THE SHASTA DAM POWER PLANT.

(*Continued from page* 124.)

A GENERAL view of the Shasta Dam power house looking west is given in Fig. 14, on this page. The photograph from which this illustration was prepared was taken on July 24, 1944, at which time the penstock connections had not all been made, although the building itself was practically complete. The illustration clearly shows the situation of the power house in relation to the spillway of the dam. A plan of the arrangement is given in Fig. 2, on page 122, *ante*. The building is a heavily-reinforced concrete structure, 452 ft. 10 in. long and 76 ft. wide, and contains 2,460 tons of reinforcing steel and about 100,000 tons of concrete.

The main entrance to the station is at the downstream end, as can be seen in Fig. 14, and the offices, main control room, laboratory and machine shop are all located in the downstream block, shown in this illustration. The initial installation consists of two 75,000-kVA main sets and two 2,500-kVA house sets. The latter are situated at the downstream end of the turbine room. The main sets are each connected to a bank of three 25,000-kVA outdoor-type transformers located on the parapet at the front of the building, as shown in Fig. 14. A general view of the interior of the generator room is given in Fig. 15, on page 202. Natural lighting in the room is afforded by glass-block panels built into the walls. This room is equipped with two 250-ton overhead travelling cranes, each with two crabs. The cranes have a span of 65 ft. 2 in. between the running rails and the runway is 380 ft. long. Each crab is equipped with a 125-ton hoist and a 25-ton hoist. The main hooks have a vertical travel of 65 ft. and a speed of 4·5 ft. per minute; the corresponding figures for the auxiliary hooks are 105 ft. and 25 ft. per minute. The crabs have a rate of cross travel of 25 ft. a minute and the crane bridge has a travelling speed of 100 ft. per minute.

These cranes were used for the erection of the turbines and generators. The heaviest pieces which had to be lifted were the generator rotors which weigh about 450 tons each. To deal with these, a special equalising-beam arrangement was constructed; it is shown in Fig. 21, on page 210, in use for lowering one of the rotors into position. Each crane is provided with a beam suspended at the ends from the main hooks of the two crabs. Below, and connected to these beams, there is a cross beam arranged for coupling to the rotor shaft. Pin connections are employed between the three beams and the upper beam and the crane hooks, the arrangement ensuring that not more than one-quarter of the total load can be transmitted to any one crab. The traversing and lifting motors of the cranes are of the three-phase type supplied from a 440-volt 60-cycle circuit. Control is effected from an operator's cage carried by the bridge.

The main turbines are of the vertical-shaft single-runner Francis type with spiral casings, and have a rating at full gate, and at a head of 330 ft., of 103,000 h.p. each. This corresponds to a generator rating of 75,000 kW at unity power factor. As mentioned in the earlier part of this article, the operating head will vary between 238 ft. and 475 ft., but the minimum figure will be reached only at infrequent intervals and is expected to be maintained only for short periods. For 75 per cent. of the time the net effective head will vary between 366 ft. and 475 ft., and the average will be about 408 ft. The turbines run at a normal speed of 138·5 r.p.m. The turbine runners are of cast steel in one piece and are provided with bolted flange connections for attachment to the main shafts. One of the runners being unloaded on to the turbine floor is illustrated in Fig. 17, on page 203, and is shown attached to the main shaft in the background of Fig. 16, on page 202. A view of the scroll case being assembled is given in Fig. 18, on page 210, and Fig. 19, on the same page, shows the scroll completed ready for the runner. The cover plate and extension assembled can be seen in the foreground of Fig. 16. The main shafts are of forged open-hearth steel, heat-treated and have a $7\frac{1}{2}$ in. diameter hole bored axially throughout their length in order to permit visual inspection of the interior metal. The guide bearings are of the oil-lubricated Babbitt-lined type and are located above the runners. The wicket gates are operated by two servo-motors driven by oil at a pressure of 250 lb. to 300 lb. per square inch. With an effective turbine head of 475 ft. and an oil pressure of 250 lb. per square inch, the servo-motors are capable of carrying out a complete opening and closing cycle in 4 seconds. Provision is made for retarding the rate of closure of the gates in order to limit the pressure rise in the penstocks.

The main governors are of the oil-pressure, relay-valve actuated type the speed-responsive elements being driven by electric motors. Energy for driving these motors is obtained from permanent-magnet alternating-current generators mounted on top of, and directly-connected to, the shafts of the pilot exciters on the main 75,000-kVA generators. Each governor is provided with two oil pumps driven by electric motors, the pumps being interconnected in such a way that they may be operated either together or independently. When operating together, either unit may be used for normal running, with the other available as a stand-by. Both pumping units are arranged to start and stop automatically. The normal operating oil pressure will vary between 250 lb. and 300 lb. per square inch.

The main generators have directly connected main and pilot exciters. These can be seen in the interior view of the station given in Fig. 15. The main generators are wound to give 60-cycle, three-phase current at 13,800 volts when running at 138·5 r.p.m. As previously mentioned, the rated output is 75,000 kVA at unity power factor. The generators are designed so that when delivering their rated output continuously the maximum temperature of the rotor and field windings will not exceed 100 deg. C., with cooling air entering at 40 deg. C. The stator cores are built up of non-ageing silicon-steel sheets, the laminations being coated with insulating varnish on each side. Guides are inserted in the core air ducts to form gradually-curving paths for the cooling air as it leaves the air gaps between the rotor and stator and enters the ducts in the stator core. The arrangement is designed to promote a smooth air flow and reduce friction losses. The stator winding is star-connected and is suitable for operation either with an earthed or insulated neutral. Three main and three neutral leads are brought out of the frame. The windings are provided with an outer protective taping of semi-conducting material to provide corona shielding. Differential protection of the windings against earths and short-circuits between phases is provided and twelve 10 ohm-resistance temperature-detector coils are located in the windings to indicate the operating temperatures.

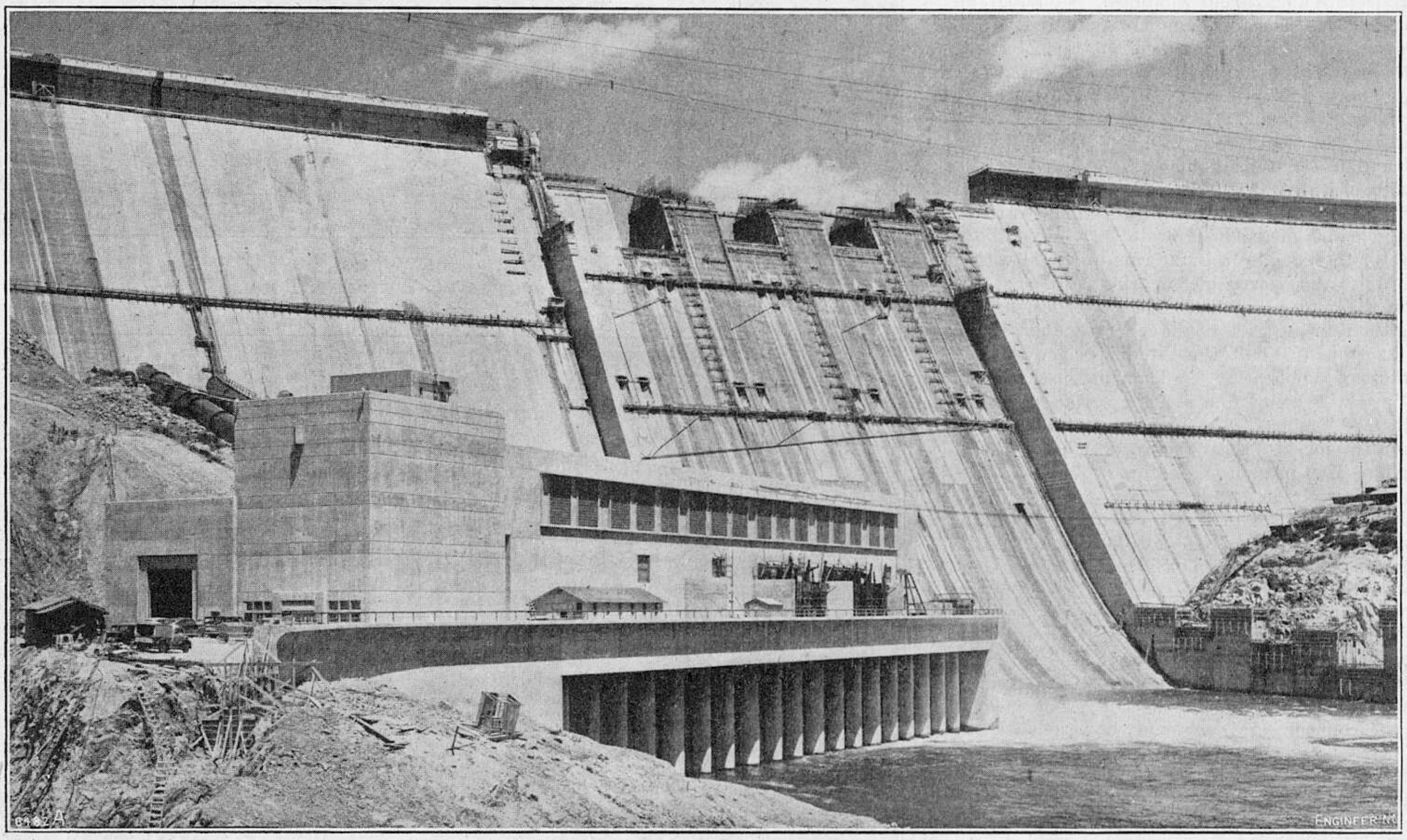


FIG. 14. GENERAL VIEW OF POWER HOUSE.

Each generator is provided with a totally-enclosed cooling system, with surface coolers for the heated air. The air is circulated by fans mounted on the generator rotors, and the surface coolers are spaced symmetrically around the stator periphery; they can be seen in Fig. 21, page 210. Thermostat relays are located in the paths of the air leaving the coolers to sound an alarm in case of abnormally high temperature. The casing of the cooling-air system is practically air tight and automatic carbon-dioxide fire-extinguishing equipment is installed. In case of fire, the carbon dioxide is released by the operation of thermostat relays located in the air passage ahead of each cooler.

The rotor rim of each generator is laminated, the pole pieces being built up of thin sheets with die-punched dovetails which fit into dovetail slots in the rotor rim. The pole pieces are held in position by tapered keys locked in place by steel plates. The field windings consist of copper strips wound edgewise, and the poles are provided with discontinuous, low-resistance amortisseur windings. A photograph showing one of the rotors being lowered into position is reproduced in Fig. 20, on page 210, Fig. 21 showing the operation completed. The rotating parts of the generator have a calculated flywheel effect equivalent to 84,500,000 lb. at a radius of 1 ft. The generator shaft is of forged open-hearth heat-treated steel and has a 6-in. diameter hole bored axially throughout its length. There is a spring-type thrust bearing above the rotor, and two guide bearings, one above and one below the rotor. Located above the rotor there is also a brake ring provided with a removable and renewable wearing surface; air-operated brakes are fitted. These are designed to bring the rotating parts of the generator and turbine to rest from one-half the rated speed within $7\frac{1}{2}$ minutes of application. The brake shoes are equipped with renewable wearing surfaces and the brakes are arranged so that they can be used as hydraulic jacks to raise the rotor off the thrust bearing. The normal excitation voltage is 250. Automatic voltage regulators are fitted and are sensitive to changes of 0·5 per cent. in generator voltage. They will respond in 0·05 second after the generator voltage has risen or fallen by 1·5 per cent. from the normal.

The main transformers, which can be seen in Fig. 14, are of the single-phase, oil-immersed, forced oil cooled, inert-gas filled outdoor type. Each has a rating of 25,000 kVA and steps up from 13,600 volts to 230,000 volts. The primary windings are connected in delta and the secondaries in star. The non-ageing low-loss core laminations are insulated with baked-on varnish on both sides. The high-voltage windings are insulated for full voltage on the line end and for 138,000 volts on the neutral end, the insulation being so graded towards the neutral end that it will be satisfactory for operation with a future earth-fault neutraliser. There are no taps on either the high-voltage or low-voltage windings. The transformers are designed for a maximum temperature of 80 deg. C. when delivering the maximum rated output continuously and supplied with cooling water at 25 deg. C. Each transformer has one 230,000-volt line bushing, one 138,000-volt neutral bushing and two 12,500-volt primary-winding bushings. The protective equipment includes a magnetic-type oil gauge, a dial-type indicating thermometer, a thermal relay arranged to operate an alarm, and a 10-ohm resistance temperature detector which forms part of the circuit of a Wheatstone-bridge temperature indicator.

The transformers are mounted on trucks fitted with double-flanged wheels and may be moved to new positions or replaced by means of transfer tracks laid on the parapet at the front of the station building. As can be seen in Fig. 14, protective walls are provided between the transformer banks. On each transformer case there is an automatic inert-gas equipment. This is designed to maintain a supply of inert gas inside the transformer case at a normal internal pressure not exceeding 5 lb. per square inch. If this pressure rises to 10 lb. per square inch, a relief valve comes into operation, and closes contacts which connect an alarm in circuit. There are also pressure devices with alarm contacts to indicate high or low gas pressure.

The two house turbines are of the vertical-shaft single-runner Francis-type with cast-steel spiral casings. They have a rating at full gate, and at an effective head of 290 ft., of 3,500 h.p. This corresponds to a generator rating of 2,500 kW at unity power factor. The capacity of each turbine is not less than 2,150 h.p. when operating under a head of 238 ft. The normal speed is 600 r.p.m. The turbine runners are one-piece steel castings and the shafts are of forged open-hearth steel, heat treated. The guide bearings are of the oil-lubricated type and are

THE SHASTA DAM POWER PLANT.

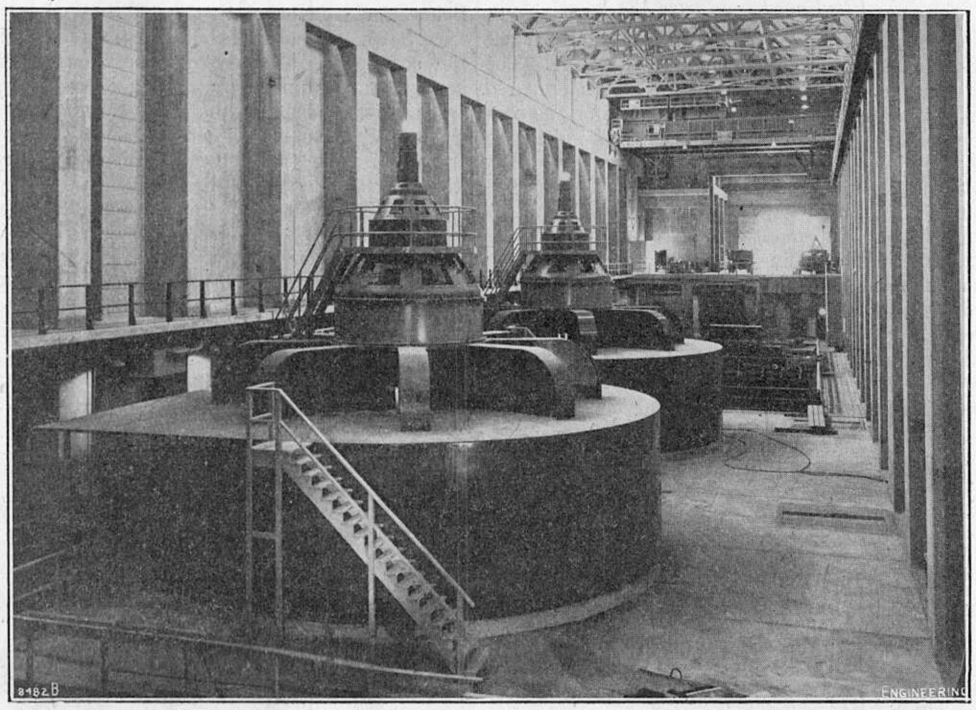


FIG. 15. INTERIOR OF GENERATOR ROOM.

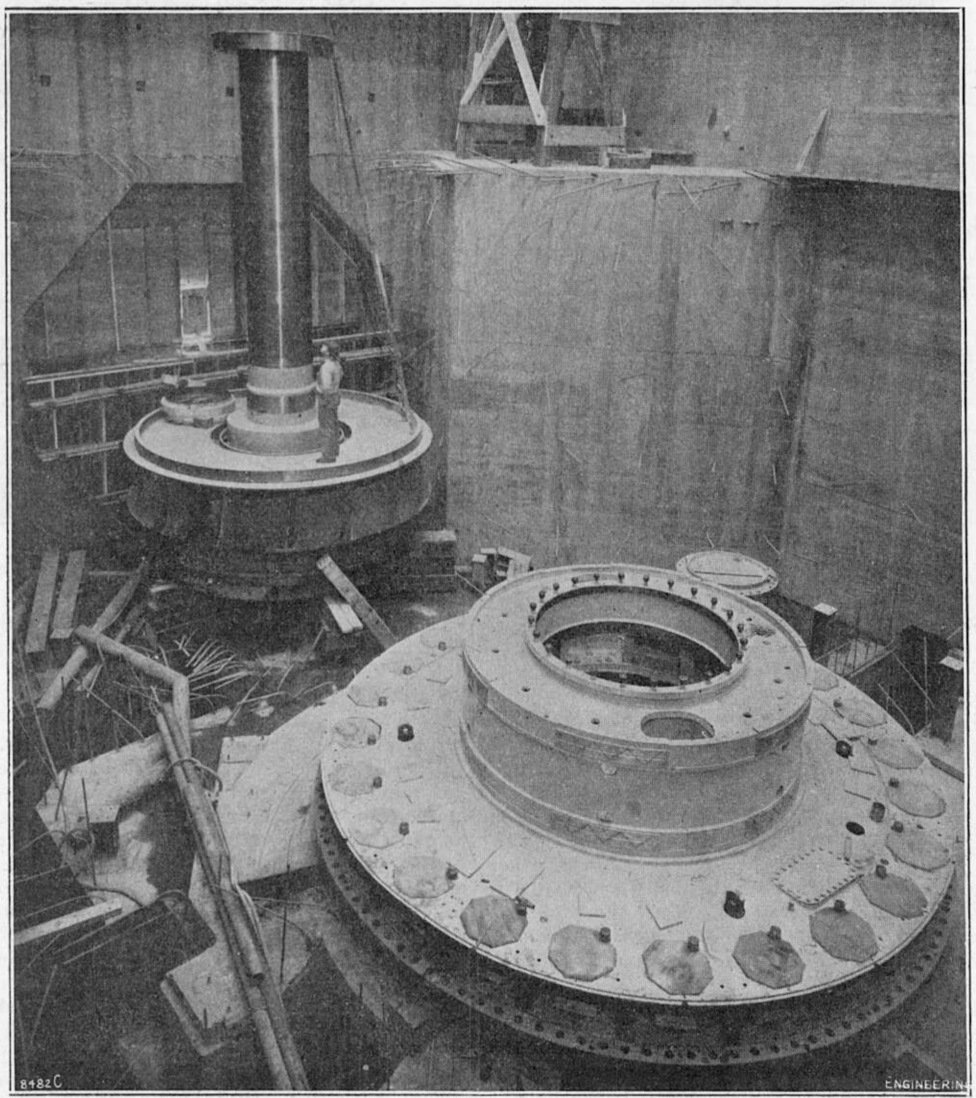


FIG. 16. TURBINE RUNNER AND COVER PLATE.

THE SHASTA DAM POWER PLANT.

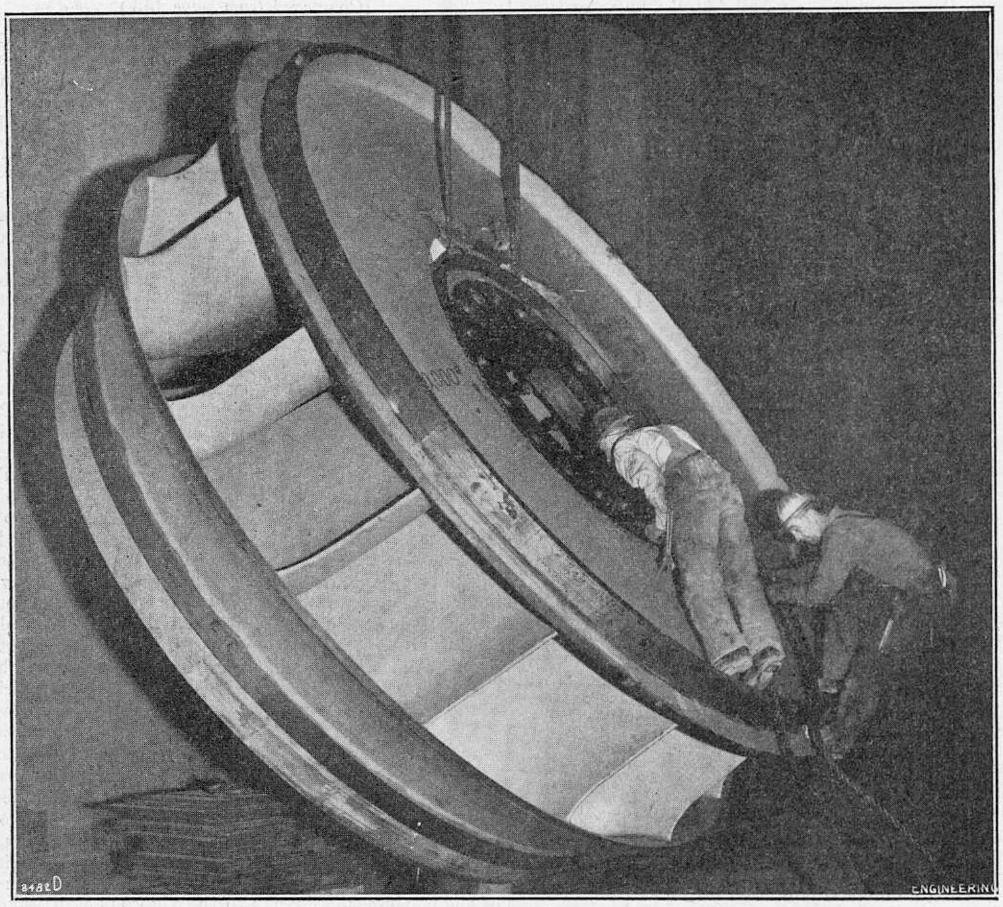


FIG. 17. TURBINE RUNNER.

located above the runner. The governors are of the oil-pressure relay-valve gate-shaft type, with electrically-driven speed-responsive element. Energy for driving the motors is obtained from permanent-magnet alternating-current generators mounted on top of, and directly connected to, the shafts of the pilot exciters, the arrangement being similar to that already described in connection with the main sets. The governors are complete with servo-motors which are capable of operating the turbine gates through a complete closing or opening stroke in four seconds with an oil pressure not exceeding 150 lb. per square inch and with an effective head of 475 ft. at the turbines. As in the case of the main turbines, provision is made for retarding the rate of gate closing in order to limit the pressure rise in the penstocks. Each governor is provided with a motor-driven oil pump.

Both the turbines and generators of the house sets are generally similar to those of the main machines. The generators have directly-connected main and pilot-exciters. They are each rated at 2,500 kVA at 0·8 power factor and generate 60-cycle three-phase current at 2,400 volts when running at 600 r.p.m. They are designed so that when delivering their rated output continuously the maximum temperature of the rotor and field windings will not exceed 100 deg. C., with cooling air at 40 deg. C. The stator winding is star connected and is suitable for either earthed or insulated neutral operation. Differential protection for the stator windings against earths or short-circuits between phases is provided. Twelve 10-ohm resistance temperature detector coils are embedded in the stator winding to indicate the highest operating temperature. As with the main sets, there is a totally-enclosed cooling system with carbon-dioxide fire-extinguishing equipment and a system of thermostatic relays. The rotating parts of the generator have a calculated flywheel effect equivalent to 63,000 lb. at a radius of one foot.

Each generator has a spring-type thrust bearing located above the rotor and two guide bearings, and is equipped with a brake ring with a renewable wearing surface. The air-operated brakes can bring the rotating parts of the generator and turbine to rest from half the rated speed within five minutes. The brakes may also be used to serve as hydraulic jacks to lift the rotor from the thrust bearing. The nominal excitation voltage is 125. Voltage regulators are provided which are sensitive to changes of 0·5 per cent. in the generator voltage and will respond in 0·05 second after a voltage change of 1·5 per cent.

(To be continued.)

LITERATURE.

A Complete Course in Elementary Aerodynamics. By DR. N. A. V. PIERCY. The English Universities Press Limited, St. Hugh's School, Bickley, Kent. [Price 21s. net.]

IT is doubtful whether any branch of engineering has developed to such a scientific exactitude as aerodynamics has done during the past ten years. In the early days of aviation, the speeds attained were so modest that any lack of accuracy in calculating the trim of an aircraft or the balance of a control surface only gave rise to forces which could easily be overcome by the strength of the pilot; to-day, at the highest air speeds, the same error in estimation can give rise to forces over 20 times as great, and, consequently, the margin of error allowable is very much smaller. It is not surprising, therefore, that aerodynamics to-day is closely allied to mathematics; in fact, it is becoming more difficult than ever to express the basic principles of aerodynamical methods without continual reference to mathematical reasoning.

The task that Dr. Piercy has set himself in presenting the subject non-mathematically and, at the same time, leaving out none of the fundamental concepts of aerodynamics, is consequently difficult and he is to be congratulated on the result achieved. The greatest difficulty in this type of presentation is the danger of over-simplification, as a result of which the reader may later on find himself confused because of the omission from the explanation of certain qualifying conditions which are of great importance. Dr. Piercy's presentation suffers in this way in one or two cases, notably when he introduces the reader to the subject of "induced drag." This induced drag is essentially the result of three-dimensional flow over a wing of finite span, and does not exist in the same sense on two-dimensional wings. The explanation given, while being easy to grasp, does not differentiate between two- and three-dimensional flow, and consequently conveys a somewhat false impression of the nature of induced drag, which might well give the reader difficulty at a later stage, in understanding the significance of the fundamental parameters, aspect ratio and wing shape. The added complication of an early introduction of the concept of wing-tip vortices might have justified itself in making more easily understandable the subsequent development of, for example, wing loading and downwash over the tail. Wing-tip vortices, which are considered fully in the last chapter of the book, may be described as the basis upon which all aeroplane theory rests. Isolated cases like the above are few in this book, and are hard to avoid in treating elementary aerodynamics without delving deeply into the theoretical implications involved.

The scope of the book is wide and covers practically all the essentials of aerodynamics. The first few chapters are devoted to a brief description and history of lighter-than-air craft, together with some consideration of the laws of aerostatics. These lead to a fundamental, but highly condensed, chapter on the nature of fluid flow past bodies; in this are expounded streamlines, boundary layers, and skin friction. The reader may be advised to study well this chapter which, with the last chapter of the book (on the famous Lanchester-Prandtl theory of wings), summarises the essentials of fluid flow. The technique of model experiments in wind tunnels, and the methods of interpreting the results in flight, are covered in the chapters following. This part of the book is of considerable interest and importance and should be studied carefully by all elementary students of aerodynamics. The rest of the book is devoted to a description of the principles underlying the estimation of airscrew and aircraft performance, and the prediction of the stability of the aircraft under the more important flying conditions.

A useful feature is the numerous examples illustrating the various principles involved; while a point to remember is that, if a more detailed study is contemplated at a later date, a more advanced book, by the same author, is already available thus affording the advantages of continuity of thought and familiarity with the method of presentation in pursuing the subject. Dr. Piercy considers, probably rightly, that the study of compressibility and the formation of shock waves are beyond the scope of an elementary course, owing to the impossibility of doing justice to the subject without mathematical arguments; yet this is a matter which causes much difficulty to the student and also to the practical engineer, who, until recently, has had little occasion to consider it. Later, perhaps, Dr. Piercy may be persuaded to add a chapter which will present this complex subject from an elementary and physical point of view.

INSTITUTION OF MINING AND METALLURGY.—The annual general meeting of the Institution of Mining and Metallurgy, which will be held at Burlington House, Piccadilly, London, W.1, has been fixed for Thursday, May 17.

GUIDANCE FOR EXPORTERS.—Copies of booklets containing "Hints to Business Men," prepared by the Department of Overseas Trade for the guidance of merchants, manufacturers and exporters, are now available. The booklets published so far cover the United States, New Zealand and British East Africa. They contain basic information concerning markets, including notes on population, currency, usual methods of payment, sales organisations, customs regulations, and hints regarding travel and accommodation. The series will ultimately cover all overseas markets. In some cases similar booklets were issued by the Department of Overseas Trade before the war, but the new series will include a number of markets not previously covered. Copies of the published booklets may be obtained gratis on application to the Department, Hawkins House, Dolphin-square, London, S.W.1.

THE EARLEY POWER STATION OF THE CENTRAL ELECTRICITY BOARD.

(*Concluded from page* 187.)

THE condenser is another part which required some alteration to adapt it to conditions at Earley. As designed for South Africa the machine was intended to operate with a circulating water inlet temperature of 72 deg. F., and was proportioned for a vacuum of 28·5 in. of mercury at the economical load. The normal circulating water temperature at Earley is 55 deg. F., but the turbine could not, without extensive alteration, take advantage of this lower temperature. On the other hand, if the condenser cooling surface were reduced and smaller circulating pumps used, the machine could be run with a 28·7 in. vacuum at this load. The condenser is otherwise of the manufacturer's normal design. It is of the two-pass type with tubes of Admiralty-type metal and ferrules at each end. The condenser has a cooling surface of 30,000 sq. ft. and is designed to maintain a vacuum of 28·28 in., with the barometer standing at 30 in., when supplied with 20,000 gallons of cooling water per minute at a temperature of 55 deg. F. This vacuum refers to the maximum continuous rating of the machine. It will be appreciated that the whole of the steam supplied at the stop valve does not pass through the turbine, since some is extracted from the cylinders at four points for the pre-heating of the feed water. By this means a final temperature of 340 deg. F. is obtained at the economical load of 32,000 kW. The absolute pressures at the extraction points under these conditions are 10·5 lb., 31·9 lb., 66·4 lb. and 139·5 lb. per square inch, the quantities of steam extracted at these pressures being about 20,000 lb., 16,500 lb., 13,300 lb. and 15,500 lb. per hour, respectively. The remainder of the steam is exhausted into the condenser, which is able to deal with 283,450 lb. of steam per hour.

The condenser has a quick-starting air ejector and a two-stage running ejector. The condensate is recovered by two motor-driven vertical-spindle extraction pumps and delivered to the boiler feed pump suction main, passing through the ejector coolers, drain cooler and a low-pressure feed heater on its way. The low-pressure heater is situated in the basement, and, at the maximum continuous output of the turbine, delivers water at 194 deg. F. This water is handled by two motor-driven Weir feed pumps and one steam-driven standby pump for the first set, these pumps being visible to the left of Fig. 10, on page 190, ante. They deliver to the three high-pressure heaters seen at the right of this figure, in which heaters the temperature is raised to 356 deg. F. at maximum continuous rating. The heater drains are cascaded to the condenser. Should there be any abnormal rise in the water level of the three high-pressure heaters an automatic by-pass valve diverts the feed water directly to the economiser. There are two bled-steam evaporators in the basement which, together, are capable of evaporating 4 per cent. of make-up feed water and are designed to operate on the pressure and temperature difference across the two highest bled-steam tappings, the second high-pressure heater acting as vapour condenser. The controls for the feed-heating system are grouped in valve desks adjacent to the turbine gauge panel for ease of operation.

The surge tanks, which are normally inserted in the feed system between the drain cooler and the low-pressure heater, are of 9,000 gallons capacity for each set and are housed under cover on the turbine house roof. Any excess of evaporated make-up feed over the surge tank capacity spills into a reserve feed tank, capacity 27,500 gallons, at a lower level outside the power house, and can re-enter the system either through the condenser for de-aeration, or be pumped directly to the surge tank in emergency. Prior to evaporation, the river water used for make-up feed is softened to about 3 deg. of hardness in a Kennicott lime and soda plant. For each set there are two river water and two softened water storage tanks on the boiler hourse roof, with level indicators grouped at the turbine floor level. Indicators for the surge and reserve tanks are on the same panel. Each tank has a capacity of 9,000 gallons. The feed water is carefully tested in the station laboratory, as is also the concentration of the water in the boilers, which water has its own chemical injecting plant. The circulating water pumps are situated in a small house at the head of the open canal leading from the river. Adequate protection is given against floating debris by a boom and self-cleaning rotating-band screens. Each condenser has its own pump which is of the vertical spindle axial flow type made by Messrs. Drysdale and Company, Limited, Glasgow, and is directly driven by a motor developing 235 brake horse-power at 730 r.p.m. The delivery capacity is 22,000 gallons per minute. The flow from the condenser is led to a seal pit adjoining the pump house, this arrangement providing syphonic recovery of head under all conditions. The water from the seal pit flows by gravity to the river in concrete culverts. The pump house also contains a petrol-driven fire pump drawing water from the open channel and feeding a comprehensive hydrant system. The transformers are protected by a high pressure water spray system fed from a receiver half full of compressed air. A fall of air pressure due to fire service automatically starts up the fire pump which makes up for the water used. An emergency 4-in. town water connection can also feed into the hydrant system.

A brief description may now be given of the electrical equipment of the station. The alternator of each set generates directly at the switching voltage of 33 kV and is capable of running continuously at any load up to 40,000 kW with any wattless output between 24,790 reactive kVA lagging and 14,100 reactive kVA leading, the inlet temperature of the cooling air being 40 deg. C. The rotor current at maximum load and 0·85 lagging power factor is 300 amperes, the the main exciter is rated for 450 amperes at a maximum of 500 volts. A pilot exciter is fitted to give stable excitation over the whole range. The stator winding is of the concentric conductor type, in which the outer conductors form the first one third of each phase commencing at the neutral point, the inner conductors the middle third, and the bull conductors the last third of the winding ending at the line terminals. The rotor is a single forging and the stator which, without end shields, weighs 97 tons, is the heaviest single piece in the station. The turbine house, incidentally, is spanned by a 100-ton electric travelling crane made by Messrs. Babcock and Wilcox, Limited. The alternator air-cooling system is a closed circuit with circulating water cooler and two separate motor-driven fans each capable of supplying sufficient air for operation at the economic load. The cooling water is maintained at a pressure below that of the atmosphere so that any leakage will be of air outwards and not water inwards.

Since the sets are switched at the Grid substation on the opposite side of the railway there is no main switchgear in the power station. The generators are normally controlled from the operating room at the substation, which room contains the control desk, instruments, relays, metering equipment and voltage regulator. There is, however, an emergency control panel in the turbine house. On the other hand, the switchgear for the station auxiliaries is housed in the station, mainly in an annexe at the turbine floor level, the appropriate transformers being situated in open-fronted cells at the basement level. The major turbine auxiliaries are supplied at 3·3 kV and the smaller motors and boiler auxiliaries at 400 volts. The 3·3-kV switchgear is of the air-break draw-out type, electrically operated and of 75 MVA rupturing capacity. The 400-volt gear is generally similar but is of 25 MVA or 15 MVA rupturing capacity, and either electrically operated or hand operated according to the duty. The boiler switchboards are housed in separate chambers between the boiler house and the precipitators. Control panels for the 3·3-kV switchboards are mounted in the turbine house. Auxiliary switchgear operation is by a 110-volt 400 ampere-hour battery. The rectifiers for the high-tension current for the precipitators are of the rotary type and are housed below the precipitators. Wherever possible the auxiliary motors are of the squirrel cage type and, with minor exceptions, protection is limited to indication of an earth fault. Each boiler is treated as a unit and a fault on any of its auxiliaries trips out the 3·3-kV supply to the associated boiler transformer.

In order to conform with A.R.P. requirements, windows are omitted below the top of the plant inside the station, while there is no horizontal roof lighting. This has made the interior rather dark, but a facing of light-coloured brick has been used on the walls internally and, in the turbine house and some other parts, very effective lighting has been secured by gas-discharge fluorescent tubes. Pyrotenax cables are used extensively for lighting and other connections. Of necessity no decoration or finish has been employed, so that the station at present does not show to advantage in this respect. On the return to peace-time conditions some windows will be provided and some glazing inserted in the boiler-house roof, and an opportunity will present itself for giving improved finish generally. In spite of this partial incompleteness, however, the station is an excellent example of planning and equipment. The consulting engineers responsible for the design and construction of the station are Messrs. Merz and McLellan, for whom Messrs. Sir Alexander Gibb and Partners acted in connection with the civil engineering work. The contractors for this part of the work are Messrs. Sir Robert McAlpine and Sons, Limited.

THE ARDENTE "LOUD HAILER."—A booklet describing their long-range powerful loudspeaking set has been sent to us by Ardente Acoustic Laboratories, Limited, Guildford, Surrey. The many and varied applications of the "Loud Hailer," as it is called, are illustrated by reproductions of photographs. We understand that nearly 20,000 of these loudspeakers have been supplied for service at sea and on shore.

THE FUTURE OF THE BRITISH STEEL INDUSTRY.*

By SIR ALEXANDER DUNBAR.

(*Concluded from page* 146.)

I WANT now to revert to the question of price. When we speak of price, it must be remembered that our costs are, to a considerable extent, dependent on the price we have to pay for our raw materials and for transport and other matters which are quite outside our own control. The most important factor of all is the price of coal and it is high time that the Government and the public understood that the foundation of industrial prosperity is not cheap steel, but cheap coal. Whereas steel prices have increased by about 50 per cent. since the beginning of the war, coal has gone up 100 per cent. and coke has increased by about 130 per cent. I am not going to attempt to allocate the blame for this state of affairs, but it is useless to press us to sell our steel at the same price as other countries if we start off with such a handicap. I can illustrate this question quite simply by pointing out that, in America, a ton of finished steel costs 2*l.* for the coal consumed in its manufacture, while in this country it costs us 4*l.* What we can do and what we must do, is to continue our research into fuel economy, and, in this respect, I think there are probably much greater opportunities for reducing coal consumption in the production of pig iron than in steel melting and treatment. Another important factor is iron ore. Much as I like the policy of using our own home-produced materials, nevertheless, I am convinced that, after the war, we must revert very largely to the use of imported ores of high-iron content, and in this connection I would point out that ocean freight rates are going to be very much higher, particularly in the first year or two, than they were prior to the war.

Even before the war, and again recently, the steel industry has been subjected to great criticism on this matter of price, though much of the criticism has been singularly ill informed. Nevertheless, up till a few months ago, it was true to say that a large proportion of the general public were under the impression that we were inefficient and that, by our system of price control, we made an unjustified profit at the expense of the consumer. Thanks to the vigorous steps taken by the Federation, I think that erroneous impression has been largely removed and that both in Government circles and in the Press, there is now a greater understanding of our position, and in many quarters we have received at least some of the praise to which our achievements, both before and during the war, fully entitle us; but though we have nothing to be ashamed of in our past record, we cannot afford to sit down in complacency. There is still a great deal to be done in continuation of the policy of modernisation which was started ten years ago, and, particularly, we have to remember that, owing to the war having prevented us from doing anything in the way of extensions or modernisation, we have five and a half years' leeway to make up.

Still, the steel industry is fully alive to the question and not only have they already formulated their plans, but these plans have been studied from the point of view of fitting into a broad national picture. Duplication, or possible duplications, have been, and are being, weeded out; the inevitable conflict of interests between different firms in the same section of the industry are being smoothed out; the extent to which we shall draw on the resources of the building trade and the electrical and other industries has been worked out; the steelworks-plant industry has been kept closely in touch with what it will have to provide, and the Government have been fully informed. To do all this while still producing the whole of the steel required for the war effort is, in itself, a magnificent achievement and I venture to say that no other industry in the country is farther advanced with its post-war plans than is the steel industry; and if I add that these plans involve the expenditure of well over a hundred million pounds, it will give you some idea of the magnitude of the problem.

There is one other national obligation that I have not yet mentioned, though it is one of the most important. It is our duty to assist British engineers to maintain their technical supremacy in the competitive markets of the world. British engineering products are renowned the world over for their excellence in design and quality—a most vital factor in obtaining orders for export trade. This is a question which is of particular importance in the realm of alloy steels, and for the assistance that has been given in the past to British engineering, Sheffield and Sheffield metallurgists have a reputation of which they may be justly proud. I have implicit confidence in their ability to maintain and enhance that reputation in the future. I remember, when in South America some years ago, I was surprised at the tremendous importance and

* Lecture delivered before the Sheffield Metallurgical Association on Tuesday, January 30, 1945. Abridged.

value of the words "Sheffield steel." They were accepted by the local population as being synonymous with first-rate quality and those words alone influenced sales to a very considerable extent.

There are two other matters of such vital importance in any consideration of the future that I feel I must mention them. The first is the question of research, and on that point, as you know, a new and strengthened Research Association has been formed by the British Iron and Steel Federation and the Iron and Steel Institute. Research in the steel industry is carried on to such a large extent within the varied works that it is difficult to say just how much is spent each year on this vital matter, but whatever it amounts to, it is certain that the expenditure in post-war years will be considerably increased and to no section of the industry is this more important than to Sheffield. Most of you know, perhaps better than I do, just what is being done, but suffice it to say that I have no fears in the matter of research work; I am confident that we shall remain technically in the forefront of world progress.

The other matter is the vexed question of cartels. One of the principal troubles about international cartels is that the people who speak and write about them are lamentably ignorant of their subject, and the people who know from practical experience all about cartels are lamentably silent. The word "cartel" has been so abused that it must be replaced by something else, but whether we call it international planning or anything else, and whether the arrangements are made by Governments or by industry or by a combination of both, I have no doubt that international arrangements of some kind are essential to the future of world trade. I will add this, that the trade agreements arranged between Governments in pre-war days were not nearly so beneficial to this country as the international cartels, such as the steel cartel, which were arranged between industrialists. It is true that in some cases, the arrangements had, or might have had, undesirable restrictive consequences and I agree that future arrangements must be free from this; but, I repeat, that international planning arrangements are essential and I hope that no Government will attempt to make such arrangements without full co-operation with the industry concerned.

REDUCTION GEARS FOR MARINE TURBINES.

IN prefacing a paper entitled "Current Practice in Marine Gearcutting," which he read before a meeting of the Institution of Engineers and Shipbuilders in Scotland, at Glasgow, on February 27, 1945, the author, Mr. A. W. Davis, B.Sc., said that the marine gear had shown no very conspicuous advance in design during the last 20 years, and that methods of cutting had scarcely changed. The use of higher steam pressures had, however, necessitated the use of higher turbine speeds, so that the double-reduction type of gear had come into favour again, notwithstanding that difficulties of manufacture had militated against its success in the past. Greater precision in gear-cutting was necessary with the double-reduction arrangement than with single-reduction gearing, and the load-carrying capacity of a reduction unit was greatly increased by a high degree of accuracy and surface finish. The Admiralty had called for gears of a high-quality finish to enable compact gear-reduction units to be built for warships, and it was now possible to comply with these requirements, but only at considerable extra cost. Standards with which to compare finished gears and classify them in accordance with their load-carrying capacity were lacking, but at the request of the Admiralty, the matter had now been taken up by the British Standards Institution, and it was hoped that a specification would soon be issued. It seemed likely that, in future, marine engineers would be faced with two standards in machine-cut gears, namely, the highly accurate gear that would permit compact but costly reduction units to be built, and the less accurate gear that would cost less but would give reasonably good results if made to more generous proportions. It was still an open question whether the industry should accept this double standard, or whether, in the long run, the best would prove cheapest and therefore be the most desirable in every case.

There was still a lack of unanimity as to the most suitable helical angle for gears, and as to the best proportions for teeth, with the result that a great variety of gears existed, calling for a correspondingly large number of hobs to cut them. The author urged greater uniformity in design practice to avoid a chaotic growth of unrelated profiles. He put forward in tabular form a suggested range of standards. The paper described the faults observable in gears and indicated how they could be traced to such imperfections in the hobbing machine as a pitch error in the lead screw, errors in the thread of the main driving worm, or in the profiles of the worm-wheel teeth, and so on.

LABOUR NOTES.

LAST week's unofficial strikes of dockers and mine workers need not have taken place, as adequate negotiating machinery exists for the adjustment of differences without stoppage of work. Alluding to the London trouble in the course of a statement in the House of Commons, Mr. Bevin, Minister of Labour and National Service, said that the stoppages were completely unjustifiable. The machinery of the National Joint Council for the Dock Industry, which was established following the Shaw inquiry 20 years ago, was capable of dealing with any legitimate grievances in a constitutional way, and it should have been used and the war effort not impeded by "this reckless act."

The number of disputes involving stoppages of work, reported to the Ministry of Labour and National Service as beginning in January, was 120. In addition, three stoppages, which began before January, were still in progress at the beginning of that month. The approximate number of workpeople involved in these 123 stoppages, including workpeople thrown out of work at the establishments where the disputes occurred, is estimated at nearly 32,000 and the aggregate number of working days lost at these establishments, during January, at 104,000.

In the 120 disputes which began in January about 29,000 workpeople were directly involved, and about 2,000 indirectly involved—were thrown out of work, that is, at the establishments where the stoppages occurred, though not themselves parties to the disputes. In the three stoppage which began before January, and were still in progress at the beginning of that month, the total number of workpeople involved during January, either directly or indirectly, was nearly 1,000. Of all the stoppages of work through industrial disputes known to have been in progress at some time in January, coal mining accounted for 89, involving about 15,000 workpeople and resulting in an aggregate loss of over 35,000 working days.

Of 159 stoppages of work, owing to disputes, which came to an end during January, 91, directly involving 11,300 workpeople, lasted no longer than a single day. Thirty-two, directly involving 6,000 workpeople, lasted two days, 15, directly involving 1,700 workpeople, three days; 13, directly involving 2,800 workpeople, four to six days; and eight, directly involving 11,100 workpeople, over six days.

One hundred and seventy disputes leading to stoppages of work began in January. Of them, 18, directly involving 1,700 workpeople, arose out of demands for advances in wages; 11, directly involving 2,300 workpeople, out of proposed reductions in wages; 33, directly involving 2,800 workpeople, out of other wage questions; six, directly involving 800 workpeople, out of questions relating to working hours; 20, directly involving 2,500 workpeople, out of questions respecting the employment of particular classes or persons; 71, directly involving 15,100 workpeople, out of other questions relating to working arrangements; and five, directly involving 1,700 workpeople, out of questions of trade union principle. Six stoppages, directly involving 2,300 workpeople, were in support of workers involved in other disputes.

In the industries covered by the statistics regularly compiled by the Ministry of Labour and National Service, the changes in rates of wages reported to have come into operation in January resulted in an aggregate increase estimated at approximately 17,000*l.* in the weekly full-time wages of nearly 85,000 workpeople, and in a slight decrease in those of about 4,000 workpeople. The principal industries and services in which increases were reported included pottery manufacture, slate quarrying in North Wales, the cast stone and cast concrete products industry in England and Wales, heating, ventilating and domestic engineering, corset manufacture, electrical contracting in Scotland, and land drainage in England and Wales. The reductions were in the cost-of-living bonus of workpeople employed in textile making up and packing, in Manchester, and in shuttle-making in Lancashire and Yorkshire.

Of the total increase of 17,000*l.* about 7,000*l.* was the result of arrangements made by joint standing bodies of employers and workpeople; 3,000*l.* took effect under arbitrated awards, and most of the remainder was the result of direct negotiations between employer and workpeople, or their representatives. The whole of the remainder was due to the operation of sliding scales based on the official cost-of-living index figures.

It is stated in the Engineering and Metal section of the Transport and General Workers' *Record* that certain modifications have been made in the agreement of March, 1941, on the subject of Joint Production Committees. These amend the clauses regulating the periods of office, retirements, and the filling of vacancies on the committees, and there is an additional paragraph in the section relating to eligibility. This paragraph reads as follows:—"Provided that these adult organised workers with not less than five years' continuous service in the industry shall be eligible for election after not less than one year's continuous service at the factory concerned."

The Chemical Section reports, in the same issue of the *Record*, that the clause in its agreement relating to temporary transfers to other jobs has been amended to provide that, where a day worker is asked by the management to take on the job of a shiftworker, either at the conclusion of his normal work for the day, or after being sent home, he shall, on resumption of work as a shift man doing ordinary shift hours, be paid on the basis of the prevailing shift rate for the particular job and all hours in excess of his normal day's work shall range for overtime payment.

Mr. Will Lawther, who was honorary President of the Mineworkers' Federation of Great Britain, has been elected President of the new National Union of Mineworkers. There were originally four candidates, and the final figures in the ballot—which was carried out by the Proportional Representation Society—were: Mr. W. Lawther, 251,950; Mr. J. R. A. Machen, 129,611. Mr. Lawther is to take up his new duties next month.

A novel feature of a Decree, issued by the Colombia Government in September last, is that trade unions may enter into legal, binding contracts of employment with one or more employers or employers' organisations for the performance of services or the execution of work by union members. Such contracts will be governed by the provisions which apply to individual contracts of employment as regards duration, revision, and termination. The contracting union is responsible for compliance with the direct obligations arising out of the contract, and will be recognised as having legal personality to exercise its own rights and those of its members under the contract. If no other arrangment is made by the parties, it is understood that the entire resources of each serve as guarantee for the fulfilment of their respective obligations. If a contracting trade union is dissolved, its members will be individually responsible for continuation of the services involved for the duration of the contract under the conditions established.

The conditions established in individual and trade union contracts of employment may, under the Decree, be superseded by the provision of collective labour agreements. A collective agreement is defined as one entered into voluntarily by one or more employers or employers' organisations and one or more trade union or federation for the purpose of establishing general conditions of work. In addition to provisions regulating general conditions, a collective agreement must include clauses defining the trades or industries covered, the place or places in which it will be in force, the time of its coming into force and its duration, the manner in which it may be extended or terminated, and the obligations resulting from non-compliance. Pending the conclusion of collective labour agreements the conditions established through conciliation and arbitration and in works regulations, as duly approved by the authorities, are to have the superior status accorded to collective agreement provisions.

In consultation with joint committees of employers and employees, the Government may, under the Decree, fix minimum wage rates for any economic region and for any type of undertaking, including industrial, commercial, professional, stock-raising and agricultural concerns. All relevant economic factors, it is stated, will be taken into account in fixing minimum wage rates, and, in no case, will a wage rate be payable which falls below the minimum rate fixed by the Government. Overtime must be paid for at not less than time-and-a-quarter, and night work at time-and-a-half. Equal wages are to be paid for equal work.

The normal maximum hours of work are fixed as follow:—In general employment, 8 in the day and 48 in the week; in dangerous or unhealthy occupations and in night work, 6 in the day; in agriculture, 9 in the day and 54 in the week. A worker may not be required to work more than 4 hours of overtime in one day or more than 12 hours, in any week, in employment in which overtime is permitted. A worker required to take duty on a legal holiday is to be paid double time or given compensatory time off.

STEEL FOUNDRY PRACTICE.

The Foundry-Practice Sub-Committee was formed in 1938, by the Steel Castings Joint Research Committee of the Iron and Steel Institute and the British Iron and Steel Federation. The personnel of the Sub-Committee has changed from time to time, and the attendance of the members has been sometimes curtailed by pressure of other work. The first report of the Sub-Committee, the chairman of which is Mr. F. Cousans, of Messrs. Thos. Firth and John Brown, Limited, however, has now been published and will be presented at the forthcoming annual general meeting of the Iron and Steel Institute. The report occupies 53 pages, and is divided into several sections, the first of which deals with the feeding of steel castings of simple shapes. The Sub-Committee decided, in the first stage of the investigation, to study the feeding characteristics of steel in dry-sand moulds, in order to determine the most economical method of feeding a casting such as a ring of which the section was 6 in. square. The problem was attacked in steps, beginning with the effect of different common shapes of heads on 6-in. cube castings, using a 0·20 per cent. plain-carbon steel made in a basic electric-arc furnace, with a standard ladle addition of 8 oz. of aluminium per ton of liquid steel. The castings made were divided into seven groups, namely, 6-in. cubes with six different types of head; 6-in. cubes with wider heads of different shapes; 6-in. cubes with ingot-type heads; 6-in. cubes with external chills; 6-in. cubes, the heads being lined with insulating mixtures; 6-in. cubes run and gated in different ways; and 4-in. and 9-in. cubes cast by methods similar to those used for the 6-in. cubes.

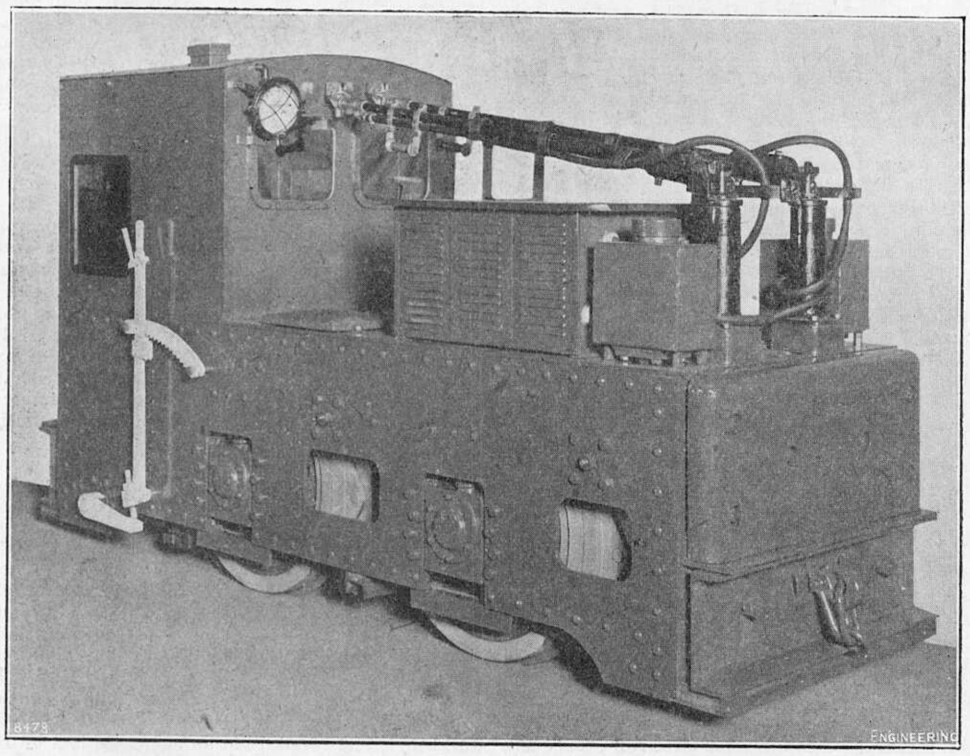
In making the latter, the Sub-Committee found that, to obtain the most economical use of the steel, the area of the bottom of the feeder head should be as large as the area of the upper surface of the casting. They realise, however, that this is seldom possible or practicable in a commercial foundry, so that horizontal feeding becomes necessary. Enlarging the bottom of the head, where it joins the casting, gives better results with a casting such as a cube than constricting the head at its junction with the casting. The shape of head normally used to feed steel castings appears to be very effective. It is advantageous to secure a differential rate of cooling in the casting and in the head. This has been obtained by lining the head with a layer, $1\frac{1}{2}$ in. thick, of material having a low thermal conductivity, thus reducing the rate of cooling in the head, and by the use of external chills to increase the rate of cooling in the body of the casting. There is a suggestion from the results obtained that hot steel poured slowly gives less piping than cold steel poured quickly. The Sub-Committee set out to find how far the head which would feed a 6-in. cube casting would feed, in a horizontal direction, longer castings of similar cross-section, and it was ascertained that satisfactory horizontal feeding did take place with the same type of head up to a length of 18 in.; when the length of the casting was increased to 24 in., it was necessary to use a larger head.

The Sub-Committee consider that the steel-foundry industry is greatly indebted to Mr. Basil Gray, of the English Steel Corporation, Limited, for the pioneer work he has carried out in developing the so-called "whirl-gate" head method of feeding castings. This head, as now understood, is something more than a spinning ingate. It should consist of a head, so placed and with such a short connection to the casting, that the relative feed through the neck is increased by the heating effect on the sand caused by the proximity of the head to the casting. To this effect is added that of spinning the steel at the bottom of the head by a whirling or tangential ingate. As much of the value of this form of results comes from its careful placing as from the spinning ingate. Tests have shown that the best type of feeding compound for use on the fluid steel, as it rises into the heads of the mould, is an impure blacklead containing from 40 per cent. to 50 per cent. of ash. The reason for its success is that as the carbon burns away slowly it leaves, on the surface of the fluid steel, a light flocculent type of ash which forms an ideal insulation of the surface of the steel in the head. Chopped straw is used on large heads and depends for its efficiency on the same effect; it chars and leaves a light insulating layer on the steel.

The general view of the Sub-Committee is that, after all the skill of the foundryman has been exercised, the degree of hot tearing on a particular design can be minimised, or often eliminated, by using steel with a lower sulphur content. With normal designs, there should be little trouble if the sulphur content is below 0·035 per cent., but for more intricate designs it may be necessary to go to still lower limits. Investigations dealing with the effect of variation in the rates of pouring castings in different foundries, and with methods of feeding 100-mm. thick plates, are already in hand. In addition, the Sub-Committee are preparing a pamphlet on the "Design of Steel Castings."

INDUSTRIAL ELECTRIC LOCOMOTIVE.

THE ENGLISH ELECTRIC COMPANY LIMITED, STAFFORD.



ELECTRIC LOCOMOTIVES FOR INDUSTRIAL USE.

In a large industrial plant, where most of the equipment is electrically driven, the operation and maintenance of a locomotive of the steam or internal-combustion engine type may present difficulties. One of the advantages of an electric locomotive in such circumstances is that many persons will be competent to take charge of it, since it operates on principles with which they are familiar. Over a period of years, Messrs. The English Electric Company Limited, Stafford, have supplied many electric locomotives to industrial concerns, and we have received particulars of two units that have been delivered recently, one to the Sunderland Corporation power station, for coal haulage and general shunting on a standard-gauge track, and the other to Messrs. Imperial Chemical Industries, Limited, for underground operation on a 2-ft. 6-in. gauge track in a mine. The first of these units is of the conventional centre-cab type, with a spring-operated bow collector on the roof of the cab. Two nose-suspended axle-hung traction motors are connected permanently in series for operation at 550 volts. Each of the two axles is power driven, so that the whole weight of the locomotive, namely, $13\frac{1}{2}$ tons, is available for adhesion. The maximum tractive effort, of 6,000 lb., is developed at a speed of $4\frac{1}{4}$ m.p.h. The corresponding horse-power at the drawbar is 68. A screw-type hand brake is provided, and the controller is arranged to give rheostatic braking.

The mining locomotive is shown in the accompanying illustration, from which it can be seen that the general layout is different from that of the unit already referred to. The total weight, in this case 6 tons, however, is taken on two power-driven axles, as in the previous example. The two nose-suspended axle-hung traction motors are arranged for series-parallel control, current being supplied from twin overhead contact wires, the positive supply and negative return both being insulated. The supply pressure is 250 volts. The maximum tractive effort, of 2,700 lb., is developed at $8\frac{1}{2}$ m.p.h., and the corresponding drawbar horse-power is 62. The screw-down hand brake can be operated in an emergency by a hand lever working on a ratchet and quandrant. This alternative method of application can be seen in the illustration. The controller is arranged to provide additional rheostatic braking, and it is fitted with a deadman's handle which cuts off the power by opening the main circuit breaker when it is released. As there is no danger from the explosion of dust or gases in the mine, the electrical equipment is not of the flameproof type. To reduce the overall dimensions when the locomotive is being lowered down the mine shaft, the cab and other fittings are removed, having been made readily detachable for this purpose. Where necessary, the electric wiring is provided with connectors, to facilitate the removal and subsequent replacement of the fittings.

THE "BLACK WIDOW" P-61 NIGHT FIGHTER AEROPLANE.

In 1940, the Royal Air Force completely defeated the Luftwaffe when the latter attempted to gain aerial supremacy by day over the British Isles. Before the end of that year, the enemy was reduced to making air attacks on this country by night, when the chances of interception by fighter aircraft were much less. These night attacks were less costly to the enemy than the previous attacks by day, and it was soon realised that the defences of London and other populous centres were unable to ward them off. In an endeavour to devise an effective defence, pursuit planes and light bombers were converted into night fighters, but since they had not been designed for this class of work their performance was not all that could be desired. When, therefore, in the autumn of 1940, a United States Army Mission returned from England with a secret list of arms requirements for both Britain and the United States, a night fighter was included in that list. This machine was required to have a high combat speed and a high degree of manœuvrability, but it needed also to have a low landing speed to minimise operational risks under conditions of total darkness and fog, and to enable the small airfields in or near built-up areas to be used. Its guns and protective armour had to be a match for the powerful weapons carried on a large bomber, to enable the latter to be destroyed or driven off. Most important of all, the night fighter had to be equipped with adequate detection apparatus and radio communication equipment.

After making a survey of the available designs and design facilities, the United States Army authorities decided to entrust Northrop Aircraft Incorporated, Hawthorne, California, with the task of developing and producing a suitable machine. It was realised that the requirements called for a relatively large machine to carry a crew of three, namely, a pilot, a gunner, and a radio-operator, and for this reason the Northrop designers were asked to incorporate two engines of an existing design, each developing approximately 2,000 h.p. They were given the choice between the then new Pratt and Whitney R-2800 engine and the Wright R-3350, both radial air-cooled engines having the output required. By November 5, 1940, a provisional design had been prepared. This underwent considerable modification as the result of conferences, and in the later stages of development, the design was scrutinised by a panel of 26 competent authorities from the United States Army and Navy and the Royal Air Force. When the basic layouts were completed and approved, the component parts were assigned to specialist groups of designers within the Northrop organisation for further investigation and tests. The new machine, which was of the "P" or pursuit class, was given the ultimate designation of P-61, but at this stage was known as the XP-61, the X signifying that it was still experimental. An official order for two XP-61

"BLACK WIDOW" P-61 NIGHT FIGHTER AEROPLANE.

NORTHROP AIRCRAFT INC., HAWTHORNE, CALIFORNIA, U.S.A.

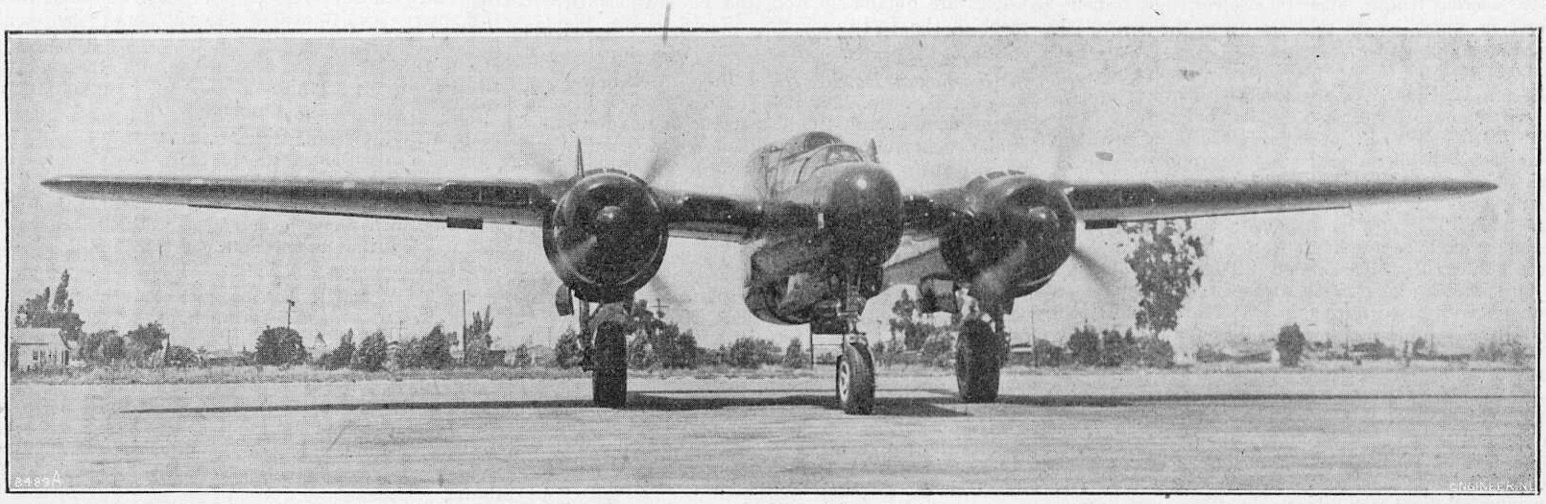


FIG. 1.

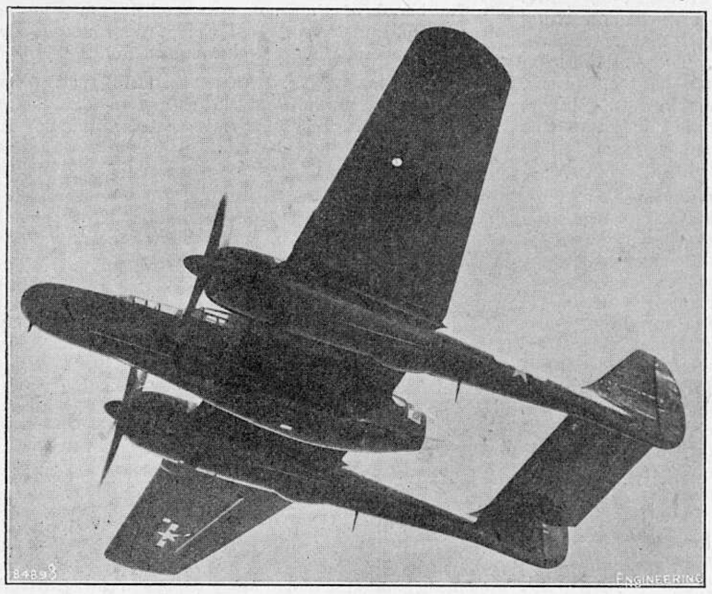


FIG. 2.

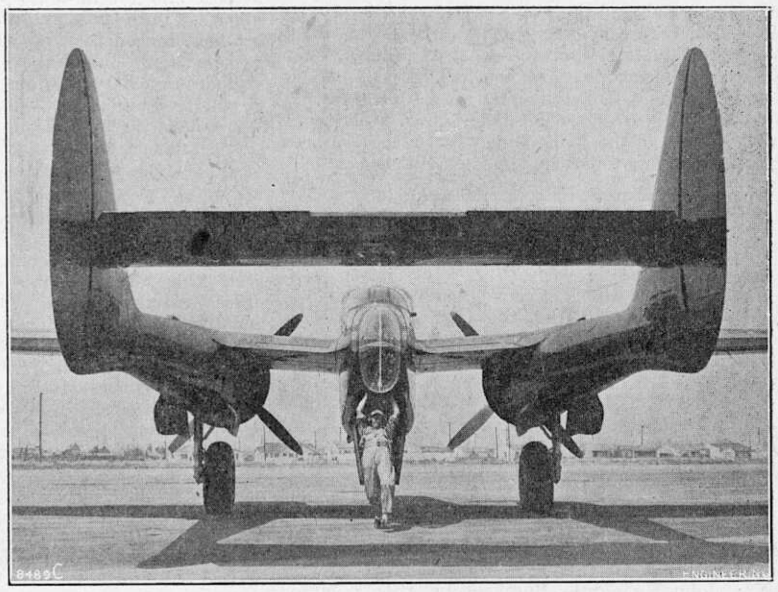


FIG. 3.

machines was received by Northrop Aircraft Incorporated on January 30, 1941. The standard Government procedure was that this order should be followed by the "Y" or service-test order for 14 machines, after flight tests carried out with the two "X" machines had shown the design to be generally satisfactory. Such was the urgency in this instance, however, that the "Y" order was placed on March 10, 1941, only 38 days after the "X" order. Of the "Y" machines, 13 would normally have been allocated to the Air Force for testing under service conditions, and the remaining machine would have been subjected to static tests to ascertain its ultimate strength. Circumstances dictated a speeding up of the normal procedure, and therefore the first production contract for many hundreds of P-61 machines was signed on February 25, 1942.

The first test flight was made on May 26, 1942, with a machine that had been given a shiny black finish, with red serial numbers and red inspection door markings. The resemblance of this colouring to that of a well-known American spider caused the machine to be nicknamed the "Black Widow" within a few hours of its first appearance. The name was accepted and given official status by the Army Air Forces. The P-61, Black Widow, is now the standard night fighter of the United States Army, and will replace all previous types. For security reasons, the Army Air Forces kept the existence of the Black Widow night-fighter secret until January 9, 1944, when one was flown over the Los Angeles Coliseum at the Army-Navy Show. Subsequently, descriptive matter relating to the machine was released, and three photographs of it are reproduced in Figs. 1, 2 and 3, on this page.

From these illustrations it will be seen that the Black Widow is a twin-engine mid-wing monoplane, with two tail booms and a fully retractable tricycle landing gear. The crew of three is accommodated in a nacelle located between the two engine nacelles. Having a wing spread of 66 ft. and an overall length of 48 ft. 9 in., the machine is as large as a medium bomber. The armament includes 20 mm. cannon and 0·50 in. calibre machine guns. The latter are mounted in a turret on top of the crew nacelle. The power plant consists of two Pratt and Whitney R-2800 engines with two-stage two-speed superchargers, each engine developing rather more than 2,000 h.p. when operating on 100-octane fuel; they drive Curtiss-Wright fully-feathering four-bladed propellers 12 ft. 2 in. in diameter, the propeller blade angle being controlled automatically or by manual selection. The main structure of the machine is of the all-metal monocoque type. The wing is a stressed-skin two-spar cantilever structure composed of two inner panels, two outer panels and two tip panels, bolted together by internal fastenings, which are accessible through removable doors. The two spars, which are claimed to be among the largest extrusions so far produced, are continued through the crew nacelle. In this machine is incorporated the first application of what is nearly a full-span landing flap, together with ailerons which retract into the upper aft surface of the wing. The advantages of this arrangement will be referred to later. The tail group, which is well shown in Fig. 3, consists of two fins and two rudders, connected by a stabiliser and an elevator. The entire tail group is supported by the two monocoque tail booms attached to the engine nacelles.

The main landing gear consists of two Goodyear wheel-and-brake assemblies and two Bendix shock-strut assemblies, which retract rearwards and upwards into the engine nacelles. When the gear is in the retracted position, hydraulically-operated doors cover the wheel wells. The nose landing gear is of the single Bendix shock-strut half-fork type which folds up into the crew nacelle by hydraulic power. Mechanically-operated doors close the opening after retraction. Dual hydraulic disc-type Goodyear brakes are fitted on each main landing wheel, and there is an emergency air brake system that can be operated from a storage bottle. The general arrangement of the landing gear can be seen in Fig. 1. Tanks and pipe-lines for petrol and lubricating oil are self-sealing, and the members of the crew are protected by armour-plate deflector shields and bullet-resistant glass. The weight of the machine is more than 25,000 lb., being about the same as that of a medium bomber. Identification is made easy by the crew nacelle, which is very narrow in profile and has a nose projecting several feet forward of the propeller hubs. This feature is seen clearly in Fig. 2.

Particulars of the special equipment carried on the Black Widow are not available for publication, but some of the fittings may be referred to. Landing lights are mounted on the under surface of each outer wing panel, and are retractable, the mechanism being electrically operated. The instruments in the cockpit are illuminated by ultra-violet light, which causes the dials to glow by fluorescence. Oxygen-breathing apparatus is provided for every member of the crew, each of whom also has an individual heater. The automatic pilot is operated by pressure from the main hydraulic system.

The performance of the Black Widow in flight, and also when taking-off or landing, is said to give the pilot full confidence even under conditions that are normally regarded as difficult and hazardous. The unusually large landing flaps leave no room for conventional ailerons of adequate size, so that very small ones are fitted, and these are supplemented by four retractable aileron panels in the aft upper surface of the wing. The panels are linked to the aileron control system, and the entire system is controlled by the wheel in the cockpit. The retractable ailerons have sometimes been termed "spoilers" but it is pointed out by Mr. Moye Stephens, the builders' chief production test pilot, that they are true ailerons, being wrongly located to act as spoilers. The true spoiler, which functions by destroying the lift of the wing over a certain area, must be located near the leading edge, and not aft, as is the case with the retractable ailerons of the Black Widow. Owing to the fact that the retractable ailerons tend to open themselves, they provide a force in opposition to that set up in the controls by the small ailerons of normal type and this renders the control very light. At slow speeds, with the flaps up, the effectiveness of the combined aileron system is equal to that of the usual system, but with the flaps down its effectiveness, as expressed in terms of rate of roll with full aileron deflection, is approximately 40 per cent. greater than that of the conventional installation. It is still effective at speeds down to and past the stall. This may be demonstrated by stalling the machine and, as the nose is dropping, rotating the wheel from side to side, when rolling will be found to occur in quick response to the wheel. A straight course can be maintained during a stall with one engine cut out and the other developing full power. This is due mainly to the effectiveness of the aileron system, though the relatively large amount of vertical surface is claimed to be an important contributory factor. If the machine is stalled in an inverted position, either intentionally, or as a result of attempting a loop or other manœuvre with insufficient initial speed, recovery may be accomplished by rolling out with the ailerons. In inverted flight, the retractable ailerons act in much the same way as landing flaps and they are still fully effective in modifying the lift of the wing though, of course, their action is inverted. The feel of the controls remains normal, and the response is excellent. Unlike conventional ailerons, the combination in the Black Widow can safely be used to raise a wing during landing, when the machine is near the stalling speed. There is not the same risk of stalling the wing tip and causing it to be dragged on the ground. These remarks on the behaviour of the Black Widow in flight have been abstracted from a report by Mr. Moye Stephens.

INSTITUTION ELECTIONS.

INSTITUTION OF CIVIL ENGINEERS.

Associate Member to Member.—John Whitehead Wilson Drysdale, B.Sc. (Glas.), Glasgow; Henry George Follenfant, M.B.E., B.Sc. (Eng.) (Lond.), Amersham, Bucks.; Francis Matthews Fuller, B.Sc. (Eng.) (Lond.), Chislehurst, Kent; Charles Prosser Gibson, M.C., B.Sc. (B'ham), Colombo, Ceylon; Richard Stanley Read, M.Sc. (Eng.) (Lond.), London, S.W.19; Frank Neilson Sparkes, M.Sc. (Bristol), Slough, Bucks.; Robert Dennis Wilkinson, B.Sc. (Manch.), Preston.

INSTITUTION OF ELECTRICAL ENGINEERS.

Associate Member.—James Anderson, London; Campbell Garden Begg, M.Sc., London, S.W.5; William Bowdler, Prescot; Commdr. John Herbert Bowen, R.N.; John Ronald L. Burchell, Liverpool; Major Kenneth Ernest Caine, R.E.; Clarence Strafford Cloughton, London, N.W.4; David Islwyn Davies, Swansea; 2nd Lt. Andrzej Michal Flatau, Polish Army; Commdr. Gilbert Nathaniel Harvey, B.Sc. (Eng.), R.N.; Frederick John Hurd, Devonport; Hugh Russell. L. Lamont, M.A., B.Sc., Ph.D., Wembley; Charles Stephen Lees, B.A., Ph.D., Stafford; John Armstrong Lewis, Brisbane, Australia; Dermot Arthur Nolan, B.A., Shenley, Herts.; Harold Dudley Offer, Birkenhead; Edwin Levi Payne, B.Eng., Penrith, Cumberland; John Carley Read, M.Sc., Rugby; Reginald Ernest Reed, B.Sc. (Eng.), Cardiff; William Hinselwood Scaife, Orpington, Kent; Joe Henry Scott, Leeds; Joseph Mieczyslaw Silberstein, Rugby; Joe Smith, Salford; William Stirling, B.Sc., Glasgow; Thomas Henry Traill, Thornton Heath, Surrey; William Patrick Trenhaile, West Malvern, Worcs.; George Ronald Turtle, B.Sc. (Eng.), Birmingham.

INSTITUTE OF PHYSICS.

Fellow.—G. D. Coumoulos, B.Sc., Dr.Nat.Sci., Ph.D., Cambridge; F. A. M. Heppner, Coventry; D. Jack, M.A., B.Sc., Ph.D., St. Andrews; S. D. Treadgold, B.Sc., London; D. G. Underwood, B.A., Billingham; R. Witty, B.Sc., Ph.D., Manchester; H. G. Yates, M.A., Wallsend-on-Tyne.

Associate.—Lieut. B. C. Abbott, B.Sc., R.E.M.E.; S. H. Ayliffe, M.Sc., Ph.D., Bath; J. G. Ballantyne, B.Sc., Hampshire; R. H. Booth, B.Sc., London; D. F. Bracher, B.Sc., Birmingham; W. Cochran, B.Sc., Edinburgh; H. O. Foulkes, M.Sc., Port Talbot; V. E. Gough, B.Sc. (Eng.), Birmingham; T. S. Hutchison, B.Sc., Greenock; N. R. Labrum, B.Sc., Surrey; A. S. P. Ledger, B.Sc., Welwyn Garden City; G. W. Malk, B.A., Bedford; J. H. Mason, B.Sc., London; J. W. McHugo, A.R.C.Sc., B.Sc., Hampshire; M. J. Moroney, B.Sc., Leicester; N. Pearce, B.Sc., Salisbury; S. E. Presgrave, B.Sc., Bath; O. J. Russell, B.Sc., Sheffield; Lieut. (Elec.) G. H. Stafford, M.Sc., R.N.; E. E. Welch, B.Sc., London; Fl.-Off. R. L. Whitmore, B.Sc., R.A.F.V.R.

BRITISH STANDARD SPECIFICATIONS.

THE following specifications of engineering interest have been issued by the British Standards Institution. Copies are obtainable from the Publications Department of the Institution, 28, Victoria-street, London, S.W.1, at the price quoted at the end of each paragraph.

Semi-Rotary Hand-Operated Pumps.—A new specification, B.S. No. 1208-1945, covers six sizes of semi-rotary hand-operated double-acting pumps for water. While such pumps are manufactured with inlets and outlets up to 3 in. in diameter, the present specification is limited to pumps having oval flanged inlet and outlet branches ranging in diameter from ½ in. to 1½ in. It has not been found practicable to standardise the internal mechanism of such pumps on a dimensional, interchangeable basis, but the standardisation of external dimensions allows the installation or replacement of a pump of a given size by another of similar size irrespective of make. It has also been found impracticable, at present, to standardise these pumps for fluids other than water. The specification prescribes materials, workmanship and performance. The latter is based on five minutes' continuous operation by normal adults of average physique, without undue fatigue, this affording a guide to the correct selection of a pump for known conditions. The pumps, which are for vertical mounting, are suitable for hot water, not actually boiling, and are of two types, namely, a cast-iron body with internal brass fittings and an all-brass body with internal brass fittings. Both types are furnished with steel operating spindles, hinged flap valves, tapped mating flanges, gaskets and operating handle. The specification excludes ancillary equipment, such as foot valves, strainers, retaining valves and air vessels. Makers will not be in a position to supply pumps to this specification for a period of three months from its date of publication. [Price 2s., postage included.]

Concrete Aggregates and Building Sands.—In revising the specification for concrete aggregates from natural sources (B.S. No. 882), the Institution have prepared a series of four new specifications for aggregates for granolithic concrete floors and for sands for various other building purposes. The revision of B.S. No. 882 and the four new specifications have now been issued under one cover. The five specifications consist of B.S. No. 882—coarse and fine aggregates from natural sources for concrete; B.S. No. 1198—natural sands and crushed natural-stone sands for plastering; B.S. No.1199—natural sands and crushed natural-stone sands for (a) external renderings, (b) cement and sand applications on interior walls or floors, and (c) cement and sand applications on expanded metal or other metal lathing; B.S. No. 1200—natural sands and crushed natural-stone sands for brickwork and masonry; and B.S. No. 1201—aggregates for granolithic floors. The revised edition of B.S. No. 882 has been considerably modified and now includes a wider range of sizes in both graded and single-sized coarse aggregates. Two classes of fine aggregate are given so that, in those areas where the higher standard material is not available, the slightly lower standard of fine aggregate may be specified. In the plastering and rendering sands specifications (B.S. Nos. 1198 and 1199) two classes of sand are given for the same reason. Some new or modified test methods have been added and are included as appendices, pending a revision of B.S. No. 812, covering the sampling and testing of mineral aggregates, sands and fillers. Changes in terminology have also been made. [Price 5s., postage included.]

BOOKS RECEIVED.

Centrifugal Pumps and Blowers. The Basic Principles of Design and Construction. By PROFESSOR AUSTIN H. CHURCH. New York: John Wiley and Sons, Incorporated. [Price 4.50 dols.] London: Chapman and Hall, Limited, 37-39, Essex-street, Strand, W.C.2. [Price 27s. net.]

United States Bureau of Mines. Miners' Circular No. 45. *Explanation and Justification of Tentative Inspection Standards for Bituminous-Coal Mines and Lignite Mines.* Washington: Superintendent of Documents.

The British Journal Photographic Almanac and Photographer's Daily Companion, 1945. Edited by ARTHUR J. DALLADAY. London: Henry Greenwood and Company, Limited, 24, Wellington-street, Strand, W.C.2. [Price 3s. 6d. net.]

Rolling Bearings. A Treatise Covering the History, Theory, Design, and Practical Application and Use of Ball and Roller Bearings. By R. K. ALLAN. London: Sir Isaac Pitman and Sons, Limited. [Price 30s. net.]

An Almanack for the Year of Our Lord 1945. By JOSEPH WHITAKER. London: J. Whitaker and Sons, Limited, 13, Bedford-square, W.C.1. [Price, library edition, 21s. net; complete edition, 10s. net; shorter edition, 6s. net.]

PERSONAL.

Sir Stafford Cripps, Minister of Aircraft Production, has acceded to the request made by SIR FREDERICK HEATON for his release and that of his colleagues from their duties as directors of MESSRS. SHORT BROS. (ROCHESTER AND BEDFORD), LIMITED, and their resignations have been accepted. The new board comprises MR. E. D. A. HERBERT, as chairman, and MESSRS. S. H. BROWN, C. P. T. LIPSCOMB, J. L. PARKER, D. E. WISEMAN, and SIR JOHN BUCHANAN.

MR. H. W. CREMER, M.Sc., F.R.I.C., M.I.Chem.E., has resigned his position as Director of Chemical Engineering Studies, University of London, King's College, and is now senior chemical engineer to Sir Alexander Gibb and Partners, with whom he has been working throughout the war on the design and construction of various Government works.

MR. T. A. EADES has been elected chairman, and MR. F. T. JACKSON, vice-chairman, of the Telecommunication Engineering and Manufacturing Association, for the current year.

MR. W. H. NOTTAGE has retired from the position of joint chief of the Patent Department of Marconi's Wireless Telegraph Company, Limited. He has occupied the position for the last 17 years, and has served the company for 34 years. Mr. Nottage's successor is DR. G. F. BRETT.

MR. W. KILPATRICK has relinquished his position as managing director of Messrs. Davy and United Engineering Company, Limited. He has also resigned his seat on the board of that company and its subsidiaries, Messrs. Duncan Stewart and Company, Limited, and Messrs. Davy and United Roll Foundry, Limited.

MR. L. SCOTT WHITE, M.Inst.C.E., M.I.Struct.E., has been nominated to represent the Institution of Structural Engineers on the Architects Registration Council of the United Kingdom, and the Admission Committee thereof, for the year ending March, 1946.

MR. C. W. MILNER, A.Inst.M.M., having completed his work with Non-Ferrous Minerals Development, Limited, has taken up an appointment with Messrs. Sir Alexander Gibb and Partners, London.

MR. J. SINGLETON-GREEN has resigned the office of honorary secretary of the Yorkshire Branch of the Institution of Structural Engineers on taking up an appointment in London. His successor is MR. J. T. STEVENS, A.M.I.Mech.E., A.M.I.Struct.E., Borough Engineer's Office, Brighouse, Yorkshire.

MR. J. S. ASKWITH, secretary of the Bolsover Colliery Company, Limited, Chesterfield, has been elected a director. He will retain his position as secretary.

MR. N. D. FRASER has been appointed to the board of the Sun Electrical Company, Limited.

MR. G. W. ROBB, rolling-stock superintendent of the Rotherham Corporation Transport Department, has been appointed general manager and engineer to the St. Helens Corporation Transport Department.

MR. M. H. TOLLIT, a director of Messrs. Guest, Keen and Nettlefolds, Limited, is now acting as general manager of the firm's bolt and nut section at Atlas Works, Darlaston. SIR ANTHONY BOWLBY, Bt., has been made general manager of the company's screw department.

The directors of the COVENTRY MACHINE TOOL WORKS, LIMITED, have purchased the whole of the share capital of MESSRS. JOHN STIRK AND SONS, LIMITED, Halifax, from the Ministry of Supply.

BIRMINGHAM ELECTRIC FURNACES, LIMITED, Tyburn-road, Erdington, Birmingham, 24, a subsidiary of the Mond Nickel Company, Limited, have decided to change their name to BIRLEC LIMITED. The policy, management and personnel of the firm are in no way affected by the change.

New premises for the REGIONAL APPOINTMENTS OFFICE of the Ministry of Labour and National Service for the North-East Coast, covering Northumberland, Durham and North Yorkshire, have been opened at 153, Barras Bridge, Newcastle-upon-Tyne, 2. (Telephone: Newcastle 22477.) The Regional Appointments Officer is AIR COMMODORE C. H. NICHOLAS.

PARLIAMENTARY GRANTS FOR SCIENCE.—The Royal Society has now been informed that H.M. Treasury has made provision in the estimates for the fiscal year 1945-46 for the following grants which are administered by the Society. For scientific investigations, 14,000*l.*; for scientific publications, 7,000*l.*; and for scientific congresses, 1,600*l.* In view of the greater amounts to be available if these estimates are accepted by Parliament, and of present changing conditions, the Society has decided that more frequent allocation is desirable. Consequently, the last dates, in 1945, for receiving applications for grants for scientific investigations will be March 31, July 31 and November 30, and the last dates for receiving applications for grants for scientific publications will be June 15 and November 15.

NOTES FROM THE NORTH.

GLASGOW, Wednesday.

Scottish Coal.—The outstanding item of news is the decision to cut the coal supplies to Scottish industrial and business premises by 25 per cent. The local output has fallen to a very low level—something in the region of 75 per cent. of the normal pre-war output; moreover, there have been widespread strikes and stoppages within the past week or two which have interfered with the supply programme very seriously. At the present time many users are unable to operate their works full-time for lack of coal. The largest steelworks in Scotland, at Motherwell, has dismissed a large proportion of men and shut down the greater part of the works pending the receipt of fresh supplies of coal. Papermakers, in many cases, have been idle for some days this week for the same reason, but the shortage is not confined to any particular group or groups. The 25 per cent. cut is likely to reduce industrial production by up to 40 per cent. The thread mills at Paisley have also had to shut down on certain days. Gasworks and other highly-rated priorities are working from hand to mouth. There is no prospect, at present, of the deep-mine output improving appreciably, but opencast operations are to be pushed forward as much as possible.

Scottish Steel.—The fuel crisis has hit the steelworks severely, and there is idle plant in many cases. Dalzell was off almost entirely last week for several days, and this week, the cogging mill, the plate mill, and half the smelting furnaces will not be able to operate for lack of coal. Clydebridge has carried on so far with difficulty, as Colvilles have concentrated whatever coal they could procure in order to obviate interruption over a wider field—and, of course, on the sound assumption that it is better to keep one works operating steadily than to have two working spasmodically. The lull in new business continues. Plates are very scarce, as shipyards are reported to be working on light types of construction, but sheets are still in exceptionally heavy demand, so much so that makers say they will be unable to overtake their commitments for many months to come. Shell-steel orders are fairly substantial, and re-rollers have limited working programmes. Scrap is plentiful, though the better qualities are scarce, which rather slows down operations at the furnaces and tends to increase the fuel burden at a time when fuel is of prime importance.

NOTES FROM THE SOUTH-WEST.

CARDIFF, Wednesday.

The Welsh Coal Trade.—Some interesting figures relating to the South Wales coal-mining industry were given last week by Mr. Iestyn R. Williams, joint secretary of the Monmouthshire and South Wales Coalowners' Association. Mr. Williams pointed out that statistics for the September quarter of 1944 showed that wages accounted for 71 per cent. of the average pithead price of coal in the area, while other costs of production accounted for 25½ per cent. and profits for 3½ per cent. He was replying to persons who complained of the great disparity between the pithead price realised for coal and the price, per ton, paid to the collier for cutting it. The price paid to the collier was only one of a large number of items which had to be paid. Wage-earners in South Wales (juvenile and adult) earned in the September, 1944, quarter an average of 22*s.* 2¼*d.* per man shift, excluding allowances in kind valued at 8¼*d.*, while the output per man shift was only about one ton. Business continued very difficult to negotiate for ordinary consumers on the Welsh steam-coal market throughout the week. There were keen inquiries, but most producers were finding it difficult to maintain directed business for the high-priority users, and after these needs had been met there was very little coal available for the free market. Exports proceeded quietly, and, as is now usually the case, were almost entirely in respect of Government directed supplies for the Forces and other vital users on the Continent and the coaling depots. Inquiry from the neutral sources was slow. All the large sorts were well booked for some time to come and were firm, while there was an actively sustained inquiry for the sized and bituminous smalls which were still virtually off the market. The best dry steams were well engaged, and were firm, while some of the inferiors were available. Cokes and patent fuel encountered a keen home demand.

Swansea Steel-Sheet Industry.—The market report prepared by the Incorporated Swansea Exchange states that, last week, steady conditions ruled in the market for tin-plates and their substitutes and that the home demand continued to be satisfactory. The export market, owing to war-time restrictions, however, remained almost idle and very little, if any, business was transacted. Steel sheets continued active and orders for early delivery were difficult to place. Iron and steel scrap was in better demand, the heavier and better descriptions finding a ready sale. The prices of tin-plates, unassorted tin-plate base uncoated plates and other iron and steel products, and non-ferrous metals were unchanged.

NOTES FROM SOUTH YORKSHIRE.

SHEFFIELD, Wednesday.

Iron and Steel.—Sheffield steel and engineering firms are making progress with arrangements for post-war trade, and in some instances have entered into negotiations for the acquisition of Government factories which they have been operating during the war period and propose to adapt for the production of peace products. It has been disclosed that the International Harvester Company are to take over from the Government a large factory at Doncaster and utilise it for the manufacture of agricultural machinery and motor lorries. The problem is the lack of sufficient labour for the carrying out of processes of manufacture as orders are received for steel products. Some sections have been helped in this direction by taking labour from specific war departments which have little work on hand. A marked impetus has been imparted to the export sections by the placing of orders with three Sheffield firms for tools and tool steels for the Turkish State Railways. The orders are the outcome of recent visits to Sheffield works of a delegation from those railways. The successful firms are Arthur Balfour and Company, Limited, Thos. Firth and John Brown, Limited, and Edgar Allen and Company, Limited.

South Yorkshire Coal Trade.—Some increase in coal outputs at various South Yorkshire Collieries is helping to relieve the coal shortage, and combined with this is an improvement in the working of empty wagons back to the colliery screens; but there is still a great deal of leeway to make up if stocks are to be increased to a reasonably safe level. Best hards, and all washed and graded steams, are heavily earmarked for the month. There is a shortage of house coal, and the gas coke obtainable is not sufficient to make up the deficiency. Coking coal is in strong request, and available supplies are quickly absorbed. A considerable tonnage of outcrop coal is being utilised to supplement the supplies of pit coal on the steam and house-coal markets.

NOTES FROM CLEVELAND AND THE NORTHERN COUNTIES.

MIDDLESBROUGH, Wednesday.

General Situation.—The consent of the Ministry of Supply to changes in the fixed maximum prices of iron and steel was not unexpected, but in some cases the extent of the alteration is rather greater than was anticipated. Slackness continues at certain iron and steel works, but most producing plants are busily employed. The total supply of pig iron is almost absorbed by local consumers and the demand promises to expand. Producers welcome the establishment of a trade pact with Sweden and the probable early resumption of substantial imports of high-grade overseas ores, larger arrivals of which have been greatly needed for some time. There are no new features in the various branches of semi-finished iron and steel. Outstanding incidents in the finished industries are extensive bookings for the lighter descriptions of steel and the dearth of orders for heavy structural material.

Foundry and Basic Iron.—The supply of foundry pig iron is barely sufficient for requirements. The tonnage stored is trifling and the make of local brands continues meagre, but steady deliveries of Midland qualities are still reaching founders in this area. The needs of light-casting plants have increased slightly. The fixed figure for No. 3 Cleveland pig has been advanced to 143*s.* The basic blast-furnaces are running smoothly and turning out adequate quantities of iron for the adjacent consuming plants, but no tonnage is available for other users. The recognised market quotation for basic iron is now 135*s.* 6*d.*

Hematite, Low Phosphorus and Refined Iron.—Hematite is still inconveniently scarce, but the prospects of some easing of the stringent situation are brighter than has been the case for some time. Strict adherence to control of distribution regulations is still essential to ensure regular deliveries to authorised users engaged on work of national importance. The new quotation for East Coast hematite is 153*s.* 6*d.* Available parcels of low- and medium-phosphoric irons are readily taken up.

Manufactured Iron and Steel.—While there is no shortage of semi-finished iron, there appears to be some difficulty in obtaining adequate supplies of steel semies. Prime billets and sheet bars, in particular, are in great request and there is a ready sale for any distributable parcels of inferior semies. There is now more activity in the finished-iron trade branches, that have been dull for a considerable time. Makers of light steel sheets are fully sold over the next quarter and manufacturers of light sections have good order books. Railway material and colliery equipment are in continued demand, but heavy plates and sections attract little attention and it is understood that steps are being taken to release tonnage of these products for export.

Scrap.—The lighter categories of iron and steel scrap are plentiful and in little demand, but good cast iron and heavy steel are wanted in large quantities.

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 MECHANICAL ENGINEERS.—*Southern Branch:* Saturday, March 17, 2 p.m., Civic Centre, Southampton. Thomas Lowe Gray Lecture: "Mechanical Engineering in the Shipyard," by Mr. J. Foster Petree. *Yorkshire Branch:* Saturday, March 17, 2.30 p.m., Royal Victoria Station Hotel, Sheffield. "Drawing Office Practice in Relation to Interchangeable Components," by Mr. C. A. Gladman, read by Mr. F. H. Rolt. *London Graduates' Section:* Saturday, March 17, 3.30 p.m., Storey's-gate, S.W.1. Annual Lecture: "British Machine Tools During the War," by Mr. A. H. Lloyd. *North-Eastern Branch:* Wednesday, March 21, 6 p.m., Neville Hall, Newcastle-upon-Tyne. "Magnesium Alloy Castings," by Messrs. Fisher and Goddard. *Institution:* Friday, March 23, Storey's-gate, S.W.1. 5 p.m., Benevolent Fund Annual Meeting. 5.30 p.m., Joint Meeting with INSTITUTION OF ELECTRICAL ENGINEERS. "Expanded Tube Joints in Boiler Drums, including Battersea High-Pressure Boilers," by Messrs. W. B. Shannon, C. W. Pratt, T. B. Webb and W. B. Carlson. *Southern Branch:* Friday, March 23, 7.30 p.m., Royal Aircraft Establishment, Farnborough. "Stresses by Analysis and Experiment," by Professor A. J. S. Pippard.

INSTITUTION OF AUTOMOBILE ENGINEERS.—*Western Centre:* Saturday, March 17, 2.30 p.m., Merchant Venturers' College, Bristol. "Light Alloy Pistons," by Messrs. E. B. Graham and C. F. Russell. *Scottish Centre:* Monday, March 19, 7 p.m., 39, Elmbank-crescent, Glasgow. Annual Meeting. "Lighting of Automobiles," by Mr. W. H. Lund. *Coventry Graduates' Branch:* Tuesday, March 20, 7 p.m., Technical College, Coventry. "Constant Speed Airscrews and Units," by Mr. H. G. Webster. *Derby Centre:* Thursday, March 22, 7 p.m., School of Arts, Derby. "Aspin Rotary Combustion Chamber," by Mr. F. M. Aspin.

INSTITUTION OF CHEMICAL ENGINEERS.—*North-Western Branch:* Saturday, March 17, 3 p.m., College of Technology, Manchester. "Removal of Oxides of Sulphur from Exit Gases," by Messrs. J. P. V. Woollam and A. Jackson. *Institution:* Tuesday, March 20, 2.30 p.m., Geological Society, Burlington House, Piccadilly, W.1. Discussion on "Industrial Research."

BRADFORD ENGINEERING SOCIETY.—Monday, March 19, 6.45 p.m., Technical College, Bradford. "Industrial Plastic Mouldings," by Mr. E. M. Elliott.

INSTITUTION OF CIVIL ENGINEERS.—Tuesday, March 20, 5.30 p.m., Great George-street, S.W.1. "Building Acoustics," by Messrs. N. Fleming and W. A. Allen. *Newcastle-upon-Tyne Association:* Tuesday, March 20, 6.15 p.m., Neville Hall, Newcastle-upon-Tyne. "New Quays at South Shields," by Mr. A. L. Harvey. *North-Western Association:* Wednesday, March 21, 6.15 p.m., Engineers' Club, Manchester. Discussion on "Labour in the Constructive Trades," opened by Mr. M. Robinson.

INSTITUTION OF ELECTRICAL ENGINEERS.—*Radio Section:* Tuesday, March 20, 5.30 p.m., Victoria-embankment, W.C.2. Discussion on "Apprenticeship in the Radio Industry," opened by Dr. J. Greig. *North Midland Centre:* Tuesday, March 20, 6 p.m., Great Northern Hotel, Leeds. "Electricity Supply Systems," by Messrs. W. Kidd and E. M. S. McWhirter. *North-Western Centre:* Thursday, March 22, 6 p.m., Town Hall, Chester. "Electrical Aspect of Farm Mechanisation," by Mr. C. A. C. Brown.

ASSOCIATION OF SUPERVISING ELECTRICAL ENGINEERS.—Tuesday, March 20, 6.15 p.m., 2, Savoy-hill, W.C.2. "Electrical Contracting," by Mr. W. H. Brooks.

INSTITUTE OF FUEL.—*North-Western Section:* Wednesday, March 21, 2.30 p.m., Engineers' Club, Manchester. "Industrial Gas Combustion," by Mr. R. Baker.

ROYAL INSTITUTION.—Thursday, March 22, 5.15 p.m., 21, Albemarle-street, W.1. "Some Physical Problems of the Solid State," by Sir Lawrence Bragg.

INSTITUTE OF TRANSPORT.—Thursday, March 22, 5.30 p.m., Institution of Civil Engineers, Great George-street, S.W.1. Twenty-Fifth Anniversary Meeting: Commemorative Address by Sir Cyril Hurcomb.

ROYAL AERONAUTICAL SOCIETY.—Thursday, March 22, 6.30 p.m., Institution of Mechanical Engineers, Storey's-gate, S.W.1. "Hydraulics for Aircraft," by Mr. R. H. Bound.

NORTH-EAST COAST INSTITUTION OF ENGINEERS AND SHIPBUILDERS.—Friday, March 23, 6 p.m., Mining Institute, Newcastle-upon-Tyne. "Marine Screw Propellers and Drag Coefficient," by Dr. G. S. Baker.

JUNIOR INSTITUTION OF ENGINEERS.—Friday, March 23, 6.30 p.m., 39, Victoria-street, S.W.1. "The History of Arch Design," by Mr. S. B. Hamilton.

MANCHESTER ASSOCIATION OF ENGINEERS.—Friday, March 23, 6.30 p.m., Engineers' Club, Manchester. Annual Meeting. "Gear Cutting," by Mr. A. S. Rowley.

THE SHASTA DAM POWER PLANT.

(*For Description, see Page* 201.)

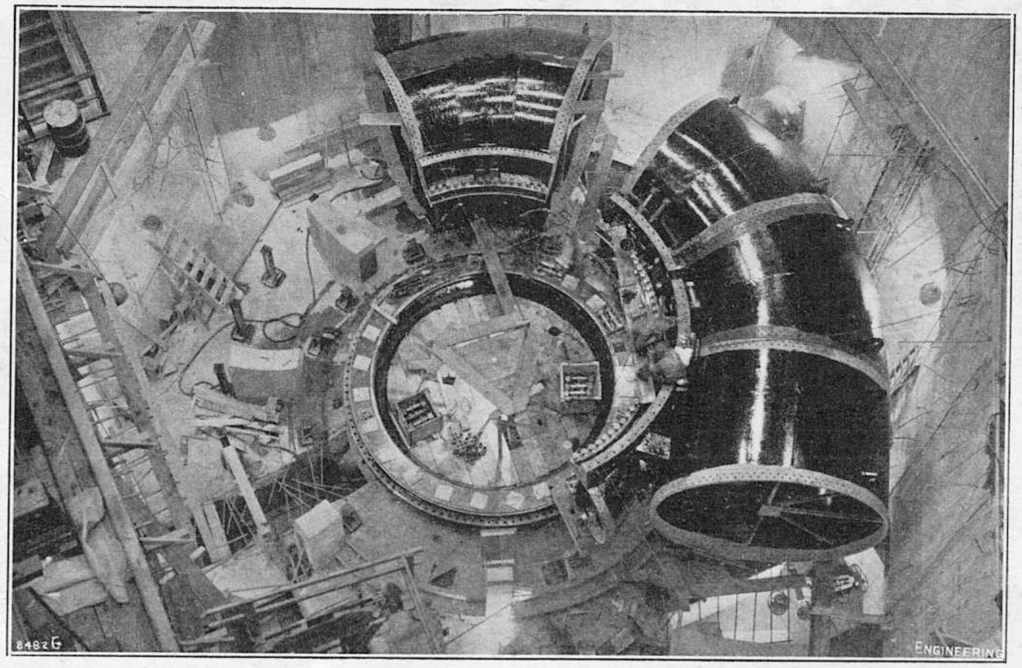


FIG. 18. TURBINE SCROLL CASE BEING ASSEMBLED.

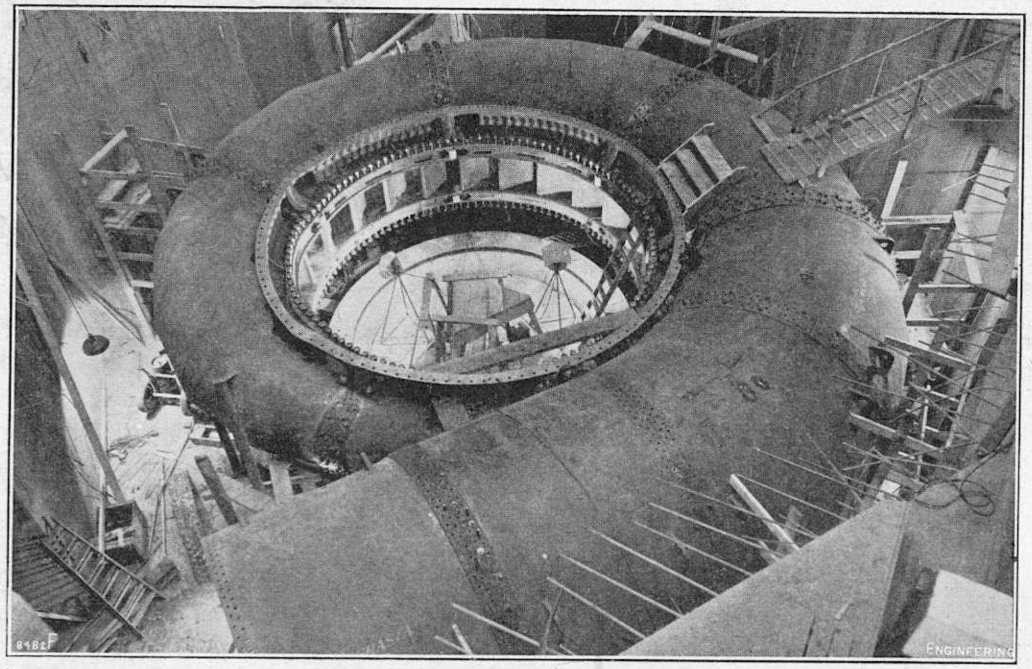


FIG. 19. TURBINE SCROLL CASE SEEN FROM MAIN FLOOR LEVEL.

FIG. 20. GENERATOR ROTOR BEING LOWERED INTO POSITION.

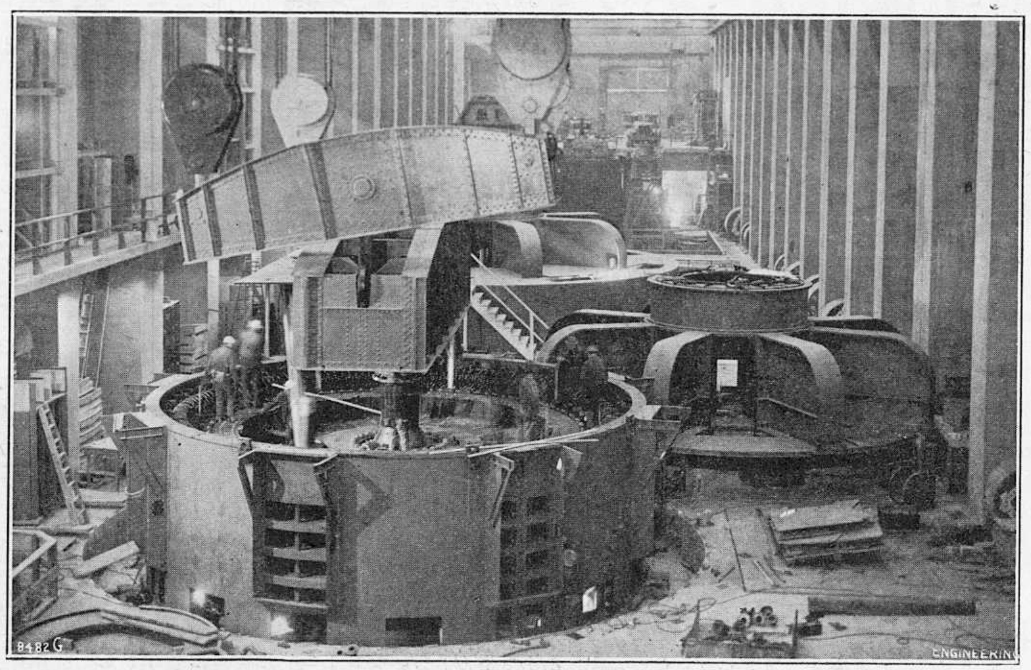


FIG. 21. LOWERING OF GENERATOR ROTOR COMPLETED.

ENGINEERING.

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

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INDEX TO VOL. 158.

The Index to Vol. 158 of ENGINEERING (July-December, 1944) is now ready and will be sent to any reader, without charge and postage paid, on application being made to the Publisher. In order to reduce the consumption of paper, copies of the Index are being distributed only in response to such applications.

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ENGINEERING

FRIDAY, MARCH 16, 1945.

VOL. 159. No. 4131.

SURFACE FINISH.

THE whole-day conference on the subject of surface finish which took place last Friday, March 9, at the Institution of Mechanical Engineers, may be accounted a conspicuous success. Judged either by the number of those who attended it or by the vigorous and constructive character of the discussion, the proceedings evidently supplied a widely appreciated opportunity for engineers and scientists to arrange their ideas and exchange points of view upon a subject in which keenness of interest and diversity of opinion are about equally blended. The scope of the subject itself is as yet far from clearly defined. The original intention of the Manufacture Group of the Institution, by whom the conference was arranged, was doubtless to consider the characteristics of surfaces of engineering components prepared by machining or related operations, but the symposium of 12 papers comprising the core of the proceedings reveals that the state of sub-surface layers and forms of treatment other than the mechanical removal of roughness are inseparably bound up with the physical condition of surfaces and their behaviour in service, while the discussion covered a still wider range of aspects.

The variety of sciences into which the study of surface finish must be regarded as merging is not only an outstanding conclusion to be drawn from the conference, but a clear indication of the general principle that the appraisement of a surface cannot be divorced from the function which the surface is intended to fulfil. It follows that, in general, a surface cannot be defined solely in terms of its roughness. Its physical condition is also important, not only in itself and in relation to the character of its texture, but also with respect to the processes or the sequence of operations by which the final surface is achieved. Acceptance of this principle entails the recognition that purely physical research is fundamentally necessary to enlarge the present state of knowledge, both of the surface and of the manner in which it reacts to a contacting surface and to lubricating substances. One basic factor in surface finish is thus in the molecular, it may be the atomic or even sub-atomic, domain, demanding examination by electron diffraction, and capable of assessment only by such means. Closely associated with this aspect, for practical purposes, are the physical and chemical inter-relations between solids and fluids generally, and between metals and liquid lubricants in particular.

These fundamental considerations do not, however, diminish the need for means of measuring, representing and specifying the degree of roughness in a surface. Such means are essential for the comparison of surfaces produced in different ways, for the control of surface finish under workshop conditions, for the appraisal of surfaces in relation to intended function and the effect of service, and generally for the study of mechanical finishing operations. In view of the absolute size of the imperfections remaining in highly finished surfaces, for which the micro-inch is the unit, it may be reasonably conjectured that measurement in terms of the wavelength of monochromatic light will some day be achieved. The optical methods so far developed are admittedly instructive and have peculiar advantages exemplified by the elegant interference fringe technique described in ENGINEERING* about a year ago; but as a means of representing the shape of a surface in a form and to a scale appropriate for analysis, or for numerical assessment of roughness, they are, according to the majority of experience, inferior to electrically indicating stylus instruments. This is not to imply, however, that the latter have been developed to a stage that can be regarded as final or even satisfactory. Their performance is at best approximate, and their records are so controlled by arbitrary limitations that the same numerical measure of roughness can be obtained from significantly different surface textures, or differing measures yielded by different types of instrument for the same texture.

On account of their commercial importance, surface finishes produced by machine tools have principally attracted the attention of stylus-instrument designers. Characteristically, they exhibit wave forms in complex combination, ranging a million-fold in wavelength, from imperfections which are departures from the correct geometrical shape of the part, down to sub-microscopic details of texture that are below the limit of stylus penetration. To draw any acceptable line of demarcation at a particular wavelength between micro-roughness and macro-roughness is to invite controversy where even a temporary degree of acceptance among instrument makers and users would rather advance than retard the study of surface finishing. The matter is additionally complicated by arbitrary selectivity of the electrical part of the instrument, which not only affects the readings but appears to be capable, with advantage, of being adapted to suit particular characteristics of surface texture. There is therefore a good deal to be said for the standardisation of instruments in respect of selectivity, and for the positive proposal to specify a progressive range of wave-bands to one of which any roughness measure of an instrument must conform.

The measurement of surface waviness must not, however, be disregarded, since it concerns defects which are associated with surface preparation and which with good reason are suspected of exerting, under certain conditions of service, a more important influence upon performance than that of micro-texture. It calls for a separate, and in many respects different, instrument and technique, so that the combination of the two measures into a unique numerical appraisement obviously presents great difficulty. Although, therefore, the designation of a requisite surface finish, as part of the specification included in an engineering drawing, is feasible when a known individual instrument is to be used for controlling the workshop product, the general or rational specification of surface finish, which must precede any useful or acceptable degree of standardisation, appears to conflict with existing practical methods of measurement. In connection with the specification, the production and the function of a finished surface, a further point of practical importance is the direction of the various types of roughness relative to the geometry of the component as a whole. It suggests—as seems evident from other considerations—that the complete assessment of any surface finish must be based on measurements in more than one direction in the surface.

* ENGINEERING, vol. 157, page 251 (1944).

Pre-occupation with extremely smooth prepared surfaces has led to the neglect of coarse distributed roughness, such as occurs on castings and surfaces which are painted, plated, shot-peened, corroded, fretted or abraded. In these and other conditions, there is no prevailing direction of machine-made irregularities, and the appraisal of roughness, when it comes to be undertaken, will call for methods, and perhaps principles, of measurement differing from those hitherto developed.

Closer consideration of such relatively large scale surface roughness is warranted by the striking effects which it may exert on fatigue strength, and hence, indirectly, on the performance of engineering structures in service. This aspect of the subject, as is well known, has received a great deal of attention; but while its general importance is recognised there remain many points of detail, notably associated with secondary influences of the structure and composition of steel, and of localised residual stresses imparted by machining processes, which need further investigation. The effects of surface finish upon the behaviour of force fits, especially in circumstances where the fit introduces critical concentration of stress, is also not completely understood. The evidence disclosed at the conference points, in the main, to the conclusion that control of surface finish can be made to contribute to improved performance. Thus, the degree of roughness imparted to aircraft surfaces by camouflage paint was reported to have a decided effect upon the maximum attainable flying speed. On the other hand, a case was mentioned where no significant improvement had been achieved by refining the surfaces of steam turbine blades. In these cases, the phenomena are governed not merely by the state of the surface, but also by the complexities of fluid mechanics, and similar considerations apply to the attractive possibilities of reducing the resistance of ships, high-speed vehicles, and solid boundaries of every sort in contact with moving fluids.

Herein, perhaps, lies some part of the explanation of reported failures to increase the performance of hydraulic machines by improvements of surface finish; but the matter goes farther than the production of an original surface on a new machine, and is qualified in many branches of engineering by the effects of exacting service conditions throughout a long life, which determine the predominant type of surface and the corresponding performance. Especially in the case of robust machines, designed primarily for reliability under unpredictable contingencies and to withstand unavoidable factors detrimental to the maintenance of good surfaces, the cost of refined workshop operations can more than outweigh their probable benefits. For engineering components of large size, where interchangeability in production is not material, the economic aspects of surface finish are obviously critical, while solely from the technical standpoint the large-scale geometry of the machining is of such importance that moderately rough surfaces, which will wear to fit more readily than smooth ones, can be advantageous. On the other hand, there is abundant evidence that under certain conditions of operation, and usually in the case of small-sized parts, an initially defective surface is not self-rectifying, and that refined surface texture can be far more valuable than extreme precision of geometrical contour.

This further example of the fundamental connection between the appraisal of finish and the function required of the surface suggests that methods of measurement in terms of the effects on performance should supplement—in certain circumstances, perhaps replace—the instrumental means of surface analysis now being actively developed. The suggestion is the more pertinent in that it bears closely on the operations employed for producing fine surface finishes. In this connection, the texture and other characteristics of the cutting tools, abrading and polishing agents themselves, as well as the cutting fluids and the whole technology of achieving fine surfaces by succession of processes, assume a degree of importance that is not always sufficiently appreciated; and they should certainly be included among the numerous subjects upon which further research must be actively pursued.

THE CANADIAN POWER POSITION.

At the termination of the two conflicts, the industrial developments which have been rendered necessary by the demands for war supplies may leave situations of considerable difficulty in many countries. Even now, with war demands apparently past their peak, some of the earlier questions of readjustment are demanding attention. Canada may be quoted as an example of a country which has increased enormously its industrial capacity during the war. The total developed water power of the Dominion at the end of the year 1944 amounted to 10,283,213 h.p., and of this one-fifth, or 2,000,000 h.p., has been added during the last five years, almost wholly for war purposes. This figure is not to be taken as a measure of the contribution which the hydro-electric installations of Canada have made to the war effort. Actually one-third of the output has been employed in war production and a single industry, that of the production of aluminium, at its peak production, was using 25 per cent. of all hydro-electric energy consumed in the country. That the present year may be marked by a decline in the total demand is suggested by the fact that figures compiled by the Dominion Bureau of Statistics show that during the first 10 months of 1944 the consumption exceeded that of the corresponding months of the previous year by less than 1 per cent., and that for the months of June to September the production was actually less in 1944 than in 1943. To some extent, the falling off in these months was due to seasonal water shortage in certain districts, but the Dominion Water and Power Bureau consider that it also reflects the beginning of readjustments in the manufacture of war material.

The most striking example of Canadian industrial war development is furnished by the great aluminium extraction plant at Arvida, in the Province of Quebec. This town is situated on the Saguenay River which flows into the St. Lawrence below the city of Quebec. The plant is the largest of its type in the world, and is supplied with electrical energy from the Shipshau generating station of the Aluminium Power Company and from the station of the associated Saguenay Power Company. The Shipshau station has an installed capacity of 1,020,000 h.p., which is almost double that of the next largest Canadian power station. As a result of the operation of the Arvida and other plants, all of which are situated in Quebec, the peak war-time production of aluminium in Canada was six times greater than it was in 1939. It will be remembered that in the first year of the war, there was a serious shortage of aluminium in this country and that an appeal had to be made for the surrender even of domestic utensils. That state of affairs is long past and as a result of the Canadian developments, and others elsewhere, there is now a surplus rather than a shortage. It appears possible that the huge war demand will not be maintained in normal peace time which, in the words of the Dominion Water and Power Bureau, "may lead to a large power surplus centred in the Saguenay River district."

Although Quebec contains 56 per cent. of the developed water-power sites in Canada, it is not the major manufacturing Province; that distinction is held by Ontario. This circumstance may lead to a difficult financial situation in the future if the decline in war demands results in a condition in which large power resources are unable to find an adequate market for their output. The Dominion Water and Power Bureau, in its annual review, *Hydro-Electric Progress in Canada during* 1944, points out that this situation may arise "unless new uses for aluminium and adequate post-war export markets enable this Canadian industry to maintain operations at a high level or other large power-consuming industries are attracted to the area." In present circumstances, with their formidable array of unknowns, long-term speculations about the future of industry in any country are not likely to be profitable, but in view of the unparalleled material destruction which has taken place, and is still continuing, it seems reasonably probable that the Canadian aluminium industry, in common with all other producers of useful commodities, may expect the demand to be maintained over a considerable period, with gradual adjustment of means to ends. A sudden failure of market demands seems unlikely, but it is possible that a difficult period of readjustment will have to be faced before reconstruction requirements result in large orders.

The power situation in Canada is by no means of interest only from the point of view of the production of aluminium; manufacturing activities of many kinds have been developed, or introduced, during the war. In British Columbia, for instance, great extension has taken place in shipbuilding and other engineering activities, and the hydro-electric developments which have been undertaken to meet the increased power demand must be expected to have a permanent influence on the industrial status of the Province. Apparently a falling-off in demand is not imminent in British Columbia, and the annual review records the starting up of the power station at Brilliant, on the Kootenay River, by the West Kootenay Power and Light Company. The present installation consists of two 34,000-h.p. units, and their total of 68,000 h.p. represents, within 700 h.p., the whole hydro-electric generating capacity added in Canada during 1944. There are now five stations on the Kootenay River, of a total installed capacity of 346,000 h.p.

Although no new generating plant was brought into operation in Ontario, the Hydro-Electric Power Commission has not ceased its extension programme, and the installation of a further 19,000-h.p. unit at the Alexander Station on the Nipigon River was started. It is expected that this machine will be in operation in July of this year; it will bring the rated capacity of the station to 73,000 h.p. The further extension of the harnessed water-power capacity of Ontario, and, indeed, of the whole of Canada, does not depend entirely on the retention or extension of the level of industrial activity which has been attained as a result of the war. General public supply, and particularly the further development of rural services, are important factors. The continuing progress in these fields is illustrated by the fact that, in 1944, the Hydro-Electric Power Commission of Ontario built 460 miles of rural distribution lines and now has a total of 21,137 miles of such lines in service. Corresponding progress can be reported for other provinces. In Quebec, the Shawinigan Water and Power Company "undertook important extensions to its rural electrification system," and on the Southern Canada Power Company's system, "rural line extensions bringing electric service to farm customers has proceeded at an unusual rate." In Alberta, the Calgary Power Company and Canadian Utilities, Limited, undertook the supply of power to three selected rural areas to determine the feasibility of more general rural service. The Calgary Company's area comprises 104 farms, and those served by Canadian Utilities, 80 farms. In Manitoba, 325 farms were connected to the transmission lines of the Manitoba Power Commission.

As is usual in these annual reports, there is some reference to the operation of steam stations situated in parts of Canada in which water power is non-existent, or are present only on a small scale. The operation of the Vancouver steam station of the British Columbia Electric Railway Company from December, 1943, to November, 1944, was not, however, an example of normal reliance on steam power; it was due to unusual, but persistent, water shortage. In addition to the operation of the Vancouver steam station, the situation was met by establishing a connection with the lines of the Puget Sound Power and Light Company in the State of Washington. In the Maritime Provinces, reliance has always to be placed mainly on steam stations and two developments took place during the year. The Nova Scotia Light and Power Company added a 10,000-kW steam turbine set to its Halifax plant; the company has a water-power station in addition to the thermal plant at Halifax, but as 1944 was unusually dry, the new steam set proved of great assistance. An entirely new steam station was put in hand by the Nova Scotia Power Commission. This is situated at Inverness on Cape Breton Island. Connection with the Nova Scotia eastern transmission system will be made by a submarine cable across the Strait of Canso.

NOTES.

BRITISH CIVIL AIR TRANSPORT.

THE long-awaited statement of Government policy for the future of commercial aviation was published on March 13 in the form of a White Paper entitled "British Air Transport" (Cmd. 6605: H.M. Stationery Office, price 2*d.* net). While not abandoning the preference for a "chosen instrument" rather than free competition on air routes, it proposes the creation of three operating corporations, only one of which—that intended to handle Empire and North Atlantic traffic—will be assigned to the British Overseas Airways Corporation as the dominant partner. The principles which have guided the formulation of the stated policy are that the units must be large enough to operate economically, but not so large as to preclude effective supervision along every route; that each unit must have an efficient organisation to handle passengers, freight and mail over every area served by its lines, with expert knowledge of transportation, and facilities for co-operation with other forms of transport; that provision must be made for the economical use and maintenance of aircraft; that the most effective arrangements must be made for the training and welfare of air crews and ground staff; that there must be close co-operation between the users and the manufacturers in selecting types of aircraft; and that the organisation should be capable of training crews for Commonwealth or foreign countries and should be able to supply those countries with technical and operational help, where required. With these considerations in view, it is proposed to set up the three corporations indicated: one to deal with Empire and North Atlantic routes and with subsequent extensions of these routes to China and the Far East, the second to cover the European air routes and the internal services of the United Kingdom, and the third to deal with the South American route. The first-mentioned corporation, as stated above, would be controlled by the B.O.A.C., but opportunity would be provided for shipping lines, interested in Empire and North Atlantic traffic, to associate themselves with both the financing and the direction of the corporation. The second organisation would be a joint undertaking in which the railway companies, short-sea shipping lines, travel agencies and the B.O.A.C. would collaborate, together with such pre-war operators in this field as might desire to participate also. The third corporation would be controlled principally by the British shipping lines operating services to South America, with the B.O.A.C. taking a minor share in the capital and management. The three corporations would join in a combined organisation for the overhaul of aircraft. The general policy of the Government is that both the internal and the external air services of the corporations should operate as far as possible without subsidies. The Postmaster General is stated to be considering the best use which can be made of the proposed services for the carriage of mails.

THE INSTITUTE OF MARINE ENGINEERS.

THE annual luncheon of the Institute of Marine Engineers, preceded by the annual general meeting, took place on Friday, March 9, the chair being occupied by the newly-elected president, Sir William C. Currie. The annual report shows a marked increase in membership and the decline evident in the first three years of the war has been fully made up. The total names on the roll on December 31, 1944, was 4,483, compared with the 4,231 on the same day of 1943. A gratifying feature has been the admission to student membership of a considerable number of junior engineer officers of the Royal Navy on passing out of the Engineering College at Devonport. The only honorary member elected was the Right Hon. A. V. Alexander, C.H., M.P., the First Lord of the Admiralty. The finances of the Institute are also in a satisfactory condition, the income of 10,603*l.* for the year ended December 31, 1944, enabling 679*l.* to be carried to the balance sheet as unexpended. The library and reading room at the headquarters in the Minories have been in daily use, but the office staff still remain at High Wycombe. The Council, having been informed that the Institute building will have to be demolished when the post-war reconstruction of the City is carried out, decided at a special meeting held in January that the site of the new building should be somewhere in the heart of the shipping community between the Bank of England and Aldgate. Definite proposals will be announced later; but the work in connection with the National Certificates in Mechanical Engineering, with Special Reference to Marine Engineering, has been continued, and essay competitions open to members of any grade have been resumed. At the luncheon, which was held at the Connaught Rooms, London, the toast of "The Lord Mayor and Corporation of London" was proposed by Sir James Lithgow, Bt., Controller of Merchant Shipbuilding and Repairs, and acknowledged by the Lord Mayor, Alderman Sir Frank S. Alexander. This was followed by the toast, "The Institute of Marine Engineers," proposed by Alderman Sir George T. Broadbridge, Bt., and responded to by the president, Sir William C. Currie. The final toast, that of "The Guests," was proposed by the honorary treasurer of the Institute, Mr. Alfred Robertson, and was replied to by Vice-Admiral Sir W. F. Wake-Walker, K.C.B., Third Sea Lord and Controller of the Navy. Admiral Emory S. Land, United States Administrator of War Shipping, added a brief reply with particular reference to the guests from Allied nations, of whom there were a considerable number.

THE LONDON PASSENGER TRANSPORT BOARD.

The report of the London Passenger Transport Board on their operations during the year ended December 31, 1944, covers a good deal more than the maintenance of transport services in the London area, as some particulars are given of the considerable amount of war work undertaken for the Ministry of Aircraft Production and other departments. This includes the production of parts for Halifax bombers, the adaptation of tanks for various special purposes, the overhaul of tanks and War Department vehicles, the manufacture of torpedo sight equipment for aircraft, and the supply and repair of numerous other components, unspecified. Meanwhile, in spite of shortage of labour and restrictions on the supply of fuel and rubber, essential transport services were well maintained, considering the conditions; although added difficulty was experienced as a result of strikes on parts of the system, persisted in despite the fact that they were not supported by the trade union executives concerned. The load on the system was eased to some extent by the collaboration of employers and employees in staggering their working hours so as to obtain a more regular flow of traffic during peak periods, and the Board, considering that there is a wider scope for this policy, commend it to the notice of those concerned with staff welfare. Steps taken in the direction of post-war planning include the appointment of a Railway (London Plan) Committee to report upon the technical and operational aspects of the County of London Plan, 1943; and consideration, in conjunction with the main-line railways, of the programme of new construction which was interrupted by the outbreak of the war in 1939. It is recognised, the report states, that the outstanding works under the New Works Pro-Programme, 1935-40, must be proceeded with as soon as circumstances permit, and that close consultation will be necessary with the planning authorities in the development of the various schemes for town and country planning, housing, and the distribution of industry.

THE ENGINEERING INDUSTRIES ASSOCIATION.

In order to present a report, by Mr. Ronald Chapman, A.R.I.B.A., and Mr. Raymond Perry, entitled "The Engineering Industries and the Building Programme," the Engineering Industries Association held an informal luncheon and discussion on March 13, 1945, at the Savoy Hotel, London, W.C.2. In the absence of the President, Viscount Davidson, Mr. E. C. Gordon England introduced the report, which outlined the contribution that the engineering industry as a whole might make to the solution of the housing problem. While there was the possibility that the engineering industries that had been expanded to meet the war-time needs of the nation might soon be faced with a catastrophic decline of work, it was certain that the building industry would be unable, by itself, to carry the whole burden of post-war housing construction, unless its personnel were to be increased far beyond the normal, or long-term, requirements for building operatives. The Association proposed that the engineering industry should offer to co-operate with the building industry by developing designs for houses, or component parts of houses, that could be manufactured on a quantity basis, with the aid of the manufacturing resources already in existence and in working order. It was not intended that the engineering industry should compete with the building industry, but that the two should unite to face a situation that was fraught with difficulties for both. The report contained some sketch designs of bathrooms and kitchens built as prefabricated units, and it was proposed to use metal, wood or plastic materials in any forms that were at the same time functionally satisfactory and in sufficient supply. The opportunity was to be taken to reconsider existing designs of houses and household equipment to see whether the new and more flexible methods of construction offered by the engineering industry would permit any basic improvements to be made. Mr. Gordon England said that the report had been drawn up after discussions with building interests and with a number of trades unions. The ideas it set forth had been well received on the whole.

THE ASSOCIATION OF SUPERVISING ELECTRICAL ENGINEERS.

The importance of the work of the Association of Supervising Electrical Engineers to the war industries was emphasised by several speakers at the annual luncheon of the Association, held at the Connaught Rooms, London, on Saturday, March 10. The chair was occupied by the president, Mr. E. R. Wilkinson, M.I.E.E., who, in proposing the toast of "The Guests," observed that, though current had had to be provided for a variety of new factories, etc., the demand should prove to be small compared with that likely to occur in peace time. He referred to the potentialities of hydro-electric stations, such as the Severn Barrage scheme, but concluded that, in this country, efficiency in coal production was the key to power generation in bulk. The toast was responded to by Mr. A. T. Lennox-Boyd, M.P., Parliamentary Secretary, Ministry of Aircraft Production, who paid a tribute to the services of the Association. There had been demands for power dictated by strategic considerations which had been satisfactorily met, he said, but the electrical industry had never failed the aircraft industry. The future would be marked by great advances in air power. As an illustration, he mentioned the new aeronautical research station to be built by the Government near Bedford, the details of which were being worked out. There would be several wind-tunnels of 40,000 h.p., each ten times larger than the largest at present in this country, and eventually one of 100,000 h.p. The power station required for operating them would be about two-thirds the size of that at Battersea. The existing research centre at Farnborough would be thus displaced, but it would take about 10 years to complete the whole scheme. It was imperative that we should never again be caught unawares, and novel and revolutionary forms of aircraft with higher speeds and loadings were in contemplation. The next toast, that of "The Electrical Industry," was proposed by Dr. C. H. Clarke, O.B.E., director of Lever Brothers and Unilever, Limited, who spoke as a consumer of electric power. He was of opinion that the recovery of export trade would be influenced by the rate at which industry was electrified. At present, that rate was too low, and the Association could help by appropriate education in this respect. Sir Cyril Hurcomb, K.C.B., K.B.E., Director-General, Ministry of War Transport, responded. The final toast, "The Association," was proposed by Sir Arthur P. M. Fleming, C.B.E., M.Sc., M.I.E.E., President of the British Electrical and Allied Industries Research Association, and wa responded to by the chairman of the Association Supervising Electrical Engineers, Mr. J. Flood.

LETTERS TO THE EDITOR.

JUBILEE OF WIRELESS COMMUNICATION.

To the Editor of Engineering.

Sir,—With reference to the record of 50 years of wireless communication reported on page 173, *ante*, your readers may be interested in the story of the first commercial wireless message, transmitted and paid for in August, 1897. At that time, Marconi's experimental system was working between the Needles Hotel at Alum Bay, Isle of Wight, and Bournemouth, and the reception (in Morse) was occasionally badly interfered with by atmospherics.

One afternoon, Marconi, at the Needles Hotel, asked me to deliver this message to the Royal Exeter Hotel, Bournemouth: "Shall be back for dinner at seven o'clock tonight. Signed . . ." Atmospherics were particularly bad that afternoon and I could make nothing of the signature. After asking Marconi several times to repeat it, I came to the conclusion it was a three-letter or four-letter word and that the second letter was "y," so I sent: "O.K." Marconi finished the transmission with: "It's most important. The sender has paid me half-a-crown for the message."

The only thing I could do was to go to the Royal Exeter Hotel and study the visitors' register, where I found that there was a visitor named Eyre; so I completed and delivered the telegram accordingly and, as it proved, correctly. The last time I saw Marconi, we had a good laugh about this incident.

Yours faithfully,
W. R. Elliott,
Secretary to the Council.

Electrical Research Association,
15, Savoy-street, London, W.C.2.
March 7, 1945.

SOUND INSULATION IN BUILDINGS.

To the Editor of Engineering.

Sir,—I am directed by my Committee to draw your attention to the article headed "Sound Insulation in Buildings," appearing on page 12, *ante*, in your issue for January 5, on Post-War Building Study No. 14, *Sound Insulation and Acoustics*, which is a report by the Acoustics Committee of the Building Research Board of the Department of Scientific and Industrial Research.

At the end of the second paragraph of the article, the following sentences occur: "An interesting detail point mentioned . . . concerns the deterioration in sound insulation in modern house property as compared with older structures of this type, and which is normally attributed to greater flimsiness of construction. It is suggested that one cause of this is the use of fibre-board in place of lath and plaster for ceiling construction."

In the report, however (paragraph 2), the reasons why buildings are noisier now are described as, on the one hand, an increase in noise sources (*e.g.*, wireless), and, on the other, the trend of modern construction "towards a greater continuity, lightness and engineering efficiency which leads to the easier transmission of sound." This dual responsibility for the worsened conditions is emphasised by repetition in paragraph 103.

Appendix II of *Sound Insulation and Acoustics* reviews the main points which have emerged from a study of timber floors by the Department of Scientific and Industrial Research. Paragraphs 323 and 324 are as follows:—

"323. Comparisons were made between lath and plaster, plasterboard, and fibreboard as a ceiling membrane. The results are of some importance. The lath and plaster ceiling was, for air-borne sounds, superior to either of the others and especially to the plasterboard by about 10 db., though the difference was not very marked for impact sounds.

324. The observations concerning plasterboard would appear to be an explanation of the deterioration in sound insulation in pre-war housing, normally attributed to the flimsiness of the construction as compared with older work."

After reading the above, it will probably appear to you—as it does to my Committee—that the author of your article has given an erroneous impression of the results of using the products of the fibre building-board industry. Perhaps I should add, in case there is any doubt on this point, that plasterboard and fibreboards are entirely distinct and different materials.

It is becoming more widely appreciated, and is emphasised in Building Study No. 14, that there is a very close connection between methods of construction and sound insulation, the materials employed being relatively of secondary importance. This being the case, it will be appreciated that a material such as ½-in. fibre board, weighing only 0·75 lb. per square foot, but having (as mentioned in your article) a sound insulation value against air-borne sound of 25 decibels as against the 50 decibels of a 9-in. brick wall weighing 110 lb. per square foot, can, in conjunction with proper structural design, be of considerable service in sound resistant construction. This is particularly true when use is made of the plaster bond qualities of insulating board, to apply a plaster finish where appropriate.

Yours faithfully,
Major W. F. Dawson,
Secretary.

Building Boards Joint Committee,
Melbourne House, London, W.C.2.
March 6, 1945.

OBITUARY.

SIR GEORGE HUMPHREYS, K.B.E.

It is with regret that we record the death of Sir George Humphreys, which occurred in a nursing home in London on March 9. George William Humphreys, who served as chief engineer to the London County Council for 18 years, was the son of the late Thomas William Humphreys and was born on December 7, 1863. He received his education at Mill Hill School and at King's College, and in the beginning of 1884 was apprenticed to Messrs. Griffiths and Hulett. While with them he set out the work and assisted in the construction of the Bodmin branch of the Great Western Railway, under the direction of Mr. J. C. Inglis, M.Inst.C.E. In October, 1885, Humphreys became engineering assistant to Mr. Woodman Hill, and during the subsequent five years was engaged in the construction of fortifications and harbour works at Shoeburyness, Sheerness, Harwich, Greenock, and elsewhere. In 1890, he was given charge of the harbour works at the French port of La Pallice, and, under the direction of Messrs. Tschokke and Terrier, of Paris, designed the appliances used and completed the deep-water entrance to the port. On the completion of these works in 1892, he supervised the construction of a small harbour at Inchkeith, Firth of Forth.

In December, 1894, he was placed in sole charge of works undertaken, for the Admiralty, for deepening the approaches to Hamoaze, Plymouth, necessitating the removal of nearly a million tons of rock below sea level. He designed the plant needed, and superintended the operations. Humphreys was subsequently in charge of harbour deepening operations at Holyhead. In July, 1902, he was appointed manager of works to the London County Council, having been selected from 105 candidates who applied for the position. When the works department was discontinued in 1910, he was transferred to the chief engineer's department, and, in March, 1912, was appointed deputy chief engineer. On January 1, 1913, Humphreys succeeded the late Sir Maurice FitzMaurice as chief engineer and county surveyor, and held this position until his retirement on November 30, 1930. During his tenure of office, considerable development took place in the construction of sewers, storm-relief sewers, and pumping plant. In 1920, he was appointed administrator of the Council's housing development schemes in various London suburbs, and, in 1921, became a member of the Commission entrusted with the preservation of St. Paul's Cathedral. For his work in this and other directions, the K.B.E. was conferred upon him in June, 1927. Following the exceptionally high tide in the Thames on January 7, 1928, which was attended by extensive flooding and loss of life, Sir George was asked to investigate, in conjunction with Sir Frederick Palmer, the adequacy of the prescribed height for river defences in London. As a result, the defence works were raised in progressive steps, throughout the County from east to west. Sir George became a member of the Institution of Civil Engineers in 1899, and was elected President in 1930. He was also a Chevalier of the Legion of Honour.

ENGINEER REAR-ADMIRAL E. GAUDIN, C.B.

The death on March 8, in his 80th year, of Engineer Rear-Admiral Edouard Gaudin, C.B., recalls one of the most famous controversies which have been associated with the Royal Navy since the application of steam propulsion to warships; namely, the so-called "Battle of the Boilers" which resulted, in the early years of the present century, in the adoption of water-tube boilers in the heavier classes of His Majesty's ships. It was on the strength of a report by Gaudin, then a young officer holding the rank of engineer, that the decision was taken to fit Belleville boilers, which had been in use for some time in the French Navy; and it was his experience and skill in the development of the naval water-tube boiler which particularly marked his subsequent career.

Edouard Gaudin was a native of Guernsey, and entered Devonport Dockyard at the age of 15. In the same year, 1880, he had the distinction of being the first entry in the new Royal Naval Engineering College at Keyham. Subsequently, after being gazetted assistant engineer in 1886, he studied at the Royal Naval College and, in 1888, was appointed to the second-class cruiser Raleigh. Promotion to the rank of engineer followed in 1890. In 1892, Sir William White visited various French naval stations and, on his return, reported to the Admiralty that the French had decided that water-tube boilers should be used in naval vessels. An improved form of the Belleville boiler was being used in French merchant ships, and the British Admiralty arranged for an officer to make a voyage in one of these ships to study the working of the boilers. Gaudin, who was one of the only two engineer officers who were qualified at that time as interpreters in French, was selected for this duty, went to Australia and back in a ship of the Messageries Maritimes, and reported favourably on the boilers.

Thenceforward, his naval service was almost wholly concerned with water-tube boilered ships. He was appointed to the gunboat Speedy in 1892, to the destroyer Zebra in 1894, and in 1895 to the President, "for service with new torpedo-boat destroyers." In May, 1897, he was promoted to chief engineer, and in the following year went to sea again in the destroyer Stag. In 1899, he was appointed to the cruiser Spartiate, with Belleville boilers, and in 1903 (by which time he had become engineer commander) to the Good Hope, similarly boilered. In 1905 he was attached to the Naval Intelligence Department, where he served until 1909, returning to sea in that year in the battleship Dreadnought. He was gazetted engineer captain in 1911, and from then onwards served at the Admiralty. For a time, he was in the department of the Director of Naval Equipment and also, for a period, was an engineer overseer; but he became most widely known among marine engineers when, shortly before the 1914-18 war, he became Assistant Engineer-in-Chief under the late Sir Henry Oram. When, in 1917, Sir Henry was succeeded as Engineer-in-Chief by Engineer Vice-Admiral Sir George Goodwin, Gaudin succeeded Goodwin as Deputy and continued in that position until his retirement, which, as stated above, took place in 1920. Admiral Gaudin took little part in engineering activities outside of his immediate work, and, few references to him are to be found in the transactions of technical societies; but he was held in high regard as an engineer by all who had dealings with him, and, will be remembered, in particular, as one who exerted considerable influence in promoting the high standard of efficiency and sustained performance in naval engineering to which so many flag officers paid tribute during the war of 1914-18.

SYMPOSIUM ON SURFACE FINISH.*

THE STRUCTURE OF SLIDING SURFACES.†

By PROFESSOR G. I. FINCH, M.B.E., F.R.S.

THE state of a surface can be described in terms of its texture and structure. Texture comprises geographical features such as ridges and valleys, pits and peaks, crystal outlines, etc., while structure is determined by the nature and arrangement of the atoms. The importance to the engineer of the macroscopic and microscopic features of surface texture and structure are now well recognised, and profilometry and microscopy have become routine techniques in fine mechanical engineering; furthermore, experience gained in the effect of surface finish on mechanical wear, corrosion, adhesion and such like surface properties, points with increasing emphasis to the importance of the roles played by the submicroscopic texture and fine structure of surfaces.

Direct access to these submicroscopic domains first became possible through the experimental discovery that moving electrons, long known to be easily stopped by matter, interact with it as if guided by systems of waves of wavelength determined by the electronic kinetic energy. A beam of electrons with a speed of the order of half that of light is easily produced and has an even shorter associated wavelength than the X-rays commonly used in the analysis of bulk structure. Unlike X-rays, electron beams, being streams of charged particles, can be deflected by electrostatic or magnetic fields; thus the diffracted rays into which an electron beam is split on impinging on matter can either be reassembled into a greatly enlarged image to reveal textural details of a fineness approaching that of the atomic spacing in crystals (electron microscopy), or the directions of the diffracted beams can be recorded, as in X-ray diffraction analysis. The resulting diffraction pattern reflects the degree and nature of the order in which scattering centres are arranged. These scattering centres are the atoms, their distance apart in any orderly arrangement being comparable with the wavelength of the diffracted electron waves.

Owing to the short wavelength and the extremely high energy of the electron beam, many times that associated with the normal X-ray or light beam, electron lenses of small aperture can be used, thus eliminating most of the difficulties associated with optical microscopy. Monochromatisation of the beam is also not difficult. The most serious limitation in the application of electron microscopy is that it is confined, for the time being, to the examination of films thin enough to transmit the electron beam. Thin films can, however, be cast on metallic surfaces and examined as replicas after stripping, with results which have already proved of considerable value.

Electron diffraction is less limited in its application. Thin films can be examined by transmission, and the surfaces of solid specimens, too thick to be penetrated by the electron beam, can be examined at grazing incidence. Owing to the low penetrating powers of the beam, the information afforded by electron diffraction is confined to a few atom layers at the surface of the material. It is precisely this circumstance which renders electron diffraction invaluable in the study of surface structure, which can, and often does, differ greatly from that of the underlying bulk structure as revealed by X-rays.

The degree of orderly complexity of the electron diffraction pattern is determined by the orderliness of the arrangement of the atoms in the surface; thus a liquid surface, in which the chief feature of order is the mean distance apart of the atoms, gives a pattern consisting only of a few diffuse broad haloes. With incipient crystal growth and increasing orderly arrangement of the crystallites, the pattern features show a corresponding increase in symmetry, precision, and wealth of significant detail. With a polycrystalline surface, the haloes characteristic of amorphous matter narrow down into rings, the dimensions and sharpness of which depend on the atomic arrangement and crystal size, respectively, and eventually the rings break up into sharply defined spots as the crystals attain to microscopic dimensions. When the crystals are orientated, the rings may either break up into arcs or undergo significant changes in their relative intensities, until finally, with a single crystal, the ring or arc pattern is replaced by an arrangement of spots, the symmetry of which reflects that of the completely ordered atomic arrangement in the single crystal as viewed by the incident electron beam.

Sliding surfaces are meant to be kept apart by the lubricant, and, if this were achieved in practice, wear, apart from corrosion, would hardly occur. The trend in mechanical engineering to-day, however, is to take such full and swift advantage of any advance in surface finish or lubrication that attention has become focused mainly on boundary conditions of lubrication and particularly on their breakdown and its consequences. The root cause of breakdown is texture, which is responsible for an uneven load distribution and for local weakening of the boundary oil film at precisely those spots where the loading tends to be excessive. With the tendency towards increased loading, it is unlikely that improvements in surface finish and lubrication will ever quite eliminate breakdown; thus breakdown has to be accepted and the plan must be to understand the nature of the resulting surface changes, and, in the light of such knowledge, to take steps to suppress harmful breakdown effects and promote those conducive to low friction and wear. Electron diffraction has thrown fresh light on these problems.

When breakdown occurs, the sliding surfaces are subjected to a mutual polishing or burnishing process which does not consist of a mere wearing away of high spots. It is now known that the "run-in" metallic surface is an amorphous glass-like layer formed by the congealing of metal softened, or even liquefied, and caused to flow into the valleys by high local frictional temperatures and pressures exerted at high spots; thus polishing not only results in textural changes, but also in a profound and important change in structure. Not all the flowed metal adheres to the surface; some is lost and thus contributes to wear. Other things being equal, this loss seems to be connected with the distance which the metal must flow before finding a lodgment. It has been found that the direction of a sliding motion in relation to that of the scratches left by the finishing process has an important bearing on the running-in of a surface. If the scratches lie at right-angles to the sliding motion, wear is at a minimum, for the flowed layer formed on the ridges can settle immediately into adjacent valleys and fill them up; but when the scratches and sliding motion have the same direction, the flowed material may travel far enough to solidify and cool before it has a chance to adhere to the substrate, and thus remains in the oil to be carried away as detritus. In either case, when running-in is completed, the subsequent behaviour of the surfaces is similar, but in the first case the final fit is closer than in the second.

The pre-history of surface finish can have a more profound and permanent effect upon wear than the final finish. If the pre-history process has broken up the crystal structure and thus hardened and toughened the material to a considerable depth below the surface, excessive wear can occur. Welds formed between areas of flowed material on the sliding surfaces no longer shear in or near the plane of sliding, but may yield only in some deeper region near the junction of the disturbed and undisturbed crystal layers. Excessive scoring and heavy wear may be the result even though, when judged by profilometry or the microscope, the original surface finish had appeared unexceptionable.

The formation of an amorphous flowed layer is not the only structural change which sliding, under the severe conditions usual to-day, may induce. On a cast-iron surface, three distinct structural changes have been observed. The first consists of the spreading over the surface of thin crystalline sheets of graphite which come from inclusions opened up by wear. The graphite crystals are orientated with their slip planes parallel to the surface and therefore can act as a boundary layer of solid, pressure-resisting lubricant during temporary breakdown of the normal oil film. Beneath the graphite layer, the normal amorphous metallic flowed layer can be recognised; and this, in turn, is generally seen to be covered by an exceedingly thin and optically quite invisible oxide layer which is either amorphous or consists of very small crystals.

An oxide layer can be detected on most "run-in" surfaces. Especially in the case of ferrous metals, the nature of this oxide may play a most important role in mitigating the effects of breakdown. In this case, when punctured as a result of excessive loading, the oxide film seems to "neck" the weld formed between the sliding surfaces and thus facilitates the rupture of the weld in the plane of sliding shear, rather than in some deep-seated portion in one or other of the sliding surfaces. Punctures in this beneficial oxide film are, under normal running conditions, self-healing. Running-in under conditions of excessive load and inadequate lubrication may, however, produce an oxide film of a kind which, far from affording protection, actually leads to excessive wear. The reasons for this are not yet clear, though they would seem to be associated with differences in crystal structure. Once the beneficial oxide film has been formed by running-in under moderate loads and ample lubrication, it regenerates itself even when mishandled by excessive loading and poor lubrication; but the undesirable kind of film endows the surface permanently with poor wearing properties which can be eliminated only by such drastic measures as re-honing.

The chief role of the extra high-pressure lubricant seems to be that of promoting the formation of hard oxide, sulphide, and similar compound films which are resistant to penetration and favour the "necking" of welds in the manner described above.

The engineer is making increasing use of surface films, with good sliding and wearing properties, deposited on substrates which in themselves do not wear well, but possess thermal and mechanical strength properties which are otherwise good for the purpose intended. Examples are tinning and, particularly, chromium plating of the cylinder liners of internal-combustion engines. Here the adhesion of deposit to substrate is all-important, and electron diffraction has shown that a *sine qua non* of good bonding is that the substrate metal should be able to affect and, indeed, largely control the crystal size and orientation of at least the initial layers of the deposited metal. Another though different case of substrate-deposit adhesion is that of the bonding of rubber to brass. It is now known that the electrodeposited brass surfaces nominally supposed to consist of α-brass alone may have a surface contamination which is easily detected by electron diffraction, though its exact nature is not yet understood. Rubber bonds to these contaminated surfaces are weak and unreliable.

* Held at the Institution of Mechanical Engineers, London, on Friday, March 9, 1945.

† Introductory paper in Group I (Physical Aspects). Abridged.

SURFACE FINISH IN RELATION TO FRICTION AND LUBRICATION.*

By D. CLAYTON, D.Sc., A.M.I.Mech.E.

IT would be expected, and it has been confirmed experimentally, that surface roughness would not affect the behaviour of lubricated surfaces when a complete fluid film exists between the elements. Lewis† has suggested, however, that the surface roughness should not be allowed to be more than 10 per cent. of the film thickness. In mechanisms normally lubricated by fluid films, therefore, surface roughness comes into play mainly when incipient contact occurs, when there is what is often called mixed lubrication. Surface roughness is thus a pertinent factor with boundary and dry lubrication.

The earliest explanations of the friction of surfaces were in terms of the asperities interlocking and the work required to lift a body over the other's asperities. This gave way to the adhesion theory, which has commanded support for a long time. It is not universally held, however; Bikerman and Rideal‡, for example, have recently maintained the importance of roughness in this connection, and Ernst and Merchant§ have considered the need for a roughness as well as an adhesion factor in their general expression for friction. So much has yet to be learnt of the fundamentals of friction, however, that no firm conclusion as to the effect of surface finish can be drawn at this stage. There are also contradictions as regards wear. Support is generally found, however, for Underwood's‖ statement that improvement of finish is more necessary for a steel surface working with the harder bearing metals, such as bronze, than with the soft white metals; an exception in the former class may be cast iron. The following items are chosen to illustrate work in this field.

Bowden and Tabor** have given an explanation of the law of Amontons that coefficient of friction is independent of (nominal) area of contact and of the load, on the basis that the real area of contact occurring between two surfaces is much less than the apparent area and that plastic flow occurs to give adhesion areas and thus friction force proportional to the load. Gongwer†† has indicated how the influence of direction of finish marks on friction varies with the sliding metal, good anti-score metals having a lower friction parallel to the marks than at right-angles to them, and poor anti-score metals the opposite; oleic acid as a particularly "oily" lubricant, reverses the latter and gives uniformity. An important detail feature of wear and friction is the transfer of material from one contact element to the other, and Sakmann, Burwell, and Irvine‡‡ have shown by a novel radiographic method that there is a greater transfer of material from a baseplate to a slider the greater the roughness, provided that the slider is harder than the baseplate; the effect on friction has not been investigated, but it is a case where such correlation would have been valuable.

It is said that putting a higher finish on the top face of a cutting tool has an important effect on finish of the

* Paper presented in Group I (Physical Aspects). Abridged.

† *Proc. of Conf. on Friction and Surface Finish* (1940).

‡ *Phil. Mag.*, vol. 27, page 687 (1939) and vol. 32, page 67 (1941).

§ *Proc. Conf. on Friction and Surface Finish* (1940).

‖ *Ibid.*

** *Proc. Roy. Soc.* A, vol. 169, page 391 (1939).

†† *Proc. Conf. on Friction and Surface Finish*, page 239 (1940).

‡‡ *Jl. Applied Physics*, vol. 15, page 459 (1944).

work by reducing the friction at the tool; this tilts the shear plane of the chip away from the new work contour, according to Ernst and Merchant's 1941 analysis. It is claimed elsewhere* that the pressure developed on a lapped tool is less than on a ground one, extending the life three to five times; "superfinishing" allows an increase of 25 per cent. in parts per hour. To chemical smoothing Beeck, Givens, and Williams† attributed the wear-reducing qualities of certain phosphorus and arsenic compounds (such as tricresyl-phosphate and triphenyl-arsine) in lubricants. The theory was that iron-phosphide and arsenide were formed at rubbing temperatures, and they, with iron, formed lower melting-point eutectics. Thus at the high points of contact, earlier melting can occur than with ordinary lubricants, with consequent smoothing; this leads to reduced wear, in contrast also to the case of sulphides and chlorides formed with extreme-pressure lubricants.

In the disc-type extreme-pressure lubricant-testing machines, increased smoothness has given increased load-carrying capacity for ordinary lubricants. Support for this is given by Evans‡ with a Timken machine; Schürig§, however, finds the contrary with an Almen machine, which has a journal bearing as test element and may therefore yield results related to those given later. Normally the grinding marks will be circumferential and it would be interesting to know what would be the result of a criss-cross pattern as in Maag gear grinding and of a pitted surface (avoiding chemical effects in the latter case). In the S.A.E. machine, finer finish also led to reduced discrimination between the various lubricants, the failure loads bunching together.

Too smooth a surface can be a disadvantage in particular cases. While the adhesion between block gauges is necessary to their use, the same phenomenon between other similarly highly finished surfaces may cause difficulty of manipulation; thus the baseplates of measuring instruments are grooved to limit the areas of contact. It is probably this same adhesion, obtained through mating from plastic deformation and not workshop precision, which in general causes seizure and scuffing between surfaces; high finish with hard materials does, however, tend to this result. Highly finished fused-silica plates "wrung" together for making échelon diffraction gratings (Williams‖) tear each other if forced apart mechanically. Taylor and Holt¶ have shown the increase of wear with increase of roughness of brake-drum surfaces, woven linings being affected more than moulded; little effect was found on friction.

With oil-seal materials, some recent friction measurements have shown the greater friction and wear of synthetic rubber with increased roughness, particularly when the roughness marks are at right angles to the direction of relative motion; leather is much less sensitive to surface finish. Stott** refers to "plunge grinding" of journals in connection with synthetic rubber, presumably to avoid a "screw thread" with an axial component of motion; he refers also to the lower coefficient of friction with porous surfaces holding oil than with well-finished surfaces, and to the low wear of a sprayed-metal journal.

Much interest has been aroused by statements on the effect of surface finish on behaviour under these conditions; it is important to recognise, however, that the latter are very ill-defined for obtaining consistent measurements of friction and wear, and this both explains the divergence of some of the results and makes caution necessary in drawing conclusions. The extremes occur where the surface is so rough that a fluid film is easily destroyed (as by a multiplication of the effects of grooves in the load-carrying films of bearings), and where the surfaces are so smooth that the time taken for a film to be squeezed out is so long that one surface appears to float easily on the other (as with surface plates). The results obtained by Heidebroek and Pietsch,†† on the decrease of time and load to bring surfaces into contact with increase of roughness, bear on the latter point. It is important to note the influence of geometrical truth in these cases; untrue surfaces, however smooth, allow contact to occur relatively easily, and the effect can be much greater than that of roughness. In journal bearings, it is difficult to get the generator line straight to 0·0001 in. and avoid taper, whereas ordinary methods will reduce surface irregularities to 0·00001 in.; spur-gear teeth and piston rings are similar.

In journal bearings, the effect of improving the finish of the journal is to decrease the value of the non-dimensional group $\frac{ZN}{P}$ (Z = viscosity, N = number of revolutions per unit time, P = load per unit of projected area) at which the friction reaches its minimum value, where incipient contact is first thought to occur as the film becomes progressivly thinner; at the same time, it decreases this minimum and makes the rise of friction with further decrease of speed and increase of load and temperature more abrupt. These results are explained by the increase of finish, allowing the average film thickness to become less before contact occurs. Burwell, Kaye, van Nymegen, and Morgan* also showed that the wear of the journal under constant-load rubbing conditions ended in two hours with the roughest surface, and that there was a straight-line relation between this total wear and surface finish values. Emphasising the rubbing aspects by using an Amsler machine with one disc stationary—that carrying the bearing metal (mainly copper-lead)—Dayton, Nelson, and Milligan† showed rougher shafts to have a greater tendency to "seize"; wearing-in smoothed the tops of the ridges on a minute scale, resulting in a large change of friction.

Buick‡ focused attention on journal finish by stating that artificial roughening improved the endurance of internal-combustion engine bearings, and this led to much discussion. One explanation involved the suggestion that the roughnesses provided a series of Reynolds-type tapered films which, near failure, were better than the larger single film. Another was that continuous surfaces were more prone to seizure than one broken up by numerous oil pockets. To define the position, it is necessary to show either that the pockets (possibly below a certain size) do not diminish the load-carrying capacity (by interfering with the hydrodynamic film) or that the loss of load-carrying capacity is compensated by the freedom from seizure conferred by the ready availability of oil from the pockets to all points of the surface when severe rubbing occurs; or, in other terms, that such a surface cannot be wiped free of oil so easily as a continuous one (note previous comment on oil seals). As oil molecules are very small compared with the roughnesses of even well-finished surfaces, it is not likely that they can be wiped away from a surface until plastic flow occurs; it may be, therefore, that the explanation may have to be found in heat effects or other phenomena. Teetor§ has suggested that the higher load-carrying capacity with piston rings with broken-up surfaces is due to better local cooling. Such explanations do not fit the case of journal bearings as well as flat contact surfaces, and indeed Clay‖ has recently shown directly that the load-carrying capacity of engine bearings increases progressively with improvement of the finish. Support for the oil pockets explanation has been claimed by quoting improved performance with sprayed-metal journals, the surface being porous (see, for example, Shaw¶).

In the case of internal-combustion engine cylinders, finish is important in regard to running-in, wear, and scuffing; numerous statements have been made on the importance of keeping a porous or oil-pocket surface to prevent scuffing and to reduce wear in regular running, and equally of increasing roughness for the sake of facilitating running-in. Quick running-in has become a necessity, first to ensure freedom from blow-by (geometrical truth is important again here also), and also to provide a quick approach to a stable oil consumption, the latter being particularly important with aero-engines. Provision of a taper face for the ring is an alternative to the roughening mentioned above; yet a further method is chemical pre-treatment—thus phosphating is advocated very generally. Attention has been concentrated mainly on the ring surfaces; thus Underwood has suggested the need for turned surfaces of the rings (and piston) when working in smooth barrels, and Hinzmann** supports this, but the Wellworthy Piston Ring Company†† have preferred a process providing a cross-hatch pattern.

It is a point for discussion whether the roughness should be provided for the rings and the cylinder left smooth, or whether the cylinder should be roughened alone or as well as the rings; the author inclines to the first view, provided that a high standard of geometrical truth of the cylinder is attained. Kudlich‡‡ has found lowest wear and greatest scuffing resistance when one rubbing surface is rough and the other smooth. The van der Horst† porous chromium plating has, however, been recommended for cylinders (as well as rings) both for accelerating bedding-in and for reducing wear in running; Poppinga‡ has also said that oil does not spread on a very smooth cylinder and that roughening occurs in running-in. Connor and Martz§ suggest that the honing method should, to avoid initial wear and scuffing, give the finish initially that a cylinder acquires on running-in; Kline‖ has expressed similar views. A separate point in connection with piston rings is the claim that high finish to the sides of the rings promotes freedom from ring clogging by not allowing carbon to cling.

"Phosphating" has several interesting feature in connection with surface finish. The soft easily worn surface promotes quick running-in; it reduces the deleterious consequences of geometrical irregularities on load-carrying capacity—the author has used it to remedy poor machining of slides, and it might find an ultimate field in avoiding the expenses of high finish. Under severe rubbing conditions, the load-carrying capacity of surfaces is increased as though by a chemically-active lubricant; thus the scuffing of piston rings and gears is deferred or prevented. Whether the mechanism is a chemical one in which the phosphorus, a known ingredient of extreme-pressure additions, plays a part, or whether there is a purely physical effect of relief to high points and better load distribution by wearing (as would be useful at the tips and roots of gear teeth to relieve concentrated load), or whether there is simple anti-welding property in the non-metallic layer, does not seem to have been elucidated. After the top surface has been worn away, a pitted surface is left which may have the advantages described above.

The various results cited above show that much that is stimulating to thought has been brought to light already, but there is no doubt as to the need for much more systematic work to establish firm relations between surface finish and lubrication phenomena; some of it dependent on progress in other fields, such as, for example, the specifying of the roughness of surfaces.

* *Machinery*, vol 65, page 393 (1944).
† *Proc. Roy. Soc. A*, vol 177, page 103 (1941).
‡ *Jl. Inst. Petroleum*, vol. 25, page 729 (1939).
§ *Proc. Conf. on Friction and Surface Finish*, page 141 (1940).
‖ *Proc. Phys Soc.*, vol. 45, page 699 (1933).
¶ *Jl. of Research*, U.S. Bureau of Standards, vol. 27, page 395 (1941).
** Inst. Auto. Engineers preprint (1944).
†† *Forsch. ungauf dem Gebiete des Ingenieurwesens*, vol. 12 (1941).

* *Jl. Applied Mech.* (Trans. A.S.M.E.), vol. 8, page A-49 (1941); and *Proc. Conf. on Friction and Surface Finish*, page 206 (1940).
† *Mechanical Engineering*, vol. 64, page 718 (1942).
‡ *Nat. Petroleum News*, vol. 33, page R262 (1941).
§ *Trans S.A.E.*, vol. 47, page 497 (1940).
‖ *Jl. I.A.E.*, vol. 12, page 9 (1944); and ENGINEERING, vol. 157, page 372 (1944).
¶ ENGINEERING, vol. 144, page 757 (1937).
** *Metallwirtschaft*, vol. 18, page 991 (1939).
†† Brit. Pat. No. 551076.
‡‡ *Trans. S.A.E.*, vol. 50, page 172 (1942).

† *The Engineer*, vol. 172, page 123 (1941); and *Jl. S.A.E.*, vol. 46, page 30 (1940).
‡ *Automobiltechnische Zeits.*, May, 1941, page 247.
§ *Proc. Conf. on Friction and Surface Finish*, page 174 (1940).
‖ *Mech. Engineering*, vol. 57, page 749 (1935).

SOME PRINCIPLES AND METHODS OF SURFACE MEASUREMENT.*

By R. E. REASON.

THE imperfect surface can generally be discussed satisfactorily in two cross-sections taken at right-angles to each other and to the surface. Very often a single cross-section will suffice. The imperfections in any cross-section are usually measured in terms of their height; but either their wavelength, or the slope of their flanks, needs also to be taken into account. It seems probable that the functional significance of imperfections of given height and shape will differ greatly according to their wavelength. Fig. 1a (on the opposite page) represents the cross-section of a surface A B which is supposed to be perfectly smooth (like a mirror) and perfectly flat. Now suppose the surface to be slightly wrinkled as shown in Fig. 1b, the height being, say, 0·0001 in. and the wavelength, say, 6 in. The eye will see nothing wrong with the surface, and to an engineer it will still have a very high order of flatness. If, however, the wavelength is progressively reduced as shown in Figs. 1c to 1e, the height remaining constant at 0·0001 in., both the visual and the mechanical quality of the surface will deteriorate until it compares only with medium-grade diamond turning. Thus an excellent "smooth" surface can be turned into quite an indifferent "rough" one simply by changing the wavelength of the irregularities and without changing their height at all. This point is vital, for on it hinges the question of what an instrument for measuring surface finish ought to measure.

In order to make a quantitative, as distinct from a merely pictorial, assessment of the cross-section of the surface, it is necessary to choose a reference surface from which measurements can be made. The fundamental reference surface may well be a supposedly perfect surface having the size, shape, and in some instances the position called for on the drawing. Fig. 2 shows diagrammatically in side and end elevation a cylindrical specimen A having a number of imperfections, and also the intended shape B, this being the fundamental reference surface. It is usual, and for average measurements essential, to describe surface finish not with respect to the fundamental reference surface considered above, but with respect to one determined relatively to the irregularities themselves. In the selected cross-section, the practical reference line

* Paper presented in Group II. Methods of Measurement and Representation of Surface Roughness. Abridged.

may therefore be displaced from the fundamental reference surface both in position and in inclination. While these displacements can usually be ignored, they should not be overlooked. As examples, the axes X_1X_1, X_2X_2, and X_3X_3, would be used for chance measurements between x_1x_1, x_2x_2, and x_3x_3 respectively.

Reference lines grazing the roots or crests have been proposed and are sometimes used. They have the advantage of permitting numerical distinction between a profile asymmetrical about the centre line and one of the same shape inverted; but they have the serious disadvantage of being difficult to position in relation to irregular surfaces independently of accidental faults and without personal judgment. The most practical reference line which avoids these difficulties appears to be the centre line; defined as a line with respect to which the r.m.s. value is a minimum. This centre line has the further property that the areas on each side of it enclosed by the curve are equal. Instruments measuring the height of a part only of all the possible range of wavelengths may be called selective, and the wavelength at each end of the range at which the instrument ceases to be sensitive may be called the "cut-off" wavelength, or simply the "cut-off." In practice, the transition from full sensitivity to zero sensitivity is not abrupt, but occurs more or less gradually, for example as shown by the transmission curves in Fig. 3, so that a nominal value has to be assigned to the cut-off wavelength.

Modern electrical integrating instruments of the simplest kind, such as are used for inspection purposes, are selective, and give a measure only of the shorter wavelengths. It is important to realise that the measurement made by the meter is not that of the surface itself, but of that representation of the surface offered to the integrating meter by the pick-up, amplifier, and filter circuits used to control the selectivity. Measurement both of the average and of the r.m.s. value is made with respect to the straight r.m.s. centre line of the current (or voltage) waveform operating the meter. While the simple centre-line system of measurement may not be ideal, it has the advantage that when the selectivity is specified, it becomes a definite measure which can be made independently of any kind of personal judgment. It would seem sensible to retain it at least until more is known about the relation between surface characteristics and performance. It may be that some function connecting the two will eventually be discovered, at any rate for a limited range of applications, in which case the apparatus could with advantage be built to show the numerical value of the function directly.

The degree of selectivity best adapted to throw light on a given aspect of the surface may differ according to circumstances. There is some experimental evidence to suggest that for assessing the scratch-marks caused by the fine finishing processes, exclusively of undulations due to chatter and like causes, an average number including all wavelengths up to 0·01 in. will provide a useful index; but on the other hand an index best adapted to describe the usefulness of the surface regardless of the cause of the imperfection may have to include much longer wavelengths. As the significance of the average or r.m.s. number tends to decrease as the wave-range is increased, two or more numbers, each taken with a different degree of selectivity, may be required for a fully practical description of the cross-section. The effect of using instruments with the degrees of selectivity shown in Fig. 3, of which H, J, and K are roughly representative of three present-day commercial instruments, is shown in Fig. 4, page 218, together with the true graphs of the selected specimens.

Standardisation of instruments in respect of selectivity is obviously required, but so little is known about the functional significance of wavelength that, at least for the present, it is necessary to assume that different degrees of selectivity must be catered for. Correspondingly the required degree of selectivity must be specified on the drawing alongside the average reading. A proposal which has been put forward, and which may be standardised, is that successive steps should form a geometric progression with a common ratio of $\sqrt{10}$ and a first value of 1 micro-inch, each step being designated by a letter. The series is given in the table in the next column. If the average reading had to include all wavelengths between two given values, these values would be indicated by attaching the appropriate letters to the required index number. If the only wavelengths to be omitted at the short-wavelength end were those suppressed by the stylus (values shorter than E or F) it would be permissible to specify only the long wavelength cut-off, for example 7J or 7K. These wavelength letters can be used as names for the units of average measurement, for if it is accepted that the relevant ordinates are always to be measured in micro-inches, it will be sufficient, and more informative, to speak for example of 7J's, or 7K's, than of 7 average micro-inches. The latter designation is really meaningless until the waveband to which it relates is defined.

If all commercial instruments were constructed with cut-offs at one or other of the standard values, as might seem best to maker and user, there would be built up, in course of time, an immense amount of coherent data amenable to statistical analysis, on the basis of which sound workshop standards for different classes of work could be laid down.

The first problem of measurement is to provide a datum. For short wavelengths (less than about 0·02 in.) this can take the form of a rounded skid sliding on the surface to be measured: the radius must be such that the up and down movement of the skid is small compared with that of the stylus. For medium wavelengths up to 1 in. or so, measurements are best made either with respect to an auxiliary reference surface (which may take the form of a slideway associated with the pick-up) or with respect to a datum generated by a shoe which nominally fits the surface at least in the direction of traverse. The length of the shoe must be at least twice the longest wavelength to be measured. For long wavelengths it is simplest to use an accurate slideway or reference surface for lengths up to a foot or so, and for greater lengths to use the point-by-point method of the auto-collimator. Very long waves occurring in the circumferential direction of a circular piece can be checked by rotating the piece in a V-block; but the angle of the V should be properly related to the number of lobes. The upper diagam in Fig. 5, page 218, shows an example of 26 chatter marks superimposed on five lobes round a gudgeon pin. The lower diagram shows the effect of changing the angle between the supports by 14 deg.; the chatter marks are suppressed by virtue of an incorrect angle. A corresponding consideration applies to the spacing of the feet of the mirror carriage in the autocollimator method.

Wavelength.	Letter.	Wavelength.	Letter.
0·000001	A	0·01	J
0·000003	B	0·03	K
0·00001	C	0·1	L
0·00003	D	0·3	M
0·0001	E	1·0	N
0·0003	F	3·0	P
0·001	G	10·0	Q
0·003	H		

Fig. 1.

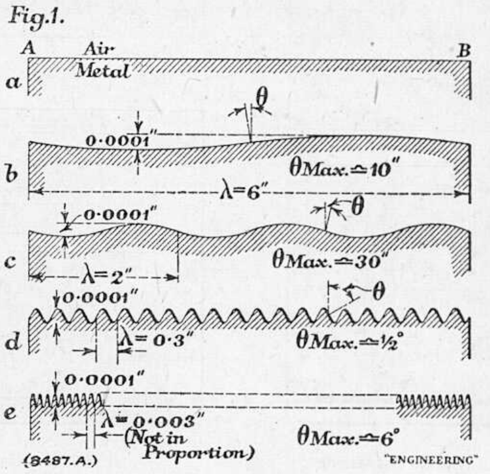


Fig. 2.

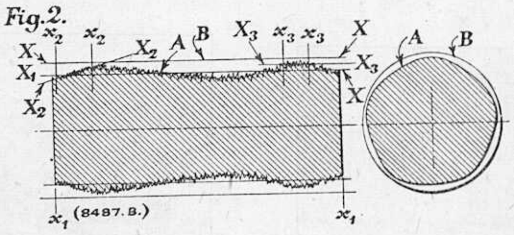
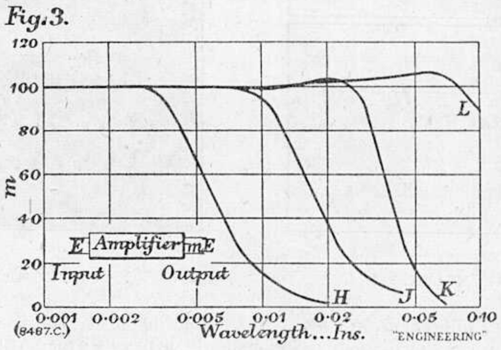


Fig. 3.



Two methods of measuring the height by optical methods are known, (a) the "light-slit" method, and (b) the interference method. In the "light-slit" method, the datum is generated jointly by a knife edge focused obliquely on the work, and by a straight graticule line or slideway in the viewing system, relatively to which the irregularities are measured. The method is probably limited usefully to magnifications below 500. In the interference method, interference fringes are formed between the surface and an inclined glass or quartz surface mounted closely above it. These fringes are viewed through a microscope the construction of which determines the resolving power. Measurement of the width and depth of some interference fringes from a finely lapped surface revealed very few scratches to the bottom of which a stylus of 0·0001 in. radius could not have reached.

In addition to the optical measuring methods mentioned above, optical comparison microscopes for comparing the appearance of a master specimen and a sample are known. These instruments only give a plan view, and do not measure the height of the undulations. They are at their best for showing differences between specimens finished by different processes, and unfortunately at their worst for showing differences between nominally similar parts, which is the purpose for which they are needed in the workshop. They tend to work selectively with regard to wavelength, the degree of selectivity depending not only on the optical constants of the microscope and its illuminating system, but also on the degree of polish and the character of the surface. The eye seems to assume that the roughness increases according to the apparent pitch of whatever markings predominate, so that as the magnification is increased, emphasis is thrown on progressively shorter wavelengths. Specimens are graded on a basis which may bear little or no relation to the readings of a stylus instrument; and while quite small differences in finish may be observable in some cases, considerable differences may be missed in others. As an example, two ground specimens which gave average readings of 4K and 32K, and were obviously different to the naked eye, could hardly be told apart with a comparison microscope having a magnification of 40 diameters (see Fig. 6, page 218).

Photometric instruments in which the quality of the surface is assessed according to the extent to which a beam of light is reflected or scattered by the surface are also known. These instruments are useful when the visual appearance of the surface is the sole criterion of quality. Their indications, however, can bear no direct relation to the height of the undulations.

The need of industry is for simple workshop instruments giving sensible measures of surface quality. Their provision is impeded mainly by lack of sound experimental data on what really needs to be measured, and on how accurately measurements should be made. When all the factors to be taken into account are considered—factors concerning the physical structure and behaviour of the surfaces, geometrical factors concerning the effect of different profiles and wavelengths, and the effect of all these in relation to stress and lubrication—it becomes clear that a great deal of work will be required before general principles can be firmly established. It is not a one-man job, and it is to be hoped that the question involved will become the subject of well-organised research, perhaps on a co-operative basis. Not until then will the need of industry be reliably satisfied.

MEASUREMENT OF SURFACE WAVINESS.*

By C. TIMMS, M.Eng.

THE inspection of surface finish has hitherto been confined mainly to the measurement of the fine surface texture caused by the cutting action of the tool. The maximum pitch or wavelength of these fine surface irregularities is in general controlled by the traverse feed of the machine. In addition to the measurement of the fine surface texture, however, the inspection of the finish may be complicated by the presence of surface waviness having a pitch greater than the traverse feed of the machine. This waviness is referred to as "macro-roughness" and is generally associated with varying conditions of the machine traverse and vibration; or it may represent a relic of previous machining marks not completely removed in the finishing operation. It is quite possible that in certain cases the amplitude of the macro-roughness may be of greater importance to the functioning of the component than the magnitude of the fine surface texture (micro-roughness). For example, it would appear that the load-carrying capacity of journal bearings would be controlled by the amount of macro-roughness rather than the micro-roughness.

The complete analysis and representation of surface finish should cover both macro- and micro-roughness, and it is desirable that methods of specifying surface finish should be developed which will take account of

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SYMPOSIUM ON SURFACE FINISH.

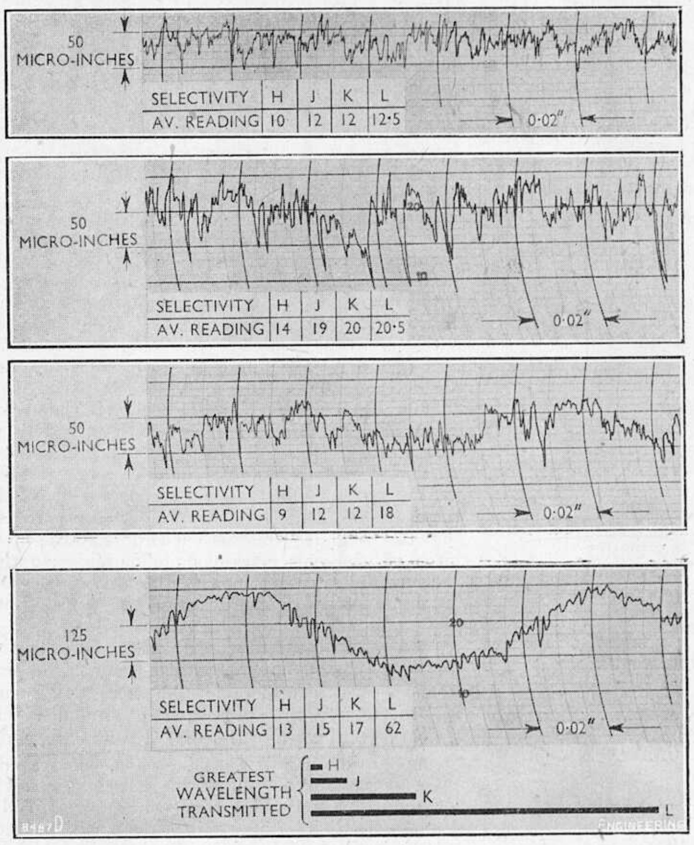


Fig. 4. Average Readings with Commercial Instruments.

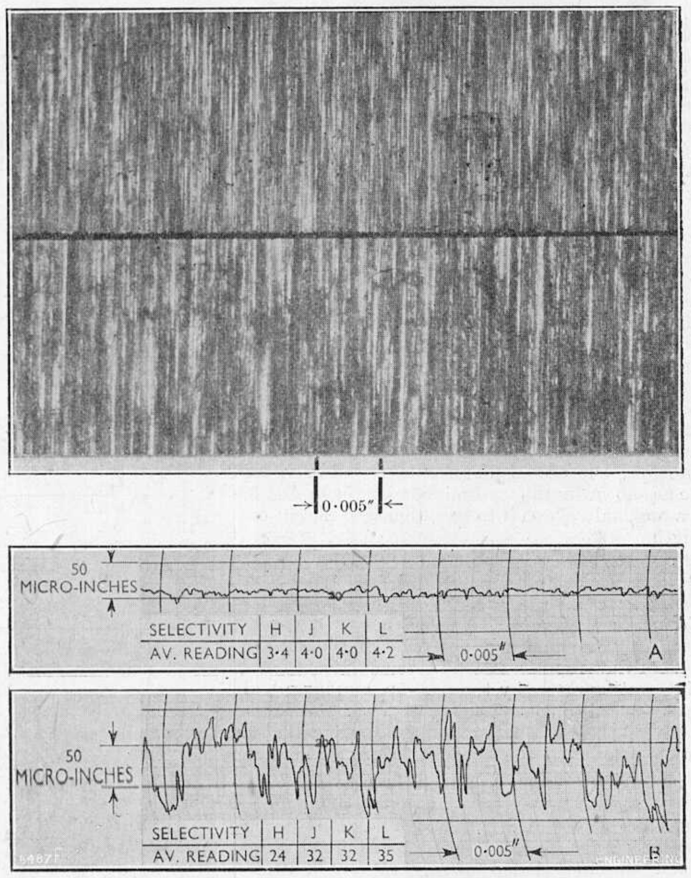


Fig. 6. Records of Two Ground Specimens.

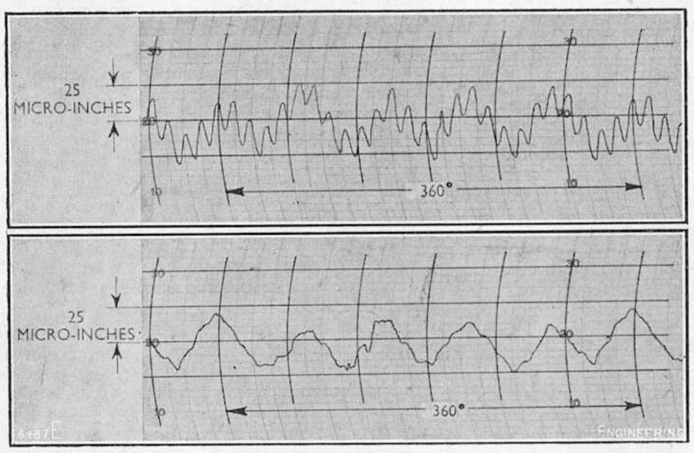


Fig. 5. Chatter Marks on Gudgeon Pin.

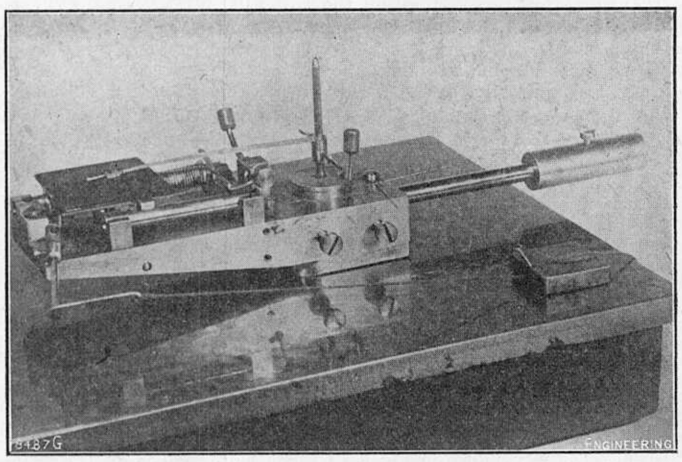


Fig. 7. Instrument for Measurement of Surface Roughness.

both conditions. In order to measure the amplitude and to study the periodic nature of the undulations, it is necessary to traverse across several cycles of the wave. With existing types of surface-recording instrument, this is not in general possible, due mainly to the restricted traverse length, which does not exceed about $\frac{1}{4}$ in. In addition, these instruments normally generate their own datum line by means of a radius skid which contacts the surface under test. The skid radius is usually about 1 in., which is sufficient to bridge across the fine surface texture. With the longer-pitched waves, however, the skid may tend to follow the shape of the surface unevenness and thus falsify the resulting record. For wavelengths up to about 0·02 in., the errors introduced by a skid of 1 in. radius can in general be neglected, but it is possible for a wave of relatively long pitch to remain undetected when exploring a surface with any of the existing instruments. The paper describes a portable instrument of simple construction designed at the National Physical Laboratory for the measurement of the grosser surface irregularities.

The general arrangement of the recording instrument is illustrated in Fig. 7. The instrument employs a direct mechanical method of magnifying the surface undulations and records them on a smoked glass plate. The mechanical amplification used is about 40 times, which is increased to 2,000 times when the record is examined at the screen of a projector, with optical magnification 50 times. The exploring probe consists of a $\frac{1}{16}$-in. diameter steel ball which passes over most of the fine surface texture but picks up the more coarsely pitched undulations. The maximum traverse length is about 2 in., which is very much longer than that used in existing surface-finish recorders.

The instrument is shown in Fig. 8, opposite, and its mode of operation on a plane surface is as follows. The exploring probe *a* is at the lower end of a vertical spindle *b*, passing with clearance through a hole in the flat soleplate *c* on which the instrument rests upon the test surface. The soleplate is $1\frac{3}{4}$ in. square, thus providing ample bearing contact area. The spindle is adjustable in position vertically by releasing the set screw *d* and it is set so that the tip of the contact point is about 0·002 in. below the surface of the plate *c*. This setting is easily made with slip gauges or with a thin shim of paper. When placed firmly on the surface, the spindle is, therefore, displaced upwards by the amount it is initially set forward.

The magnifying movement consists of two brass discs *e* and *f* (shown in the enlarged view) coupled together by three inclined steel ligaments *g*, 0·002 in. thick, spaced at 120 deg. The lower disc is fixed to the soleplate and the spindle is an easy fit in the boss of this disc, but is locked in the corresponding boss of the upper disc by the set screw *d*. Any axial movement of the spindle must thus be accompanied by a rotational motion which actuates the recording point *h* carrying a scribing needle at its free end. For small displacements the rotational motion is proportional to the axial, and it is easy to obtain a mechanical amplification of about 40 times at the scribing point.

To record the surface profile it is necessary to traverse the glass plate in the direction at right-angles to the movement of the scribing needle, by an amount proportional to the distance the instrument is moved by hand over the surface. With this object the glass plate is carried on a slide *j* constrained to move on two cylindrical guides *k* and *l*. It is moved along the guides by the rotation of the arm *m* about a pivot *o*, the drive being by direct contact between the arm and a steel pin *n* in the slide, acting against the compression spring *p*. The arm is rotated by means of a fine cord *q*, which passes through the hole *r*, and is anchored to the surface under test by a brass block fixed thereto by wax or plasticine. With this arrangement it is possible to have a traverse length up to about 2 in., which is reduced to about 0·25 in. on the record plate. The instrument is moved over the surface by hand, applying just enough pressure to keep the soleplate in close contact. If the traverse is required in a true straight line the instrument is moved along in contact with a straight-edge held on the surface. For use on external cylindrical work the counterweight *s* is replaced by a steel plate *t*, as shown in Fig. 9, opposite. This plate, with the soleplate, forms a 90 deg. V, by which the instrument can be located on the test-piece and

SYMPOSIUM ON SURFACE FINISH.

Fig. 8.

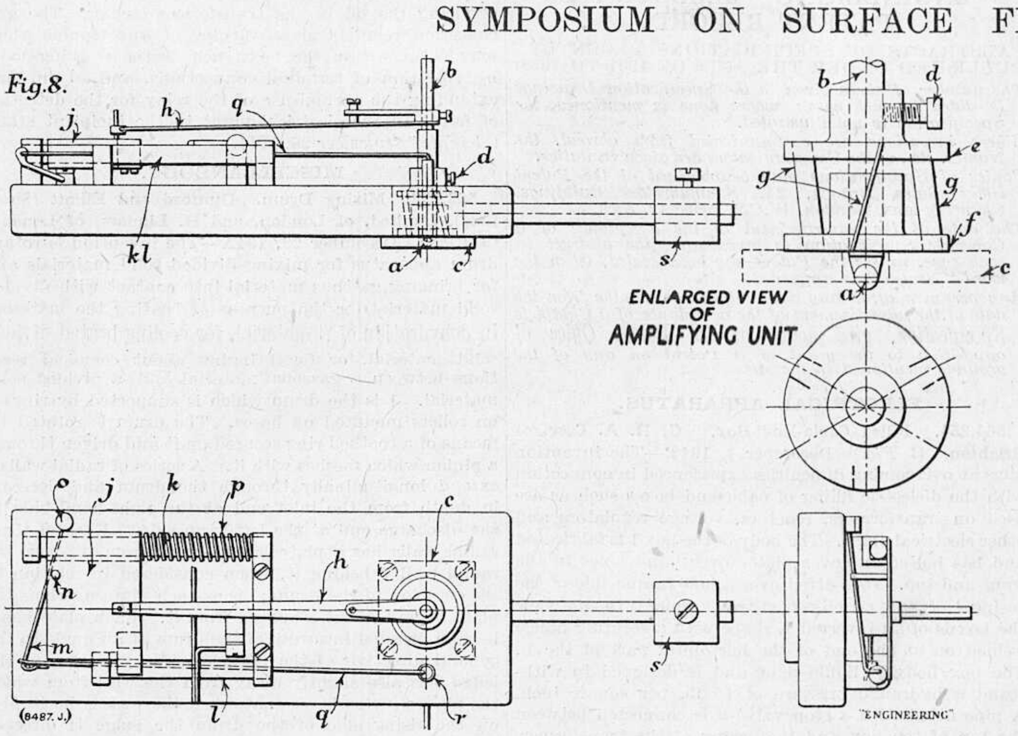


Fig. 9.

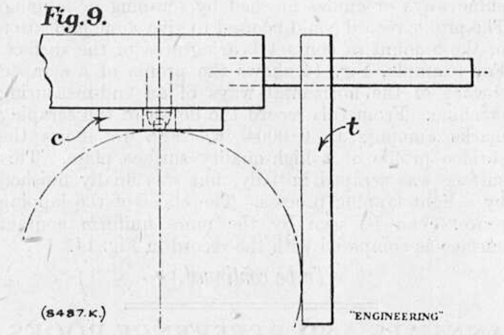
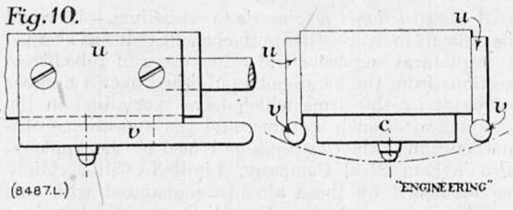


Fig. 10.



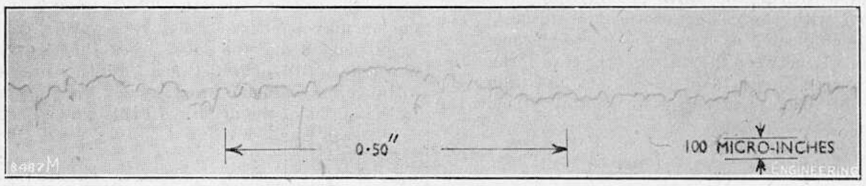


FIG. 11. MACRO-PROFILE OF EXTERNAL CYLINDRICAL TURNED SURFACE.

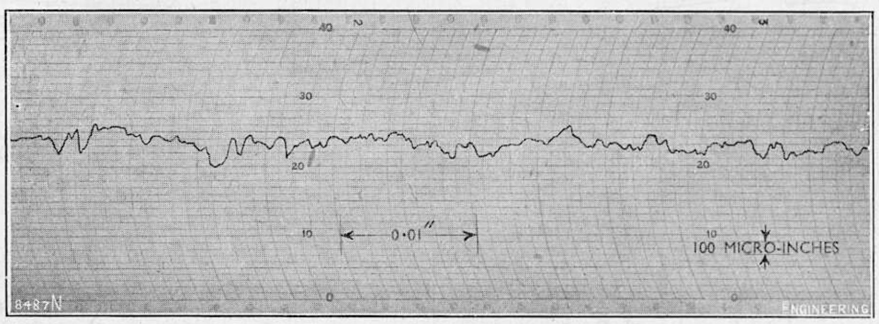


FIG. 12. "TALYSURF" RECORD OF SURFACE PROFILE.

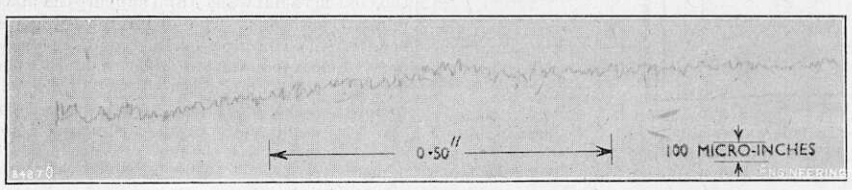


FIG. 13. MACRO-PROFILE OF INTERNAL CYLINDRICAL GROUND SURFACE.

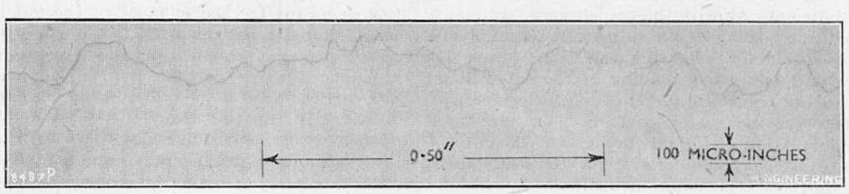


FIG. 14. PROFILE OF SCRAPED SURFACE.

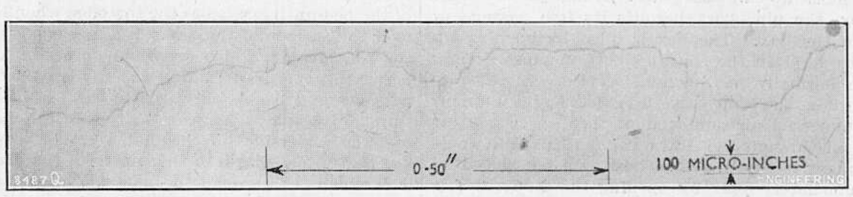


FIG. 15. PROFILE OF HIGH-QUALITY SURFACE PLATE.

moved either circumferentially or longitudinally as required. Internal cylindrical surfaces can also be inspected if the diameter permits the instrument to be inserted. For this purpose two side plates *u*, carrying parallel steel cylinders *v* as shown in Fig. 10, are attached to the body of the instrument.

In Fig. 11 is shown the macro-profile of an external cylindrical turned surface in a direction parallel to the cylinder axis. This record indicates two quite different grades of macro-roughness, *i.e.*, irregularities of wavelength varying from 0·01 in. to 0·05 in. superimposed on a relatively long wave. The smaller irregularities are of an erratic nature, *i.e.*, there is no consistency as regards depth or shape of the irregularities along the length of record considered. Since the micro-roughness is mainly controlled by the traverse feed of the machine, it would appear desirable to exercise some control on the amount of macro-roughness which can be tolerated, both as regards the amplitude of these irregularities and also the wavelength. At present macro-roughness is loosely defined as comprising all surface irregularities the wavelength of which exceeds the traverse feed of the machine. The wavelength of the grosser irregularities may be as great as 0·5 in. It is possible that a wavelength of this order may not be completely removed in any subsequent machining process, for example, grinding or honing, due to the very fine finishing cut used and the possible tendency for the machine tool to follow the waveform of the surface irregularities.

In addition, it should be realised that this record shows little evidence of the micro-roughness of the surface, due to the fact that the exploring probe is a $\frac{1}{16}$-in. diameter ball, and so passes over most of the fine surface texture. In order to examine the micro-roughness of this surface, measurements were made with the "Talysurf" instrument. Fig. 12 shows the surface profile of the same specimen made with the "Talysurf" instrument. On comparing this record with the record in Fig. 11, it should be noted that when using the macro-recorder a traverse length of 0·5 in. corresponds to a chart length of 3·3 in. With the "Talysurf" or similar instruments a traverse length of only 0·01 in. corresponds to a chart length of about 2 in., which is equivalent to 0·066 in. on the macro-record. When comparing these two records, therefore, it is important that due allowance is made for the great difference between the horizontal scales of these two instruments. The "Talysurf" record, Fig. 12, shows the micro-roughness of the surface with little evidence of the grosser surface irregularities. It is extremely doubtful, even using the full instrument traverse of 0·25 in., which would correspond to a chart length of 50 in., whether the resulting record would give a representative picture of the surface profile. In this particular example, quite clearly the macro-roughness is the more important of the two types of surface defect.

From these two records, therefore, it would appear necessary that surface finish examination should first consist of a preliminary survey to determine the magnitude and character of the macro-roughness. This examination could be quite readily and quickly carried out by some simple and inexpensive instrument, similar to the one described in this paper. This test would indicate immediately whether the surface warranted further examination by the more refined type of recording instruments used for measuring micro-roughness. Fig. 13 shows the macro-profile of an internal cylindrical ground surface which again indicates the variations in the macro-roughness along the surface. In this case the wavelength of the finer macro-roughness is smaller and more uniform than in the previous example. This type of recording instrument is also very suitable for examining the surfaces of machine ways or guides finished by scraping or lapping. The profile record could be used to give some indication of the amount of contact bearing area of the surface. For example, Fig. 14 shows the profile of a scraped surface of the horizontal ways of an end-measuring machine. From this record the depth of the scraping marks amounts to 0·0004 in. Fig. 15 shows the surface profile of a high-quality surface plate. This surface was scraped initially, but was finally finished by a light lapping process. The effect of the lapping process can be seen by the more uniform contact surface as compared with the record in Fig. 14.

(*To be continued.*)

ANNUALS AND REFERENCE BOOKS.

A Constructional Engineer's Compendium.—It would be difficult to over-estimate the benefit that has accrued to structural engineers and other users of rolled-steel sections from the handbooks published over a number of years by the firms which have specialised in the production of such sections, and the appearance of a new edition of the *Compendium* issued by the Appleby-Frodingham Steel Company, Limited, will certainly be welcomed by those already acquainted with this valuable reference book. In addition to special sections on sheet piling, welding, and high-tensile steel, the book contains much useful information on reinforced concrete and timber as constructional materials and reproduces also a number of British Standard Specifications and, by permission of H.M. Stationery Office, the Home Office Specification for chains and shackles. The edition being limited, it has been necessary to make a charge to prevent indiscriminate applications for copies; but, to any one engaged in this branch of engineering, the book may be commended as excellent value for the guinea that is asked for it. It is published by the Appleby-Frodingham Steel Company, Limited, Scunthorpe, Lincolnshire.

Aircraft of the Fighting Powers. Vol. V.—1944 *Aircraft.*—In reviewing the previous edition of this well-produced reference book, we commented on its relatively low price, surmising that it might be attributable in part to the unusual editorial policy of describing, in each issue, only the aircraft actually in operational use during the year under review. That policy is still maintained, as also is the high standard of production in both text and illustrations; and though this year the price has been increased from 21*s.* to 31*s.* 6*d.*, we see no reason to modify on that account the good opinion previously expressed. Among the new British aircraft types described are four improved Spitfires, the Barracuda and the Albemarle; the Warwick and York civil transports, and the Hamilcar glider. Outline drawings, the majority to a scale of 1/72nd full size, accompany all descriptions; and incidental features of the book are a compendium of aircraft markings, a compact summary of Allied and enemy designation systems, and a colour chart illustrating the colour standards adopted by the Ministry of Aircraft Production. As before, the compilers are Mr. H. J. Cooper and Mr. O. G. Thetford, and the editor, Mr. D. A. Russell, M.I.Mech.E. The book is published by the Harborough Publishing Company, Limited, Allen House, Newarke-street, Leicester.

The Steam Boiler Yearbook and Manual (III).—As in former editions, the 1945 issue of this yearbook is divided into two parts, the first consisting of short chapters dealing with various aspects of current boiler practice and the second containing a summary of papers on the subject, delivered before institutions or published in the technical Press. Of the 25 chapters in Part I, six are new, and others have been more or less extensively revised. An addition to Part I is a short section containing book reviews, etc., including a list of the first 28 of the Fuel Efficiency Bulletins issued by the Ministry of Fuel and Power; this is useful as far as it goes, but it is unfortunate that the delays in publication, referred to in the preface, appear to have prevented this list from being brought more up to date, as at least ten more Bulletins have been produced. The *Steam Boiler Yearbook*, which is edited by Mr. Sydney D. Scorer, A.M.I.Mech.E., is published by Messrs. Paul Elek (Publishers), Limited, Africa House, Kingsway, W.C.2, at the price of 30*s.*

Apprentice Training Scheme of Westland Aircraft Limited.—On page 475 of our 156th volume (1943), we gave a detailed account of the apprentice training scheme in vogue in the works of Westland Aircraft, Limited, Yeovil, Somerset. We have now received a pamphlet in which are set out the regulations governing the selection, acceptance and training of apprentices by the firm. Particulars of remuneration and working conditions, technical education, scholarships, training in citizenship, prospects, and other matters of interest to apprentices and their parents, are given in the pamphlet.

"ENGINEERING" ILLUSTRATED PATENT RECORD.

ABSTRACTS OF SPECIFICATIONS RECENTLY PUBLISHED UNDER THE ACTS OF 1907 TO 1939.

The number of views given in the Specification Drawings is stated in each case; where none is mentioned, the Specification is not illustrated.

Where inventions are communicated from abroad, the Names, etc., of the Communicators are given in italics.

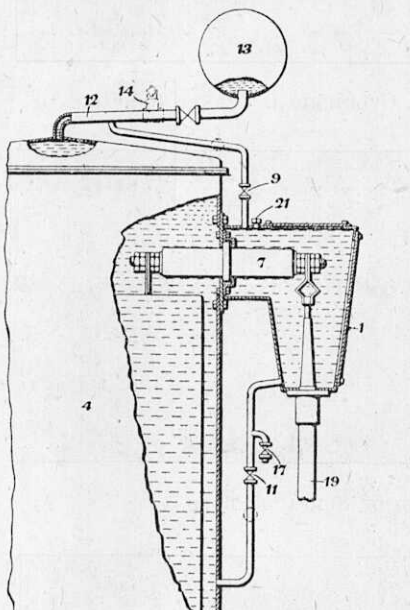
Copies of Specifications may be obtained at the Patent Office Sales Branch, 25, Southampton Buildings, Chancery-lane, London, W.C.2, price 1s. each.

The date of the advertisement of the acceptance of a Complete Specification is given after the abstract in each case, unless the Patent has been sealed, when the word "Sealed" is appended.

Any person may, at any time within two months from the date of the advertisement of the acceptance of a Complete Specification, give notice at the Patent Office of opposition to the grant of a Patent on any of the grounds mentioned in the Acts.

ELECTRICAL APPARATUS.

564,354. Filled Cable-End Box. G. R. A. Carr, of Brighton. (1 *Fig.*) December 7, 1942.—The invention aims at overcoming difficulties experienced in connection with the dielectric filling of cable-end boxes such as are used on transformers, reactors, voltage regulators and other electrical plant. The body of the box 1 is fabricated and has bolted-on cover plates over hand holes in the front and top. It is fitted over a hole in one side of the casing 4 of, say, an oil-cooled transformer. In side view the box is of an inverted L shape with a securing flange welded on at the end of the horizontal part of the L. The box body is liquid-tight and is designed to withstand a hydraulic pressure of 15 lb. per square inch. A pipe fitted with a stop valve 9 is connected between the top of the box and the casing of the transformer. Another pipe with a stop valve 11 connects the box at the bottom with the casing of the transformer. The top pipe is connected at its upper end to the main expansion pipe 12 between the casing of the transformer and the conservator vessel 13 of the plant, just under the gas-collection relay 14 fitted in the usual way below the



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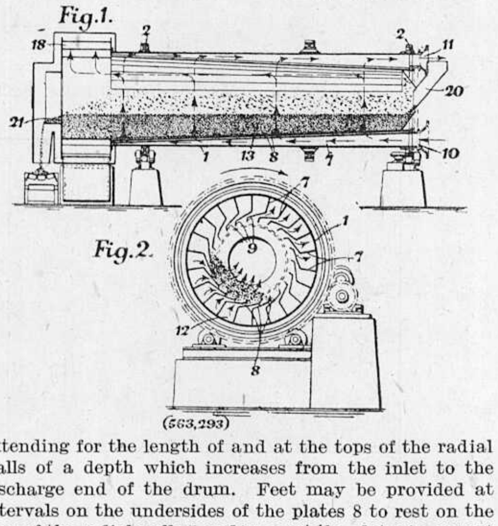
stop valve in this expansion pipe. The bottom pipe is connected to the main tank 4 of the associated plant at approximately 2 ft. above the bottom. The pipe has a branch connection with a drain valve 17 slightly above the stop valve 11. At the bottom of the box 1 is a fitting for the cable sheath 19, the conductor being connected in usual way with the transformer terminal 7. At the top of the box is fitted a pet cock 21 for admission of compressed air for emptying the box. Thus the cable-end box 1 can have a filling of the same liquid as is used in the transformer. Moreover, the pipe connections between the casing and the box provide a circuit for circulation of the oil through the box by the aid of the transformer cooling system. By this means the oil in the box 1 is maintained always in a sound condition. A hydrostatic head is also maintained on the oil within the box, so that voids cannot form and no ingress of moisture can take place. If any gas is formed in the box, the pipe-work permits its free passage up and out of the box. The box is filled by opening the stop valves 9, 11 in the top and bottom pipes. These valves are normally left open in service. In order to empty the box, the stop valve 9 is closed and a supply of dry compressed air admitted at the pet cock 21 to drive the oil through the drain valve 17, which would be subsequently closed. The box can be placed in service immediately after by opening the stop valve 9. Cooling off, "topping up" and de-aeration of the oil are not necessary. Reconditioning of the oil in the box can be effected as part of the cleaning process adopted for servicing the oil in the transformer casing. The gas-collection relay 14 gives warning of any trouble which may occur within the box, such as the working loose by vibration of terminal connections, and so on, thus extending the normal use of the relay for the detection of faults in the electrical plant in the incipient stage. (*Accepted September* 25, 1944.)

MISCELLANEOUS.

563,293. Mixing Drum. Dunford and Elliott (Sheffield), Limited, of London, and H. Lindars, of London. (9 *Figs.*) December 28, 1942.—The invention is rotary drum apparatus for mixing divided solid materials and for bringing gaseous material into contact with divided solid material for the purpose of heating the material, in dehydration of a material, for cooling heated divided solid material, or for bringing about chemical reactions between a gaseous material and a divided solid material. 1 is the drum which is supported by rings 2 on rollers mounted on bases. The drum is rotated by means of a toothed ring secured on it and driven through a pinion which meshes with it. A series of radial walls 7 extend longitudinally through the drum and decrease in depth from the inlet end at the right-hand side to the discharge end at the left-hand side. Each of these radial walls has a plate 8, extending from it over the radial wall 7 behind it, when considered in relation to the rotation of the drum; thus each plate overlaps the plate behind it but is spaced from it. Each plate has a ledge 9 directed inwardly of the drum at an angle to the general direction of the plate 8. The direction of the ledge 9 is also slightly away from the wall from which the plate 8 extends, so that when the wall is horizontal on the rising side of the drum the ledge is directed slightly downwards and material is not lifted by it above the bed of material. The ledge 9 is shown plane, but it may be curved slightly inwardly of the drum. Each plate 8 may be so disposed that it extends from its radial wall 7 at a distance from the inner end. This distance may become progressivley larger from the inlet to the outlet of the drum. In this way cups are formed



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extending for the length of and at the tops of the radial walls of a depth which increases from the inlet to the discharge end of the drum. Feet may be provided at intervals on the undersides of the plates 8 to rest on the tops of the radial walls 7 and support the plates in correct relative positions. The drum rotates against a fixed head at the charging or inlet end, the head having a port 10 corresponding to passages 12 between the radial walls 7. It also has a second port 11 also corresponding to passages 12. The port 10 is arranged to the left of the vertical diameter of the drum and below the horizontal diameter, and the port 11 is arranged diametrically opposite to the port 10. This port constitutes means for introducing heating gas into certain of the passages 12 which are below the body of material 13 treated in the drum when the latter is rotated and the port 11 constitutes means for the exhaust of the gas after it has passed through the mass 13. An extra port 18 for heating gas is connected to an exhauster and has a collecting hopper for dust carried off with the gas. The fixed head carries a feed hopper 20 and the discharge is over a wall 21. In use the drum 1 is rotated. This causes the bed of divided solid material to be raised on the rising side of the drum and assume a position in which its surface is at the angle of repose of the material. The material is continually raised on this side until it falls downwards over the inclined surface of the bed. The ledges 9 assist in raising the material from the bottom of the bed until it reaches the top edge when it falls down over the surface of the bed. Heating gas is admitted to the passages 12, which are immediately opposite to the port 10 in the fixed head. The gas travels through the passages and passes outwards to the bed of material 13 through the spaces between the tops of the radial walls 7 and the undersides of the plates 8. It passes through the bed of material into the centre of the drum, whence it is exhausted through the port 11. A certain proportion of the heating gas is exhausted through the outlet 18. (*Accepted August* 8, 1944.)