1902.

After spending three years at sea, he obtained an appointment as assistant to the late Mr. William Esplen, then a leading consulting marine engineer and naval architect on the Mersey, and spent the next three years in his office. In 1905, he joined the staff of Lloyd's Register of Shipping as a surveyor, being stationed first in Liverpool and afterwards in Manchester. This led to his appointment, in 1911, as manager in the Manchester Dry Docks Company, with whom he remained until 1913, when he became superintendent engineer of the Blue Funnel fleet. During his 31 years tenure of that office, he was responsible for many changes. The fleet consisted of some 85 ships of varying ages, so that there was a constant flow of new ships and ample opportunity to introduce developments in the design of their propelling machinery. In the new tonnage he fitted, first, turbine machinery and, soon afterwards, oil engines of various types, eventually designing his own pattern of heavy-oil engine. He also adopted the Scott-Still combined steam and oil engine, which was tried in the Dolius and provided the material for the second of the six Marine Oil Engine Trials reports of the Institution of Mechanical Engineers. He was a member of the committee who organised these trials, which were spread over the period from 1924 to 1931, and was one of their most active supporters.

Mr. Freeman was closely concerned with the professional engineering societies interested in marine machinery. He was a member of the Institution of Civil Engineers, the Institution of Mechanical Engineers, the Institution of Naval Architects, the Institution of Engineers and Shipbuilders in Scotland, the North East Coast Institution of Engineers and Shipbuilders, the Institute of Marine Engineers, and others; and was a past President of the Liverpool Engineering Society and of the Society of Consulting Engineers and Marine Surveyors. He served on the Councils of the Institutions of Naval Architects and Mechanical Engineers, and the Institute of Marine Engineers, and was a vice-president of all three. He delivered the 1932 Thomas Lowe Gray Lecture to the Institution of Mechanical Engineers on "Modern Types of Propelling Machinery." The University of Liverpool conferred upon him the honorary degree of Master of Engineering; and, in 1920, he received the C.B.E. for his work in connection with the Board of Invention and Research, whose representative he was on the Engineer-in-Chief's Committee at the Admiralty. Mr. Freeman retired from the Blue Funnel Line on September 30, 1944; but his retirement was gradual, and he continued to be active in the affairs of various societies—especially the Institutions of Naval Architects and Mechanical Engineers, and the Institute of Marine Engineers—until, some years ago, failing health prevented his attendance at their meetings. He will be long remembered, however, as a thoroughly practical engineer, who could offer shrewd counsel with a notable clarity of thought and words, and whose friendship was greatly valued.

MR. W. T. OTTWAY, C.B.E.

When a man has spent his working lifetime in a family business, there is not, as a rule, much more that can be said about him in an obituary notice; but those of our readers who knew Mr. W. T. Ottway, C.B.E., who died on March 10 at his home in Ealing, will understand that, if our notice of his career is short, it is not for any lack of appreciation of a craftsman of unique distinction; for he was the head of a firm of optical-instrument makers —W. Ottway and Sons, Orion Works, Ealing—whose known history extends back to some time before 1640 and which has continued for more than 300 years in the hands of the one family.

Walter Thomas Ottway was a Londoner, born in 1883, and was apprenticed to the family firm at the age of about 14, while the business was being carried on in Upper-street, Islington. His ancestor, Thomas Francis Ottway, was the head of the firm when, in 1640, the fire which destroyed the first Royal Exchange in the city of London destroyed with it all record of the earlier history of the business. The Royal Exchange of that day consisted of a courtyard surrounded by a piazza and a number of shops; it is not now known when the Ottway business was first established there, but the building dated from 1568. After the fire, the business was removed to Carey-street, Strand; then, in 1700, to King-street, Holborn; in 1800, to St. John Street-road, Clerkenwell; in 1812, to Patenham-street, Clerkenwell, and in 1837, back to St. John Street-road. Then, in 1889, it was transferred to the Tyndale Works in Upper-street, Islington; and, ten years later, to the newly-built Orion Works in Ealing, where Walter Thomas Ottway spent some 53 years of his working life. He was trained more particularly in the manufacture of telescopes, but for many years his personal interest had been largely in periscopes and surveying instruments. It was for his war work in the production of instruments that he received the C.B.E. He was a founder of the British Optical Instrument Manufacturers' Association (now the Scientific Instrument Manufacturers' Association), but otherwise took little part in the activities of scientific or industrial societies, finding ample occupation in the management of his works. To go round those works in his company was to realise something of the pride and competence of the true craftsman, and that heredity can be a force in industry.

EFFECT OF ADDITIONS TO TITANIUM.

Fig. 2. EFFECT OF ALLOYING ADDITIONS ON TENSILE PROPERTIES OF BINARY TITANIUM ALLOYS.

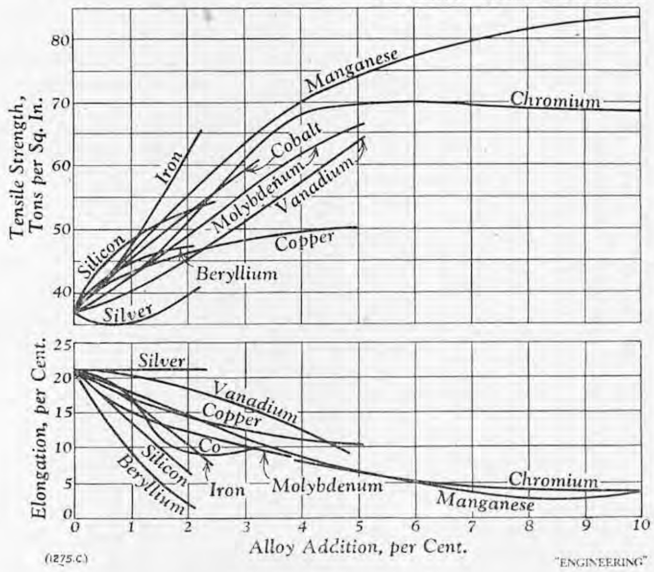
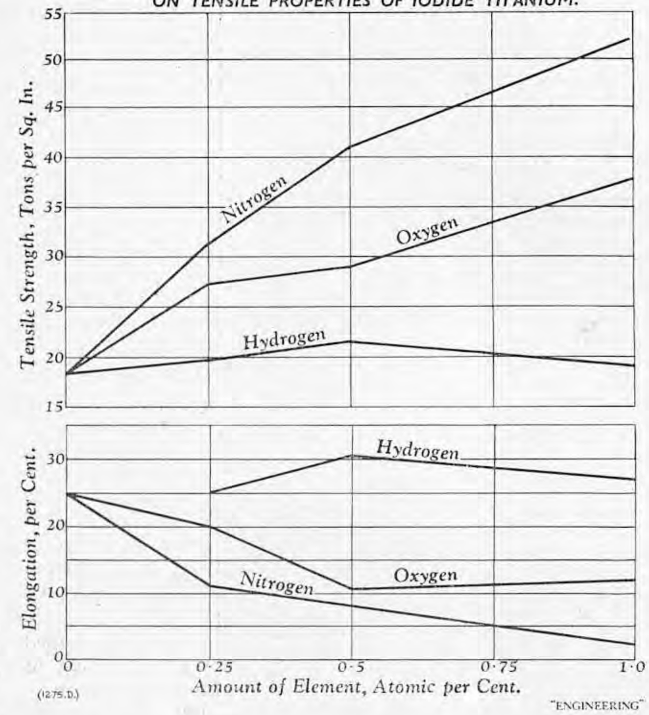


Fig. 3. EFFECT OF ADDITIONS OF GASEOUS ELEMENTS ON TENSILE PROPERTIES OF IODIDE TITANIUM.



TITANIUM—A SURVEY.*

By P. L. TEED, A.R.S.M., F.R.Ae.S.

(*Continued from page* 252.)

ALLOYS OF TITANIUM.

Alloys with Metals.—From a consideration of relative inter-atomic distances, it would be anticipated that the metal would form a solid solution with each of those of Group 1B and of Groups V-VIII of the Periodic Table. Thus, it is metallurgically likely that binary alloys could be made with copper, silver, gold, vanadium, niobium, tantalum, chromium, molybdenum, tungsten, manganese, iron, cobalt and nickel. Experiments have shown that with all these, and certain other elements, alloys can be made. The qualities of many have not yet been fully explored, so it may well be that some have not been correctly evaluated. Fig. 2 indicates the influence of varying amounts of the different elements on the ultimate tensile stress and elongation of the titanium to which it has been added. Most of these produce increases in strength, but, with the single exception of silver, all cause decreases, some startling, in elongation. Simultaneous additions of two or more of some of the metals listed can give desirable increases of static strength, with a less serious reduction in the ductility than when a single alloying constituent is employed.

Alloys with Gaseous Elements.—Titanium possesses to an outstanding degree the ability to form solid solutions with oxygen, nitrogen and hydrogen. Extremely small quantities of oxygen and nitrogen have a marked influence on the strength of the metal in which they are dissolved. This is clearly shown in Fig. 3, in which the amount of dissolved gas is shown, for the sake of convenience, as an atomic percentage.

The question may be asked : " How can these gases be got into the metal ? " In the case of oxygen the most usual mechanism is by diffusion. Titanium-oxygen alloys containing up to more than 5 atomic per cent. of the gas have been prepared from a piece of thin strip made of iodide titanium having the following determined impurities : oxygen, 0·02 per cent. by weight, i.e. 0·06 atomic per cent. ; nitrogen, 0·03 per cent. by weight ; iron, 0·02 per cent. by weight ; tin, strong trace ; antimony, strong trace ; copper, faint trace ; silicon, faint trace ; vanadium, faint trace ; magnesium, faint trace ; manganese, faint trace.

The strip was heated in air for several minutes in the range 500 deg. to 750 deg. C. This produced an adherent film of titanium oxide, the thickness of which depended on the length of the heating period. The strip was then heated at 850 deg. to 950 deg. C. *in vacuo* for 30 hours, producing throughout the metal a uniform diffusion of the original surface film. The initial heating in air at 500 deg. to 750 deg. C. did not introduce any appreciable increase in the nitrogen content of the metal. Similarly, nitrogen can be introduced into titanium by heating in an atmosphere of the gas at about 800 deg. C. and subsequently *in vacuo*, to allow uniform diffusion. Although, as seen in Fig. 3, nitrogen is a more powerful strengthening addition to titanium than oxygen, with alloys of equal hardness the cold-working properties of the alloy produced by oxygen additions are better than those of that made by nitrogen ones.

Hydrogen can get into titanium in a number of ways, such as by acid pickling, heating above about 350 deg. C. in an atmosphere containing free hydrogen, or hydrogen containing gaseous compounds, including aqueous vapour. It does not appear to perform a useful function, but it can be easily removed by soaking *in vacuo* at a temperature of 800 deg. C. for a period which will depend on the thickness of the section.

Alloys with Non-Metallic Solids. Most non-metallic solids alloy with titanium, forming limited solid solutions and/or compounds. Information in this field is limited. In the case of carbon there appears to be enough evidence to indicate that up to 0·25 per cent. it goes into solid solution in the metal, increasing its tensile strength but reducing its ductility. Above this amount, and up to about 1 to 1·25 per cent., carbon is present in titanium as a finely disseminated carbide. In this form it has little influence on the static mechanical properties, but there is insufficient evidence on its effect on impact resistance, fatigue and notch fatigue. For welding, carbon in excess of 0·15 per cent. is undesirable. As can be seen from Fig. 2, titanium alloys with the metalloid silicon, giving rise to results which are not attractive.

TABLE IV.—*Composition and Properties of Some Titanium Alloys.*

Constituents Other than Ti.	Condition.	0·2 Per cent. Proof Stress, Tons per sq. in.	Ultimate Stress, Tons per sq. in.	Elongation, Per cent.
0·2 Fe, 0·02 N_2, 0·1 O_2	Annealed sheet, bar, forgings	34	39	23
As above	½ hard sheet	42	49	12
1·8 Cr, 0·9 Fe, 0·15 O_2, 0·04 N_2, 0·03 C	Annealed sheet and strip	36	56	19
2·0 Cr, 2·0 Fe, 0·15 O_2, 0·04 N_2, 0·06 C	Annealed sheet, bar, forgings	56	62	14
7 Mn	Sheet	58	63	14
4 Mn, 4 Al	Annealed bar, forgings	60	65	18
2·7 Cr, 1·3 Fe, 0·25 O_2, 0·02 N_2, 0·05 C	As above	58	67*	16*
5·0 Cr, 3 Al, 0·5 C	As above	68	74	10

* Depending on grain size and heat treatment, properties ranging from 90 tons per sq. in. tensile and 6 per cent. elongation down to 60 tons per sq. in. tensile and 30 per cent. elongation can be obtained.

AVAILABLE ALLOYS.

Table IV sets out the nominal chemical compositions and some room-temperature mechanical properties of such alloys as are at present commercially obtainable at a price from about 1½ to 2 times that of the pure commercial metal.

Since the proof and ultimate stresses disclosed in Table IV are superior to those of all steels used for aircraft forgings with the exception of S.99, it is at once apparent that titanium alloys give scope for weight economy in the production of forged parts. Experience so far has shown this to be true, but at a monetary cost which may be prohibitive in civil, and even in military, aircraft.

In Table V a comparison is made between the costs of the same forged part, a tank support fitting, made in the American alloy steel 8630, and the titanium forging alloy containing 4 per cent. aluminium and 4 per cent. manganese (RC 130B). The figure of 80*l*. is sufficiently startling to require confirmation. This is available in Table VI, in which cost per lb. of weight saved is given for a number of gas-turbine items.

TABLE V.—*Relative Cost Analysis—Tank Support Fitting.*

Item.	8630 Steel.	Titanium Alloy RC 130 B.
Weight of rough forging	23·5 lb.	13·8 lb.
Material cost	£2·13	£87·0
Forging	0·67	27·0
Machining	20·60	355·0
Total cost of finished part	£23·40	£470·0
Weight saved	—	5·9 lb.
Cost per lb. weight saved	—	£80

* Paper presented to the Royal Aeronautical Society in London on Thursday, January 29. Abridged.

The price which has to be paid in order to save weight is attributable to four causes, one of which is current inexperience in forging and machining the new material. Table V shows that at present, the relative costs of a particular titanium alloy part in comparison with an alloy steel one are: material, 41 times as much as the steel; forging, 40 times as much as the steel; machining, 17 times as much as the steel.

Forging.—The fundamental qualities of titanium prevent the adoption of the simplest forging techniques. As mentioned already, titanium, when hot, not only combines with oxygen, nitrogen and hydrogen (whether elemental or not), but this metal/gas alloy film diffuses through the basic matrix, profoundly altering its mechanical properties. Furthermore, in drop-stamping this coating interferes with the flow of the metal in the die. The heating of the forging stock therefore demands control of the chemical composition of the atmosphere of the furnace, the rate of heating and, also, the maximum temperature of the stock, which requires to be low to minimise film or scale formation. On the other hand, the lower the temperature the greater the difficulty in inducing the metal to flow without cracking.

TABLE VI.—*Cost and Weight Analysis of Steel and Titanium-Alloy Gas-Turbine Parts.*

Item.	Material and Approximate Weight of Finished Part in Steel and in Titanium Alloy, Lb.		Approximate Cost of Weight Saving per lb.
Compressor rotor disc	Steel AMS 6342 Titanium alloy	25·0 14·0	£21
Compressor stator blade	Steel AMS 5613 Titanium alloy	0·06 0·04	£62
Turbine support	Steel AMS 6322 Titanium alloy	3·0 2·0	£69
Compressor rotor blade	Steel AMS 5613 Titanium alloy	0·10 0·06	£84

Faced with this dilemma, the practical man has compromised on a range of 880 deg. to 980 deg. C. In this temperature zone, the stock is deformed with more difficulty than would be experienced in forging alloy steel, therefore heavy and expensive plant is desirable. Subsequent to forging, a prolonged anneal at 650 deg. to 700 deg. C. is beneficial. Some of the two-phase alloys, however, are unstable even after such a treatment and subsequently undergo embrittlement if used at temperatures in the range 250 deg. to 450 deg. C.

There is an additional reason for avoiding high temperatures. With the titanium alloys now used for forgings (mainly 2·7 Cr, 1·3 Fe, 0·25 O_2, etc.) grain growth takes place rapidly at high temperatures. This will influence adversely the subsequent room-temperature ductility, impact resistance and fatigue properties of the alloy. Above 1,150 deg. C. the oxygen content of those alloys whose mechanical properties depend on the presence of this gas within the material tends to decrease, with subsequent decrease in static mechanical properties at room temperature.

Table VI emphasises how important, yet varying, is the influence of machining on the cost of an item. With a simple form such as a rotor disc, the price difference between steel and titanium alloy is relatively low, but with a part of greater complexity, such as a turbine support, the gap broadens markedly. The figures recorded in these two tables are the result of actual experiment by intelligent people well versed in the manufacturing techniques normally employed for making such parts in conventional materials. The cost figures for the titanium alloy arise from the use of established techniques applied to a material with which experience is almost non-existent. Almost certainly both forging and machining costs will be greatly reduced but, in the present state of the art, there are wide differences of opinion as to the best ways of doing this.

(*To be continued.*)

"BROWN COAL": ERRATUM.—In the article on "Brown Coal," on page 274, *ante*, it was stated (in the first paragraph) that the probable German reserves of brown coal were 56,758,000 tons. The figure should have been 56,758 million tons.

MODULAR CO-ORDINATION IN BUILDING.

THE first steps were taken towards the formation of a Modular Society at a meeting held at the Royal Society of Arts, London, on March 4, with Mr. A. C. Bossom, F.R.I.B.A., M.P., in the chair. The society is interested in promoting the general adoption of a recognised unit dimension, or module, as a basis of standardised design in the building industry. This proposal was the subject of the Alfred Bossom Lecture delivered to the Royal Society of Arts on December 10, 1952, which was reported on page 768 of our issue of December 12.

Mr. Hartland Thomas reported that as a result of the inaugural meeting held on January 23, 1953, there were now 185 members, and that steps were being taken to make the society a legal entity. The four speakers were Messrs. D. Fraser, S. Johnson-Marshall, F. J. Samuely, and W. A. Balmain, respectively representing the building, architectural, civil engineering, and building pre-fabrication trades and professions. All the speakers were in favour of the adoption of a module, or a limited number of modules, which could then be applied to the design and construction of buildings falling into different classes and categories. Mr. Fraser stressed that, by using a module, such standardisation could result, that much cutting and waste of material on site would be avoided, and also that there could be standardisation of many prefabricated parts. In this connection, he cited the case of a block of 100 new flats, in which there were no less than 18 different sizes of door frames. One disadvantage that had been suggested was that monotony in design might result, but he did not think so, as standardised components could be fitted together in different ways, to give entirely different effects. Mr. Marshall considered the standardisation of components was overdue, and said that he had himself designed buildings to 8 ft. 3 in., 4 ft. 0 in., and 3 ft. 4 in. modules, and that the Royal Institute of British Architects and the British Standards Institution favoured the 40-in. module. Mr. Samuely also considered standardisation was necessary, but favoured a small module, which would then be more frequently multiplied than divided. Mr. Balmain pointed out that a standardised module reduced costs as mass production was made possible, and uniformity made for a reduction in the cost of assembling and the cost of measuring the work done.

In the discussion which followed, many speakers spoke in favour of modular co-ordination, but some did not appear fully to understand the background to the subject; that background is simply that by adopting basic units of dimension, in the horizontal and vertical planes, for different classes and categories of structure, the architect will not then use dimensions which require, for example, an undue variety of door-frame sizes, and the manufacturer will not make board of such a width, for example, that much of it has to be wasted after cutting at site. Also, by standardising a module for factories, for example, manufacturers will be able to stock pre-fabricated roof-trusses, on the American principle.

UNITED KINGDOM IRON AND STEEL PRODUCTION.—Steel production in February averaged 352,400 tons a week, representing an annual rate of 18,325,000 tons. These figures are new high records, the previous best weekly rate being that of January, 1953, namely, 346,300 tons, or an annual rate of 18,009,000 tons. Pig-iron production was at a weekly average rate of 213,500 tons in February, compared with an average of 213,900 tons a week in January, and of 197,400 tons in February, 1952.

TOOL-STEEL DIE BLOCKS.—Bowser, Monks and Whitehouse, Ltd., 45a, Market-place, Doncaster, have informed us that they are starting production on a range of standard tool-steel die-blanks in thicknesses from ⅞ in. to 2 in., under the trade name of U-blanks. These die-blanks have been designed to fit the majority of standard die-sets at present in use throughout industry, and leaflets are available which give the material sizes and recommended heat treatment for the Swedish "Uddenholm" tool-steel from which they are made. The steel is a chromium-tungsten-vanadium steel with a maximum hardness of 220 Brinell before hardening.

SOIL STABILISATION FOR AIRFIELD PAVEMENTS.

THE economy in both costs and time that could be achieved by "stabilising," that is, strengthening the natural sub-grades below airfield runways, perimeter tracks and aprons, rather than by constructing them of such strength as to bear the imposing wheel loads, was the theme of a paper presented to the Airport Engineering Division of the Institution of Civil Engineers on March 3. The paper, entitled "Methods of Soil Stabilisation and their Application to the Construction of Airfield Pavements," was given by Mr. Donald Maclean and Mr. P. J. M. Robinson. After outlining the functional requirements of stabilised soils, the authors went on to state the characteristics of mechanically stabilised soils and of soils into which cement, bitumens or self-polymerising chemicals had been injected. They concluded with some brief comments on the performance of the plant available at the present time.

This latter point provided material for several speakers in the subsequent discussion; like the authors, the speakers expressed concern that so little equipment of British origin should be available and that there was almost complete dependence on American-made machines for this work. It was stated in the paper, however, and later confirmed by Mr. Maclean, that serious attempts were being made to devise a good specification for a machine that would adequately mix the soil and the injected stabilising reagent at a single pass; in particular, Mr. Maclean mentioned the studies being made at the Road Research Laboratory to find an optimum speed of rotation of the tillers in relation to the forward speed of the machine, and to determine the best form of tyre to be used on the rotors. Single-pass mix-in-place machines were thought to be the development most likely to achieve economic working, though it was conceded that, at present, stationary mixers of either the continuous-feed or batch type have a higher mixing efficiency than the mix-in-place machines.

When introducing the paper, Mr. Robinson expressed the opinion that soil-cement stabilisation was generally practicable in the United Kingdom and that all forms of soil were amenable to the method, the most difficult being clay with a high organic content, such as is found in the Fens; the difficulty of stabilising this latter material he attributed to the resilience of the vegetable matter, which made compaction a difficult task. A great advantage of soil stabilisation generally, he continued, was the certainty with which the work could be undertaken, because of the reliance that could be placed on a preliminary laboratory investigation. In this respect, he expressed full confidence in the efficacy of the simple compression test which is used for obtaining an indication of the suitability of any proposed method of dealing with a particular soil.

Col. W. P. Andrews, in the course of the discussion, drew attention to the use in the United States of a freezing and thawing test; in his reply, Mr. Maclean agreed that such a test provided useful information and might be adopted here with advantage when more important issues had been settled. Early in the paper, the authors expounded the difference between "rigid" and "flexible" as applied to pavements. The accepted connotation of these two terms in this context—as was pointed out by Dr. H. Q. Golder during the discussion—is at variance with their more general meaning; thus, a rigid base is one that has sufficient flexural strength to enable it to bridge local areas of the subgrade which are not affording full support to the base, whereas the flexible base is one that has such small strength in bending that the base so distorts as always to be in full contact with the subgrade. Dr. Golder suggested that the terms "rigid" and "flexible" might be more accurately replaced by "tensile" and "non-tensile"; but Mr. Maclean, while not denying the existence of the difficulty which Dr. Golder had mentioned, thought that the accepted terms were now so well understood as to make the introduction of alternative terms unnecessary.

THE SAFETY FACTOR IN CONSTRUCTION.—I.*

By G. ANTHONY GARDNER, O.B.E., M.I.Struct.E.

THE building of structures with a margin of strength over and above that necessary for the net stability of the structure in use has been the practice of engineers since the time when theoretical static mechanics began to evolve as a scientific approach to design; and, indeed, prior to that, the idea of having "something in hand" was undoubtedly present. At a time like the present, when economy in the use of structural materials is imperative, the problem of the factor of safety takes on a political significance, and the engineer and physicist are required, as a matter of ethics, to push the margin to that minimum beyond which it would, in fact, be risky to go. This criterion is satisfied, perhaps, if it can be demonstrated that a structure evinces signs of incipient failure when it is subjected to loadings a fraction over those which it had apparently safely withstood for some years in normal use; but, even in this case, an agreement on what constituted incipient failure would not be reached without deliberation.

There are two primary types of failure to be guarded against, namely, deformation to unserviceability, and progressive overstressing and breakdown of resistance. The first of these may have to be related to conditions of use and, in some cases, to æsthetic or psychological considerations—as, for example, where even the appearance of deflection is objected to or where the sensation of springiness is unpleasant; and, in the second category, we may have to take into account the phenomenon of fatigue. Deformation to unserviceability may, in certain cases, have very little relationship to the factor of safety as such. The designer must be actuated by the layman's criterion of fitness for purpose, and any deformation of the structure which may lead to inconvenience or to cracking or other damage must be avoided.

Supposing that, in any form of structure, we wished to design and construct it with that small margin which would just ensure strength and stiffness throughout the period of use for which we required it, we are nevertheless faced with a number of fundamental difficulties. The expected variations in the mechanical properties of the materials could be known with practical accuracy and we could select lower-limit values for its strengths in direct compression, tension, shear and bearing, and also for its elasticity in the several states compatible with these stresses. We could also compute with practical accuracy all the loads and forces to be resisted and we could ensure that the workmanship in the finished structure was perfect. But that very extensive science which we designate the theory of structures is a concatenation of rational approximations, and not a series of absolute values. This being so, caution has to be exercised in using the theories.

The basic processes of design must embody some factor of safety to cover the approximations inherent in fundamental theories and the further approximations which arise from rational simplifications of these theories in use in the process of earning a living. Unfortunately, the precise value of these factors cannot be laid down with absolute certainty in any particular case and therefore, they have to be lumped in with the general factor to which it is customary to subject either the basic yield stress of the material or the loads on the structure, or both. Not only must these intrinsic approximations be present in the working theories, but they have a varying significance according to the type of structure and the nature of the parts of the structure under consideration; and there is a further complication of the effect of the type of structure itself on the significance of the various theories which may be employed in the process of designing its parts.

Take the theory of beams, or members subjected to cross bending. We cannot perceive the complicated functioning of a beam, but must apply the simple law of the lever and puzzle out how it is that the external leverage resulting from the weight on the beam and the counter resistance of the supports is resisted by an internal leverage. Galileo was one of the first to try to puzzle this out, in the Seventeenth Century, but, not knowing Hooke's law, he arrived at a wrong conclusion. Hooke's law, that stress is proportional to strain in a practically homogeneous structural material, within certain limits of stress, is itself an approximation, albeit a very close one; and on this law the whole mathematical theory of the elastic behaviour of structural members has been built up. By relating this law to the law of the lever, we can readily ascertain what must go on inside a simple rectangular beam of homogeneous material and can evaluate the beam's internal resistance moment, or movement to the external bending moments or movements, and ascertain the stresses in its fibres. In addition to this equilibrium in rotation there is, *ipso facto*, an equilibrium in translation, up and down.

The convenient division of the internal resistances into direct flexural stress and related shear stress does not, in fact, exist in the beam, but the complex combination evolved from considerations of balance and Hooke's law gives rise to direct stress trajectories which indicate the distribution of tension and compression in every fibre of the beam. This simple theory of homogeneous beams, having been evolved, is then applied to the stress analysis of a very wide range of beam sections, from scaffold poles, tubes, rolled-steel joists, built-up plate girders and masonry dams, and is largely utilised for the design of heterogeneous beams, such as those of reinforced concrete; and its approximate accuracy, within the present limits of stress to which beams are designed, is such that no practical beam will evince signs of failure if designed to these principles. This simple theory of the behaviour of beams and girders connotes some deformation, i.e., bending of the beam, and it is common usage to compute this deflection from considerations of direct flexural stresses only, ignoring the additional small deformation arising from shear stresses. This brings in a further approximation when applied to evaluating the resistances of the supports of a beam continuous over two or more spans.

There are broadly two main divisions into which we consider structures to be classed, namely, those of a trussed formation and those of a portal type. Structures in the first class are normally designed on the assumption that they have hinged joints, so that the members of which they are comprised are free, theoretically, to compress or stretch and change in their angular relationship one to another. This assumption is at variance with the facts, since the bolted, riveted or welded connections employed in the actual structures, together with the continuity which, for ease of fabrication and lateral stiffness occurs in the case of members in line, produce resistances of a nature proper to the other divisions of structures, namely, those of the portal type. The portal structure depends for its stability on that very stiffness in the joints of its members which is the disturbing factor in trussed types. The articulated truss is essentially a more economical type of structure than the portal, since the members in the truss are primarily subjected to direct axial forces which tend to utilise the whole cross-section of each member, in comparison with the beam action which operates in the members of the portal and which is limited by stresses at the extreme fibres.

When the articulated structure is loaded, the tendency of the joints to rotate evokes a flexural resistance from the members by reason of the stiffness which the joints embody due to their practical construction; but it gives rise to stresses in the joints and members in excess of those which the designer has calculated, while increasing the sum total of energy which the load evokes from the structure in the process of deforming it. It also alters some of the assumptions upon which the individual members have been designed, especially in respect of the strut members, which considered as functioning like pin-ended or partially constrained struts, are found to be suffering "S" bending. These secondary conditions due to joint stiffness are kept within certain bounds of probability by further approximate rules, based on considerations of the flexural stiffness of the members in the plane of the truss, but the exact relationship to the factor of safety is obscure in any particular case, though probably on the side of safety.

What I feel is needed to enable us boldly to sail nearer to the wind, supposing that to be desirable, is not so much a deeper prosecution of analytical methods, but a systematic empirical investigation of all our structural problems, for the purpose of checking and amending those quasi-rational approaches which are convenient in ordinary commercial design. This would I think, enable us to retain our general methods and heighten our working stresses towards a closer approach to an absolute factor of safety, so that we might know with certainty that, if we worked on stresses of a high percentage of the yield stresses, we should still retain just enough in hand to meet the contingencies of imperfections in materials and workmanship. We noted that the fortuitous interdependence of members in trussed construction is the very basis of the functioning of portal construction and that something which is an adjunct in the one case becomes the primary consideration in the other; but also we know, due to the researches of Professor J. F. Baker, that the portal is capable of more punishment than an articulated structure, by reason of its flexural continuity and its propensity to re-accommodate itself to a stress distributed compatible with its maximum efficiency.

In general, those rational hypotheses which have been found convenient for rapid use in design tend to evolve structures which embody a degree of ultimate resistance which is greater than that represented by the factor (itself approximate) which is implicit in the normal analytical approach along the general lines of rigid body statics and the theory of elastic deformations. For example, in the trussed structure, the inherent rigidity of joints tends to give a multi-portal action which is an addition to the action of an articulated frame, and in the portal itself accommodation takes place. This accommodation arises from the phenomena which occur after the flexural stresses pass from those complying approximately with Hooke's law to those which occur when the plastic range is approached. These phenomena indicate how a member in flexure can develop a static resistance greater than that represented by the proportional stress increase relative to the usual elastic hypotheses on which beams are ordinarily designed.

This brings us to the crux of the matter, namely, the substitution of a load factor for a stress factor as a basis of design. In the one case, we decide on some fraction of the yield strengths of the material and design the structure in accordance with the laws of elasticity, supposing that the structure would just begin to evince signs of incipient failure if the loads and forces which it has been designed to carry were increased by the amount which the safety factor represents; and in the other, from a knowledge of what ultimate loads and forces inter-related structural members of various sectional forms and types can take, to design on the phenomena of incipient collapse, and apply a safety factor to that.

This latter method is at present in its infancy so far as general design is concerned, and its protagonists are working hard to develop its fundamentals into a *modus operandi* which the practising structural engineer can use universally. I incline to the view, at present, that the plastic approach will make its greatest contribution as a means of informing us as to what encroachments, if any, we can make on the present factors of safety in structures designed elastically. It may be conceded that a structure in use must be relied upon to respond elastically where fluctuating loads and forces are to be sustained, even if it may adjust itself plastically in the initial process of settling down to its job. A change can only be the outcome of slow evolution and further experience, so some small factor must be used in connection with design methods as such. The precise value of this factor is rather indeterminate and variable, and a number of other factors have to be taken into account, relating to materials, workmanship and variations in loading.

We may enumerate the categories to be insured against as follows: the fundamental limitations in our theoretical approach, already touched on;

* The first of two Cantor Lectures, delivered to the Royal Society of Arts, London, on February 23, 1953. Abridged.

approximations of weights and other forces; approximations and errors in the computation of loads and forces; approximations in assessing the conditions under which parts of a structure interact one with another; approximations and errors in mathematical computations; faults in materials, and faults in workmanship and erection. The intrinsic difficulty is to know what precautionary value to attach to each. We have found from experience that, working on the elastic basis of deformations and using design stresses which are some 60 to 70 per cent. of the yield stresses of the materials, signs of failure are not apparent; in other words, an elastic-stress margin of about 35 per cent. covers all the above items. This gives a round average of 5 per cent. error in each category.

Lastly, we come to faults in materials, workmanship and erection. Structural materials are manufactured to very dependable limits; in mild steel, for example, serious faults in structural sections are not common and are generally easily detected. The variations in sectional dimensions of hot-rolled shapes may be appreciable, according to whether the rolls in the rolling mills are new or worn, but these variations tend to be controlled by the weight tolerances. A ¼ in. slackness in depth in a rolled-steel joist 8 in. deep would, other sectional dimensions being equal, cause a loss of flexual efficiency of about 5 per cent., and here again we could arrive at lower limit values which could be used as definite reduction factors. Faults in workmanship are of two kinds, one being imperfections inherent in the usual shop practice or in the machines used, and others due to sub-standard work. The shop processes in a structural steelworks are not of the precision type appropriate to mechanical engineering, and tolerances in fitting are rather in 100ths than 1,000ths of an inch. Members deemed to be straight may be somewhat in winding, and the fit of one part to another may not be dead true. Strains may be induced in the process of riveting or welding up the structures. Holes out of alignment, loose rivets and imperfectly abutted parts are faults amenable to routine inspection and remedial measures, and, in general, the average standard is as high as the nature of the work permits; but some of these faults are liable to aggravation in site erection. We can only surmise that the 5 per cent. is adequate to cover all cases.

In relationship to shop practice and design of details, a number of further approximations are involved, which effect stress distributions. These are chiefly related to stress variations in the region of rivet and bolt holes, whereby in parts in compression and shear the gross un-holed section is assumed and, in parts in tension, the stress is taken as uniform over the net section. In structures primarily subjected to static loading, two well-known but practically indeterminate conditions are included in this respect, namely, the stress concentration at the margins of holes in tension members and a similar concentration of bearing stress, assuming bearing to take place at the periphery of bolts and rivets; but, in structures subjected to continual stress variations, the effect of these "stress-raisers" on fatigue is being given close attention, and design stress reductions are recommended in relationship to the number of stress cycles and the range of stress variation, whether a change of stress of the same kind or a reversal of stress ranging between tension and compression. These fatigue considerations become more important in welded structures due to the greater rigidity of welded joints, compared with riveted ones.

Evidently, the margins of safety at present approximate to a limit beyond which it would be imprudent to pass without a systematic stock-taking. What is wanted is not so much a continual prosecution of analytical methods for the purpose of ascertaining absolute values, but a thorough programme of tests framed to check the margin between working loads and the onset of progressive failure in all kinds of structural members, and, indeed, complete structural frames, designed and fabricated to the present standards. This would employ, full-time, a staff of practising engineers, physicists, mathematicians, computors, laboratory assistants and mechanics, and would entail a large expenditure over a number of years; but it would bring fruitful results and settle many queries.

LABOUR NOTES.

SHIPBUILDING activity on the Clyde has recently been handicapped by a strike of platers' helpers. The stoppage commenced on March 4 at the Clydebank shipyard of Messrs. John Brown and Company, Limited, and spread steadily during the next few days until by Wednesday last, ten Clydeside shipyards were involved, six at Greenock and four on the upper reaches of the river. It was estimated that at least 1,400 platers' helpers were then on strike, equal to about one-third of the number of helpers employed in the area. The men's action, which was unofficial, was taken as a protest against what they considered to be unreasonable delay in dealing with a national wage claim presented on their behalf by their union, the National Union of General and Municipal Workers.

The platers' helpers ask for a share in the piecework earnings of the squad in which they work, on the ground that they are required to work with the other members of the squad at piecework speed and that skilled platers engaged on piecework are paid at piecework prices or at lieu rates. The claim, if approved, would amount to an increase of 15*s*. 6*d*. a week for helpers engaged at piece rates, with proportionate increases for those on time rates, and it is stated by the strikers that the claim was originally presented nearly two years ago. The men's case came before the Industrial Court in July last, when a verdict was recorded against them. Since then, informal negotiations between the union and the employers' representatives have continued.

The position is rath er complicated in some ways as a number of unions are involved. The platers' helpers rank as unskilled men and are members of either the Transport and General Workers' Union or the National Union of General and Municipal Workers. Most of those employed at Clydeside shipyards belong to the latter union. The platers themselves are skilled men and belong to the United Society of Boilermakers. The claim involves the interests of all these and some of the trouble appears to have been due to the difficulty of bringing the unions together. It was announced in London last Tuesday that the national executive committee of the N.U.G.M.W. had arranged to call a national delegate conference on March 24 to consider the situation. Meanwhile, the union urged the strikers to return to work without delay.

Demands for a secret ballot on the question of a return to work were very firmly defeated at a meeting of strikers at the Longbridge works, Birmingham, of the Austin Motor Company, Limited, on Monday. The meeting took place in private and was the third mass meeting of strikers to be held since the stoppage began on February 17. It was reported to have been attended by about two-thirds of the two thousand members of the National Union of Vehicle Builders who were on strike. It may be noted that voting on the resolution asking for a secret ballot was by show of hands. The stoppage was called by the union as a protest against the firm's alleged refusal to re-engage a former senior shop steward, who was one of about 700 employees discharged on redundancy grounds in September last year.

The rejection of the demand fo a secret vote appeared to come as something of a surprise to many of those stated to be in close touch with the strikers and was held in some quarters not to be a true indication of the men's real feelings. At least three-quarters of the 18,000 persons employed at the Longbridge works have been rendered idle by the strike of the vehicle builders, and have lost around 400,000*l*. in wages. Among the 10,000 employees belonging to other trades and to other unions than the strikers, but out of work owing to the stoppage, there were some who contended that their own unions would not have involved them on such an issue. Dissatisfaction was stated to have been especially noticeable among women employees. A further mass meeting of the strikers is due to be held next Monday.

Shop stewards employed at Longbridge works and belonging to the Transport and General Workers' Union decided at the annual meeting of shop stewards of that union, on February 28, to break away from the works joint shop stewards' committee. The union has well over 4,000 members among the employees at Longbridge works and, at a meeting of the union's members on March 8, a resolution to establish a new shop stewards' committee at the works was carried by a large majority. The meeting expressed its appreciation of the "necessity for a lead being given" and pledged its active support for the formation of a committee wholly concerned with wages, hours of work and conditions of employment. Mr. E. J. Beard, the union's district organiser, stated afterwards that speeches at the meeting showed considerable satisfaction at the creation of an efficient negotiating machine based on true trade-union principles.

A strike of steelworks employees engaged at the Redcar iron and steel works of Messrs. Dorman, Long and Company, Limited, at Middlesbrough, commenced on March 8 and, by mid-week, some 400 of the firm's skilled men were involved. The dispute arose owing to an alteration of the weekly production quota above which a bonus is paid. This basic-output figure was revised on March 5 by a joint committee comprising representatives of the unions concerned and of employers in the North-East Coast area. The company claimed, in consequence, that the men's action was a rejection of that agreement, and an offer by the strikers to return to work on condition that negotiations were resumed at works' level was declined. The men affirm that the new figure, 3,800 tons, will mean a reduction of 15*s*. a week each in their earnings. A mass meeting of those involved in the stoppage was due to take place to-day.

There was a decrease of 23,700 in the number of unemployed persons in Great Britain during the five weeks between January 12 and February 16, last. The total number of persons out of work on the latter date was 428,820, of whom 40,900 were only temporarily unemployed, but a further 175,900 workpeople had been disengaged for more than eight weeks. Statistics issued by the Ministry of Labour and National Service, on Monday last, show that the total of 428,820 comprised 264,260 men aged 18 and upwards, 144,590 women aged 18 and upwards, 8,387 youths under 18, and 11,583 girls under 18. These figures included all unemployed persons on the registers of the employment exchanges, with the single exception of those severely disabled people who were only capable of work under special conditions. The total unemployment figure included 75,280 married women. The level of unemployment on February 16 represented 2·1 per cent. of the estimated total number of employees in Great Britain, compared with 2·2 per cent. on January 12, 1953, and 1·9 per cent. on February 11, 1952.

The total working population in Great Britain declined from 23,292,000 at the end of December, 1952, to 23,280,000 at the end of January, 1953, a decrease of 12,000, of whom 8,000 were women. Of the total on January 31 last, 15,869,000 were men and boys, and 7,411,000 women and girls, compared with 15,873,000 men and boys, and 7,419,000 women and girls at the end of December. These figures include all persons aged 15 and over who work for pay or gain, or who register themselves as available for such work. The total comprises the Armed Forces, men and women on release leave, registered unemployed, and employers and work-people in civil employment, including gainfully-occupied persons over pensionable age. Part-time employees are counted as full units.

A representative of Scunthorpe steelworks has been visiting North-East towns interviewing unemployed men with a view to giving them work at Scunthorpe. About 50 men are needed. A good many North-East men have already secured employment at Scunthorpe works in recent years. The men wanted include labourers, welders, electricians, maintenance fitters, boilermakers and also draughtsmen.

INSPECTION OF GAS-TURBINE BLADES.

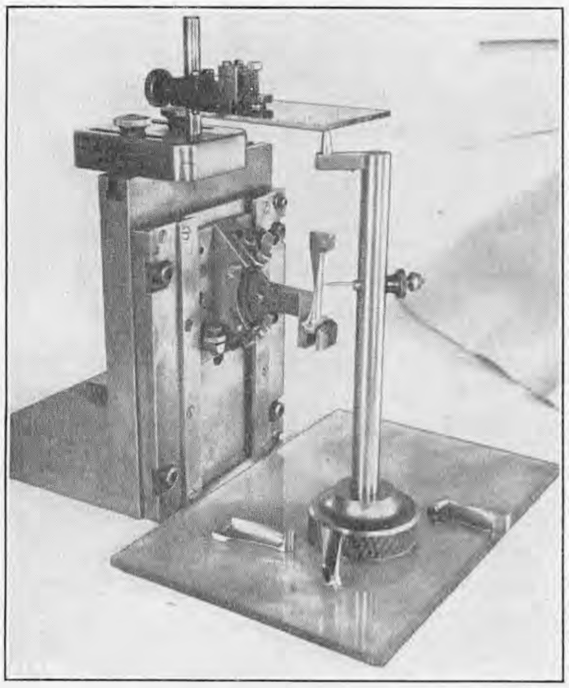


FIG. 1. RECORDING BLADE PROFILE ON SMOKED-GLASS PLATE.

Fig. 2.

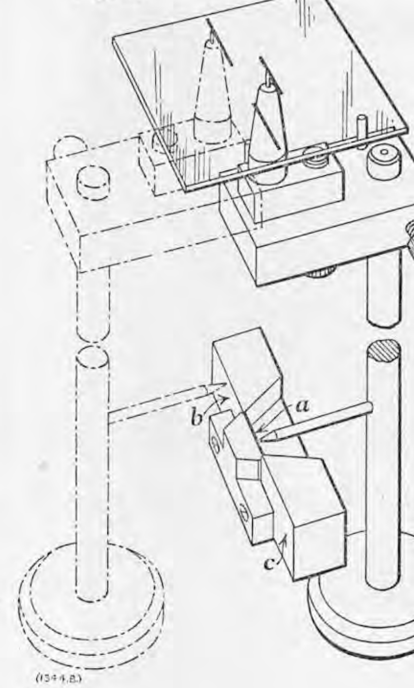
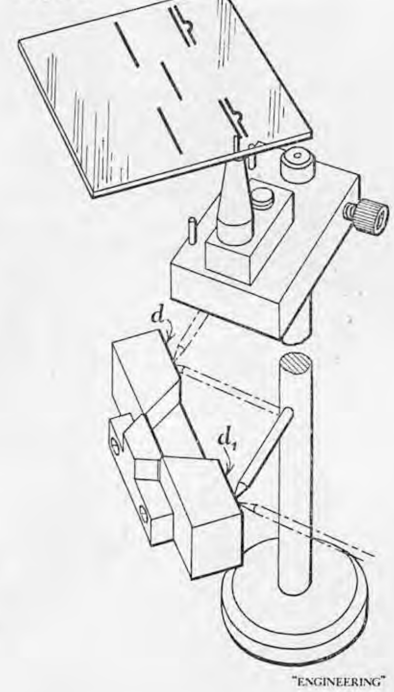


Fig. 3.



INSPECTION PROBLEMS OF MODERN JET ENGINES.*

By C. GARSIDE.

THE advent of the modern jet engine has introduced many inspection problems not previously encountered in the conventional piston engine. This is particularly so in the axial-flow jet engine, which has many of the basic features of the piston engine, such as the compressor impeller and supercharger impeller. The metrological examination of the components on these earlier engines was effected by the use of measuring equipment well known in the engineering industry—micrometers, verniers, comparators, limit gauges and inspection fixtures designed by the jig and tool department for specific applications. In addition, there are such precision instruments as mechanical and optical dividing heads, slip gauges, sine plates, measuring projectors and universal measuring machines, etc. The centrifugal-flow jet engine introduced the first new problem encountered in the manufacture of aero-engines, namely, the turbine blade. In the earlier periods of manufacture, this component did not present such a serious difficulty, due to the lengthy machining operations and relatively small number of blades per engine, but it was the forerunner of a considerable amount of development by several manufacturers of inspection equipment in an attempt to devise simple methods of measuring the profile of the blade. This paper is based on the methods of inspection and types of instruments used in this technology.

AXIAL-FLOW COMPRESSOR.

The development of the axial-flow jet engine has resulted in a demand for a large number of compressor blades in addition to turbine blades, which has brought about the problem of rapidly inspecting very large quantities of these components, of complex non-geometric shapes. One of the major problems has been that of developing equipment which, operating on an engineering tolerance system, can accurately interpret the aerodynamic requirements of the designer. Three features require careful control, namely, the aerofoil profile of the blade, the dimensional accuracy of the root fixing, and the relationship between the root and the aerofoil profile. The co-ordination of these characteristics created difficulties in dimensioning the drawings relative to a suitable datum so that easy interpretation of the requirements can be made, and each aero-engine manufacturer had his own method of dimensioning. In an attempt at unification, the Society of British Aircraft Constructors formed a sub-committee to investigate the most suitable method. Discussions have taken place over a considerable period in conjunction with the Society of Automotive Engineers, in the United States, and the S.B.A.C. have now issued a standardised method for compressor blades.

The undernoted list of the terms and definitions used in conjunction with blades will facilitate an understanding of the various characteristics.

Blade platform = The rectangular or rhomboid portion connecting the blade root to the blade proper.

Aerofoil = The complete shape at any section of the blade proper, normal to a line perpendicular to the engine axis.

Aerofoil thickness = The dimension between the concave and the convex profiles of the aerofoil section taken normal to the concave section profile.

Chord = The line joining the intersection points of the camber line and the blade profile at any section.

Section = Defines the radial location of an aerofoil and is dimensioned from a reference point on the blade root or fixing.

Stagger angle = The angle subtended by the chord line and the axis of the compressor.

Twist = The change in angular position of the aerofoil along the blade length.

Circumferential and axial lean = A uniformly progressive displacement error in the aerofoil position relative to the X and Y datum.

MANUFACTURE OF BLADES.

Designers' requirements regarding blade manufacture vary throughout the industry, but it is reasonable to assume that one of their aims is to obtain as close a forging as possible, firstly, to save expensive materials and, secondly, to reduce machining to an absolute minimum. This has been quite successfully achieved in some instances to the extent that, with the exception of leading and trailing edges which require some metal manipulation due to forging "flash," etc., blade profiles require no machining at all. These particular precision forgings provide the greatest difficulty in inspection, due to the fact that the machining operations are few in number—mainly machining of the root fixing—and the "floor to floor times" are low, generally an average of 15 to 30 seconds per operation. Further problems are introduced when the blades are located from the unmachined profile, due to slight variations in forging influenced by such factors as blade temperatures during stamping, temperature of die, mass of blade metal, growth during die life and general forging technique. It is necessary, therefore, to plan inspection to achieve complete control of blades from receipt of forgings to final blade accuracy, economy of inspection time, detection of defectives at the earliest stage, and the avoidance of unnecessary inspections. This control is effected by stage inspection, employing method A for precision forgings where the blade aerofoil is produced to drawing requirements, and method B for forgings machined all over.

Method A: Stage 1.—Proof inspection of the "first off" a pair of dies, prior to mass production, to ensure that die size, formation and positioning of the aerofoil sections to the datum are correct.

Stage 2.—If stage 1 is satisfactory, carry out 100 per cent. inspection of bulk supplies to verify the repetition of the proof sample within certain limits. Forgings are related to die sets by identification marks forming part of the die, which enables correlation to be maintained at all times.

Stage 3.—Percentage dimensional checks during the manufacturing process by statistical quality control (100 per cent. inspection at each operation would be too costly, due to the rapid production on multiple-fixture machines). It is the general practice to use the same blade location on the inspection fixture as on the machine. The quality control chart will then indicate which tool is incorrect, should the dimension fall outside the control limit. Direct measurement or comparison is used at this stage. This method induces the setter to observe critically the movement of size inside the control limits, and, from the data provided, to adjust his machine accordingly.

Stage 4.—A 100 per cent. final inspection of all major features. This is considered necessary because the blade is such a vital component in the safe functioning of the engine. To reduce the human element to the absolute minimum, semi-automatic measuring machines can be provided for rapidly checking the important dimensions; but, as these machines only check at various points on the blade, it is also the practice in the case of the aerofoil section to examine the continuity of the shape by projection or pantograph instrument against a master reference drawing.

Method B: Stage 1 is the same as in Method A.

* Paper presented at a meeting of the Institution of Engineers and Shipbuilders in Scotland, held in Glasgow on February 24, 1953. Abridged.

INSPECTION OF GAS-TURBINE BLADES.

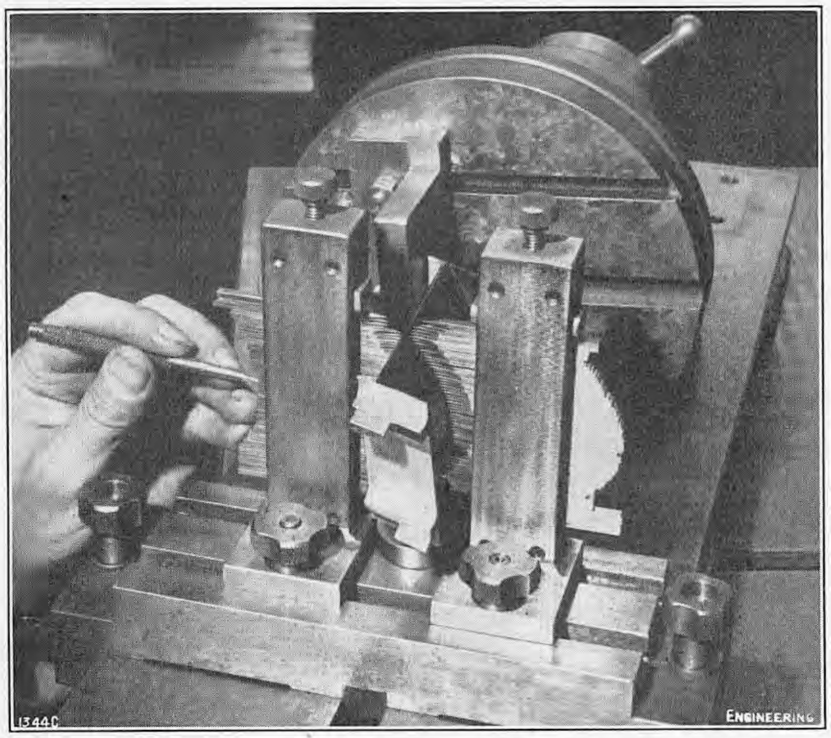


FIG. 4. "NEEDLE SLIP" FIXTURE.

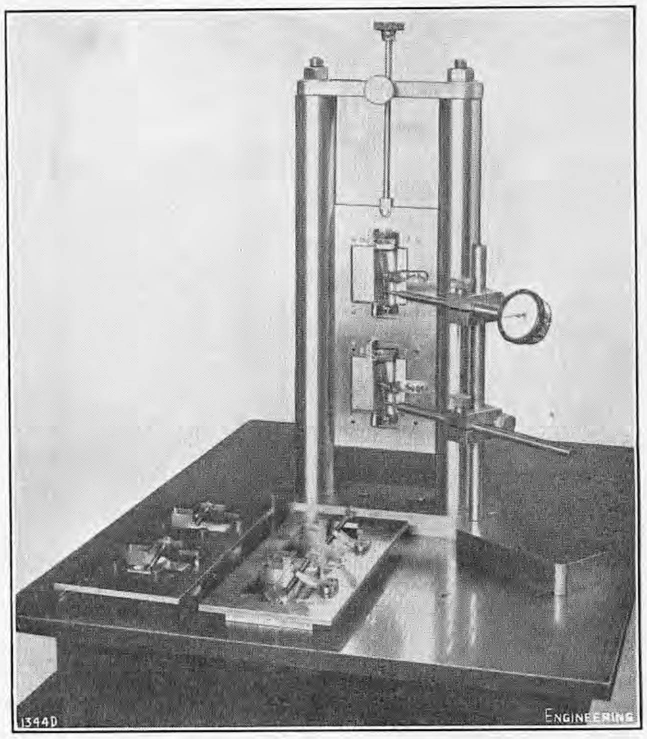


FIG. 5. FIXTURE FOR CHECKING BLADE PROFILE.

Stage 2 can be reduced to a percentage inspection on a controlled sampling basis, using limit gauges for the important features.

Stage 3 is again a system of statistical quality control of the important dimensions by patrol inspection at definite time cycles, but, owing to the greater number of machining operations carried out on these blades, inspection sub-stages are introduced whereby certain dimensions, prior to a change of location or heat-treatment operation, etc., are inspected 100 per cent. In most cases, these are finished dimensions and receive no further inspection.

Stage 4 is the same as in Method A.

PROFILE INVESTIGATION.

Several types of instruments have been designed for contour and profile examination, and probably the most useful and versatile of these is the system of recording profiles on smoked glass. The method employs a simple instrument, shown in Fig. 1, on page 345, which has a base and platform capable of being raised, including a suitable fixture for holding a blade, die or cam. The upper part of the fixture is designed to carry a piece of ordinary glass plate, 3 to 4 in. square. The scriber itself affords a means of holding two tracer points in fixed relationship to each other. This relationship is such that if the lower, or tracer point is traversed over the surface of the work, the upper point moves through an identical path. This path is recorded on the glass plate, which has previously been smoked by candle flame or similar means, and which is supported at such a height that the upper fine-pointed scriber always maintains contact. The glass plate is then removed and optically projected on to a viewing screen at any desired magnification, usually $\times$ 20, and compared with a master reference drawing.

If accuracy is to be maintained in recording the trace, it is essential that all errors in the alignment of the tracer and scriber points should be eliminated. For this purpose, use is made of a small steel setting-block (Figs. 2 and 3) that is, in effect, a method of obtaining a reference-plane that has no thickness. Attached to one side of the block and in line with the central notch is a second small block, and all reference faces of these two blocks are ground flat and parallel. The faces a, b and c are traversed with the tracer held normal to the reference faces. If the axial setting of the tracer point relative to the scriber is correct, the traces recorded on the smoked glass plate will appear as a continuous straight line. Any departure from this condition, as shown in Fig. 2, signifies a misalignment that can be measured when the smoked-glass trace is projected. Similarly, for checking the angular alignment, faces d and d_1 are traced with the axis of the tracer point inclined at 45 deg. to each face. This operation is then repeated, but with the 45 deg. inclination in the opposite direction. During this second operation, a looping action is imparted during the trace to distinguish the first and second set of lines, for, should the adjustment be correct, the lines will coincide. If, however, an offset appears, measurement can be obtained by projection, as previously.

Another type of instrument, very useful and relatively simple to make, is one known as the "needle slip" profile fixture, shown in Fig. 4, herewith. This consists of two slotted holders fitted to a T-slotted base. Each holder carries a large number of thin steel slips having a point at one end, and the holders are separated at a positive distance by a suitable disc. The blade is then held by a horizontal head which can turn through 360 deg., and it is a simple matter to push each slip through the slot so that the point contacts the blade form. The slips can be locked in position with the top screws, and the whole "set-up" removed to the projector and compared with the master drawing. The weakness of this method is in its inability to check leading and trailing edge radii. These methods are ideally suitable for proof-testing "first off" forgings, etc., and, being non-destructive tests, can be used for reference purposes when investigating queries on production blades.

It is sometimes necessary to cut several sections from a blade form for analysis. When this is done, the sections are cemented to a glass plate and projected against master reference layouts. Photographs can be taken of the result and copies sent to the forging manufacturers for examination. Several other instruments are available for proof checking, investigation, etc., but as these are also suitable for production inspection, they are dealt with later.

As already mentioned, inspection control of manufacturing process is carried out by statistical quality control and the use of inspection fixtures situated near each machine stage. The inspector patrols the lines at definite time cycles commensurate with the production output, selects the required sample number of components at random, and measures the selected features. The average results are tabulated on a data sheet and, when a satisfactory number of checks are recorded, the control chart is introduced and the control limits set. This chart is then plotted at each visit to the machine and the spread of size watched for undue tendencies. Figs. 5 and 6 illustrate examples of the inspection fixtures used at the patrol stage. Fig. 5 shows a fixture for checking blade profile comparisons at an intermediate machining stage, and Fig. 6 shows a fixture for checking the sectional thickness of blades between operations.

PRODUCTION INSPECTION INSTRUMENTS.

An increasing amount of development has been carried out during recent years on various types of measuring equipment, with the result that to-day there are several excellent machines of the comparator type available, suitable for rapidly inspecting either compressor or turbine blades. These comparators have been developed both in this country and abroad and fall mainly into the categories of optical projection, electrical and pneumatic. The choice of any one of these types is a problem confronting the inspection planning engineer, who must consider the cost of equipment, production, output, and the ability of one type of instrument only to satisfy design requirements. The advantages and disadvantages are summarised below.

Optical Projection.—Advantages: several dimensions checked simultaneously; simple fixtures; the whole surface examined; no wear on measuring surface; practically no moving parts. Disadvantages: restricted field—low magnification; skilled interpretation of result required; internal surface not easily projected; multiple errors not easy to segregate from individual features.

Electrical.—Advantages: measuring unit can be remote from indicating instrument; high magnification possible; mechanism carrying pointer very light; measuring unit can be made very small. Disadvantages: variations in voltage or frequency may affect accuracy; heating of coils can create inaccuracies; fixed scale with moving pointer gives small range at high magnification.

Pneumatic.—Advantages: very small number of moving parts—often none; measuring pressure very light—in some instances consists of an air jet only; can be arranged to give average value of several simultaneous readings; high magnification possible; indicator can be remote from measuring unit. Disadvantages: elaborate air-pressure regulation and filtering necessary; meniscus errors present on water-tube method, although slight at

INSPECTION OF GAS-TURBINE BLADES.

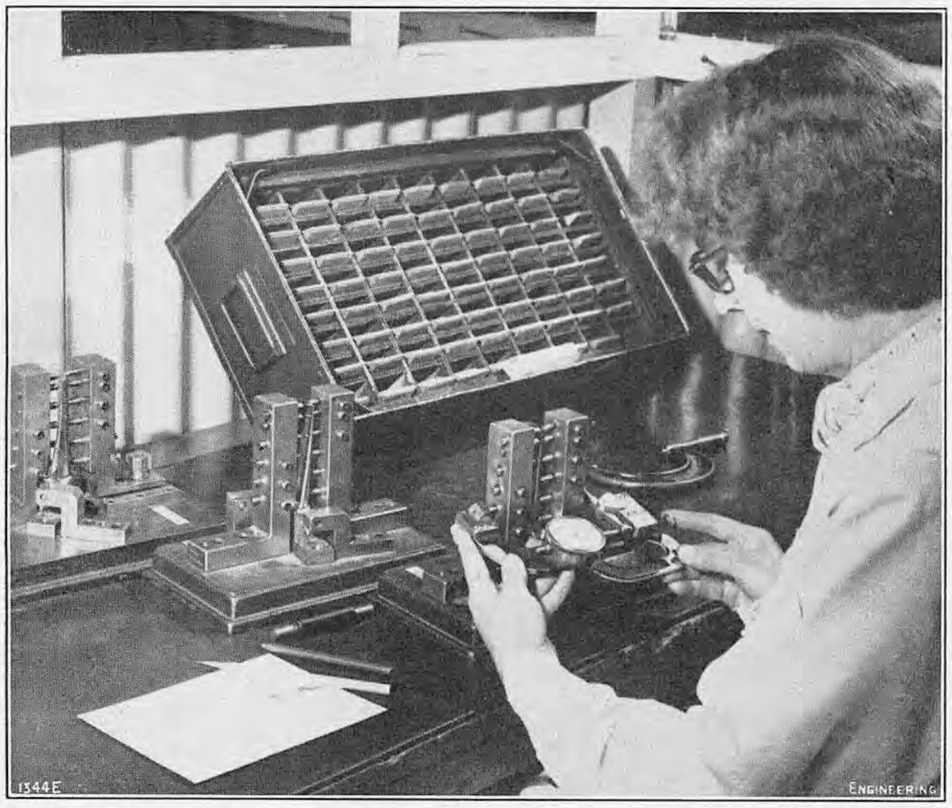


FIG. 6. FIXTURE FOR CHECKING SECTIONAL THICKNESS OF BLADE.

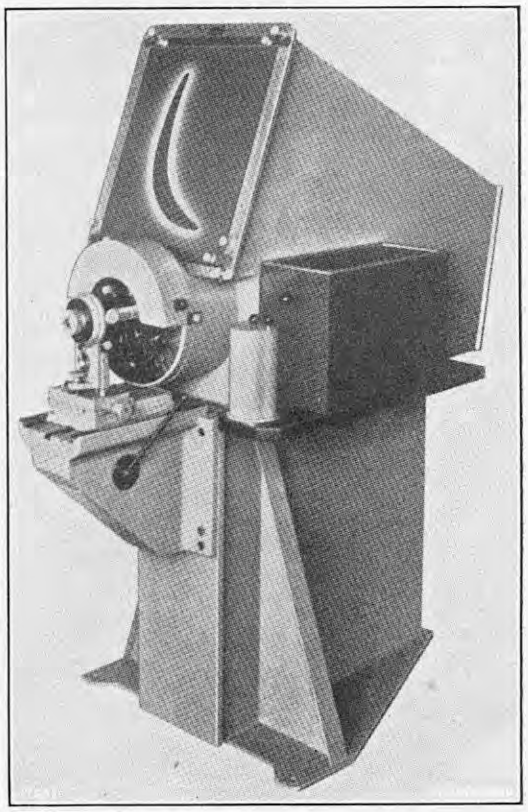


FIG. 7. SOCIÉTÉ GENEVOISE BLADE PROJECTOR.

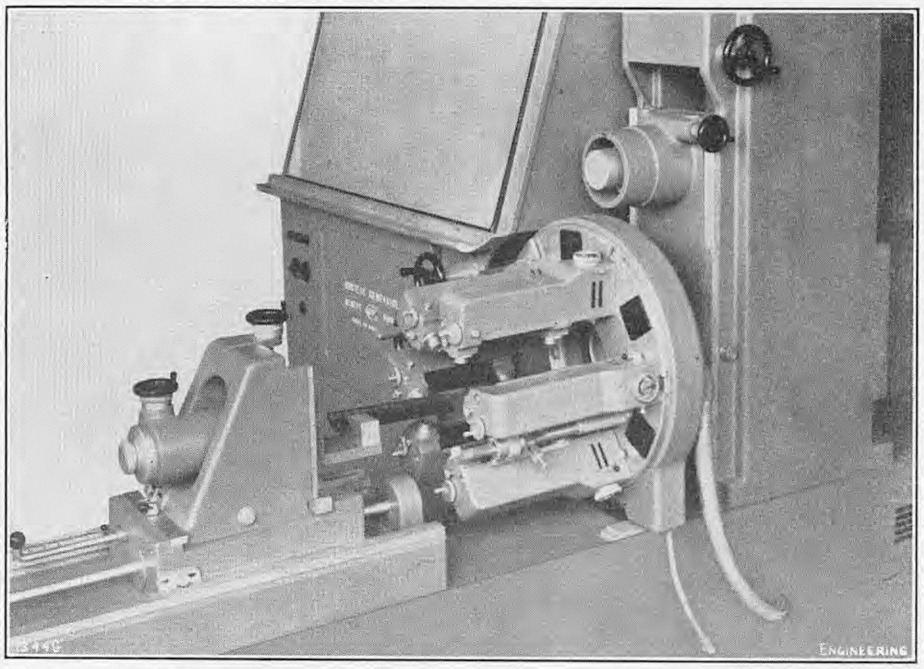


FIG. 8. PROJECTOR FOR SIMULTANEOUS EXAMINATION OF TWO SECTIONS OF A BLADE.

high magnification; scale on some instruments not linear; air compressor required, consequently the instrument is not easily portable.

With regard to blade inspection, and in particular with a high production rate, it has been found necessary to utilise optical projection, in addition to one of the alternative methods, because the electrical or pneumatic types give a very high rate of inspection output, due to the fact that all dimensions such as angular displacement, aerofoil thickness, blade width, length, circumferential and axial lean, etc., can be checked simultaneously, and the result read at a glance; but these instruments only check at selected points and do not explore the whole blade surface. Optical projection carries out this necessary function but has a much slower output, due to the skilled interpretation requirements of the resultant projection—within the tolerance envelope—by the operator. In some instances, the twist error of the blade can be outside the drawing limits and still remain within the envelope, due to the wider tolerances of other characteristics.

A special type of projector, shown in Fig. 7, herewith, has been devised for the inspection of blade profiles. The blade is held horizontally by its root fixing and with its tip facing the projection lens. The section of the blade to be examined is illuminated all round its contour by a band of light produced by four lamps, mounted at equal angular intervals round a circular plate that can be swivelled about the optical axis. The blade is coated with a thin film of magnesium oxide, which has a strong diffusing effect, with the result that the illumination is deflected and picked up by the main objective of the optical system and reflected back on to the screen by mirrors at a magnification of either $\times$ 10 or $\times$ 20. This magnified image can be compared with a master profile drawing, attached to the screen, by means of a lamp arranged inside the instrument which gives a degree of luminosity all over the screen. Different sections of the blade can be examined in turn by simply moving it lengthwise through appropriate distances by the handle provided. A particular feature of this instrument is that two different types of projected image can be produced on the screen by the manipulation of diaphragm slits in the illuminators. The diaphragms can be adjusted to illuminate either that part of the blade between the focal plane and the root of the blade or between the focal plane and the objective. In the first instance, a sharp black image of the blade on a white background appears on the screen. In the second, the image is reversed and the blade profile appears white on black.

A further development of this projector is shown in Fig. 8, on this page. The basic principles are identical and the main differences are greater illumination due to the use of additional lamps, and the ability to inspect much larger blades by the use of plain or annular objectives. The annular objectives are rather exceptional, as they have a hole through the middle. Consequently, it is possible to project profiles of blades that have shrouded tips, and very long blades without shrouds. This instrument is also equipped with double illumination, that is, two rows of illuminating lamps instead of one, which permits simultaneous projection of two sections of a blade. The distance between these two rows of lamps can be adjusted so that, within reasonable dimensions, any two sections of a blade can be chosen. The simultaneous projection of two sections is achieved by placing two semi-transparent glass plates halfway between the blade sections being illuminated in such a manner that the two images lie in the focal plane of the objective. The rays emitted by the illuminated section near the root end pass through the glass plates (one on each side of the blade) to the objective, and the rays from the second section at the tip end are deflected on to the semi-transparent glass plates and reflected back to the objective. Again, the projected image can be white on a black background or vice versa, and at a magnification of $\times$10 or $\times$20. The principal advantage of these projectors is that, at a single glance, the complete contour of a section of the blade, including the leading and trailing edge radii, may be inspected.

(To be continued.)

THE WORLD'S SHIPBUILDING.

TABLE I.—NUMBER AND TONNAGE OF MERCHANT VESSELS OF 100 TONS GROSS AND UPWARDS LAUNCHED DURING THE YEARS 1918-1952.

Year.	Great Britain and N. Ireland.†		Other British Commonwealth Countries. Coasts.		Other British Commonwealth Countries. Canadian Lake Ports.		Belgium.		Denmark.		France.		Germany.		Holland.		Italy.		Japan.		Norway.		Spain.		Sweden.		United States of America. Coasts.		United States of America. Great Lakes.		*Other Countries.		Totals.		Year.
	No.	Tons.	No.	Tons.	No.	Tons.	No.	Tons.	No.	Tons.	No.	Tons.	No.	Tons.	No.	Tons.	No.	Tons.	No.	Tons.	No.	Tons.	No.	Tons.	No.	Tons.	No.	Tons.	No.	Tons.	No.	Tons.	No.	Tons.	
1918	301	1,348,120	184	230,514	22	49,390	No	Returns	13	26,150	3	13,715	No	Returns	74	74,026	15	60,791	198	489,924	51	47,723	18	17,389	36	39,583	741	2,602,153	188	430,877	22	17,089	1,866	5,447,444	1918
1919	612	1,620,442	235	298,495	28	60,233	2	2,433	46	37,766	34	32,633	No	Returns	100	137,086	32	82,713	133	611,883	82	57,578	41	52,609	53	50,971	852	3,579,826	199	495,559	34	24,322	2,483	7,144,549	1919
1920	618	2,055,624	90	174,557	13	29,087	5	8,371	30	60,669	50	93,449	No	Returns	99	183,149	82	133,190	140	456,642	30	38,855	13	45,950	46	63,823	467	2,348,725	42	127,528	34	42,047	1,759	5,861,666	1920
1921	426	1,538,052	49	118,303	5	11,372	3	17,909	37	77,238	65	210,663	242	509,064	98	232,402	86	170,948	43	227,425	35	51,458	11	47,256	27	65,911	167	1,004,093	7	11,284	78	63,465	1,379	4,356,843	1921
1922	235	1,031,081	37	53,347	2	9,418	4	7,497	23	41,016	62	184,509	187	525,829	60	163,132	42	101,177	49	83,419	23	32,391	2	7,776	14	30,038	55	97,161	4	21,977	53	77,316	852	2,467,084	1922
1923	222	645,651	41	37,072	3	4,191	5	1,102	24	49,479	27	96,644	109	345,062	35	65,632	21	66,523	44	72,475	48	42,619	7	4,488	10	20,118	69	96,491	14	76,326	22	19,308	701	1,643,181	1923
1924	494	1,439,885	29	29,815	2	15,064	2	3,997	33	63,937	26	79,685	108	175,113	41	63,627	19	82,526	31	72,757	34	25,139	2	3,859	12	31,211	71	90,155	8	49,308	12	21,673	924	2,247,751	1924
1925	342	1,084,633	47	32,220	4	13,858	3	4,206	21	73,268	35	75,569	121	406,374	47	78,823	31	142,046	23	55,784	48	28,805	1	127	17	53,750	94	78,766	7	50,010	14	15,165	855	2,193,404	1925
1926	197	639,568	39	22,842	3	10,836	8	3,627	25	72,108	34	121,342	60	180,548	47	93,671	27	220,021	26	52,405	25	9,237	6	25,671	14	53,518	73	115,217	5	35,396	11	18,970	600	1,674,977	1926
1927	371	1,225,873	24	20,119	5	10,131	8	4,693	20	72,038	22	44,335	105	289,622	68	119,790	25	101,076	19	42,359	12	5,363	5	22,899	18	67,361	58	124,270	8	54,948	34	80,802	802	2,285,679	1927
1928	420	1,445,920	47	22,959	1	734	3	16,243	31	138,712	20	81,416	81	376,416	74	166,754	29	58,640	37	103,663	12	10,401	7	11,852	20	106,912	57	86,092	6	5,265	24	67,260	869	2,699,239	1928
1929	489	1,522,623	47	21,327	3	11,814	4	8,361	34	111,496	16	81,607	85	249,077	77	186,517	32	71,497	40	164,457	51	39,604	8	37,023	29	107,246	59	100,632	4	25,431	34	54,498	1,012	2,793,210	1929
1930	481	1,478,563	77	43,292	2	458	5	12,265	38	137,230	18	100,917	92	245,557	74	153,072	36	87,709	37	151,272	53	53,843	13	25,213	31	131,781	92	214,012	8	32,675	27	21,613	1,084	2,889,472	1930
1931	148	502,487	31	13,612	—	—	7	897	30	125,974	22	103,419	58	103,934	99	120,296	33	165,048	42	83,721	20	18,163	11	48,117	20	112,703	55	202,227	2	3,638	18	12,879	596	1,617,115	1931
1932	100	187,794	14	3,424	2	1,336	7	1,537	18	22,413	23	89,310	15	80,799	30	26,232	8	47,441	44	54,422	8	11,129	3	11,132	12	43,000	18	143,559	—	—	5	3,063	307	726,591	1932
1933	108	133,115	20	12,958	—	—	5	4,497	19	34,016	29	34,073	43	42,195	25	35,899	3	16,560	30	74,290	7	9,718	7	18,044	14	60,860	14	10,771	—	—	6	2,020	330	489,016	1933
1934	173	459,877	16	9,112	—	—	4	831	21	61,729	10	15,950	57	73,733	31	46,905	6	26,638	155	152,420	12	18,857	8	18,358	12	49,542	21	24,625	—	—	10	8,842	536	967,419	1934
1935	185	499,011	28	10,047	2	1,142	10	1,775	33	122,095	10	42,783	78	226,343	48	57,133	4	22,667	177	145,914	23	25,716	7	3,051	22	105,538	14	32,607	—	—	8	6,258	649	1,302,080	1935
1936	328	856,257	25	6,239	—	—	16	4,249	35	97,537	17	39,208	161	379,981	69	93,831	7	11,345	180	294,861	33	33,162	9	1,283	33	154,044	57	101,258	12	10,627	17	34,042	999	2,117,924	1936
1937	309	920,822	38	13,880	—	—	17	17,071	26	131,411	9	26,544	174	435,606	112	183,509	6	21,918	180	451,121	38	41,993		*	38	161,008	103	195,767	20	43,678	31	46,252	1,101	2,690,580	1937
1938	267	1,030,375	59	28,151	2	1,949	21	30,197	35	158,430	7	47,290	193	480,797	142	239,845	13	93,503	146	441,720	42	54,654		*	40	166,464	62	163,114	43	38,137	47	58,967	1,119	3,033,593	1938
1939	201	629,705	41	36,142	1	450	8	22,788	31	158,644	9	44,375	109	*300,106	130	189,833	28	119,757	121	*323,775	36	46,912	1	1,050	37	210,280	94	376,419	76	45,570	18	33,618	941	2,539,424	1939
1940	229	842,910	21	18,886	—	—	No	Returns	4	*18,350	4	*21,800	No	Returns	18	*36,567	10	*61,972	No	Returns	5	*10,070	—	—	31	153,727	93	528,697	74	50,713	6	10,506	495	1,754,198	1940
1941	245	1,185,894	34	90,595	—	—	No	Returns	No	Returns	No	Returns	No	Returns	No	Returns	No	Returns	No	Returns	No	Returns	4	12,150	31	163,554	177	1,031,974	10	3,265	9	3,741	510	2,491,173	1941
1942	273	1,270,714	115	720,672	—	—	No	Returns	No	Returns	No	Returns	No	Returns	No	Returns	No	Returns	No	Returns	No	Returns	7	5,880	36	141,568	803	5,479,766	58	191,054	8	5,715	1,300	7,815,369	1942
1943	243	1,136,804	151	1,002,850	1	3,600	No	Returns	No	Returns	No	Returns	No	Returns	No	Returns	No	Returns	No	Returns	No	Returns	12	15,543	45	146,114	1,584	11,448,360	41	131,162	1	343	2,078	13,884,776	1943
1944	279	919,357	135	692,405	2	4,800	6	*22,523	No	Returns	No	Returns	No	Returns	No	Returns	No	Returns	No	Returns	No	Returns	8	30,934	45	157,183	1,242	9,288,156	19	50,911	2	3,234	1,738	11,169,503	1944
1945	307	893,515	56	141,893	14	4,097	5	*10,447	7	*22,466	No	Returns	No	Returns	No	Returns	6	*9,538	No	Returns	4	*5,965	11	20,147	32	112,760	842	5,839,858	38	127,723	4	4,270	1,326	7,192,679	1945
1946	314	1,120,526	58	83,019	7	2,632	13	17,451	13	39,051	20	*23,205	No	Returns	23	33,290	57	61,742	No	Returns	20	34,428	17	41,289	50	146,875	95	500,909	1	385	2	9,900	690	2,114,702	1946
1947	343	1,192,759	59	124,432	4	4,900	17	26,132	15	60,695	36	91,911	No	Returns	65	87,801	45	62,247	No	Returns	45	36,854	16	10,692	52	222,598	65	162,095	5	2,753	20	16,752	787	2,102,621	1947
1948	342	1,176,346	65	110,130	16	13,479	34	52,456	20	99,426	46	138,260	No	Returns	97	142,485	47	111,555	No	Returns	49	46,974	31	21,521	56	245,896	42	123,503	7	2,915	20	24,797	872	2,309,743	1948
1949	320	1,267,467	38	77,588	3	24,159	16	45,402	26	86,134	59	154,859	No	Returns	100	169,295	46	99,150	84	147,974	47	59,213	27	15,428	71	323,099	60	619,357	6	13,949	23	28,731	926	3,131,805	1949
1950	275	1,324,570	29	50,101	3	24,412	11	66,317	27	125,490	52	180,846	173	‡154,506	120	228,118	17	107,464	97	347,945	57	53,402	25	27,205	63	347,892	47	435,464	5	1,567	12	17,577	1,013	3,492,876	1950
1951	261	1,341,024	25	27.223	7	50.986	11	72.373	25	115,398	43	222,632	169	318,339	128	216,869	21	112,318	85	434,286	41	94,383	35	39,596	77	404.067	50	134,639	14	31,244	30	27,187	1,022	3,642,564	1951
1952	254	1,302,548	23	44,368	5	51,729	9	56,970	26	103,596	39	212,664	213	520,172	156	295,905	29	131,951	92	608,373	38	80,418	24	21,206	69	454,349	51	373,522	13	94,023	33	43,784	1,074	4,395,578	1952

* Returns not complete. † Prior to 1938, figures relating to Great Britain and Ireland include ships launched in Eire. ‡ Returns may not be complete.

THE WORLD'S SHIPBUILDING.

During 1952 there were launched in Great Britain and Northern Ireland 254 merchant ships totalling 1,302,548 gross tons, 75 being steamers, aggregating 448,510 tons, and 179 motorships, comprising 854,038 tons. The total is smaller by 38,476 tons than that for 1951, which was the highest since 1930. These statistics are given in the *Annual Summary of Merchant Ships Launched in the World during* 1952, issued by Lloyd's Register of Shipping, 71, Fenchurch-street, London, E.C.3. The *Summary* includes all ships of 100 tons gross or more launched in 1952, whether they were completed during that year or are still under construction. Table I, herewith, gives the number and gross tonnage of the vessels launched in all the leading maritime countries of the world during the period 1918-1952. It should be noted that, since 1914, complete returns for Russia have been available for the years 1927 to 1929 only, and, for Poland, for the years prior to 1939 and the two years 1948 and 1949 only. Moreover, for some years past, no returns have been received from China. In Table II are shown the number and tonnage of the merchant vessels launched in the principal shipbuilding districts of Great Britain and Northern Ireland in 1950, 1951 and 1952.

In Table I, the tonnage shown for Great Britain and Northern Ireland is 29·6 per cent. of the world output for 1952. In 1913, some 1,932,000 tons of shipping were launched in the British Isles—58·0 per cent. of the world output. The annual average

Table II.—*Showing the Number and Tonnage of Merchant Vessels Launched in the Principal Shipbuilding Districts in Great Britain and N. Ireland during the Years* 1950-52.

District.	1950. No.	1950. Tons Gross.	1951. No.	1951. Tons Gross.	1952. No.	1952. Tons Gross.
Aberdeen ..	16	12,934	13	6,735	6	8,973
Barrow ..	3	59,634	1	20,600	2	30,964
Belfast ..	11	130,720	10	118,174	14	129,977
Clyde—						
Glasgow ..	58	254,355	55	280,104	57	277,199
Greenock ..	26	183,992	20	147,969	22	170,566
Dundee ..	4	18,803	7	30,097	3	23,802
Hartlepools ..	7	35,693	9	50,506	8	45,347
Hull ..	38	19,894	34	14,640	37	14,302
Leith ..	14	30,552	15	28,568	14	28,877
Liverpool ..	8	66,703	10	67,498	13	68,403
Middlesbrough ..	19	105,344	16	125,556	13	122,756
Newcastle ..	22	206,501	24	243,499	25	201,338
Sunderland ..	34	191,418	28	197,333	26	170,892

total for the years 1919 to 1932 was 1,173,000 tons, or 39·6 per cent. of the world's output. Table II indicates that the Clyde maintained its leading position among the shipbuilding districts of this country with an increased aggregate of 447,765 tons. The Tyne was second with a reduced total of 201,338 tons; Sunderland third, also with a reduced total of 170,892 tons; and Middlesbrough and the Hartlepools fourth, with 168,103 tons. Belfast was fifth with an increased total of 129,977 tons. Three ships exceeding 20,000 tons, all steam oil-tankers, were launched in British yards during the year. They are the 21,800-ton British Sailor, which was the largest tanker launched in the world during the year, the 20,350-ton World Enterprise, and the 20,125-ton World Concord. There were also launched in this country during 1952 two steamers and three motorships between 15,000 and 12,000 tons; 12 steamers and 38 motorships between 10,000 and 15,000 tons; and four steamers and nine motorships between 8,000 tons and 10,000 tons. Excluding vessels of less than 1,000 tons, 17 steamers and 40 motorships, making together 643,125 tons and built for the carriage of oil in bulk, were launched. This tonnage represents a decline of 190,809 from the figure for 1951, but tankers nevertheless represent 49·6 per cent. of this country's output in 1952.

The tonnage launched abroad comprised 820 ships, aggregating 3,093,030 tons, and made up of 161 steamers (1,071,988 tons) and 659 motorships (2,021,042 tons). As is indicated in Table I, the leading foreign shipbuilding country in 1952 was Japan, followed in order by Germany, the United States, Sweden, the Netherlands and France. The four largest ships launched overseas were the 22,000-ton motorship Kungsholm, built in Holland; the 21,700-ton steamer Santa Maria, launched in Belgium; the 21,392-ton oil-tank motorships Bethsabee, constructed in France, and the 21,335-ton oil-tank steamer Petrokure, built in Japan. Fourteen steamers and six motorships launched abroad were between 15,000 and 20,000, and 35 steamers and 65 motorships were between 10,000 and 15,000 tons.

In 1952, motorships formed 65 per cent. of the world output of shipping, compared with 75 per cent, in 1951. The steamers included 29 ships, aggregating 60,432 tons, which are to be driven by a combination of reciprocating and turbine engines. Geared turbines are to be fitted in 109 vessels, making together 1,253,234 tons. The tonnage of steamers fitted for burning oil fuel under their boilers is about 1,466,000, and electric drive will be employed in one steamship of 8,000 tons and 13 motorships, aggregating 11,028 tons. A total of 485 ships, making together 2,757,753 tons, or 62·74 per cent. of the shipping launched in the world during 1952, are being built under the survey of Lloyd's Register. Of this total, 215 ships, aggregating 1,245,859 tons are being built in the United Kingdom and represent 95·65 per cent. of the tonnage launched in this country.

THE DESIGN OF BRITISH POWER STATIONS.*

By S. D. WHETMAN, B.Sc., and A. E. POWELL, B.Sc. (Eng.).

THIS paper describes some of the design features of five British power stations, which were designed and mainly constructed before the Electricity Act of 1947. They were commissioned between 1942 and 1951, one (Earley) being a war-emergency station. Reliability was the first consideration, with overall economy (as opposed to highest possible thermal efficiency) coming second. For this reason, simplicity was preferred to complications which might offer problematical improvement in efficiency. Nevertheless, four of the stations have appeared among the ten most efficient in successive years, and one (Littlebrook B) has shown the highest efficiency in the country.

Table I gives the general design particulars of each station.† The Blackwall Point station is situated on the south bank of the Thames, on the site of an old station which was demolished to make room for the new building. The relatively conservative steam conditions were chosen on the expectation of a low load factor, since the plant was to operate in parallel with Barking. Owing to space limitations, the boiler fans and electrostatic precipitators are on the boiler-house roof. Earley, three miles east of Reading, was designed to meet an urgent need due to growing loads to the west and south-west. The choice of site was determined by the adjacent 132/33-kV substation, and the proximity of the main-line railway and the River Thames. Simplicity, economy in the use of materials and speed of construction were overriding considerations, but some unusual features were introduced into the design by the use of plant originally intended for South Africa. The steam conditions were quite suitable for a station which was expected to operate at a low load factor on a two-shift basis.

Cliff Quay is on the left bank of the River Orwell, two miles from the centre of Ipswich. The steam conditions were selected to comply with the requirement that reliability was of paramount importance. With a total installed capacity of 270 MW, it is the largest station which has been built in this country without a break in the construction programme. Poole was projected in 1938, but work was stopped between 1939 and 1945. The station is situated on a reclaimed mud flat in Holes Bay. The improved efficiency obtainable from the 900 lb. per square inch and 925 deg. F. steam conditions finally selected justified the higher capital expenditure, even taking into account the moderate load factor at which the station was expected to operate. This station, like Blackwall Point, was not provided with a railway connection, either for construction or operation.

Littlebrook B is situated on the south bank of the Thames, some 15 miles below London Bridge. The station was planned for base-load working and the alternators were the first hydrogen-cooled machines to go into operation in this country. The steam cycle was influenced by thermo-dynamic, technical and metallurgical considerations. The temperature of 825 deg. F. at the turbine stop valve made the use of heat-resisting alloys one of choice rather than of necessity. It also permitted a series arrangement of convection superheater and reheater, an arrangement which, after considering the variety of fuels which might have to be used, was preferred to that of placing the superheater and reheater in the radiant zone. The pressure at which the steam is reheated was chosen to suit the turbine design and is a little higher than the optimum. The feed-water temperature at maximum load is 421 deg. F., which permits the final high-pressure heater to be connected to the exhaust from the high-pressure cylinder. This provides a satisfactory arrangement of economiser and air heater, and gives a maximum air temperature of about 500 deg. F. and an exit gas temperature of 285 deg. F. As, in 1938, there was in this country no experience of boilers (particularly reheater units) having a rating equivalent to 60 MW, and the boiler availability was not expected to be as high as that of the turbines, two boilers were arranged to serve each turbo-alternator. At the present time, one reheater boiler per machine would be recommended, giving a much simpler arrangement of pipework.

TURBINES.

The main particulars of the turbine and condensing plant are given in Table II. The 50-MW and 60-MW sets at Poole and Littlebrook are of the three-cylinder double-flow low-pressure type, and the 30-MW, 40-MW and 45-MW sets at the other stations are of the two-cylinder double-flow low-pressure type. All the turbines, with the exception of the second pair at Poole, are designed for the most economical rating at 80 per cent. of the maximum, the full load being obtained by the use of an overload valve. An overload valve is not now provided on any standard-size turbine in this

* Paper read before a joint meeting of the Institutions of Mechanical and Electrical Engineers on Thursday, March 5, 1953. Abridged.

† A full account of the Earley station were given in ENGINEERING, vol. 159, page 185 (1945); of the Poole station in vol. 167, page 476 (1949); and of the Cliff Quay station in vol. 169, page 674 (1950). A short description of Littlebrook B appeared in vol. 171, page 468 (1951) and of the Blackwall Point Station in vol. 171, page 692 (1951).—ED., E.

TABLE I.—GENERAL DESIGN PARTICULARS OF POWER STATIONS.

Description.	Blackwall Point.	Earley.	Cliff Quay.	Poole.	Littlebrook B.
Year of design	1945	1940	1939	1945	1938
Year of commissioning	1951	1942	1949	1950	1949
Installed capacity, MW	90	120	270	200	120
Steam pressure, lb. per sq. in.—					
Boiler stop-valve	635	635	635	950	1,250
Turbine stop-valve	600	615	600	900	1,235
Steam temperatures, deg. F.—					
Boiler stop-valve	865	850	850	940	850
Turbine stop-valve	850	815	825	925	825*
Number and capacity (MW) of turbo-alternators	Three—30/24	Three—40/32	Six—45/36	Two—50/40 Two—50/50	Two—60/48
Number and capacity (thousands of pounds of steam per hour) of boilers	Three—365/292	Seven—200/160	Nine—365/292	Eight—300/240	Four—265/200

* Reheat to 825 deg. F.

TABLE II.—TURBINE AND CONDENSING PLANT.

Description.	Blackwall Point.	Earley.	Cliff Quay.	Poole.		Littlebrook B.
Type of blading	H.P. impulse L.P. impulse and reaction	Reaction	Impulse	Nos. 1 and 2, Impulse	Nos. 3 and 4, Reaction	Impulse
Number and capacity of turbines—						
Max. continuous rating	Three 30-MW	Three 40-MW	Six 45-MW	Two 50-MW	Two 50-MW	Two 60-MW (reheat)
Economic rating	24-MW	32-MW	36-MW	40-MW	50-MW	48-MW
Number of stages—						
High pressure	22	38	22	12	20	16
Intermediate pressure	—	—	—	14	20	14
Low pressure	1 (impulse) 7 (reaction)	6	3 (plus multi-exhaust)	3 (plus multi-exhaust)	6	3 (plus multi-exhaust)
Back pressure with water at 60 deg. F. at economical rating, in. of mercury	1·0	1·5	1·0	1·0	1·2	0·85
Number of turbine exhausts	2	2	2 (Baumann)	2 (Baumann)	2	2 (Baumann)
Number of condensers per machine	2 shells	1 shell	2 shells	2 shells	1 shell	2 shells
Number of passes in water space	3	2	3	3	3	3
Cooling surface, sq. ft.	32,000	30,000	50,000	48,000		72,000
Quantity of cooling water, gallons per min.	21,200	20,000	33,000	31,700		41,500
Cooling-water velocity through tubes, ft. per sec.	5·3	4·81	5·44	5·6		5·3
Condenser tubes	1-in. diameter, 18 S.W.G.	¾-in. diameter, 18 S.W.G.	1-in. diameter, 18 S.W.G.	1-in. diameter, 18 S.W.G.		1-in. diameter, 18 S.W.G.
Tube material	Admiralty brass	Admiralty brass	Cupro nickel*	Aluminium bronze		Cupro-nickel
Number of cooling-water pumps and rating, gallons per min.	Three—24,000	Three—22,000	Six—36,000	Four—35,000		Two—42,000
Pump materials—						
Casings	Cast iron	Cast iron	Cast iron	Cast iron		Cast iron
Impellers	Stainless steel	Gunmetal	Stainless steel	Stainless steel		Stainless steel
Chlorination	Yes	Yes	Yes	Yes		Yes
Type of cooling-water pumps	Vertical-spindle centrifugal	Vertical-spindle axial-flow	Vertical-spindle centrifugal	Vertical-spindle centrifugal		Vertical-spindle centrifugal
Type of screens	Vertical rotary band	Vertical rotary band	Vertical rotary band	Vertical rotary band		Vertical rotary band
Screens capacity, gallons per hour	Two—2,250,000	Three—1,320,000	Six—2,500,000	Four—2,250,000		Two—2,500,000

* Aluminium bronze used in two condensers and replaced.

NULL METHOD OF MEASURING PERIODIC STRAINS.

(*For Description, see Opposite Page.*)

Fig. 1. BRIDGE-CIRCUIT USING CARRIER WAVE.

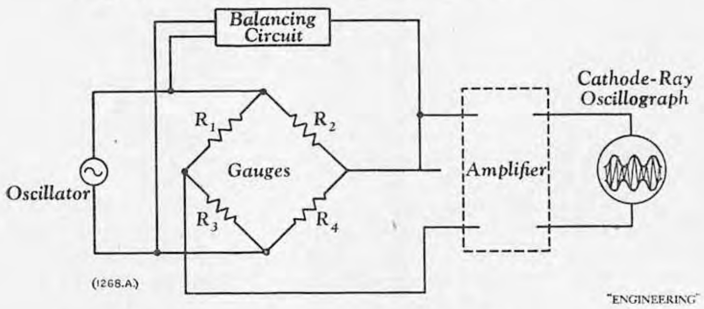


Fig. 2. BRIDGE-CIRCUIT BALANCING ARRANGEMENTS.

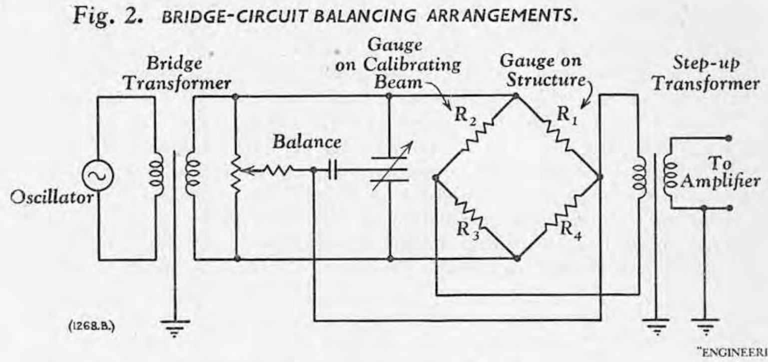


Fig. 3. STRAIN DIAGRAM.

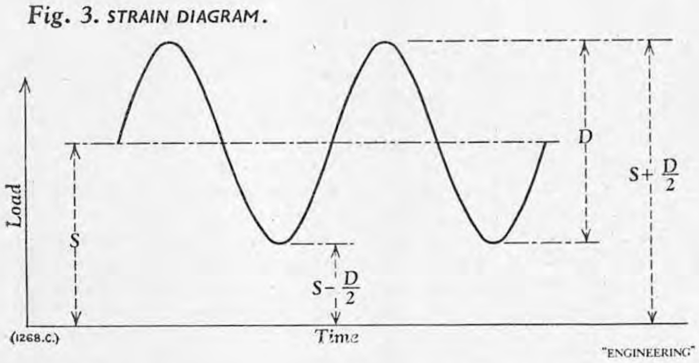


Fig. 4. OSCILLOGRAM CORRESPONDING TO FIG. 3.

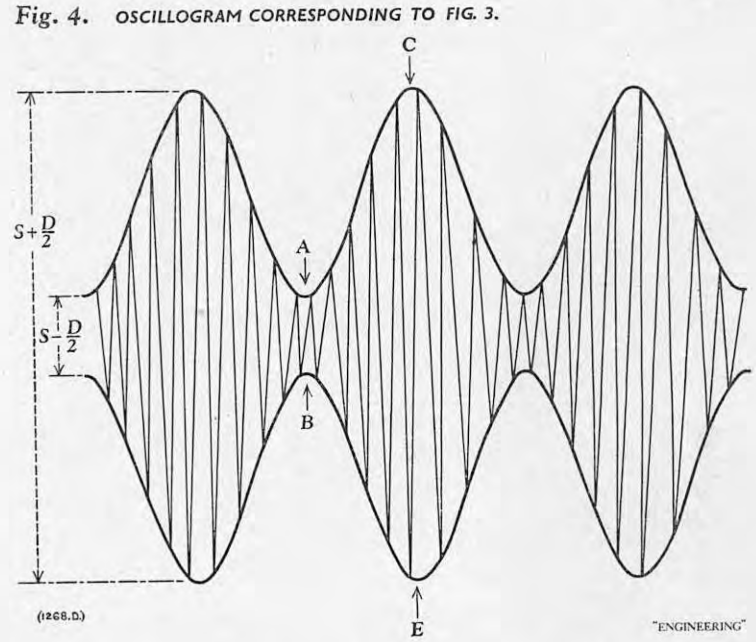


Fig. 5. EFFECT OF STRAINING CALIBRATING BEAM BY $S-\frac{D}{2}$

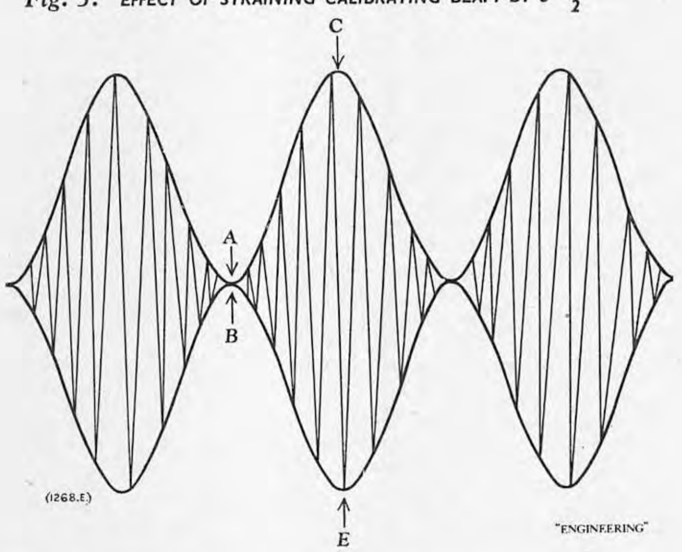


Fig. 6. EFFECT OF STRAINING CALIBRATING BEAM BY S.

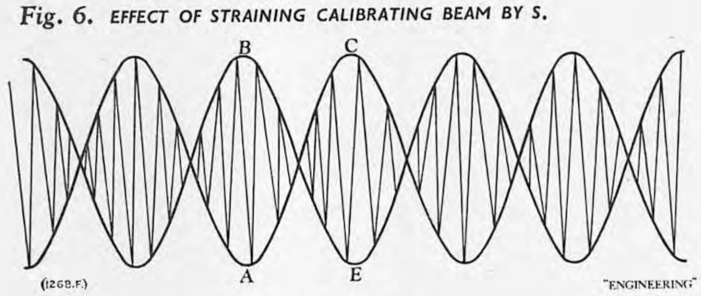
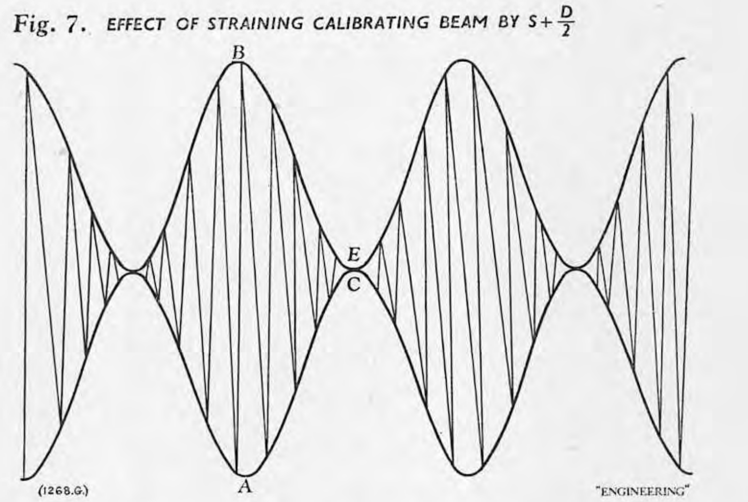


Fig. 7. EFFECT OF STRAINING CALIBRATING BEAM BY $S+\frac{D}{2}$



country bigger than 30 MW, on the ground that it complicates the design of the high-pressure cylinder. Nevertheless, the price of the by-pass type of machine seems to be no greater than that of the other, and experience of the operation of the two designs with temperatures up to 925 deg. F. does not suggest that the latter type is any better than the former. The first two Poole machines, together with the Cliff Quay and Littlebrook machines, are fitted with a device to assist the governor to act rapidly in cutting off steam in the event of a sudden loss of load. The Earley turbines are fitted with a device to unload the turbine on falling vacuum, and with a second line of defence which shuts off the steam when the vacuum reaches a comparatively low limit. This has two advantages: it allows some reduction to be made in the size of the atmospheric valve and exhaust pipe-work to the atmosphere, and reduces the liability of the low-pressure turbine to become overheated.

The Littlebrook reheat turbines have governor and emergency stop valves in the steam chests of the intermediate pressure turbines to prevent the machines being run up to excessive speed, in the event of loss of load, by the steam stored in the reheater system. In order to prevent an excessive build-up of pressure between the high-pressure steam chest and the intermediate-pressure steam-chest valves, owing to the operation of the latter, relief valves are fitted in the reheater pipe system. As a further measure of protection, a device, actuated by a pressure exceeding the setting pressures of the reheated-steam relief valves, is provided at the high-pressure turbine exhaust. This shuts off the main steam supply to the machines by closing the emergency stop valve in the high-pressure steam chest, and simultaneously trips the generator field switch. Supervisory gear is fitted on the Littlebrook and Poole machines. This records the eccentricity and relative expansion axially of the turbine shafts relative to the high-pressure and intermediate-pressure cylinders. It has proved of considerable value when bringing the machines on load.

(*To be continued.*)

ELECTRIC STRAIN GAUGES.—A course of six lectures on "Electric Strain Gauges" will be given by Mr. S. A. Andrews at the South East London Technical College, Lewisham-way, London, S.E.4, beginning on Thursday, April 16, and thereafter at weekly intervals. Applications for admission should be made to the Head of the Electrical Engineering Department, Mr. C. W. Robson. The fee for the course is 17*s*. 6*d*.

MEASURING PERIODIC STRAINS.

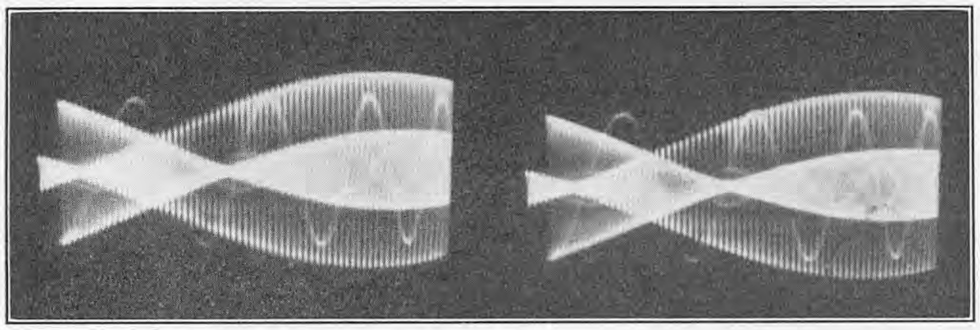


FIG. 8. INDICATION OF STATIC-STRAIN COMPONENT.

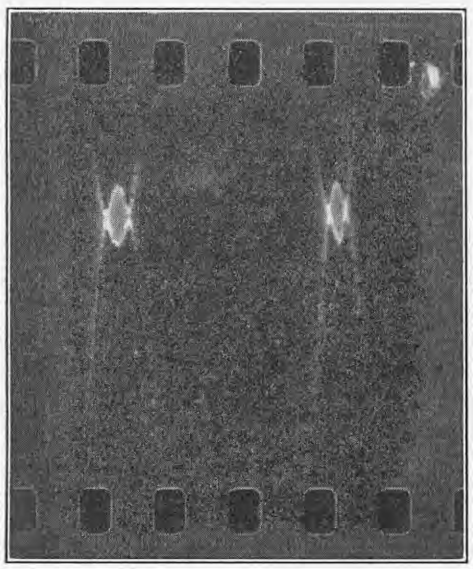


FIG. 9.

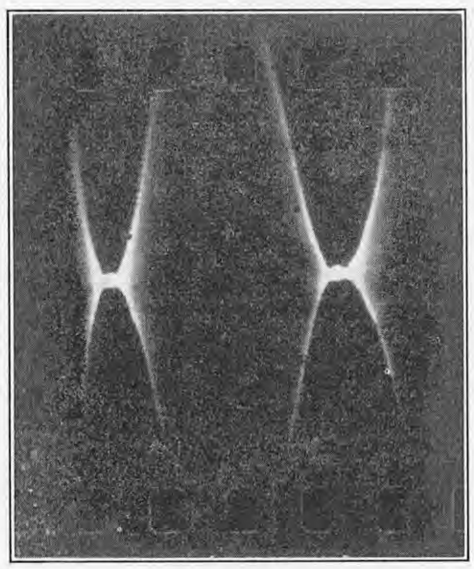


FIG. 10.

FIGS. 9 AND 10. SENSITIVE INDICATION OF DYNAMIC-STRAIN COMPONENT.

NULL METHOD OF MEASURING PERIODIC STRAINS.

By J. H. LITTLEWOOD, M.Sc., and C. MASKERY, B.Sc. (Eng.), A.M.I.Mech.E.

As a preliminary to a programme of fatigue testing, it was decided to develop an accurate method, using electrical resistance strain gauges, of measuring periodic strains. Accurate work using a conventional carrier-wave technique requires an oscillator with a constant output voltage, a stable amplifier and a stabilised extra-high-tension supply for the cathode-ray oscillograph. It was largely to avoid the need for these refinements that the scheme described below was evolved. Basically, the scheme involves comparing the dynamic and static components of the strain in a structure with the static strain in a calibrating beam. The latter quantity is measured in terms of a micrometer dial gauge reading.

It is a common practice in the measurement of strain to arrange four strain gauges in the form of a Wheatstone bridge, as shown in Fig. 1, opposite. One of the gauges is fixed to the structure and the remaining three to unstrained surfaces. A suitable balancing arrangement is embodied in the circuit and the bridge is supplied with power from an oscillator. The output voltage of the bridge is amplified and applied to a cathode-ray oscillograph.

It is customary to record the strain in the structure and then to calibrate the apparatus. During the time between beginning the record of strain and making the calibration, the sensitivities of both the amplifier and cathode-ray tube may have changed; in addition, the voltage applied to the strain-gauge bridge by the oscillator may also have changed. Such changes would be present as errors in the final result. Furthermore, the amplifier may have an imperfect frequency response and phase shift, both of which can also affect the accuracy of the final measurements. Meters are also a source of error, particularly if the calibration voltage is not strictly sinusoidal and the meter registers a root-mean square value. Finally, an error is inevitably involved in obtaining the photographic record when transferring the oscillogram from the curved surface of the cathode-ray tube to the plane surface of a film.

The authors' apparatus, shown diagrammatically in Fig. 2, opposite, is conventional carrier-wave equipment. An oscillator, generating a low-frequency carrier wave, provides the power to a bridge of four strain gauges through a balanced and screened bridge transformer. One strain gauge, R_1, is fixed to the structure under test, and another, R_2, to a calibrating beam. R_3 and R_4 are gauges fixed to unstrained metal. The modulated output voltage from the bridge circuit is applied through the step-up bridge transformer to the amplifier, and then to a cathode-ray oscillograph. Resistive and capacitive balance are made possible by means of a current injection into the signal lead from the bridge to the primary winding of the step-up transformer. Before a load is applied to the structure under test, the bridge is balanced by adjusting the resistive and capacitive controls. When the bridge is balanced there is no output voltage to the Y-plate, and the cathode-ray oscillogram is a straight line when sweeping with the time base on the X-plate.

If a periodic load is now applied to the structure, it will give rise, in general, to both static and dynamic components of strain. Let the static component, shown in Fig. 3, opposite, be denoted by S, and the dynamic component by $\pm\frac{D}{2}$, so that the maximum strain is $S+\frac{D}{2}$ and the minimum strain is $S-\frac{D}{2}$. The cathode-ray oscillogram corresponding to this condition is reproduced in Fig. 4, the width of the trace being proportional to the strain; the maximum width, therefore, corresponds to $S+\frac{D}{2}$ and the minimum to $S-\frac{D}{2}$.

The calibrating beam is now subjected to a static strain until the oscillogram changes to the form shown in Fig. 5, the troughs A and B being coincident. On the assumption that the gauges on the calibrating beam and those on the structure have equal sensitivities, the static strain so applied is equal to $S-\frac{D}{2}$ and is observed on the micrometer dial gauge as, say, x_1. The strain in the calibrating beam is now increased until the oscillogram changes to the form shown in Fig. 6. The reading, x_2, on the micrometer dial gauge is now equivalent to S, the static strain in the structure. If the strain in the beam is again increased until the oscillogram changes to the form shown in Fig. 7, that is until C and E are coincident, the strain then being applied to the calibrating beam is equal to $S+\frac{D}{2}$. If the reading on the dial gauge is x_3, then $x_3-x_1=D$, the full range of the dynamic strain, and $\frac{x_3+x_1}{2}=S$, the static strain; this latter value can be further checked against the magnitude of x_2.

The equality of height of the peaks, as in Fig. 6, cannot be detected so easily as the coincidence of the troughs, as in Figs. 5 and 7. The former condition can, however, be detected, with great precision if the time base on the cathode-ray tube is arranged to sweep twice during each cycle of strain; the peaks B and C, Fig. 6, are then made coincident, and equality can be attained, because any difference in amplitude is visible on the oscillogram as can be seen from the photographic record reproduced in Fig. 8, herewith.

As the authors' method compares static strain in the calibrating beam with the peak to peak range of dynamic strain, it is not dependent on the wave form of the dynamic load. In fact, if the load wave form contained any secondary peaks, they, too, could be measured by the same method.

The only portion of the modulated carrier wave which is of interest in the measurement of the range of strain is the point of coincidence of the troughs. If, therefore, extra amplification is provided to enlarge the picture to at least five times the diameter of the face of the cathode-ray tube, the troughs may be examined in great detail. This arrangement avoids the usual limitation of accuracy of work with cathode-ray tubes, namely, the ratio of the size of the spot to the diameter of the screen. When the oscilloscope beam is in sharp focus, and the bridge in balance capacitively, a very delicate indication is possible, as is illustrated in Figs. 9 and 10, herewith.

It is essential that the carrier-wave form should be good, as otherwise harmonics would prevent a good balance being obtained for the bridge. In practice, a "constant K" two-octave filter with a 600-ohm load is inserted at an intermediate position in the amplifier chain, the carrier-wave frequency being at the mid-point (geometric mean of limits) of the pass band. Error due to differences in sensitivity of the gauges on the structure and calibrating beam will, of course, be present if the structure cannot be calibrated statically. In general, however, with fatigue-testing machines static calibration is possible, and the gauge factor differences may be eliminated.

The accuracy of these dynamic-strain measurements was the same as that found for static-strain measurements. The chief factor limiting accuracy was found to be a lack of constancy in the range of strain being measured; when, however, the amplitude remained fairly constant for short periods, successive measurements taken during such periods agreed within $\pm 0{\cdot}25$ per cent. To obtain a delicate indication on the cathode-ray tube it is essential to use a time-base sweep for the X-plates: a disadvantage is then met when the frequency of the fatigue machine is very low (less than about 600 r.p.m.) for it is not very easy to follow by eye the slow-moving trace of the cathode-ray oscilloscope.

The apparatus described above was developed for use in the Research Department, Engineering Division, Derby, of the Railway Executive. Since the authors prepared this article, their attention has been drawn to a paper which deals with work in which the same principles were employed, namely, *The Use of Electric Strain Gauges to Measure Repeated Stresses*, H. V. Grover, *Proc. Inst. Experimental Stress Analysis*, vol. 1, No. 1 (1943).

ANNUALS AND REFERENCE BOOKS.

Electrical Trades Directory (The Electrical Journal Blue Book), 1953.

Seventy-first edition. Edited by S. G. RATTEE, A.M.I.E.E. Benn Brothers, Limited, 154, Fleet-street, London, E.C.4. [Price 50s. including carriage.]

SINCE last year the name of the old-established journal with which this Directory is connected has been changed from *The Electrician* to *The Electrical Journal*, and this has led to an alteration in the title of the Directory. This, however, in no way reduces its usefulness, for it may claim with some justification to be the only comprehensive directory of the British electrical and allied industries. Following the practice of recent years, the contents are now arranged in 13 sections covering the whole structure of the industry. As a result, the Classified Section is now entitled Products and Materials. Under this heading appear the names and addresses of manufacturers and suppliers of electrical and allied goods and materials, and firms who give services, all arranged in alphabetical order under headings indicating the products obtainable or work done. There is also a useful list of trade names with descriptions of the products so marked. Reference to the various sections is facilitated by the introduction of guide cards.

Post Office London Directory for 1953.

Kelly's Directories, Ltd., 186, Strand, London, W.C.2. [Price, 100s.]

THE 154th annual issue of the *Post Office London Directory*, while outwardly differing little from its immediate predecessor, has undergone the usual thorough revision, including, in particular, a considerable number of alterations to telephone numbers and corrections and additions to the street plan, which was redrawn for the 1952 edition. The usual features of street, private residents, commercial and professional and trade sections, which occupy the greater part of the 2,876 pages, are supplemented by sections dealing with Government departments and official offices, law, banking, Parliamentary, City, ecclesiastical, and transport references, making the complete work probably the most comprehensive publication of its kind in the world.

Industrial Diamond Trade Names Index and Yearbook for 1953.

Fourth edition. N.A.G. Press Limited, 226, Latymer-court, Hammersmith, London, W.6. [Price 3s. 6d.]

THIS informative reference manual, which is compiled jointly by the Industrial Diamond Information Bureau and the *Industrial Diamond Review*, is intended "for Users of Diamond Tools, Hard Abrasives, Sintered Carbides, and Materials for the Precision Engineer." The inclusion of the last-mentioned category greatly extends the field and probably accounts for at least a third of the 1,900 trade names listed, since it brings in makers of precision tools, measuring instruments, scientific apparatus, etc. Engineers in general may find and the booklet of service, even if they are not directly concerned with industrial diamonds or hard abrasives, but they may also find some of the references a little inadequate; "A.P.I.," for instance, refers only to "Gauges: Pratt & Whitney Div. of Niles-Bement-Pond Co.," with no mention whatever of the American Petroleum Institute, from which the initials are derived. The name index is followed by a classified subject index, arranged under some 40 headings and relating principally to the items concerned with industrial diamonds, sintered carbides, and apparatus in which they are used.

DAMAGE TO ELECTRIC TRACTION PORTAL STRUCTURE.—The upright member of a broad flanged beam portal structure, which carries the overhead conductors across the tracks of the Liverpool Street-Shenfield electrified lines of the Eastern Region British Railways at Goodmayes was recently damaged by the derailment of a goods wagon. The beam was bent over at an angle of 45 deg., but was rapidly repaired overnight by heating and drawing it back to its original position. This form of support has been standard with British Insulated Callender's Construction Co., Ltd., for many years, and the incident is a tribute to its strength and flexibility.

TYPE TEST OF LEYLAND 9·8-LITRE DIESEL ENGINE.

THE O-600 engine made by Leyland Motors, Limited, Leyland, Lancashire, has recently completed a 500-hour endurance type test at the makers works. The test programme was arranged by the Inspectorate of Electrical and Mechanical Equipment of the Ministry of Supply, who supervised the test and supplied the lubricating oil used. The engine tested was a 9·8-litre Diesel production model designed for 12,000 hours normal running before major overhaul, fitted with a stationary radiator, oil cooler, and pusher-type fan. It was selected from a batch of production engines. The fuel used for these tests was Diesel oil with a cetane value of 47, and the normal rated load chosen was 105 b.h.p. at 1,800 r.p.m., being the intermittent rating of the engine for commercial purposes.

The tests were arranged in non-stop cycles of 16 hours to avoid running through the night: a method of running which was considered to be more severe than a non-stop run of 500 hours, because the components would be subjected to strains created by the expansion and contraction of the engine when warming-up and when cooling at the end of a run. Each 16-hour cycle, except the sixteenth, was made up as follows:—

Running Time in hours.	Output in b.h.p.	—
4	105	Rated load.
4	52·5	Half load.
1	117	10 per cent. overload
3½	105	Rated load.
3½	52·5	Half load.

A constant speed of 1,800 r.p.m. was maintained throughout the test. The sixteenth run was similar to the others, except that it included a 30-minute test at no load, made at the end of the first eight hours, to check the efficiency of the injection system. All readings of the lubricating oil, cooling water, exhaust and ambient air temperatures were taken at intervals of one hour and the consumption of lubricating oil was recorded. To ascertain the suitability of the engine for driving electrical generating sets and other constant-speed apparatus, special attention was also given to checking the performance of the governor.

The results of the tests indicated that the 500-hour run had served as a running-in period and performance had increased, a horse-power of 125 being obtained at 1,800 r.p.m. for the 10 per cent. overload rating, 8 h.p. in excess of the figures for the planned test cycle. The torque obtained at 1,100 r.p.m. was 412 lb.-ft. and fuel consumption had fallen from 0·354 pint to 0·34 pint per brake horse-power per hour. Lubricating-oil consumption throughout the test was about one gallon for 255 hours running, with a small increase towards the end of the run. After these tests the engine was completely stripped for inspection of the parts, all of which were found to be in good condition.

AUCKLAND HARBOUR BRIDGE.—It has been announced in Auckland, New Zealand, that the British Government have not given permission to the Auckland Harbour Bridge Authority for raising a 4,500,000*l*. sterling loan on the London market; this sum representing about half that required for the construction of the new bridge across the harbour, the necessary approach viaducts and reclamation work in the harbour. An article describing the proposed bridge appeared in ENGINEERING, vol. 174, page 673, (1952).

BRITISH NON-FERROUS METALS RESEARCH ASSOCIATION.—A pamphlet, entitled "The B.N.F. Service to Industry," has recently been issued by the British Non-Ferrous Metals Research Association, 81-91, Euston-street, London, N.W.1. It contains a brief history, an account of the growth of the Association, and particulars of its organisation and technical services. Photographs of the Association's laboratories, plant, equipment, and library are reproduced, and lists of members and subscribers, the officers and Council, as well as information regarding the researches now in hand, are included. Copies of the pamphlet are obtainable on application to the director at the address given above.

BOOKS RECEIVED.

Advanced Mathematics in Physics and Engineering. By PROFESSOR ARTHUR BRONWELL. McGraw-Hill Book Company, Incorporated, 330, West 42nd-street, New York, 36, U.S.A. [Price 6 dols.]; and McGraw-Hill Publishing Company, Limited, 95, Farringdon-street, London, E.C.4. [Price 51s.]

Ferrous Analysis. Modern Theory and Practice. By E. C. PIGOTT. Second edition, revised. Chapman and Hall, Limited, 37, Essex-street, Strand, London, W.C.2. [Price 84s. net.]

Industrial Brazing. By H. R. BROOKER and E. V. BEATSON. Published for *Welding and Metal Fabrication*. Iliffe and Sons, Limited, Dorset House, Stamford-street, London, S.E.1. [Price 35s. net.]

Commercial and Industrial Refrigeration. By C. WESLEY NELSON. McGraw-Hill Book Company, Incorporated, 330, West 42nd-street, New York 36, U.S.A. [Price 5·90 dols.]; and McGraw-Hill Publishing Company, Limited, 95, Farringdon-street, London, E.C.4. [Price 50s.]

The Principles of Physical Metallurgy. By PROFESSOR GILBERT E. DOAN. Third edition. McGraw-Hill Book Company, Incorporated, 330, West 42nd-street, New York 36, U.S.A. [Price 5·50 dols.]; and McGraw-Hill Publishing Company, Limited, 95, Farringdon-street, London, E.C.4. [Price 47s.]

British Diesel Locomotives and Railcars. Locomotive Manufacturers' Association of Great Britain, 82, Victoria-street, London, S.W.1. [For private circulation.]

Control of Electric Motors. By PAISLEY B. HARWOOD. Third edition. John Wiley and Sons, Incorporated, 440, Fourth-avenue, New York 16, U.S.A. [Price 7·50 dols.]; and Chapman and Hall, Limited, 37, Essex-street, London, W.C.2. [Price 60s. net.]

Introduction to the Foundations of Mathematics. By PROFESSOR RAYMOND L. WILDER. John Wiley and Sons, Incorporated, 440, Fourth-avenue, New York 16, U.S.A. [Price 5·75 dols.]; and Chapman and Hall, Limited, 37, Essex-street, London, W.C.2. [Price 46s.]

United States National Bureau of Standards. Applied Mathematics Series No. 9. *Tables of Chebyshev Polynomials* $S_n(x)$ *and* $C_n(x)$. The Superintendent of Documents, U.S. Government Printing Office, Washington 25, D.C., U.S.A. [Price 1·75 dols.]

Advanced Mechanics of Materials. By PROFESSOR FRED B. SEELY and PROFESSOR JAMES O. SMITH. Second edition. John Wiley and Sons, Incorporated, 440, Fourth-avenue, New York 16, U.S.A. [Price 8·50 dols.]; and Chapman and Hall, Limited, 37, Essex-street, London, W.C.2. [Price 68s. net.]

Elements of Food Engineering. Vol. I. By PROFESSOR MILTON E. PARKER, PROFESSOR ELLERY H. HARVEY, and E. S. STATELER. Reinhold Publishing Corporation, 330, West 42nd-street, New York 36, U.S.A. [Price 8·75 dols.]; and Chapman and Hall, Limited, 37, Essex-street, London, W.C.2. [Price 70s. net.]

Overseas Economic Surveys. Mexico. By R. G. STONE. H.M. Stationery Office, Kingsway, London, W.C.2. [Price 3s. 6d. net.]

Textbook of Engineering Materials. By PROFESSOR MELVIN NORD. John Wiley and Sons, Incorporated, 440, Fourth-avenue, New York 16, U.S.A. [Price 6·50 dols.]; and Chapman and Hall, Limited, 37, Essex-street, London, W.C.2. [Price 52s. net.]

Messung des Wärmeübergangs an verdampfendes Ammoniak. By DR.-ING. HERMANN SCHWIND. Verlag C. F. Müller, Karlsruhe, Germany. [Price 5·60 D.M.]

Stahldraht. Seine Herstellung und Eigenschaften. By PROFESSOR ANTON POMP. Second revised and enlarged edition. Verlag Stahleisen m.b.H., Breitestrasse 27, Düsseldorf, Germany. [Price 38 D.M.]

United States National Bureau of Standards. Applied Mathematics Series No. 18. *Construction and Applications of Conformal Maps.* Proceedings of a Symposium held on June 22-25, 1949, at the University of California. Edited by E. F. BECKENBACH. The Superintendent of Documents, U.S. Government Printing Office, Washington 25, D.C., U.S.A. [Price 2·25 dols.]

Selected Problems in the Preparation, Properties and Application of Materials for Radio Purposes. Radio Research Special Report No. 25. H.M. Stationery Office, Kingsway, London, W.C.2. [Price 1s. 6d. net.]

Power Plants for Aircraft. By PROFESSOR JOSEPH LISTON. McGraw-Hill Book Company, Incorporated, 330, West 42nd-street, New York 36, U.S.A. [Price 8.50 dols.]; and McGraw-Hill Publishing Company, Limited, 95, Farringdon-street, London, E.C.4. [Price 72s. 6d.]

University of Illinois. Engineering Experiment Station. Reprint Series No. 49. *Progress Reports of Investigation of Railroad Rails and Joint Bars.* By R. E. CRAMER and R. S. JENSEN. The Director, Engineering Experiment Station, University of Illinois, Urbana, Illinois, U.S.A. [Price 30 cents.]

Uganda Electricity Board. Fifth Annual Report and Accounts for Year Ended 31st December, 1952. Offices of the Board, P.O. Box 559, Kampala, Uganda, East Africa. [Price 1s.]