THE INNER GRAVING DOCK, COLOMBO HARBOUR.

AT the beginning of the present century, the docking and shipping facilities at Colombo Harbour, Ceylon, consisted mainly of a slipway, which had been completed in 1902, and was designed for craft with deadweights up to 1,200 tons. In 1906, however, the Colombo Port Commissioners constructed a graving dock with a floor length of 700 ft. and a depth of 30 ft. over the sill at low water. These facilities proving inadequate to deal with the larger departmental craft which had either been obtained or the purchase of which was contemplated, and further accommodation also being necessary to meet the Naval requirements of the East Indies Squadron, which uses Colombo as a refilling base, the construction of extended facilities had to be considered. The possibilities of providing this additional accommodation by increasing the length of the slipway, the position of which will be clear from the site plan reproduced in Fig. 2, on page 550, was first investigated. This solution, was, however, found to be not only expensive, but incapable of serving all the requirements of the port. A proposal to construct a small dry dock was, therefore, considered next, and examination disclosed that the most suitable site for this was at the head of the existing graving dock, the position of which is also indicated in Fig. 2.

The proposed area for this extension had the advantages that it was clear of other structures, while borings showed that rock existed at such levels as would allow the whole of the works to be founded on it. In addition, the new dock would be conveniently placed to take advantage of the existing repair shops and other amenities, while the existing pumping plant could also be utilised. Finally, the work of construction could be carried out without sinking a cofferdam and with a minimum of interference with other facilities. Indeed, the sole disadvantage was that ships wishing to use the proposed inner dock would have to pass through the outer dock. It was felt, however, that this objection was more apparent than real, as under the working conditions existing at Colombo, the larger merchant vessels, which occupy the outer dock, are seldom detained for more than a week, and the Cruisers on the station for not more than ten days. On the other hand, the departmental craft and sloops from the Persian Gulf, for the use of which the new dock was intended, would be in occupation for much longer periods and would be seldom rigidly tied for a day or so to a particular docking programme.

It was, therefore, decided to proceed with the project of constructing an inner dock on the site shown in Fig. 2. Incidentally, it was suggested that this dock should be 300 ft. long on the floor and 20 ft. deep over the sill at low water, the entrance being 54 ft. wide. While, however, the site permitted the construction of a dock of these dimensions, equipped with the usual leaf type gates, it was pointed out by the Naval Authorities that if it could be made 50 ft. longer, it would enable flotilla leaders, destroyers and submarines to use it. A length of 350 ft. was accordingly adopted, investigations showing that 40 ft. of the required extra length could be provided by using a Box flap-type gate, opening into the outer dock, instead of a leaf gate; and that by siting this gate inside the head wall of the existing dock and thereby shortening the effective length of the latter by only 5 ft. 4½ in., the whole of the constructional work could be carried out in the dry, as the new gate could be used as a cofferdam during the removal of the wall. The work has been carried out to the designs of Messrs. Coode, Wilson, Mitchell and Vaughan-Lee, 9, Victoria-street, London, S.W.1, under the direct supervision of Mr. T. A. Owles, M.Inst.C.E., Harbour Engineer. Figs. 3 and 4, on Plate XXII, show longitudinal section and plan of the new dock, while typical sections are reproduced in Figs. 5 and 6. A view of the completed dock, looking towards the gates, appears in Fig. 1, and various details of the dock and gate are illustrated in Figs. 7 to 10, on Plate XXII, and Figs. 11 to 17, on page 551.

Construction work proper was started in January, 1936, the excavation for the dock walls being first carried out in heavily-timbered trenches. These trenches were 27 ft. wide at the top between the runners, and were excavated until solid rock was encountered. Where rock was reached above the minimum foundation level of −29·00, drilling and blasting were employed. The rock level was very irregular. In fact, a vertical cliff with a difference in level of over 20 ft. and running diagonally across the length of the dock, was revealed as the work was opened up. In some places excavation was continued down to over 40 ft. below low-water mark before sound rock was encountered. As shown in Fig. 6, this excavation was filled in with 10 to 1 mass concrete to the minimum foundation of the walls. This section also indicates the irregularity of the rock to which attention has been called. As soon as satisfactory foundations had been obtained, the concreting of the walls was put in hand, 7 to 1 mass concrete being used for this purpose. This concrete was faced with pre-cast block work to form the steps and broad altars at levels −23·58 and −11·50, respectively, and the same material was used for the coping at +9·00. Chases for pipes and drains were left in the structure at appropriate places, as indicated in Fig. 4. The construction adopted at the junction between the old and new docks will be clear from Fig. 5. This shows, on the right, the mass concrete wall which has been built in behind the existing wall to a depth of −29·00, and has been connected to the latter by vertical keys. The details of the construction of these keys showing their relationship to the old side wall and the new 7 to 1 concrete, will be clear from Fig. 7. As shown on the left of Fig. 5, a pump chamber has been formed in 7 to 1 concrete behind the existing wall, and has been connected to the latter by horizontal keys.

The excavation and concreting were carried out with the assistance of six 2½-ton to 3-ton locomotive cranes. The cranes on the dumpling dealt with the blocksetting and concreting work, while those on the back of the wall were used for excavation and timbering. The spoil was loaded into flat trays and skips, and after being deposited in side-tip waggons was run out to a site some ¾ mile away, where it was used for the reclamation of swamp land. The con-

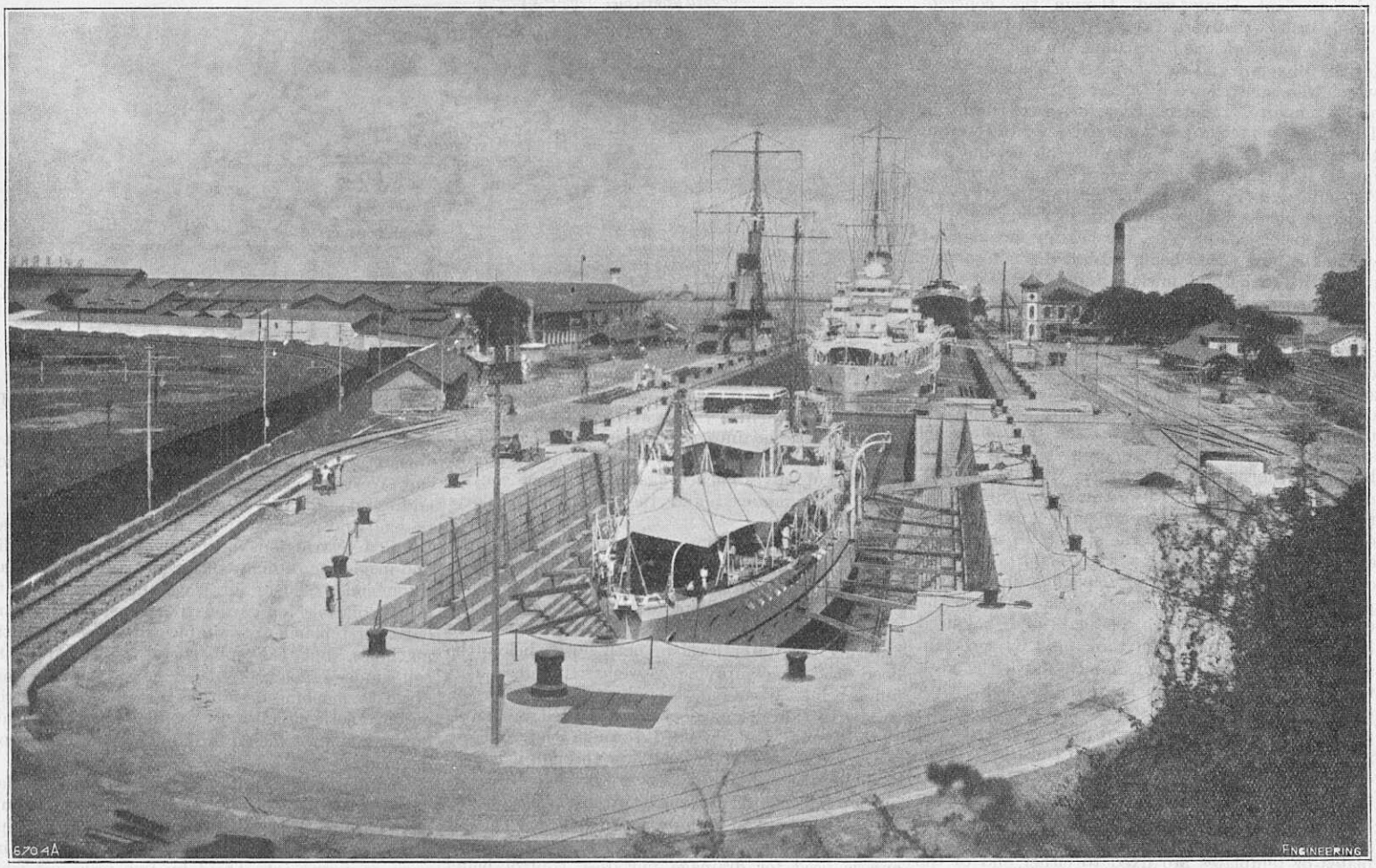


FIG. 1. GENERAL VIEW OF NEW DOCK.

crete was all mixed at a central point near the works, where two petrol-driven mixers, each with a capacity of ¾ cub. yard, were installed. Batching was effected in special end tipping Decauville waggons which were fitted with partitions to provide sand and metal bunkers. The concrete was run out in skips mounted on Decauville flat trolleys, and was handled by the cranes, as required. Excavation was greatly assisted by pneumatic spades, which were found very effective for dealing with the laterite and rotten rock, of which most of the spoil consisted. The walls were carried up on a height of +1·50, and as they reached completion to this height the cranes were transferred to a projecting gantry. The dumpling and the concreting of the floor was carried out from this position, the same mixing plant being used, though the concrete supply track was diverted along the back of the wall.

While this work was proceeding, the hinge castings for the Box gate and certain parts of the gate itself, which were constructed by Messrs. Sir William Arrol and Company, Limited, Glasgow, were received. The hinge was set in position inside the head wall of the existing dock, as shown in Fig. 5, and the quoins forming the entrance were set and faired up. As indicated in the same illustration, pre-cast concrete blocks with a fine granolithic facing were employed for this purpose, the bearing face against which the gate abuts being rubbed down to a true plane with carborundum slabs and water.

The construction of the gate, which was shipped out as plates and angles, will be clear from the elevation, plan and section given in Figs. 8 to 10, respectively. As will be seen, it is of cellular construction the outer skin plating extending from the top to the bottom edge of the lowest rib and the inner plating from the top to the bottom. The spaces between the ribs are sub-divided by vertical bulkheads, forming a series of watertight compartments, as shown in Fig. 10. Under working conditions, certain of these compartments act as buoyancy chambers, so as to reduce the stresses in the lifting and lowering gear, as well as the weight of the gate on the hinge and supports. Openings in the skin plating and ribs permit access of the water to the remaining compartments. The gate is so balanced by means of air and water tanks and by a certain amount of kentledge immediately above the keel, that the operating winch has only to deal with a maximum pull of 15 tons on each rope, when the gate is being lifted or lowered at low water. The gate has a horizontal hinge, which consists of semi-circular machined steel castings, which run along the sill and are fixed to it. The keel, details of which are given in Figs. 11 to 15, is built up of greenheart timbers bolted to the steelwork. Round plates or templates are fixed to either end of the keel post, and the greenheart timber is spotted from wires stretched between these templates and thereafter dressed very accurately to within a few ten-thousandths of an inch. As the timber keel is kept in constant contact with the heel castings, debris cannot lodge in the hinge. The end posts are bolted to channel-irons secured to the gate, as shown in Fig. 17.

The gate itself was shipped out as plates and angles, with the exception of the bottom hinge, which was sent out in one piece with the greenheart facing already in position, though the final dressing was not effected until after erection. Erection was carried out on a jetty, the necessary riveting and caulking up being effected by local labour, as was the dressing of the greenheart keel post and vertical timber. When it had been completed, the gate was launched from the jetty on to a special slipway which had been constructed for the purpose, the launching weight being about 100 tons. This operation is shown diagrammatically in Figs. 18 to 20, on page 551. To ensure stability, not only were two of the permanent tanks at the upper end of the gate partially filled with water, but two additional tanks, which were completely filled, were provided. By this time the entrance had been finished, so that the gate could be floated direct to the site, lowered on to the sill and manipulated by hand tackle into the vertical or closed position, as shown in Fig. 16. Prior to this operation, the ballast water was pumped out and the water level in the graving dock was lowered until the keel was near the sill castings. The lifting rope was pulled and the control ropes slackened, so that the trunnions were touching the guides, while the control valves were opened and adjusted, so as to trim the keel. These valves were again closed when the keel had slid into position in the sill castings. The gate was then closed by means of a winch, and the control valves opened again. Next the control ropes were removed and the gangways-supports fixed in position.

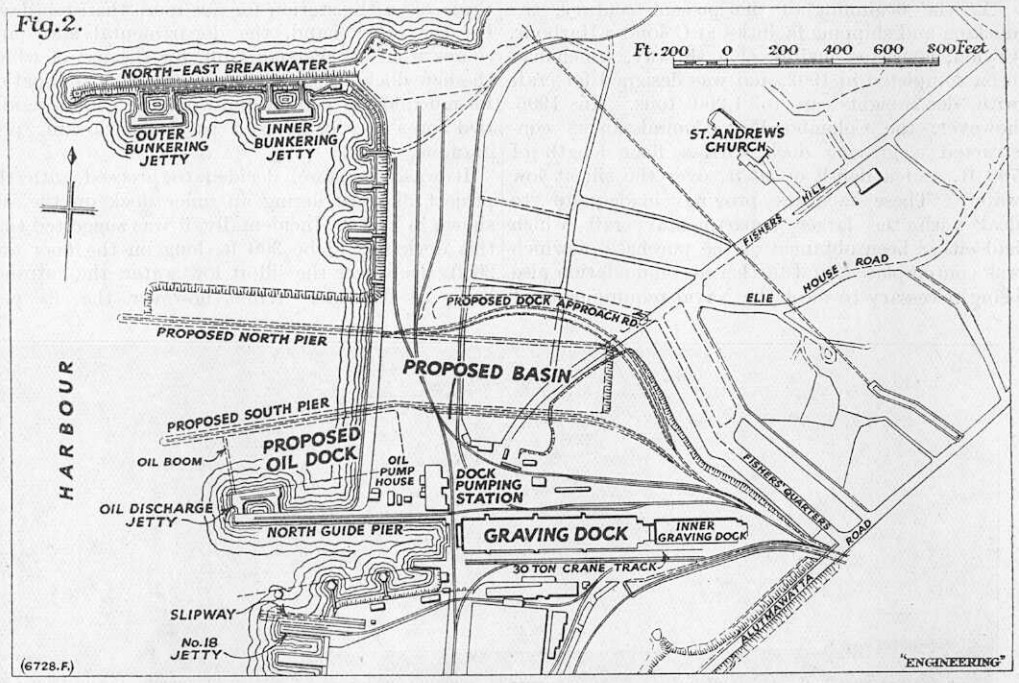
In normal operation the gate is raised and lowered by means of an hydraulic-engined winch. The control wire passes on pulleys round the back of the gate and is anchored on the south side of the entrance. The actual working operation consists in lowering the water level in both docks below the flood holes, this emptying as well as the subsequent filling being carried out through a culvert formed in the north side of the dock as indicated in Fig. 4. This culvert was tunnelled through the concrete of the old dock wall and the flow through it is controlled by a hydraulic penstock. The culvert opens into a pump chamber in which two electrically-driven vertical centrifugal pumps are installed. One of these pumps has a capacity of 300 gallons per minute and is used for drainage purposes, control being effected automatically by a float. The second, having a capacity of 30,000 cu. ft. per hour is designed to deal with very heavy rain and for use as a dewatering pump should it be necessary to keep the outer dock flooded. Once the water levels in both docks are the same the gate can be lowered by the winch until it is water borne. It is then so balanced that it will open when the winch is slacked off, though as a precaution push-off gear consisting of hydraulic rams with a throw of about 2 ft. 6 in. has been installed. The actual raising or lowering operation does not occupy more than 4 minutes.

Some 75,000 cub. yards of laterite and rock were excavated during construction and were deposited on the swamps. About 11,500 cub. yards of this was rock. The concrete used amounted to 28,500 cub. yards, of which 4,100 yards was of 10 to 1, 21,000 yards of 7 to 1 and 3,400 yards of 4 to 1 either in pre-cast blocks or mass facing to the floor. The bollards, keel blocks and other castings were cast locally at the Government Factory of the Public Works Department and all the other works were carried out departmentally, the total cost, excluding supervision, being about 82,500*l*.

LAUNCH OF H.M. SUBMARINES "TRIAD" AND "TRUANT."—Two further submarines for the British Navy were launched at the Naval Construction Works, Barrow-in-Furness, of Messrs. Vickers-Armstrongs Limited, on May 5. These ships, H.M.S. Triad and Truant are respectively the 177th and 178th submarines to be launched at Barrow.

THE INNER GRAVING DOCK, COLOMBO.

Fig. 2.



LITERATURE.

Winding Alternating-Current Motor Coils. By G. A. VAN BRUNT and A. C. ROE. London: McGraw-Hill Publishing Company, Limited. [Price 18*s*.]

THIS is an essentially practical treatise by two authors, one of whom is connected with the American Westinghouse Company. It appears to be addressed primarily to foremen or managers of re-wind and repair shops operating on a large scale, detailed instructions being given for the winding and insulation of many different types of stator and rotor coils. There are several chapters on the design of coils for various purposes, and in particular for replacing unsuitable windings on existing machines, but the subject is treated from the coil-winder's point of view, little attention being given to machine design or the effect of electrical and magnetic circuits. A useful chapter is included on records, for which a form of card index is recommended.

One of the more interesting chapters is the last. This deals with glass insulation, of which accounts have recently appeared in the technical press. Spun glass of an especially fine character is twisted into yarn or woven into braid by two processes which appear to correspond roughly to the handling of cotton and artificial silk, respectively. These materials can be used in place of asbestos string or ordinary insulating tape. They are apparently somewhat fragile, and are, therefore, usually impregnated. The resulting insulation is thinner and denser than the more conventional types. This improves the space factor and heat conduction, thereby increasing the possible rating of any frame size. The book is clearly written and well illustrated and can be recommended for use within the limitations imposed by the subject-matter and style.

Trade Marks and their Protection under the Trade Marks Act, 1938, with Notes on Protection Abroad. By REGINALD HADDAN. London: Sir Isaac Pitman and Sons, Limited. [Price 5*s*. net.]

THE recent changes in the trade mark protection given by the Trade Marks Act of 1905 include two important features, namely, the possibility now created of transferring registered trade marks without the goodwill of the business, and a new classification of the arts or products in respect of which trade marks may be registered. These changes alone are sufficient to justify the claim in this treatise by Mr. Reginald Haddan, that no excuse is necessary for the publication of a book "intended to explain the new law and practice to trade mark owners and others concerned." The "others concerned" are presumably those who wish to have a general view of the subject, to enable them to

THE INNER GRAVING DOCK, COLOMBO.

(For Description, see Opposite Page.)

Fig. 11. SECTION CC

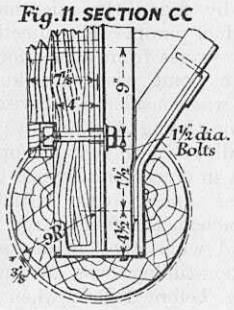
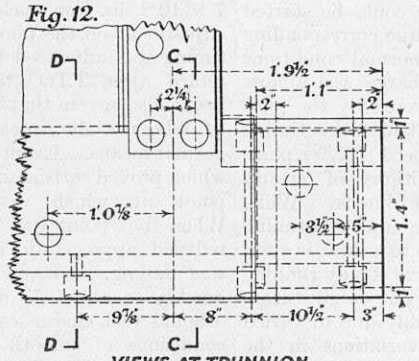


Fig. 12.



VIEWS AT TRUNNION

Fig. 13. TRUNNION END

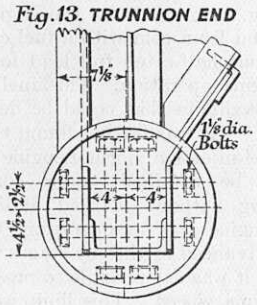


Fig. 14. SECTION DD

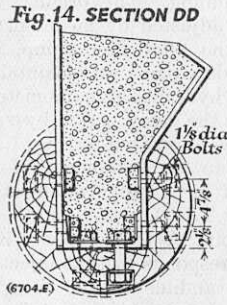


Fig. 15.

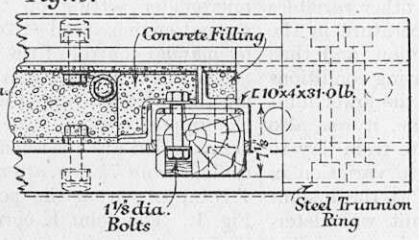


Fig. 16. END ELEVATION OF GATE

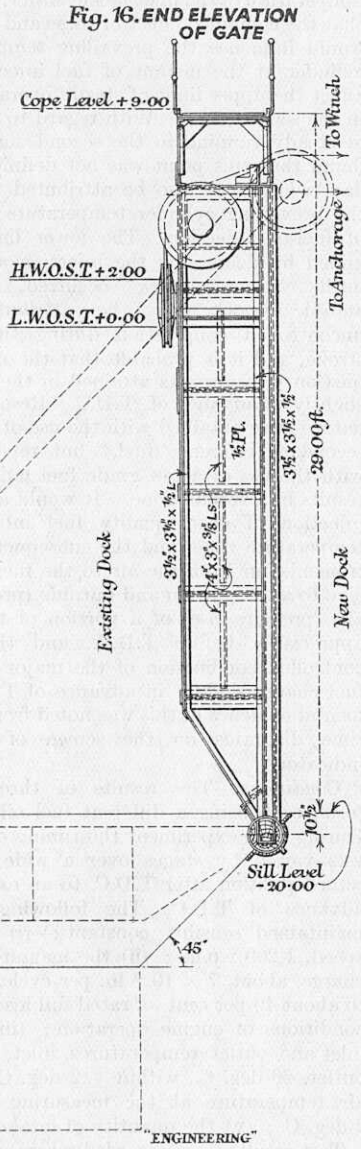


Fig. 17. CROSS SECTION OF END POST

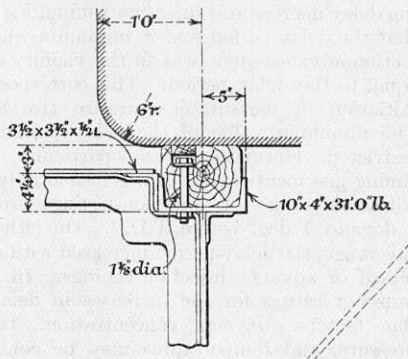


Fig. 18.

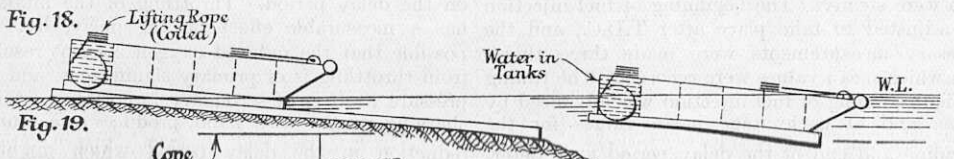


Fig. 19.

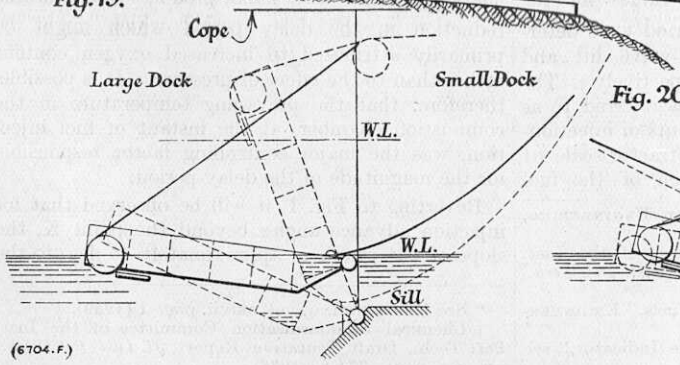
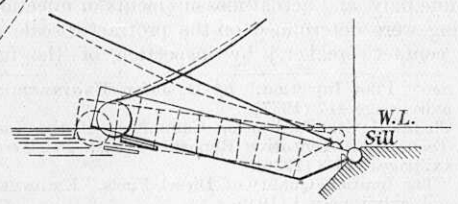


Fig. 20.



(6704.F.) "ENGINEERING"

appreciate what is told to them by their advisers, for without advice the subject is difficult. An indication of its difficulty is conveyed in the book in connection with the regulations governing renewals, of which the complaint is made that "these meticulous rules are a considerable source of annoyance, both to trade mark owners and to registration agents."

Mr. Haddan's book opens with an explanatory chapter on the nature of trade marks, and includes both the old and the new definitions. The sections dealing with defensive marks, ownership separated from goodwill, and registered users, among those which follow, may be selected for mention as useful commentaries. The observation, on page 53, that "it has been held that it is inexpedient to place on the register unnecessary disclaimers," might be held also to apply to patents. There is an interesting section, containing some 20 pages, dealing with the infringement of trade marks. Although practice under the new Act is not yet extensive, it might have been well if the author had pointed out that, apparently, the Comptroller does not consider an agent or concessionaire of the manufacturer to be necessarily entitled to registration as a user. Attention may be drawn to an error in the duty payable on the change-of-address form cited on page 66; the correct duty is 10*s*.

Spontaneous Fluctuations of Voltage. By E. B. MOULLIN. London: Oxford University Press (Humphrey Milford). [Price 17*s*. 6*d*.]

THERE has been intense activity during recent years in that field of scientific research which deals with the complex study of physical phenomena. Investigations have been carried out from many angles and a technique is in course of development which shows promise of leading to far-reaching and important implications. Some aspects of the problems recently studied have been dealt with in the Oxford Engineering Science Series; the present publication is a further volume in that admirable collection. It is devoted to a survey of the experimental work carried out during the last 15 years relating to Brownian motions, shot effect, and kindred phenomena.

After a short study of thermal fluctuation voltage, the author proceeds to discuss the general theory of shot voltage, dealing with the experimental verification of the equation for shot voltage, and including a critical examination of the process of thermionic conduction. This is followed by some consideration of measurements of shot voltage in space-charge limited diodes, with an attempt at their interpretation. A summary is given of Schottky's recent fundamental paper discussing the relation between thermal fluctuations and shot effect. The volume concludes with a chapter bearing on various practical questions and dealing with technical problems involving fluctuations, including the response of rectifiers to fluctuation voltages, the relative importance of shot and thermal fluctuation in amplifiers, signal-to-noise ratio as a function of coupling to an aerial, and thermal fluctuations in communication cables. It is now clear that the fluctuation voltage which is rectified in a radio receiver is dominated by the component due to thermal agitation in the input circuit to the first valve. It would seem to be worth while to make a precise study of the residual motion and thermal fluctuation voltage as a function of magnetic field and time period, since galvanometers of extreme sensitivity are vital to physiologists. The notes dealing with the practice of measuring fluctuation voltages will prove invaluable to those students of this branch of physical science.

Reports on Progress in Physics. Vol. V. London: The Physical Society. [Price 20*s*. net.]

PRESENTED as a survey of recent developments in physical science, the progress reports of the Physical Society provide valuable material for those engaged in industrial research and also serve to acquaint the non-specialist with the advances made in the various branches of the subject. In the present volume, Dr. R. C. Brown discusses theories on recently-observed surface-tension phenomena and, concerning the Brownian motion, refers to the theoretical limits of measurability reported by Gerlach. In the section on elasticity, the applica-

tion is described of the method of relaxations, for the analysis of load distribution in frameworks, to a study of beams of variable cross-section. It has been shown recently that molecules of a liquid have a certain degree of order, as in a solid, and calculations of the physical properties of liquids have followed. Extensive future use of thermo-plastic resins for cable sheathing is indicated ; pure hydrocarbons would appear to be the more suitable for this application, on account of their low dielectric losses. The use of resins for machine bearings is also important, as their employment enables friction losses to be materially reduced. The development of radio-meteorographs is commented upon, the Harvard instrument, in particular, having been found very reliable.

By rotating a longitudinally-vibrating body, its independence of the Fitzgerald contraction has been demonstrated. This experiment is described by Dr. E. G. Richardson, who also surveys recent investigations on acoustics. Dr. R. W. Powell, of the National Physical Laboratory, describes means recently employed for measuring high and low temperatures. An account of optical-glass manufacturing developments, contained in one of the reports, concludes by giving details of the progress made in annealing methods. A table indicating the present state of spectroscopic analysis, with a useful bibliography, has been contributed by Professor A. G. Shenstone, who describes the method by which rulings of 30,000 lines per inch have been made on aluminised pyrex blanks.

Recent researches on the scattering of elementary particles have established the existence of large attractive forces between protons at relatively short distances, but in the general treatment of the interaction between particles, it is now clear that both nuclear disintegration and scattering must be considered. Cosmic-ray intensity, increasing with height to a maximum of 40 times the value at sea-level and then decreasing to about one-third of the maximum value, has been measured. Yukawa's theory is discussed, and it is concluded that future investigations of hard cosmic rays will increase knowledge of the fundamental properties of particles. An interesting article by Mr. A. W. Barton, on the teaching of physics, concludes the Reports, the utility of which is materially augmented by the extensive bibliographical references.

THE INFLUENCE OF INJECTION-TIMING ON THE DELAY PERIOD IN A COMPRESSION - IGNITION ENGINE.

By J. RIFFKIN, Ph.D., A.M.I.Mech.E.

ON page 1, *ante*, the writer gave an account of a series of investigations carried out in the Mechanical Engineering Department of the University of Birmingham to study the ignition quality of Diesel fuels, and below an account is given of further investigations carried out in the same laboratory in order to ascertain the influence of injection-timing on the delay period in a compression-ignition engine. Trials were run to determine the effect produced on the ignition delay period, etc., by varying the timing of fuel injection over a wide range. A Tangye single-cylinder, four-stroke cycle, open combustion chamber, compression-ignition engine was provided with a special injection system* to enable the injection-timing to be conveniently varied over a wide range while the engine was in operation. Three different fuel oils were supplied in turn, and engine performance data, including measurements of the delay period, were recorded for each change of injection timing.

In a preliminary investigation, attempts were made to ascertain whether the engine could be started by hand from cold, and, if so, whether it would operate under steady conditions with an injection advance angle outside the usual working range. The fuel was commercial Shell Diesoline, and the engine was rotated by hand with an arbitrarily chosen injection advance angle in the vicinity of 100 deg. before T.D.C. With this timing for the beginning of fuel injection, the attempts to start the engine were unsuccessful. Advancing the injection beyond this timing also failed to fire the charge, but eventually it was found that with an injection advance angle in the neighbourhood of 80 deg. before T.D.C., the engine could be started by hand from cold with a fuel charge corresponding to about half-rated full load for normal conditions of engine operation. This fuel charge was almost the maximum that could be delivered by the pilot pump.* It was further found that with this timing for fuel injection, normal engine speed (1,200 r.p.m.) could be attained under conditions of steady running without marked audible knock. While the engine was in operation, the injection-timing was advanced further by stages up to a limit beyond which it was not possible to preserve steady running at normal speed. This limit was not definite from day to day, which fact was probably due to varied atmospheric conditions and to variations in the temperature of the inlet jacket water. It is suggested that the combined effect of these and other variables would influence the prevailing temperature in the cylinder at the instant of fuel injection, and thus affect the upper limit of steady operating conditions in the second zone. With regard to the lower limit of steady running in the second zone, it was also found that this point was not definite from day to day, which may also be attributed to variation in the prevailing cylinder temperature at the instant of fuel-oil injection. The lower limit was determined by decreasing the injection advance timing until violent knock occurred. This severe audible knock may be attributed to rapid uncontrolled combustion during the compression stroke, and it is probable that the maximum combustion pressure was attained in the vicinity of, or slightly in advance of, T.D.C. Results of a similar nature were obtained with the use of the high-grade secondary reference fuel,† but repeated attempts with the use of a low-grade fuel failed to give any results in a second zone. It would appear that the injection of good quality fuel into a particular temperature zone, and the subsequent rate of heat transmission from the air to the fuel, were conducive to auto-ignition and burning (producing noticeable pressure rise) of a portion of the fuel charge appreciably before T.D.C., and then rapid uncontrolled combustion of the major portion of the fuel charge slightly in advance of T.D.C. Experimental evidence of this was noted from the pressure-time diagrams on the screen of the electrical indicator.‡

Conditions.—The results of three independent tests, each using a different fuel oil, are recorded. During each experiment the timing of fuel injection was varied by stages over a wide range from a retard position after T.D.C. to an extreme point in advance of T.D.C. The following factors were maintained sensibly constant :—(i) normal engine speed, 1,200 r.p.m. ; (ii) the magnitude of the fuel charge, about 7×10^{-5} lb. per cycle, corresponding to about 40 per cent. of rated full load under normal conditions of engine operation ; (iii) jacket water inlet and outlet temperatures, inlet, 12 deg. C. and outlet, 60 deg. C., within $\pm$ 2 deg. C. ; (iv) intake-air temperature at the measuring orifice, within 2 deg. C. ; (v) the quantity of intake air.

Test results were recorded when operating conditions were steady. The beginning of fuel injection was adjusted to take place after T.D.C., and the necessary measurements were made three times, from which mean values were recorded. The timing for the beginning of fuel injection was advanced by stages, and at each stage mean values for the beginning and end of the delay period were determined by inspection of the fuel-valve lift and pressure-time indicator diagrams respectively.† The calibrated scale on the gearbox* was referred to as a guide only, and actual measurements of injection-timing were determined on the protractor scale of the contact breaker,§ by inspection of the fuel valve-lift diagram on the screen of the electrical indicator.*

In the first test, the fuel used was the high-grade secondary reference fuel† and the magnitude of the fuel charge was maintained constant at about 7×10^{-5} lb. per cycle by fixing the micrometer adjustment on the pilot fuel pump. The injection-timing was advanced by stages from a position of retard after T.D.C. to a point when the knock became so severe that it was considered inadvisable to advance the injection-timing further by the normal means. Eventually, a method was adopted which proved satisfactory in proceeding beyond that point at which severe knock was initiated. When that point was reached, the fuel charge was reduced appreciably, and while the engine speed was falling, the injection-timing was advanced quickly to about 75 deg. before T.D.C. when the original fuel charge could be " reinstated " under conditions of smooth running. The original fuel charge was conveniently adjusted by means of the micrometer setting on the pilot fuel pump, and normal engine speed (1,200 r.p.m.) was maintained by manual control of the hydraulic dynamometer.

The effect produced on the delay period by varying the injection-timing is illustrated in Fig. 1., on the opposite page. Mean measurements of the delay period are recorded for a range of injection-timings from $7\frac{1}{2}$ deg. after T.D.C. to $27\frac{1}{2}$ deg. before T.D.C., *i.e.*, from the point A to the point K in Fig. 1. The point K corresponds to that injection-timing at which severe audible knock occurred, and the delay period was then 15 deg. As injection began at $27\frac{1}{2}$ deg. before T.D.C., and measurable pressure rise started at $12\frac{1}{2}$ deg. before T.D.C., it is probable that the rapid uncontrolled combustion, so far in advance of T.D.C., was responsible for the severe knock. An inspection of the curve connecting delay degrees and injection-timing, Fig. 1, shows that the delay period was a minimum when the injection advance angle was in the vicinity of a value equal to the delay period. This corresponds to the initiation of measurable pressure rise at T.D.C. The minimum value of the delay period was not restricted, however, to the particular injection-timing just mentioned, but was measurably constant within a range of injection-timings from about 3 deg. to 7 deg. before T.D.C. On either side of this range, the delay period increased with increasing retard or advance injection-timings. In seeking a cause or causes for the increases in delay period, the factors, oxygen concentration, turbulence, pressure, and temperatures may be considered in turn. The quantity of air aspirated per cycle was sensibly constant over the range of injection-timings ; thus the oxygen concentration was practically constant and may therefore be eliminated as a contributory factor. It is doubtful if slight variations in turbulence, resulting from different piston positions at the instant of fuel injection, had any measurable influence on the delay period. According to the experimental evidence of Ricardo, and Le Mesurier and Stansfield, it would appear that the effect of turbulence on the delay is negligible, but is apparently important for the completion of combustion subsequent to the delay period. With regard to the variation in pressure at the instant of fuel injection, it is doubtful if pressure itself exercised any appreciable measure of control on the delay period. Throttling of the intake-air has a measurable effect on the delay, but it is possible that the reduced oxygen content resulting from throttling is of primary significance, and that pressure itself is of secondary importance. Supercharging, on the other hand, produces a measurable reduction in the delay period which might be primarily attributed to increased oxygen content rather than to the effect of pressure. It is possible, therefore, that the prevailing temperature in the combustion chamber, at the instant of fuel injection, was the major controlling factor responsible for the magnitude of the delay period.

Reverting to Fig. 1, it will be observed that for injection advance angles beyond the point K, the slope of the graph is approximately 45 deg. to the

* See " Pilot Injection," by D. Jafar, ENGINEERING, vol. cxliv, page 417 (1937).

* See " Pilot Injection," by D. Jafar, ENGINEERING, vol. cxliv, page 417 (1937).

† Chemical Standardisation Committee of the Inst. Pet. Tech. Draft Tentative Report, *Jl. Inst. Pet. Tech.*, vol. xx, pages 774-8 (1936).

‡ " The Ignition Quality of Diesel Fuels," ENGINEERING, vol. cxlvii, page 1 (1939).

§ " Cathode-Ray Oscillograph Engine Indicator," see ENGINEERING, vol. cxl, page 183 (1935).

* See ENGINEERING, vol. cxlvii, page 1 (1939).

† Chemical Standardisation Committee of the Inst. Pet. Tech., Draft Tentative Report, *Jl. Inst. Pet. Tech.*, vol. xx, pages 774-8 (1936).

base line; *i.e.*, to the left of the point K, further increases in injection-timing would probably be accompanied by equal increases in delay. At the point K, the injection-timing was $27\frac{1}{2}$ deg. before T.D.C., the delay was 15 deg., and measurable pressure rise began at $27\frac{1}{2} - 15 = 12\frac{1}{2}$ deg. before T.D.C. If the injection-timing be further increased by θ deg., then measurable pressure rise would begin at $(27\frac{1}{2} + \theta) - (15 + \theta) = 12\frac{1}{2}$ deg. before T.D.C. Hence, if the slope of the graph beyond the point K be truly at 45 deg., then measurable pressure rise would continue to begin at $12\frac{1}{2}$ deg. before T.D.C. for further increases in injection-timings.

In Fig. 2, the delay period, exhaust temperature, and load are plotted against injection-timings. The

Fig. 1. **HIGH GRADE REFERENCE FUEL**

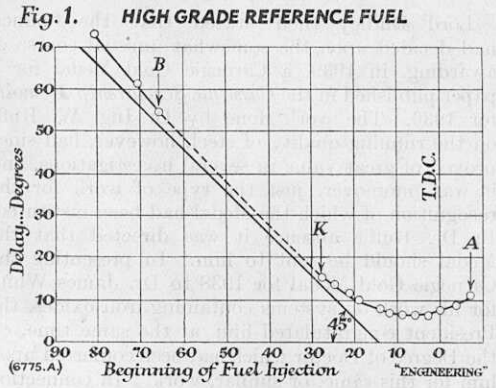
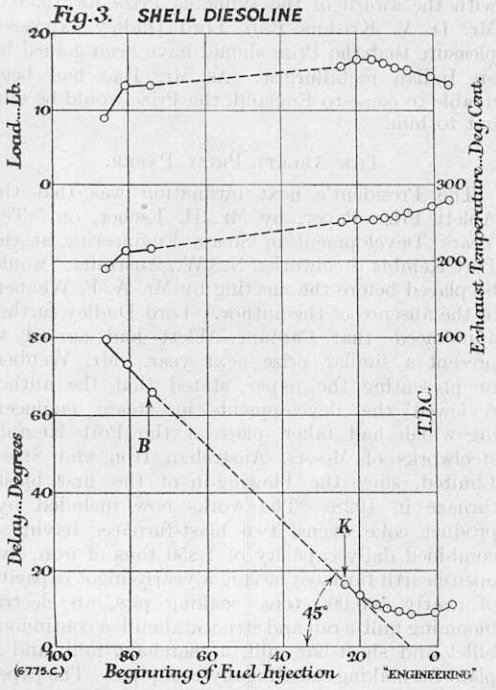


Fig. 3. **SHELL DIESOLINE**



severe knock at the point K was associated with marked reductions in the exhaust temperature and load. In the second zone, *i.e.*, to the left of the point B, the power output and the exhaust temperature were considerably less than the corresponding values in the first zone (A to K). In the second zone, steady engine operation was accompanied by a clear exhaust, indicating satisfactory combustion of the fuel. It was noted also that the heat carried away by the jacket water in the second zone was greater than that in the first zone. During steady engine operation in the second zone, an inspection of the pressure-time diagrams on the screen of the electrical indicator provided evidence of a slight, yet measurable, pressure rise in advance of the main pressure rise denoting the beginning of rapid uncontrolled combustion. It is suggested that this "primary" slight pressure rise during the compression stroke may be attributed to "slow-burning" of a portion of the fuel charge, which, in turn, was largely responsible for the excess heat carried away by the jacket water. In an attempt to draw up a heat balance for the second zone, it was found that the excess heat carried away by the jacket water was considerably less than the heat equivalent of the reduced power output. It is probable that this reduced power output was due to a portion of the fuel charge coming into contact with the cylinder wall and acting in the nature of a lubricant, instead of undergoing combustion.

In the second test the fuel used was commercial Shell Diesoline, and the fuel charge was maintained constant at about 7×10^{-5} lb. per cycle, corresponding to about 40 per cent. of rated full load under normal conditions of engine operation. The injection-timing was advanced by stages up to a limit determined by severe audible knock, *i.e.*, the point K in Fig. 3. Entry into the second zone was made possible by adopting the method already described in the first test. Fig. 3 shows that the curves are similar in form to those obtained when the high-grade secondary reference fuel was used (Fig. 2). For advance injection angles beyond the

Fig. 2. **HIGH GRADE REFERENCE FUEL**

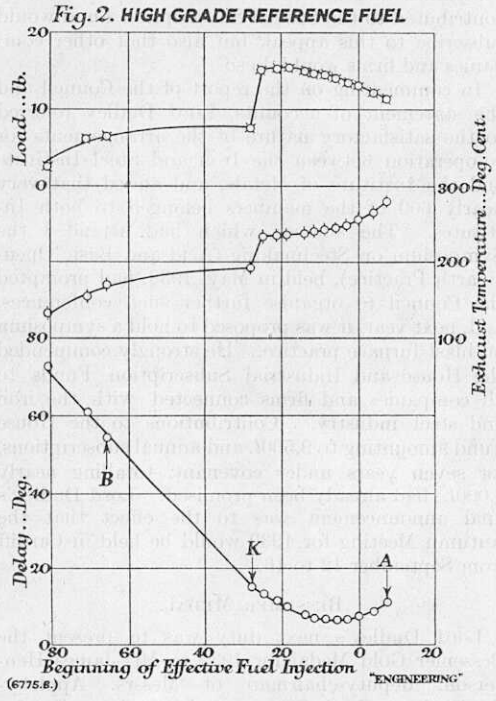
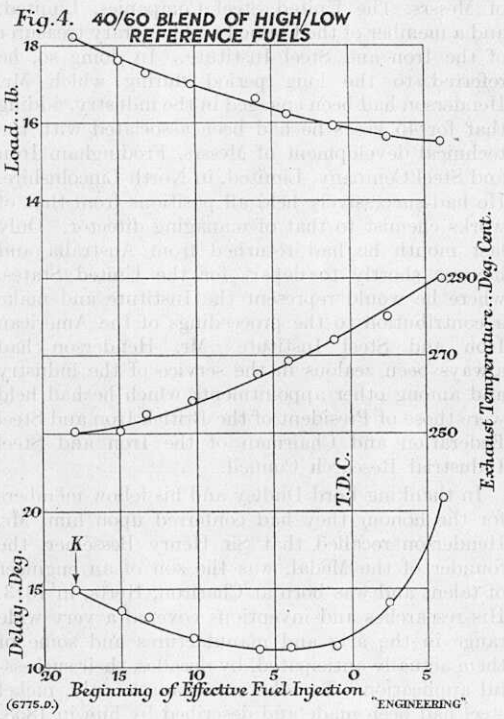


Fig. 4. **40/60 BLEND OF HIGH/LOW REFERENCE FUELS**



point K, Fig. 3, further injection advance timings would be accompanied by equal increases in delay. At the point K, corresponding to an injection advance timing of 24 deg. before T.D.C., the delay period was $15\frac{3}{4}$ deg., therefore measurable pressure rise began at $8\frac{1}{4}$ deg. before T.D.C. The point B represents entry into the second zone and relates to an injection-timing of 74 deg. before T.D.C. Measurements were recorded implying that, what may be termed a "primary pressure rise," was initiated at $19\frac{1}{2}$ deg. before T.D.C., whereas the beginning of rapid uncontrolled combustion was at $8\frac{1}{4}$ deg. before T.D.C. Thus, for further increases in injection-timings beyond the point K, the rapid uncontrolled combustion would continue to begin at $8\frac{1}{4}$ deg. before T.D.C. In the second zone, it was observed that steady engine operation was accompanied by low power output, low exhaust temperature, and a clear exhaust, indicating complete combustion. Samples of the exhaust gases were collected and analysed for both zones of engine operation, and the results showed conclusively that combustion in the second zone was as complete as that in the first zone. It was further recorded that the heat carried away by the jacket water during engine operation in the second zone was greater than that for the first zone. The reduction in power output for the second zone could not, however, be fully accounted for by the increased heat losses to the jacket water. Again, the heat carried away by the exhaust gases in the second zone was appreciably less than that in the first zone. It is assumed, therefore, that for the second zone, a portion of the fuel charge did not undergo combustion, and that the position of the piston during fuel injection enabled this portion of the fuel to come in contact with the cylinder wall and act as a lubricant.

In the third test, the fuel used was a blend by volume of 40 per cent. high-grade and 60 per cent. low-grade secondary reference fuels, and the fuel charge was maintained constant. The test results are illustrated graphically in Fig. 4, and it will be observed that the timing of fuel injection was restricted to a range of from 6 deg. after T.D.C. to 18 deg. before T.D.C. The delay period passed through a minimum value of 11 deg. for an injection advance angle in the vicinity of 6 deg. For measurable pressure rise to begin at T.D.C., this fuel required an injection advance angle of $12\frac{1}{2}$ deg. under the test conditions. Severe audible knock originated at the point K, and repeated attempts to find a second zone associated with smooth running were unsuccessful. It is probable that for injection advance angles appreciably beyond the point K, the prevailing temperature in the combustion chamber at the instant of fuel injection, and the subsequent rate of heat transmission from the air to this fuel, were inadequate to fire the charge. It was not possible to start the engine by hand from cold with an injection advance timing appreciably beyond the point K, *i.e.*, 18 deg. before T.D.C.

Conclusions.—The timing of fuel injection influenced the value of the delay period, and the prevailing temperature in the combustion chamber at the instant of fuel injection was probably the major controlling factor. When the injection-timing was varied over a wide range from a retard to an extreme advance position, the delay period at first decreased, passed through a minimum value, and then increased with increasing injection advance-timings. With a high-grade fuel, an injection advance angle was attained when severe audible "knock" occurred, and further increases in injection advance timings would be accompanied by equal increases in the delay period. With a high-grade fuel, the Tangye engine could be started by hand from cold and operated steadily with an injection advance timing appreciably beyond the point at which severe audible knock occurred. The existence of a second zone of operation would appear to be governed by the ignition quality of the fuel. With a low-grade fuel, an injection advance timing was reached at which severe audible knock occurred, and beyond this point it was not possible to enter a second zone associated with steady running. It is probable that the prevailing temperature in the cylinder was then too low to initiate the necessary physical and chemical changes preparatory to combustion of the low-grade fuel.

The author desires to record his thanks to Professor S. Lees, M.A., for his interest in this work, which made possible the use of the test engine and the acquisition of other necessary equipment, as well as for his advice and helpful suggestions.

AIR-RAID PRECAUTIONS FOR THAMES BRIDGES.—The London County Council, after consultation with the Ministry of Transport, has decided to purchase at once materials that might be required to repair damage done to the Thames bridges during air raids. Screens for shielding navigation lights on the bridges and certain of the piers are also to be constructed and stored in event of emergency.

THE IRON AND STEEL INSTITUTE.

THE seventieth annual general meeting of the Iron and Steel Institute commenced on Wednesday, May 3, in the Hall of the Institution of Civil Engineers, Great George-street, Westminster, S.W.1, and was concluded on Friday, May 5. The Chair at the opening session was occupied by the President, the Earl of Dudley, M.C.

REPORT OF THE COUNCIL.

The minutes of the previous meeting having been dealt with, the annual Report of the Council, which concerned the activities of the Institute during the year ending December 31, 1938, was presented to the meeting. This showed that the total membership of the Institute, on December 31 last, was 2,630, compared with 2,487 on December 31, 1937. While the Council considered that the increase in the membership was satisfactory, they believed that the potential membership of the Institute was still substantially greater, and they hoped that the increased service and facilities offered by the Institute would encourage others to join. The Council deeply regretted to have to record the deaths of thirty-one members, which had occurred during 1938. Among these were Mr. F. Bainbridge, Dr. T. Baker, Professor W. A. Bone, the Ninth Duke of Devonshire, Mr. A. Hutchinson, Sir W. J. Jones, Professor W. H. Merrett, Mr. M. Métayer, Sir Robert Mond, Mr. R. Vondracek, Dr. A. Wahlberg, Mr. L. D. Whitehead, and Professor F. Wüst. The Andrew Carnegie Gold Medal for 1938 had been awarded to Dr. James White for his paper, "Equilibrium at High Temperatures in Systems Containing Iron Oxides," published in the *Carnegie Scholarship Memoirs* for 1938. An Andrew Carnegie Gold Medal had also been awarded to Dr.-Ing. W. Ruff for his paper, "The Running Quality of Liquid Malleable Iron and Steel," published in the *Carnegie Scholarship Memoirs* for 1936. The Williams Prize for 1938 had been awarded to Mr. D. V. Krishna Rao for his paper, "The New Steel Plant of the Mysore Iron and Steel Works, Bhadravati, India," published in vol. cxxxviii of the *Journal* (No. II, 1938). The prize of 50*l.* offered by Captain C. A. Ablett, O.B.E., M.Inst.C.E., for the best paper on a subject connected with engineering in iron or steel works, to be presented at the annual general meeting of the Institute, in May, 1939, had been gained by Mr. H. Escher, the title of his paper being "Ten Years' Development in Steam Engineering at the Port Kembla Works, N.S.W., Australia." Other sections of the report of the Council dealt with the transfer of the Institute's offices to No. 4, Grosvenor-gardens, London, S.W.1, to the scheme of co-operation with the Institute of Metals, and to last year's meetings, all of which matters have already been dealt with in our columns. The activities, during the year under review, of the various joint technical committees of the Institute and the Iron and Steel Industrial Research Council were briefly reviewed, while a list of the honours and appointments conferred upon members was also included. The report concluded with a list of the Institute's representatives on various governing bodies and committees.

HONORARY TREASURER'S REPORT.

The report presented by the honorary treasurer of the Institute, Mr. James Henderson, showed that the income of the general fund of the Institute for the year ending December 31, 1938, was 13,480*l.*, an increase of 819*l.* over the corresponding figure for the previous year. The expenditure, however, amounted to 15,807*l.*, representing an increase of 1,382*l.*, which, it was pointed out, was mainly due to an increase in salaries owing to the additional staff required to cope with the greater activities of the Institute. Furthermore, printing costs, as a result of the larger volume of publications issued to members, had also increased. The receipts of the Special Subscription Fund, as before, had been taken into account, the amount received being 2,853*l.*, against 3,001*l.* in the previous year. After the usual transferences to reserve accounts, the income and expenditure account showed a balance of 104*l.*, being excess of income for the year. The Council again expressed thanks to the companies and associations that had made contributions to this Special Fund and to those individuals who had personally interested themselves in the payment of subscriptions. The Council had now decided to issue an appeal for donations to a House Fund and for special annual subscriptions for a period of seven years. The objects were to provide a sum of not less than 15,000*l.* in order to pay the cost of securing and equipping the new premises of the Institute at No. 4, Grosvenor-gardens, and to provide an assured annual income from the industry of not less than 4,000*l.*—additional to that derived from membership fees and other sources of income. The industrial subscriptions were intended to take the place of the special subscriptions from the industry, which had been received since 1933. The Council hoped that not only those companies and associations which had previously contributed to the Special Subscription Fund would subscribe to this appeal, but also that other companies and firms would do so.

In commenting on the report of the Council and the statement of accounts, Lord Dudley referred to the satisfactory nature of the arrangements for co-operation between the Iron and Steel Institute and the Institute of Metals, and added that very nearly 600 of the members belonged to both Institutes. The success which had attended the Symposium on Steelmaking (Acid and Basic Open-Hearth Practice), held in May, 1938, had prompted the Council to organise further such conferences, and, next year, it was proposed to hold a symposium on blast-furnace practice. He strongly commended the House and Industrial Subscription Funds to all companies and firms connected with the iron and steel industry. Contributions to the House Fund amounting to 9,500*l.* and annual subscriptions, for seven years under covenant, totalling nearly 2,000*l.*, had already been promised. Lord Dudley's final announcement was to the effect that the Autumn Meeting for 1939 would be held in Cardiff from September 12 to 16.

BESSEMER MEDAL.

Lord Dudley's next duty was to present the Bessemer Gold Medal for 1939 to Mr. James Henderson, deputy-chairman of Messrs. Appleby-Frodingham Steel Company, Limited, a director of Messrs. The United Steel Companies, Limited, and a member of the Council and honorary treasurer of the Iron and Steel Institute. In doing so, he referred to the long period during which Mr. Henderson had been engaged in the industry, adding that for 45 years he had been associated with the technical development of Messrs. Frodingham Iron and Steel Company, Limited, in North Lincolnshire. He had successively held all positions from that of works chemist to that of managing director. Only last month he had returned from Australia and he was shortly to depart for the United States, where he would represent the Institute and make a contribution to the proceedings of the American Iron and Steel Institute. Mr. Henderson had always been zealous in the service of the industry and among other appointments which he had held were those of President of the British Iron and Steel Federation and Chairman of the Iron and Steel Industrial Research Council.

In thanking Lord Dudley and his fellow-members for the honour they had conferred upon him, Mr. Henderson recalled that Sir Henry Bessemer, the founder of the Medal, was the son of an engineer of talent and was born at Charlton, Herts, in 1813. His researches and inventions covered a very wide range in the arts and manufactures and some of them actually anticipated, by decades, their successful application. To take one example only, nickel steel had been made and described by him in 1858. His first patent had been taken out in 1838 and his last in 1883, and during these 45 years he had spent over 10,000*l.* in patent fees alone. His name however, would always be associated with his steel-making process, whereby the mass production of steel, from cast iron, had first been made possible. He had patented this in 1855, and first made it public in a paper read before the British Association in 1856. Bessemer was the second president of the Iron and Steel Institute, following after the Seventh Duke of Devonshire, and serving from 1871-73. In the latter year he had handed over the sum of 400*l.*, the interest on which was to provide a Gold Medal, to be awarded at each of the annual meetings of the Institute. The third president of the Institute had been Sir Lowthian Bell, F.R.S., and, in 1874, he had been the first recipient of the Bessemer Medal. The second recipient had been Sir William Siemens, F.R.S., and he had been followed by a long list of metallurgists of world-wide renown. For this reason, he was proud to have been awarded the Medal. He would like to take the opportunity of paying tribute to his late chief, Mr. Max Mannaberg, who had started the works at Frodingham; he felt it an honour to have been associated with him in that great undertaking.

CARNEGIE MEDALS AND WILLIAMS PRIZE.

Lord Dudley then stated that the Council had decided upon the somewhat unusual course of awarding, in 1939, a Carnegie Gold Medal for a paper published in the *Carnegie Scholarship Memoirs* for 1936. The work done by Dr.-Ing. W. Ruff, on the running quality of steel, however, had since proved of great value in several investigations, and it was, moreover, just the type of work for the recognition of which the Medal had been instituted. In Dr. Ruff's absence it was directed that the Medal should be sent to him. In presenting the Carnegie Gold Medal for 1938 to Dr. James White for his work on systems containing iron oxides, the President congratulated him, at the same time, on the Degree of Doctor which had been conferred upon him for this same, or similar, work. In connection with the award of the Williams Prize for 1938 to Mr. D. V. Krishna Rao, Lord Dudley expressed pleasure that the Prize should have been gained by an Indian metallurgist. As Mr. Rao had been unable to come to England, the Prize would be sent out to him.

THE ABLETT PRIZE PAPER.

The President's next intimation was that the Ablett Prize Paper, by Mr. H. Escher, on "Ten Years' Development in Steam Engineering at the Port Kembla Steelworks, N.S.W., Australia," would be placed before the meeting by Mr. A. F. Webber, in the absence of the author. Lord Dudley further announced that Captain Ablett had agreed to present a similar prize next year. Mr. Webber, in presenting the paper, stated that the author reviewed the developments in steam engineering which had taken place at the Port Kembla steelworks of Messrs. Australian Iron and Steel, Limited, since the blowing-in of the first blast-furnace in 1928. The works now included by-product coke ovens, two blast-furnaces having a combined daily capacity of 1,850 tons of iron, five open-hearth furnaces having a yearly ingot capacity of nearly 500,000 tons, soaking pits, an electric blooming mill, a rail and structural mill, a continuous billet and sheet-bar mill, a merchant mill, and a plant for making centrifugally-cast pipes. The paper was divided into two parts. In the first, which dealt with steam generation, the author described early difficulties, the introduction of pulverised fuel and the conversion of the gas-fired boiler plant to use this fuel, with the difference that blast-furnace gas would be the principal fuel and pulverised coal the auxiliary fuel. In the second part, dealing with steam utilisation, the general distribution of the steam and its use in the blast-furnace plant, turbo generators, open-hearth plant, rolling mills, and coke ovens were discussed.

Captain Ablett, speaking on the paper, stated that some fifteen months previously he had visited the Port Kembla plant, so that the paper was of personal interest to him. While in Australia he had been struck by the potentiality for further activities on the part of the Institute in that part of the world. When describing the reconstruction of the original gas-fired boilers the author stated that the necessary space had been provided for the installation of blast-furnace gas heaters, if required at a later date. With these heaters, he had stated, the efficiency in firing would be raised from the present 80 per cent. to 87 per cent. The figure of 87 per cent., which it was hoped to obtain, continued Captain Ablett, was remarkable, as it almost equalled the boiler-plant efficiency of the Battersea Power Station of the London Power Company, which was

said to be the most efficient boiler plant in existence. In conclusion, he hoped that the prize for 1940 would produce more than the eight papers which had been submitted in 1939.

HETEROGENEITY OF STEEL INGOTS.

At the conclusion of the preliminary business, various sections of the "Eighth Report on the Heterogeneity of Steel Ingots" were presented for discussion. As has previously been the case, the present report has been prepared by a joint committee of the Iron and Steel Institute and the British Iron and Steel Federation for presentation to the Iron and Steel Industrial Research Council. The report contains nine sections, which deal with experiments on segregation in steel; the determination of oxygen in steel by the vacuum-fusion, chlorine, and aqueous- and alcoholic-iodine methods; the determination of the temperature of liquid steel by a "quick-immersion" thermocouple; the investigation of the causes of cracking in ingot moulds; and the counting and evaluation of inclusions in steel. We published a brief summary of the report on page 544, *ante*. A general introductory outline of the report was given at the meeting by the Chairman of the Committee, Dr. W. H. Hatfield, F.R.S., who stated that the meetings of the Committee had been extremely interesting and mutually helpful. A satisfactory feature was that the effect of the work of the Committee was now obvious in the steel plants of this country. The present report showed that the oxygen content of steels could be determined with great accuracy, while the sub-committee on pyrometry, of which Dr. Schofield was a member, had been successful in creating a pyrometer, by the aid of which the temperature of liquid steel could effectively be measured in the furnace. It was now possible to tackle the physical chemistry of steelmaking and to try to convert this art into a science. With that object, Dr. T. Swinden had undertaken to act as Chairman of a Physical-Chemistry Joint Consultative Conference, in which the Heterogeneity Committee would collaborate with the Open-Hearth Committee. In conclusion, Dr. Hatfield drew attention to the interest and importance of Section V of the report, in which the high degree of homogeneity obtainable in relatively small ingots under modern production conditions was demonstrated.

Section II of the report, which dealt with "Segregation in Steel," and was by Professor J. H. Andrew, and Messrs. H. T. Protheroe, R. T. Percival and A. J. MacDougall, was briefly presented by Mr. Percival.

Principal C. A. Edwards, F.R.S., in opening the discussion on Section II, said that while he was ready to agree that it was quite possible that a column of steel, when kept quiescent for a long time, might conceivably develop a concentration gradient from one end to the other, he did not think that there was any evidence to indicate that two distinct immiscible liquid layers were produced when molten steel lay quiet. In considering this matter, there was no need to depart from well-established theoretical considerations. It should, he thought, be recognised that selective freezing and diffusion proceeded simultaneously. In other words, with each crop of relatively-pure crystals, the molten liquor from which they had grown became richer in impurities and, so long as the concentrated impurities in this portion of the liquid were in contact with the main body of the liquid within the ingot, the impurities were distributed through the residual liquid by diffusion. The next speaker, Mr. T. F. Russell, said that the authors had concluded that major segregation was rather due to the formation of an immiscible liquid phase, high in sulphur, phosphorus and probably carbon, within the melt, and this phase, being of lower density than the metal surrounding it, tended to rise towards the surface. If this were correct, and the holding of the molten mass for from 10 to 12 hours was sufficient to separate the two liquids, the matter would have been more convincingly proved if the authors had then cooled the melt as rapidly as possible to prevent inter-action between the two liquids during cooling. A further objection calling for consideration was that apparently in no case had the authors finished up with a steel which was in any way comparable with a commercial steel. During the course of their experiments they had converted two alloys which could be considered more or less as steels of commercial composition into alloys which were not of commercial composition, and, therefore, any deductions from these experiments should be applied to commercial ingots with a maximum amount of reserve.

Dr. E. Gregory said that as a member of the Heterogeneity Committee he had at first been sceptical concerning the theory that major segregation in steel ingots might be due to the formation of an immiscible liquid rich in impurities. If, however, the authors were prepared to modify their theory and to consider liquid steel as a mixture of two partially immiscible layers, he would be quite in agreement that this might be a cause of major segregation. The paper showed that if steel were maintained in a molten condition for a sufficiently long period, followed by slow cooling, the impurities tended to rise to the top of the ingot, and this had been verified at his own works by a fairly extensive series of experiments. The last speaker, Dr. L. Northcott, remarking that the authors had shown that in their ingots there was a tendency for the impurities—the sulphur and the phosphorus—to rise to the top, said that heterogeneity in ingots, as he saw it, was the resultant of two factors, namely, segregation due to differential solidification and a "specific-gravity" segregation. The authors had concentrated on the specific-gravity segregation. He felt, however, that he could not agree with their liquid immiscibility theory.

In a brief reply, Professor Andrew said that when any theory was put forward which differed from the orthodox, it was rarely possible to find anyone to agree with it. Principal Edwards did not like departing from the old idea of differential solidification, but it was not always possible to maintain past views, and the authors had found great difficulty in reconciling the figures indicating the segregation from the bottom to the top of a 172-ton ingot, quoted in their paper, with the ordinary preconceived ideas of differential solidification. The idea of immiscible liquids did not seem to be popular, but this feature was to be found in a number of inter-metallic systems. A liquid containing carbon in solution and also sulphur and phosphorus, forming an immiscible layer and floating to the top of the molten steel, seemed to him a tenable theory. However, the work was going on, but it must be realised that there were very great difficulties to be faced.

Section III of the report was then submitted to the meeting. This dealt with "Oxygen Determinations on a Series of Bath Samples Taken from an Acid Open-Hearth Furnace," and was by Drs. G. E. A. Bramley and W. R. Maddocks, and Mr. G. Tateson. The contribution was presented by Dr. Bramley, after which the President announced that it would be discussed jointly with Section VI, constituting the second report of the Oxygen Sub-Committee; this would be presented immediately after the luncheon interval. The meeting then adjourned until 2.30 p.m.

When the members reassembled on Wednesday afternoon, May 3, Lord Dudley called upon Dr. T. Swinden, Chairman of the Oxygen Sub-Committee, to present Section VI of the report. This section covered a very wide field and constituted the second report of the Sub-Committee.

Dr. A. McCance, in opening the discussion, said that the work under consideration had been separated into its various fields and each investigator had made an intensive attack on a limited objective. The net result had been a decided increase in the accuracy with which oxygen could now be determined in steel. Only as recently as five years ago, if half-a-dozen samples had been sent to different analysts, the results would have had a tolerance of approximately 50 per cent. below and above the mean value, but, at the present time, as the result of the work of the Sub-Committee, the tolerance was within what would be expected from any analytical work. The results had been obtained not by any new principles but by attention to small details. For instance, in the contribution by Mr. H. A. Sloman, graphite filings had been used instead of powder and this had enabled the temperature in the vacuum-fusion method to be raised by 200 deg. or 300 deg. C., and had reduced the "blank" to a figure of roughly 0·005 ml. or 0·006 ml. per hour, which was almost negligible. If he might suggest a line of development to the Sub-Committee, it would be to try and bring this method within the orbit of practical works conditions. The aluminium reduction method for the gravimetric determination of total oxygen in plain carbon steels, investigated by Messrs. N. Gray and M. C. Sanders, showed great promise of practical application as it did not require such elaborate apparatus. It was, therefore, well worth developing and examining in greater detail. The chlorine and iodine methods were still largely research methods; nevertheless, work on these lines should be continued. The accuracy with which the results obtained by the fractional vacuum-fusion method had been confirmed by other methods was somewhat surprising. A great deal depended upon the extent to which the various fractions, as represented by iron oxide, manganese oxide, silica, and so on, overlapped. The experiment demonstrated, however, that accurate results could be obtained in spite of this overlapping.

Dr. Lewis Reeve also referred to the question of overlapping and stated that the degree of definiteness of separation seemed to be more marked in some steels than in others. His own work in the United States had been carried out mainly on weld metal, and, as he had pointed out, there was only a matter of 100 deg. C. in which to work as far as the ferrous and manganous oxides were concerned. Slight errors in the temperature of the iron-oxide fraction might lead to a greater or lesser degree of overlap with the manganese-oxide fraction. A point which should be emphasised in the practical application of these results was the fact that the total time for a fractional vacuum-fusion analysis was, at the present time, extremely small compared with the total time required for a residue analysis. It was a matter of hours as compared with days for a residue analysis. The next speaker, Mr. T. E. Rooney, referred to Section III, by Drs. Bramley and Maddocks and Mr. Tateson, presented just prior to the luncheon interval. He stated that the authors had referred to the partial insolubility of iron carbide in alcoholic iodine; he confirmed that, with a steel containing 1·14 per cent. of carbon, the carbide was not completely decomposed. He would not like to say, however, that the carbon remained purely as undecomposed Fe_3C; it might be partially decomposed, perhaps, into another carbide. Dr. McCance had stated that residue methods were research methods, but many industrial laboratories were now very well equipped and had a sufficiently skilled staff to make use of such methods.

Mr. E. Taylor Austin, who also referred to Section III, said that the behaviour of iron carbide, using the alcoholic-iodine solution was, to say the least, somewhat uncertain, and in that respect it resembled very closely the behaviour of iron phosphide. Recent work carried out by the British Cast Iron Research Association, using the aqueous-iodine method, showed that, while the iron carbide was only partially decomposed in the original treatment, in subsequent treatment for the removal of phosphorus, the carbide, at all events in the amounts which were examined, was completely decomposed. The next speaker, Mr. J. H. Whiteley, who also discussed Section III, said that, as a result of tests made on samples sent to him by the authors, he had come to the conclusion that there was a clear case for stating that oxygen was not soluble in steel, at any rate in the cold. It was a matter which merited further attention. There was another element, namely, sulphur, which might be soluble in steel, but, unfortunately, the methods employed could not cope with it. It was unfortunate that the iodine solution decomposed the sulphides, because there was some evidence that sulphur was definitely soluble in steel, under some conditions at all events. Dr. C. H. Desch, F.R.S., who closed the discussion, stated that although Mr. Whiteley had regretted that in the iodine method the sulphides were dissolved, this regret was not shared by those

who were working on oxygen determinations. Mr. Whiteley's problem, which was important, would have to be tackled by a different process. Reference had been made to the fact that carbide remained insoluble in the iodine solution and caused high results. It appeared, however, that it was the cementite in massive form which was insoluble and not the finely laminated material.

In a brief reply, Dr. Swinden agreed with Dr. McCance that the main objective now should be to bring the vacuum-fusion method within the orbit of works' conditions and that the method used by Gray and Sanders should be further examined. In connection with Dr. McCance's obvious lack of enthusiasm for residue methods, it might be said that in the Committee there were differences of opinion on that particular point. Clearly, however, something was required to divide the total oxygen into its respective oxides, and the alternative was one or other of the residue methods or the method of fractional extraction. The latter, he felt, was a practical alternative to the residue method and might ultimately lead to a works' method for determining the iron, manganese and other oxide fractions. At the same time, he would not like his remarks to be taken as any disparagement of the work of those who were investigating residue methods. There was some satisfaction in handling the actual oxides, but some alternative method of checking the results obtained was necessary. He agreed that the industry was wanting results, but, before publishing results, it was necessary to make quite certain that the methods employed were entirely satisfactory.

The last portion of the report to be discussed was Section VII, which dealt with pyrometry, and constituted the "Second Report of the Liquid-Steel Temperature Sub-Committee." The Chairman of the Sub-Committee, Mr. E. W. Elcock, briefly introduced the contribution and Dr. F. H. Schofield outlined its principal features.

Mr. H. H. Burton, who opened the discussion, said that he had found Dr. Schofield's apparatus to be thoroughly reliable. He had been somewhat surprised—as he believed Dr. Schofield himself had been—at the uniformity of the temperatures within the open-hearth furnace. With the aid of the instrument, it had been possible to follow some of the quite legitimate expedients of the furnacemen in cooling the steel slightly, in the last stages of the reaction, to get the bath ready for tapping. It had been found that in a good many heats there was a not unnatural tendency for the furnaceman to shut off the gas slightly when all the reactions were completed. In his opinion, the quick-immersion thermocouple was destined to be a most valuable instrument in the hands of metallurgists, and since its adoption he had abandoned the use of optical pyrometers. The next speaker, Mr. K. M. Tigerschiöld, asked regarding the nature of the difference between the readings obtained with the optical pyrometer and those obtained with Dr. Schofield's apparatus. Speaking again in reply to this, Mr. Burton said that when using the optical pyrometer for determining the temperature of a stream of molten steel, for example, there was a tendency to sight the instrument on what appeared to be the brightest spot. This, in his opinion, gave false values, and had resulted in variations in readings of as much as 120 deg. C., in some cases, and 60 deg. in others.

Mr. W. J. Todd said that although Dr. Schofield's thermocouple had been introduced at Messrs. Hadfields' works, they were continuing to use the disappearing-filament type of optical pyrometer as well. Work was being continued with the disappearing-filament pyrometer with the object of elucidating certain variations which were taking place, and this investigation would be aided by the Schofield quick-immersion thermocouple. The last speaker, Mr. N. H. Bacon, stated that he had found by experience that the Schofield apparatus was very reliable. He then gave a series of results obtained with it, which confirmed the findings recorded in the contribution. He added, in conclusion, that it was very important to have definite control over the temperature of the steel if fine-grain material were required.

The President intimated that the reply to the discussion would be given in writing, and that, owing to the advanced hour, the discussion on Sections VIII and IX would also be conducted by correspondence.

Fluorspar in Basic Open-Hearth Practice.

"The Refining of Metal in the Basic Open-Hearth Furnace. The Influence of Fluorspar on the Process" was the title of the last paper considered on Wednesday afternoon. The author, Mr. W. B. Lawrie, in presenting it, said that the addition of fluorspar to the basic open-hearth furnace to facilitate the removal of sulphur, had been suggested by Saniter in 1892. The influence of the fluorspar was probably indirect, the fluorspar giving greater fluidity to the slag and enabling it to carry additional lime. In the actual sulphur removal, the manganese probably played the part of a catalyst, undergoing a cycle of reactions in suitable slag conditions. Apart from the sulphur removal, however, the manganese passed from the metal to the slag, or from the slag to the metal, the direction of migration depending on the slag conditions. Moreover, it had been noticed that chromium behaved in a manner very similar to manganese, while nickel was unchanged in the furnace. Incidentally, the presence of fluorspar rendered the slag useless as a fertiliser, because the phosphates became insoluble in the weak soil acids. It had been suggested that this was due to the formation of a fluor-apatite, $CaF_2.3CaO.P_2O_5$. Carbon was removed best by a slag of low basicity; consequently, the use of fluorspar was undesirable where large quantities of carbon had to be eliminated.

The only speaker in the discussion, Mr. A. G. Hock, said that the author dealt, in many cases, with comparatively small variations in the composition of the steel bath and of the slag, and it might be pertinent to refer to a real difficulty which presented itself in any attempt to formulate quantitative relationships. It was necessary, first of all, to be satisfied that the sample examined was really representative of the bath under a particular set of conditions. He was not at all sure that the results obtained did always represent an average of the metal bath and the slag, and it was difficult, therefore, to criticise opinions given regarding certain other results. In a brief reply, Mr. Lawrie said that his contribution was largely qualitative and did not presume to be quantitative. In any case, the problem was one of extreme difficulty in view of the state of existing knowledge on the subject.

At this stage the proceedings were adjourned until 10 a.m. on the following day.

(*To be continued.*)

LETTER TO THE EDITOR.

THE EBBW VALE STEEL WORKS OF MESSRS. RICHARD THOMAS AND COMPANY, LIMITED.

To the Editor of Engineering.

Sir,—With reference to the article on the Ebbw Vale Works of Messrs. Richard Thomas and Company, Limited, published in your issue of April 28, on page 489, we should be glad if you would make it clear that the whole of the rolling mill plant was built to the designs of Messrs. The United Engineering and Foundry Company, of Pittsburgh, U.S.A., who were retained by Messrs. Richard Thomas and Company, Limited, as consultants for this rolling mill installation.

Messrs. Davy and United Engineering Company, Limited, of Sheffield, are now the sole builders for the whole of the British Empire of machinery designed by Messrs. The United Engineering and Foundry Company, but the magnitude of the Richard Thomas contract was such that, in order to give the deliveries required, the work was spread among several machinery builders in this country of whom Messrs. Fraser and Chalmers Engineering Works were one.

Yours faithfully,
Messrs. Davy and United Engineering Company, Limited.
W. Reid,
Managing Director.

May 5, 1938.

Colliery Industry in Great Britain.—The total tonnage of coal raised at mines in Great Britain, during the week ending April 22, was 5,029,100, the wage earners employed numbering 772,000.

SILENCERS FOR ROAD DRILLS AND ROCK DRILLS.

The silencing of the exhaust from the pneumatic percussive drill is a matter upon which a good deal of public attention has been focused from the very widespread use in cities of this type of drill for road construction, and other forms of urban activity, while the benefits of more silent operation on those who have to handle the tools in such places as mine workings and quarries are becoming increasingly recognised. The problem is, however, by no means as simple a one as might, at first sight, appear; two difficulties, for instance, demanding solution being the avoidance of back pressure and the prevention of ice formation which, in winter, may choke the outlet. Much research has been applied to this apparently simple subject and exhaust silencers for drills have been more than once described in these columns. The illustrations, Figs. 1 to 4, on the opposite page, show two forms of silencer recently developed by Messrs. Vokes, Limited, 95-103, Lower Richmond-road, Putney, London, S.W.15. It should be noted, however, that the difference in principle embodied in the two forms is dictated by considerations of weight and space. In some types of tool there is no objection to a silencer of reasonable dimensions and weight, but in other types, particularly such small tools as pneumatic hammers and riveters, the projection must be as small as it can be made compatible with efficiency.

The silencer shown in Figs. 1 and 2, and known as the M.S.T. type, is employed on drills having a single exhaust outlet where the size of the silencer is not so material because the exhaust passage is set obliquely to the drill barrel. The principle employed in the M.S.T. silencer is that of compelling the exhaust air to traverse a tortuous path which so varies in cross-sectional area that alternating expansion and contraction repeatedly occurs. The body of the silencer is a cylinder approximately 4 in. in diameter by 4½ in. long and weighing 4½ lb. A short length of pipe, screwed at one end to connect up to the drill, passes axially through the cylinder but not quite concentrically. This tube is perforated along one side and is sealed at one end by an inverted cone, the object of which is to break up the air stream and to transmit pulsations to the wall of the tube. The ends of the cylinder are formed of metal discs enclosing a layer of sound-absorbing material. Surrounding the central pipe is a series of eccentrically-situated tubes of thin metal arranged as indicated in Fig. 2. Alternately, at the top and bottom of these tubes is either a number of circular holes or a slot. The spaces between the tubes have a crescentic cross-section. The air entering any of the spaces does so at a point where the width of the space is only about half as much as the maximum and on leaving the space these conditions are repeated. It is claimed that this alternate increasing and decreasing of volume sets up the recurring expansion and contraction by which the silencing is effected. The final exit is through a tapered slot. As all the passages and orifices are ample in area, no appreciable back pressure is set up and there is no tendency for ice to form in cold weather due to sudden expansion on the final release of moisture-laden air.

The second type of silencer, known as the V.D.I., is intended for drills of the French type having a single screwed or flanged exhaust at right angles to the barrel, and in which only the minimum projection from the tool can be allowed. It consists of a shallow cylinder with a short pipe connection. With a 1½-in. gas connection the external diameter is 6½ in. and the depth 2¾ in. The weight is 3½ lb. The principle here adopted is that of damping out both sound and shock by pads of absorbent material. The air does not pass through the pads but through a flattened helical spring the coils of which are disposed in a radial direction. The spring pulsates along with the pads. The arrangement is clearly shown in Figs. 3 and 4. The exhaust air passes through the central opening of the spring and is then returned between the coils to pass out by way of a series of holes on the inner side of the silencer casing. The purpose of the spring is to prevent the formation of ice. It is generally desirable, apart from the question of exhaust silencing, to remove moisture from the compressed air fed to a machine or tool. Messrs. Vokes have developed pipe-line filters for this purpose which, it is claimed, not only remove air-borne water but such deleterious solids as dust, scale and rust.

Production of Pig-Iron and Steel in Great Britain.—The monthly memorandum of the British Iron and Steel Federation, Steel House, Tothill-street, London, S.W.1, shows that there were 95 blast-furnaces in operation at the end of February, compared with 88 at the end of January, and 78 at the end of December, 1938. The production of pig-iron during February totalled 603,600 tons, against 516,000 tons in January and 693,300 tons in February, 1938. The February output of steel ingots and castings amounted to 1,170,900 tons, compared with 971,100 tons in January and 1,057,000 tons in February, 1938.

SILENCERS FOR PNEUMATIC DRILLS.

CONSTRUCTED BY MESSRS. VOKES, LIMITED, LONDON.

(For Description, see Opposite Page.)

Fig. 1.

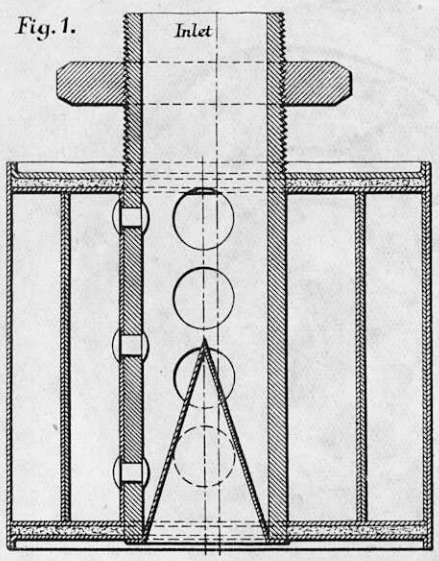


Fig. 3.

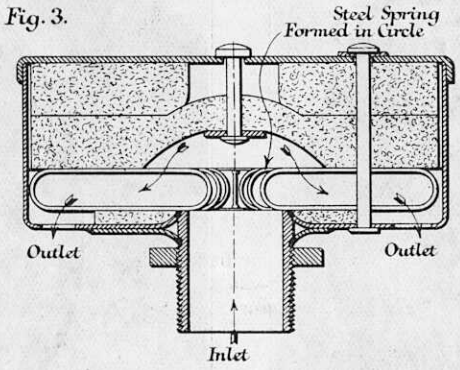


Fig. 2.

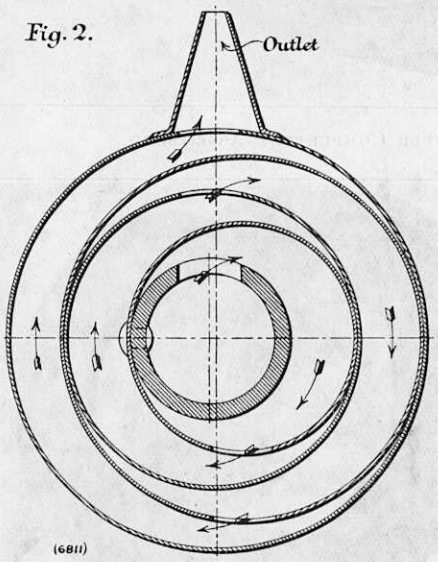
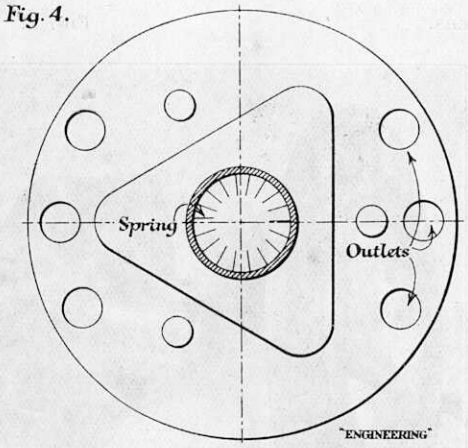


Fig. 4.



THE LATE ADMIRAL SIR R. HENDERSON, G.C.B.

WE note with regret the death of Admiral Sir Reginald Guy Hannam Henderson, G.C.B, which occurred on May 2, at the Royal Naval Hospital, Haslar, Portsmouth. Admiral Henderson, who was appointed Third Sea Lord and Controller of the Navy in 1934, continued in this capacity until March 1 last, when he was compelled to retire owing to ill-health. A scion of a naval family, Reginald Henderson was the son of the late Commander J. H. Henderson, and was born on September 1, 1881. At fourteen years of age he became a naval cadet in the Britannia and passed out as midshipman in 1897. After service with the Channel Squadron and in China, he became a sub-lieutenant in 1900. Promotion to the rank of lieutenant came after only nine months' sub-lieutenant service, and, in 1903, he qualified as a gunnery officer at Whale Island gunnery school, subsequently serving in this capacity on various ships in the North American, West Indian and Channel Squadrons. Returning to Whale Island as a senior staff officer in 1910, he was promoted to the rank of commander three years later. In this same year, 1910, he took part, as gunnery expert, in Admiral Mark Kerr's Naval Mission to Greece, his task being the introduction of modern methods of gunnery training into the Greek Navy.

On the outbreak of war in 1914, Commander Henderson was appointed executive officer of H.M.S. Erin and continued in this capacity for two years and six months. When, however, Sir John Jellicoe relinquished the command of the Grand Fleet to become First Sea Lord at the Admiralty in 1917, Commander Henderson was one of the officers specially selected to accompany him. Means to combat the German submarine menace were being actively sought, and to Commander Henderson belongs a large share of the credit for the successful operation of the convoy systems. It was mainly owing to his determination in overcoming the scruples of a number of senior officers that the scheme was introduced, and, in recognition of his services in this direction, he was promoted to the rank of captain in October, 1917, and received the C.B. in 1919. After the conclusion of hostilities he served for two years as Flag Captain of H.M.S. Hawkins and Chief of Staff to the Commander-in-Chief in China, and, from 1923 until 1925, was on the staff of the Royal Naval College, Greenwich. The succeeding two years were spent in command of H.M. aircraft carrier Furious, and, soon after being made rear-admiral, in March, 1929, he proceeded to Roumania as head of a Naval Mission. In 1931 he was appointed rear-admiral in command of aircraft carriers and on relinquishing this command was promoted to the rank of vice-admiral in October, 1933. Early in 1934, Vice-Admiral Henderson was created Third Sea Lord and Controller of the Navy. The expansion in our naval strength which has taken place during the past two or three years threw a heavy responsibility upon his shoulders, but owing to his abilities the work was carried out smoothly and efficiently. He was promoted to the rank of admiral in January, and, as we have stated, continued in office at the Admiralty until March 1, when ill-health compelled him to retire. He was made a K.C.B. in 1936, and a G.C.B. as recently as last month.

THE LATE ENGINEER VICE-ADMIRAL SIR HENRY J. ORAM, K.C.B., F.R.S.

THE death at the age of 80 of Engineer Vice-Admiral Sir Henry John Oram, which occurred at Cranleigh, Surrey, on May 5, recalls a period of great difficulties and notable innovations in naval engineering practice. In a long and distinguished career at the Admiralty, Admiral Oram saw the passing of the old simple and compound expansion engines, the development of the large triple-expansion engine, the introduction of water-tube boilers, steam turbines and oil-fuel firing, and a great extension of the use of electricity and hydraulic power. As a junior engineer at the Admiralty he was concerned with the earliest triple-expansion engines, while as Engineer-in-Chief of the Fleet he was responsible for the introduction of the geared turbine.

Sir Henry was the son of Mr. J. J. Oram, of Plymouth, and was born on June 19, 1858. From school he entered Devonport Dockyard as an engineer student, and in 1879, after six years training, entered the Navy as an assistant engineer, and proceeded to the Royal Naval College, Greenwich. In 1882, he was appointed to the Indian troopship Crocodile and this was the only ship he served in. Appointed to the staff of Sir James Wright, at the Admiralty, in May, 1884, he spent the remainder of his career at Whitehall. Promoted to Engineer in September, 1884, he passed through the old grades of chief engineer, staff engineer, fleet engineer and inspector of machinery, and on the introduction of the new titles in 1903 he was made an engineer rear-admiral. Sir James Wright had been succeeded in 1887 by Richard Sennett, on whose retirement, in 1889, the late Engineer Vice-Admiral Sir John Durston became Engineer-in-Chief. In 1903, Sir Henry was made Deputy Engineer-in-Chief to Sir John Durston, and in 1907 succeeded him, holding the position of Engineer-in-Chief of the Fleet until 1917. "Under him," said *The Times*, "was created the port dreadnought fleet, which formed the backbone of the Navy in the conflict with Germany, and the very high standard of efficiency attained under the stress of war in the engine-rooms of ships of all types and classes reflected the highest credit upon his professional skill, sound judgment and administrative ability."

The thorough training in scientific principles underlying engineering practice, received at Devonport and Greenwich, was reflected in Sir Henry's lectures at Greenwich, in his revision and extension of the textbook on *The Marine Steam Engine*, first published by Sennett in 1882, and also in his addresses. As president of the Junior Institution of Engineers in 1909,* he dealt with current problems of marine engineering; in 1911, at the Jubilee meeting of the Institution of Naval Architects, he contributed a valuable review entitled "Fifty Years' Changes in British Warship Machinery,"† while as president of the Institute of Metals in 1914, he devoted a great part of his address‡ to the urgent problem of the improvement of condenser tubes. Admiral Oram naturally took an active part in the various committees appointed from time to time to deal with questions relating to naval engineering, and his position among his contemporaries was recognised by his election as an honorary member of the Institute of Naval Engineers, and as a fellow of the Royal Society. He was made a C.B. in 1906 and K.C.B. in 1910.

ENGINEERING TRAINING AND EDUCATION.

Busk Studentship in Aeronautics.—A vacancy has arisen for the Busk Studentship in Aeronautics for the year 1939-40. The Studentship is of the value of 150*l.* and is tenable for one year from October 1. The object of the Studentship, which is open to any British subject of British descent who has not attained the age of 25 on October 1, is to enable the holder to engage in research, or preparations for research, in aeronautics and specially in such subjects as stability problems, meteorological questions bearing on flight, or the investigation of gusts, treated either experimentally or mathematically. The Busk Student is expected to devote his whole time to research on a subject approved by the Trustees, and at the close of his Studentship to make to them and to the University of Cambridge a report on his work; he may also be asked to deliver a lecture on the subject. Subject to the permission of the Trustees, the Student may carry out his research either at home or abroad. Forms of application for the Studentship, which should be returned before June 10, may be obtained from Professor B. Melvill Jones, Engineering Laboratory, Cambridge.

GENERATION OF ELECTRICITY IN GREAT BRITAIN.—The official returns rendered to the Electricity Commissioners show that 2,046 million kilowatt hours were generated by authorised undertakings in Great Britain during April compared with 1,849 million kilowatt hours in April, 1938. This is an increase of 197 million kilowatt hours, or 10·7 per cent. During the five months of 1939 up to the end of April the total electricity generated by authorised undertakers was 9,591 million kilowatt hours, compared with 8,487 million kilowatt hours during the corresponding period of 1938, an increase of 13 per cent.

* See ENGINEERING, vol. lxxxviii, page 703 (1909).
† See ENGINEERING, vol. xcii, page 18 (1911).
‡ See ENGINEERING, vol. xcvii, page 397 (1914).

TORSIONAL-VIBRATION DAMPER FOR HEAVY-OIL ENGINES.

CONSTRUCTED BY MESSRS. AKTIEBOLAGET ATLAS DIESEL, ENGINEERS, STOCKHOLM.

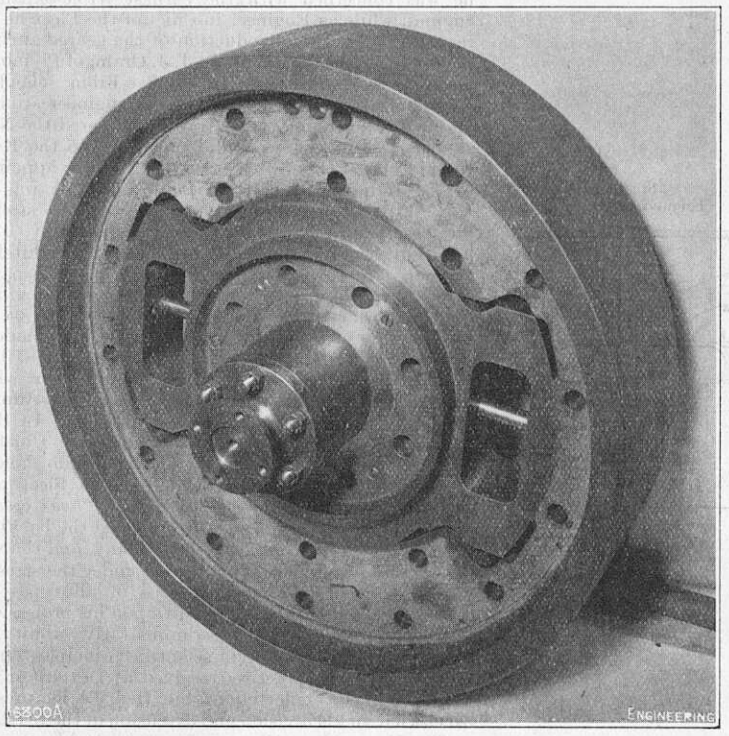


FIG. 1. VIEW SHOWING OIL CHAMBERS.

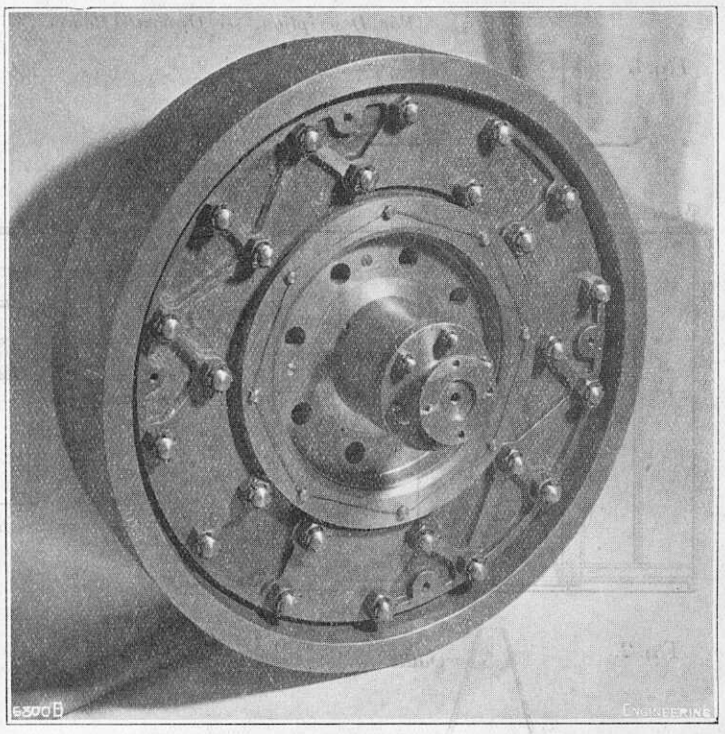


FIG. 2. DAMPER COMPLETELY ASSEMBLED.

TORSIONAL-VIBRATION DAMPER.

THE present tendency in the design of internal-combustion engines is in the direction of higher speeds and a larger number of cylinders. As a result, the torsional vibrations induced in the crankshaft have become increasingly pronounced and more difficult to keep within permissible limits. In earlier engines running at relatively slow speeds, it has usually been possible to proportion the size of the rotating masses and the diameter of the shaft in such a way that the resonance frequencies occurred at speeds outside the working range, but an increase in the speed and the number of cylinders involves a corresponding increase in the number of resonance speeds, so that in many modern engines this solution is no longer possible. In such cases, the only available means of keeping the additional stresses caused by torsional vibration within permissible limits is to fit a vibration damper.

The vital importance that is now attached to the question of dampers has resulted in numerous designs being put forward and tested with varying degrees of success, without any of them proving definitely superior. Recently, however, a damper designed on principles evolved by Mr. Edvin Thege and built at the works of Messrs. Aktiebolaget Atlas Diesel, Stockholm, has been tested and is claimed to satisfy all demands with regard to damping power, simplicity of construction and ease of attendance. The damper is illustrated in Figs. 1 to 10, on this and the opposite pages, and it should be explained at the outset that the model illustrated in Figs. 1 to 3 is of slightly more recent design than that shown in Figs. 4 and 5. The differences in the two designs are, however, of only a minor nature, the principle of operation being identical in the two cases. This principle can best be followed by reference to Figs. 4 and 5. It will be seen that the damper consists of two principal parts, an inner portion or hub *a* bolted to the shaft in which the torsional vibrations are to be damped, and a rim or damping mass *b*, which is free to move on the hub and brings about the actual damping. As will be clear from Fig. 4, and also from Figs. 1 and 3, the hub is designed with two different diameters, the rim being free to move on both diameters with a good sliding fit through a certain angle relative to the hub. In the case of the design shown in Figs. 4 and 5, the angle through which the rim can move relative to the hub is limited by the stops *c* attached to the latter. A reference to Figs. 1 and 3 will show that these stops are formed directly in the hub and rim, this being the only difference between the two designs, except that the spaces between the projecting portions of the hub and rim are larger in the earlier design. The rim is guided on the hub by the two side plates *d*, these plates being a sliding fit on the bronze rings *e*.

When the damper is in action, the damping mass moves relative to the hub between the stops *c* and in a definite relation to the vibration to be absorbed. A

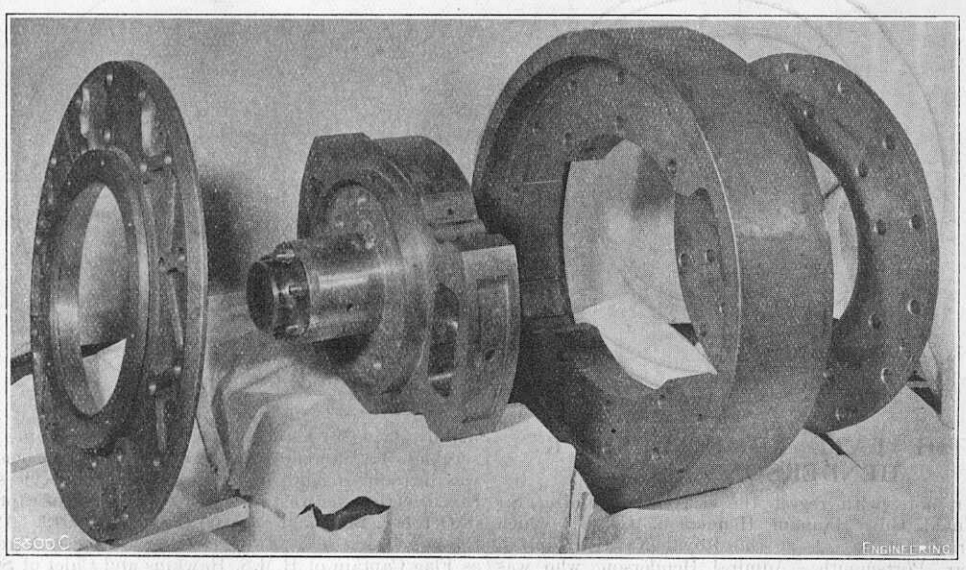


FIG. 3. HUB, RIM AND SIDE PLATES.

Fig. 4.

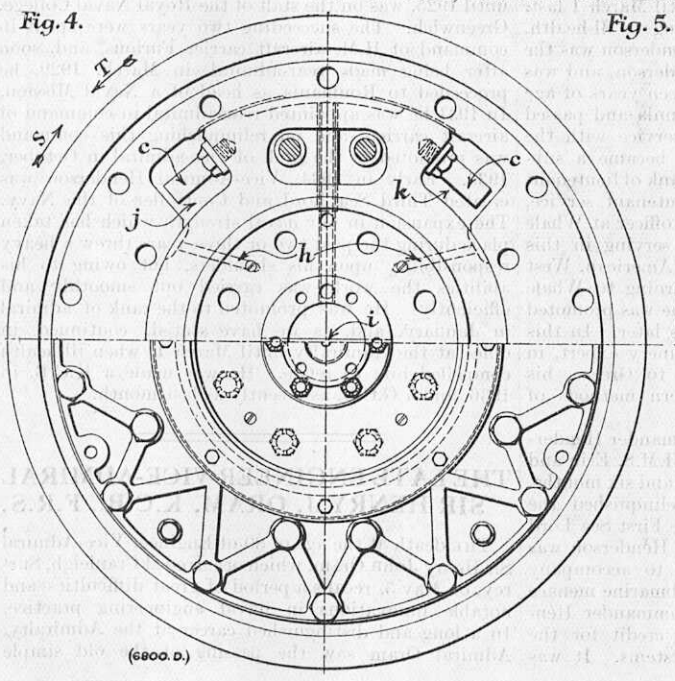
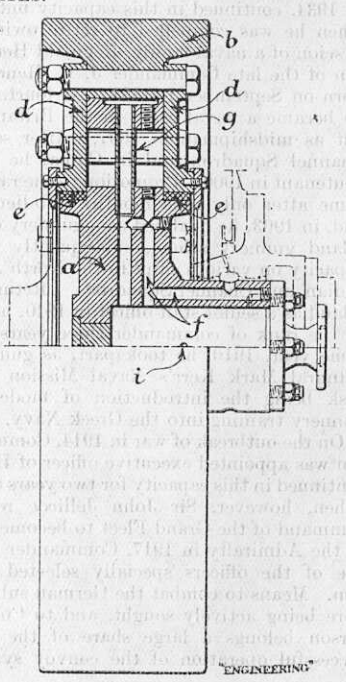
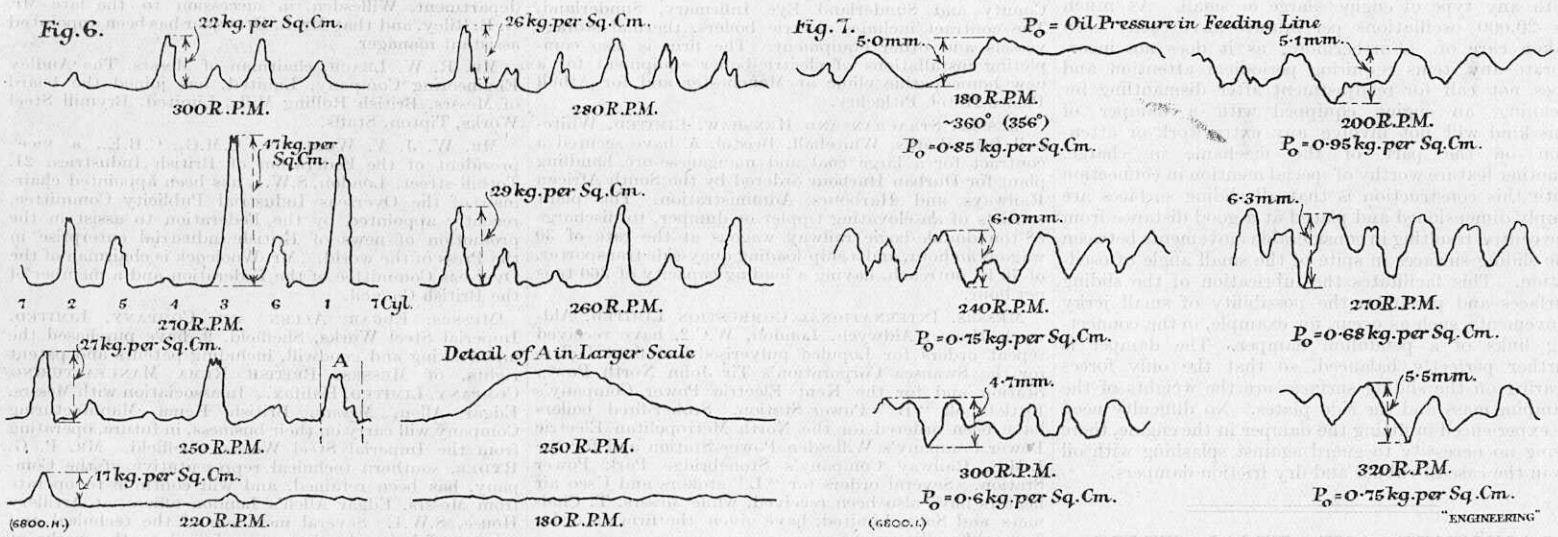


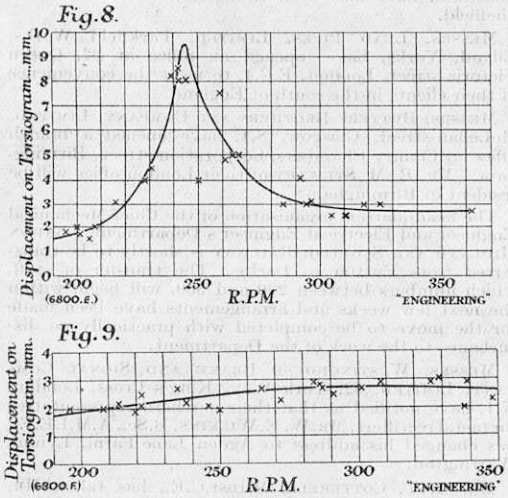
Fig. 5.

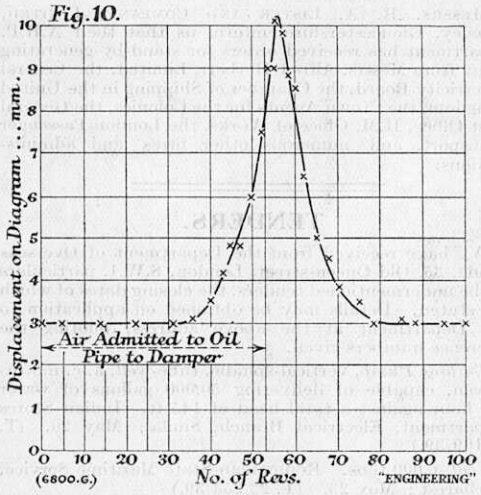


TORSIONAL-VIBRATION DAMPER FOR HEAVY-OIL ENGINES.

CONSTRUCTED BY MESSRS. AKTIEBOLAGET ATLAS DIESEL, ENGINEERS, STOCKHOLM.







continual knocking against the stops would soon destroy these, or other parts of the damper, but this is prevented by the introduction of lubricating oil into the chambers formed between the hub, the rim, and the side plates. This oil forms a cushion which absorbs the blows before the mass strikes the stops. The latter, therefore, only serve to limit the movement in the absence of oil. The oil used as cushions in the manner described above is introduced to the damper from the nearest bearing, being conducted to the larger periphery of the hub through the channels f and the pipe g. From there it is conducted by means of a groove, communicating with a corresponding groove on the rim, to the above-mentioned chambers, fills these, and is then conveyed by means of similar grooves on the smaller periphery of the hub to the discharge channels h, leading out through the side of the hub. The oil cannot, however, absorb any blow from the damping mass unless completely closed in. The edges of the grooves are, therefore, designed in such a way that in certain extreme positions they cut off communication between the grooves and the chambers. Between these extreme positions the damping mass moves freely without any other retarding force than the friction in the sliding surfaces. For the damper to function well, it is essential that the damping mass is retarded relative to the hub when the edges of the channels cut off communication with the chambers as described above, and it is, therefore, most important that there should be no stationary air in the oil chambers and no air bubbles in the oil. The oil channels in the hub are, therefore, designed in such a way that any air carried over with the oil will be separated and collected in the central cavity, where the open tube i is arranged for the discharge of the air. As the oil is conducted to the chambers between the hub and the damping mass from the larger diameter and is discharged from the smaller diameter, the chambers can be kept well filled with oil by means of centrifugal force, and it will not be necessary to maintain any special oil pressure in the feed line. The arrangement of the oil passages in the design shown in Figs. 1 to 3, is identical, but as stated earlier, the stops c are omitted, and the cushioning spaces for the oil are reduced in size.

The method of operation is as follows. Suppose that at a certain point of its oscillation, the hub is moving in the direction T, Fig. 4, the damping mass will move in the direction S. After a certain movement, the oil channels to the chamber j will be cut off, thereby causing an impact against the oil cushion formed in the chamber. The movement of the hub will then be modified to a certain extent, more or less depending on the elasticity of the oil cushion, the moment of inertia of the hub and the rim, and the relative speeds of the hub and rim. The direction of movement of the rim is simultaneously reversed and, after hitting the oil cushion, it will move in the direction T with the same velocity as previously in the direction S. After the first impact, the hub commences a new oscillation, the amplitude of which is less than would have been the case if no impact had taken place, and the phase of which is displaced with respect to the oscillation before the impact. In the course of this new oscillation, the hub passes the position of equilibrium. The oil channels in the chamber k are cut off and a fresh impact takes place, after which the whole process is repeated from the beginning. The oscillations of the hub are, therefore, confined between the two points of impact in the chambers j and k, and the amplitudes will not be magnified by heavier oscillating forces, as the rim will in this case have a higher speed relative to the hub and a harder impact will result. It is evident from the above that the process will be the same whatever the frequency of oscillation of the hub, and no resonance can arise in the damper, as there is no natural vibration.

Suppose the hub without damper to oscillate according to the formula

$$\phi = A \sin \omega t$$

where ϕ is the angle of oscillation from the mean position, A is the amplitude of the angle of oscillation, ω is the frequency, and t is the time.

The energy absorbed in the damper at each impact will then be given by the formula

$$\Phi = I_2 \omega^2 (A^2 - a^2)\, 2\, \frac{\left((1-k^2)\left(1+\frac{I_2}{I_1}\right)\right)}{\left(1-k+2\frac{I_2}{I_1}\right)^2}$$

where I_1 is the moment of inertia of the hub, I_2 is the moment of inertia of the rim, a is the angle of oscillation at which the impact occurs, and k is a constant characteristic for the damper.

After each impact the hub will pass into a new oscillation given by the formula

$$\phi_1 = A_1 \sin (\omega t + \gamma)$$

where A_1 is the amplitude of the new oscillation, and γ is the angle of displacement relative to the oscillation prior to the impact. The frequency ω is not altered by the impact.

The angle of displacement γ for each impact is determined by the formula

$$\tan \gamma = \frac{v_1}{\omega} \frac{1}{a + \frac{\left(1-k-2k\frac{I_2}{I_1}\right) A^2}{2\frac{I_2}{I_1}(k+1)a}}$$

where v_1 is the speed of the hub at the moment of impact.

As will be seen from the above formulas, the damper absorbs the greatest amount of energy if the impact takes place as the hub passes the point of equilibrium, that is, when $a = 0$. The phase displacement between the force impulses and the oscillation also contributes to absorb energy.

A comprehensive programme of research and tests of dampers fitted on engines of widely differing types in actual service have established that the damper is uniformly reliable in performance and requires a minimum of attention. Figs. 4 and 5 show a damper designed for a 7-cylinder, two-stroke engine of 1,280 brake horse-power. A diagram showing the oscillations on the crankshaft of this engine without the damper is reproduced in Fig. 8, while Fig. 9 shows the oscillations with the damper fitted. The cylinder diameter is 340 mm., the piston-stroke 570 mm., and the inertia of the flywheel is 5,000 kgm². The normal speed of the engine is 300 r.p.m. It may be mentioned that 10 mm. displacement on the torsiogram corresponds to an angular torsional deflection of the crankshaft of 2·12 deg. The moment of inertia of the damping mass for the curve reproduced in Fig. 9 is 464 kgm². The effective reduction in the amplitude of the resonance frequencies due to the damper, is clearly brought out by the diagrams, and it will also be noted that with the damper fitted, practically similar oscillations occur over the whole speed range.

Tests were also made with a view to ascertain the behaviour of the damper when air is carried over by the oil. For this purpose, the engine was run at constant speed, and air at a pressure of 1 kg./cm.² was introduced to the oil feed line until the damper lost its absorbing power, after which the air supply was cut off. During the course of the experiment, a torsiogram was taken, from which the diagram reproduced in Fig. 10 has been constructed, the speed of the engine being 268-270 r.p.m. From this curve it can be seen that the engine only required to run 35 revolutions, after which the damper had separated the air and re-attained full absorbing power. Tests have also been made on both cold and hot oil, but no difference to speak of could be observed in the efficiency or performance of the damper.

A number of pressure recordings have been taken in one of the oil chambers by means of quartz crystals and an oscillograph. A few of the pressure curves obtained are reproduced in Fig. 6, while Fig. 7 shows an oscillogram of the movement of the damping mass relative

to the hub. The maximum possible relative movement of the two parts is 31·5 mm.

The damper is very inexpensive to manufacture and on account of its small size it can be designed for use with any type of engine—large or small. As much as 20,000 oscillations per minute have easily been taken care of. Furthermore, as it does not incorporate any items requiring periodical attention and does not call for readjustment after dismantling for cleaning, an engine equipped with a damper of this kind will not involve any extra work or attention on the part of the mechanic in charge. Another feature worthy of special mention in connection with this construction is that all sliding surfaces are amply dimensioned and placed at a good distance from the centre, resulting in considerable movements between the sliding surfaces in spite of the small angle of oscillation. This facilitates the lubrication of the sliding surfaces and precludes the possibility of small jerky movements, such as occur, for example, in the connecting links of a pendulum damper. The damper is further perfectly balanced, so that the only forces bearing on the sliding surfaces are the weights of the damping mass and the side plates. No difficulty need be experienced in fitting the damper in the engine, there being no necessity to guard against splashing with oil as in the case of rubber and dry friction dampers.

LAUNCHES AND TRIAL TRIPS.

"ETHERTIME," "ETHERTEST," "ETHERTONE," and "ETHERTAUT."—Four open swim barges, each to carry 105 tons. All launched during April. Main dimensions of each: 69 ft. 6 in., by 18 ft. 2 in., by 6 ft. 6 in. Built by Messrs. Harland & Wolff, Limited, North Woolwich, London, E.16, for Messrs. Etheredge's Transport and Shipping Agency, Limited, London.

"TINTERN ABBEY."—Single-screw general-cargo and timber-carrying steamer; triple-expansion engines. Trial trip, May 2. Main dimensions, 317 ft. 1 in., by 45 ft. 2 in., by 23 ft. 4 in. Built and engined by Messrs. William Gray and Company, Limited, West Hartlepool, to the order of Messrs. Frederick Jones and Company, Cardiff.

"CLAYMORE." — Single-screw self-propelled grab dredger; 106-b.h.p. Ruston engine. Launch, May 3. Main dimensions, 90 ft., by 23 ft. 10 in., by 7 ft. 6 in. Built by Messrs. Harland & Wolff, Limited, North Woolwich, London, E.16, for Messrs. British Portland Cement Manufacturers, Limited, London.

"TORINIA."—Single-screw oil-tank motorship; single-acting, solid-injection, four-cycle, supercharged ten-cylinder Werkspoor Diesel engine constructed by Messrs. R. and W. Hawthorn, Leslie and Company, Limited, Hebburn-on-Tyne. Launch, May 4. Main dimensions, 500 ft., by 64 ft. 3 in., by 37 ft. Built by Messrs. Swan, Hunter, and Wigham Richardson, Limited, Wallsend-on-Tyne, for Messrs. The Anglo-Saxon Petroleum Company, Limited, London.

"CAPE SIRETOKO."—Single-screw steam trawler for fishing in the northern waters of Iceland, Bear Island, and the White Sea; triple-expansion engine fitted by Messrs. C. D. Holmes and Company, Limited, Hull. Main dimensions, 175 ft., by 30 ft., by 16 ft. Built by Messrs. Cochrane and Sons, Limited, Ouse Shipbuilding Yard, Selby, Yorks, for Messrs. Hudson Steam Fishing Company, Limited, Hull.

SCHOOL AND TEST GROUND FOR MOTOR DRIVERS.—A training school has been opened near Taplow station for Great Western Railway road-motor drivers. The school comprises a class-room, mess-room, garage, and a system of roadways. The latter includes a skidding patch, various types of road junctions for practice in turning and reversing, gradients, and a variety of road signs. The lectures to be given will include the subjects of road sense, avoidance of accidents, the care of vehicles, and the Highway Code. Instruction will be given in the use of three principal types of commercial vehicles, light and heavy vehicles, and the articulated lorry. Training will extend from a week to a fortnight, and it is expected that 150 to 200 drivers, recruited from the company's staff in London, Birmingham, the Midlands, and parts of the West of England, will pass through the school annually.

THE INSTITUTE OF PETROLEUM.—The summer meeting of the Institute of Petroleum will be held at Birmingham from Monday, May 22, until Wednesday, May 24. On the first day, at 7 p.m., an informal reception will be held by the President, Professor A. W. Nash, at the Grand Hotel, Birmingham. Technical sessions will take place at the University, Edmund-street, on the morning and afternoon of May 23, and on the morning of May 24. Fourteen papers will be presented, dealing with fuels for spark-ignition engines and for compression-ignition engines, lubrication, and economics. On the evening of May 23, a reception will be held by the Lord Mayor, the Pro-Chancellor, and the Vice-Chancellor, in the Great Hall of the University, Edgbaston, and on the evening of May 24, a dinner and dance will take place at the Grand Hotel. During the afternoon of May 24, alternative visits will be paid to Messrs. Austin Motor Company, Limited, Messrs. Morris Commercial Cars, Limited and to Warwick Castle. Registrations for the meeting should be sent as soon as possible to the secretary of the Institute, The Adelphi, London, W.C.2.

CONTRACTS.

MESSRS. BASTIAN AND ALLEN, LIMITED, 24, Bedford-square, London, W.C.1, have received an order for electric boiler-house equipment for the new Durham County and Sunderland Eye Infirmary, Sunderland. The contract includes electric boilers, thermal storage vessels and other equipment. The firm is also completing installations of electric-boiler equipment for a new homeopathic clinic at Manchester and for Atholl Palace Hotel, Pitlochry.

MESSRS. STRACHAN AND HENSHAW, LIMITED, Whitehall Iron Works, Whitehall, Bristol, 5. have secured a contract for a large coal and manganese-ore handling plant for Durban Harbour ordered by the South African Railways and Harbours Administration. The plant consists of an elevating tippler or dumper, to discharge 88-ton double-bogie railway wagons at the rate of 30 wagons an hour, and a ship-loading quay-side transporter, of 70 ft. outreach, having a loading capacity of 360 tons per hour.

MESSRS. INTERNATIONAL COMBUSTION LIMITED, Aldwych House, Aldwych, London, W.C.2, have received repeat orders for Lopulco pulverised-fuel fired boilers for the Swansea Corporation's Tir John North Power Station and for the Kent Electric Power Company's Littlebrook "B" Power Station. Stoker-fired boilers have been ordered for the North Metropolitan Electric Power Company's Willesden Power Station and for the L.M.S. Railway Company's Stonebridge Park Power Station. Several orders for "L" stokers and Usco air heaters have also been received, while Messrs. T. Chalmers and Sons, Limited, have given the firm an order for coal-handling plant.

MESSRS. R. A. LISTER AND COMPANY, LIMITED, Dursley, Gloucestershire, inform us that their A.R.P. department has received orders for stand-by generating plant from Messrs. Alfred Herbert, Limited, the Central Electricity Board, the Chamber of Shipping in the United Kingdom, the Crown Agents for the Colonies, the General Post Office, H.M. Office of Works, the London Passenger Transport, and numerous other firms and administrations.

TENDERS.

WE have received from the Department of Overseas Trade, 35, Old Queen-street, London, S.W.1, particulars of the undermentioned tenders, the closing dates of which are stated. Details may be obtained on application to the Department at the above address, quoting the reference numbers given.

Turbine Pump, vertical-spindle, tube-well, a.-c. motor-driven, capable of delivering 50,000 gallons of water per hour against a total head of 145 ft. Indian Stores Department, Electrical Branch, Simla; May 20. (T. 22,109/39.)

Coal, 6,000 tons. Roumanian State Maritime Service, Bucharest; May 23. (T. 22,253/39.)

Structural Steelwork for coaling plant at Capital Park, Pretoria. South African Railways and Harbours, Johannesburg; July 17. (T. 22,292/39.)

BOOKS RECEIVED.

British Standards Institution. No. 800/1939. *British Standards Specification for Limits of Radio Interference.* Revised, March, 1939. London: Offices of the Institution, 28, Victoria-street, S.W.1. [Price 2*s.* net.]

Iron and Steel Institute. Special Reports. No. 24. *Second Report of the Alloy Steels Research Committee.* [Price 10*s.* to Members; 16*s.* to Non-Members.]

No. 25. *Eighth Report on the Heterogeneity of Steel Ingots.* [Price 10*s.* to Members; 16*s.* to Non-Members.] London: Offices of the Institute.

What Engineers Do. Engineering for Everyman. By W. D. BINGER. Revised and enlarged edition. London: Faber and Faber Ltd. [Price 8*s.* 6*d.* net.]

Electro-Acoustics. By PROF. DR. ERWIN MEYER. London: G. Bell and Sons, Ltd. [Price 10*s.* net.]

Power-Factor Economics. By P. L. ROGERS. New York: John Wiley and Sons, Inc. London: Chapman and Hall, Ltd. [Price 12*s.* 6*d.* net.]

The Welding of Cast Iron by the Oxy-Acetylene Process. By L. TIBBENHAM. London: Sir Isaac Pitman and Sons, Ltd. [Price 4*s.* net.]

Intermediate Engineering Drawing. Including a Course in Plane and Solid Geometry and an Introduction to Design. By A. C. PARKINSON. Second edition. London: Sir Isaac Pitman and Sons, Ltd. [Price 7*s.* 6*d.* net.]

Higher Mathematics. With Applications to Science and Engineering. By PROFESSOR R. S. BURINGTON and C. C. TORRANCE. London: McGraw-Hill Publishing Co., Ltd. [Price 30*s.*]

Egypt. Ministry of Public Works. Physical Department. Paper No. 35. *The Nile Basin.* Vol. V. *The Hydrology of the Lake Plateau and Bahr El Jebel.* By DRS. H. E. HURST and P. PHILLIPS. Bulak, Cairo: Publications Office, Government Press. [Price £T.100 or 20*s.*]

Minutes of Proceedings of the Punjab Engineering Congress, Lahore. 1938. Vol. XXVI. Lahore: The Punjab Engineering Congress, P.W.D. Secretariat.

The Modern Diesel. High-Speed Compression Ignition Oil Engines and Their Fuel Injection Systems. Fifth edition, revised. London: Iliffe and Sons, Ltd. [Price 3*s.* 6*d.* net.]

A Premier of the Internal Combustion Engine. By DR. H. E. WIMPERIS. New and revised edition. London: Constable and Co., Ltd. [Price 5*s.* net.]

PERSONAL.

MESSRS. THE BRITISH THOMSON-HOUSTON COMPANY, LIMITED, Rugby, inform us that Mr. C. B. Kingsford has been appointed manager of their switchgear sales department, Willesden, in succession to the late Mr. G. E. Riley, and that Mr. L. Drucquer has been appointed assistant manager.

MR. R. W. LEACH, chairman of Messrs. The Audley Engineering Company, Limited, has joined the board of Messrs. British Rolling Mills, Limited, Brymill Steel Works, Tipton, Staffs.

MR. W. J. V. WOOLCOCK, C.M.G., C.B.E., a vice-president of the Federation of British Industries, 21, Tothill-street, London, S.W.1, has been appointed chairman of the Overseas Industrial Publicity Committee, recently appointed by the Federation to assist in the promotion of news of British industrial enterprise in the Press of the world. Mr. Woolcock is chairman of the Overseas Committee of the Federation and a member of the British Council.

MESSRS. EDGAR ALLEN AND COMPANY, LIMITED, Imperial Steel Works, Sheffield, 9, have purchased the undertaking and goodwill, including patents and patent rights, of MESSRS. BRITISH REMA MANUFACTURING COMPANY, LIMITED, Halifax. In association with Messrs. Edgar Allen, Messrs. British Rema Manufacturing Company will carry on their business, in future, operating from the Imperial Steel Works, Sheffield. MR. P. G. RYDER, southern technical representative of the Company, has been retained, and will continue to operate from Messrs. Edgar Allen's London offices, at Artillery House, S.W.1. Several members of the technical and sales staff have also been transferred to the works at Sheffield.

MESSRS. LEAD PIPES, LIMITED, Parkfield Works, Elland, Yorks, have opened an office at 32, Queen Victoria-street, London, E.C.4, to meet the convenience of their clients in the south of England.

MESSRS. BUTTERS BROTHERS AND COMPANY, LIMITED, McLellan-street, Glasgow, S.1, have opened a branch office at County Chambers, Corporation-street, Birmingham. MR. R. M. STEWART of their London office will be resident in Birmingham.

The headquarters organisation of the Chief Mechanical Engineer and Electrical Engineer's Department, LONDON MIDLAND AND SCOTTISH RAILWAY is shortly to be transferred from Euston to Derby. The transfer of staff, which numbers between 200 and 300, will begin within the next few weeks and arrangements have been made for the move to be completed with practically no disturbance to the work of the Department.

MESSRS. WESTINGHOUSE BRAKE AND SIGNAL COMPANY, LIMITED, 82, York Way, King's Cross, London, N.1, have notified us that their northern representative for metal rectifiers, MR. W. E. WILKINS, B.Sc., A.M.I.E.E., has changed his address to Agden Lane Farm, Lymm, Warrington.

MR. G. T. COTTERELL, M.Inst.C.E., has taken MR. N. CAMPBELL LITTLE, M.Inst.C.E., into partnership in the firm of Messrs. A. P. I. Cotterell and Sons, consulting engineers, 54, Victoria-street, London, S.W.1, and 10, Orchard-street, Bristol.

THE INSTITUTE OF THE PLASTICS INDUSTRY.—On May 24, the members of the Institute of the Plastics Industry are visiting Coventry. Messrs. Alfred Herbert Limited inform us that they have arranged to demonstrate to them, in their works, plastics moulding machines, presses, and die and mould-making machines, all of which will be in operation. These machines will include a Reed-Prentice hydraulic injection moulding machine, a Stokes fully-automatic moulding machine and 100-ton moulding press, a Daniels 50/75-ton hydraulic hobbing press and a motor-driven pre-forming press. For the production of dies and moulds, Keller, Gorton, Reed-Prentice and Taylor Hobson machines will be demonstrated.

THE INSTITUTION OF CIVIL ENGINEERS.—The annual general meeting of the Institution of Civil Engineers was held at the Institution, Great George-street, London, S.W.1, on Tuesday last, May 9. In the ballot for the election of the President, Vice-Presidents and Members of Council, Sir Clement Hindley, K.C.I.E., was elected President in succession to Mr. W. J. E. Binnie, and Mr. Maurice FitzGerald Wilson, Sir Leopold Savile, K.C.B., Professor C. E. Inglis, O.B.E., F.R.S., and Sir John E. Thornycroft, K.B.E., were elected Vice-Presidents. The five new Members of Council are Mr. Walter Miller Campbell (South Africa), Mr. Joseph Newell Reeson (Australia), Sir Standen Leonard Pearce, C.B.E., Mr. Vernon A. M. Robertson, and Mr. C. L. H. Humphreys.

COLD FILLING COMPOUND FOR PAPER AND RUBBER-INSULATED CABLES.—A compound, which does not require the application of heat before it is used for filling joints or terminal boxes, is being introduced by Messrs. W. T. Henley's Telegraph Works Company, Limited, Holborn Viaduct, London, E.C.1. This material which it is claimed will be of particular use in mines, oil refineries and cordite factories, as well as in places where the boxes are mounted on poles, and the source of heat is therefore remote, is suitable for voltages up to 11 kW. It consists of a black compound and hardening agent, which are mixed together just before use and can be poured at atmospheric temperature. Initial setting begins almost immediately after the two constituents are mixed and the compound reaches its final condition as a pitch-like semi-plastic solid in the course of a week or two. It has a melting point of 56 deg. C. and a breakdown strength of 32 kV for a 2-mm. gap.

NOTES FROM THE SOUTH-WEST.

CARDIFF, Wednesday.

The Welsh Coal Trade.—A good demand was again encountered in practically all trades on the Welsh steam coal market last week. A development of special interest during the week was the receipt of further inquiries from American users following the more serious turn of events in the miners' strike at various coalfields of the United States. Unfortunately, however, most of the demand from this source was for fairly prompt shipment, and following the sustained activity experienced during recent weeks, sellers generally had only very limited coal to offer for delivery over the next month or so. German buyers were also again showing interest in the market, and were asking for offers for the supply of duff coals. Cokes were in better request following the improvement in the inland iron and steel and allied trades, and supplies were moving off more freely. Some large inquiries were encountered for cokes from users in Yugo-Slavia, and one inquiry was for something like 100,000 tons. Supplies of best large qualities were difficult to obtain over some while to come, and what occasional small quantities sellers had to offer commanded enhanced prices. Inferiors, however, could still be obtained without much difficulty, though quotations were fully maintained. Stems for the popular dry-sized descriptions continued well filled ahead, and the tone remained very firm. Bituminous smalls maintained their recent improved activity, but the demand for the dry small sorts continued disappointingly small, and prices were unimproved. Patent fuel continued to display a good activity, while pitwood was still quiet.

The Iron and Steel Trade.—Activities were well sustained in the iron and steel and allied trades of South Wales and Monmouthshire. There was a moderate demand passing, and works were kept busily occupied in fulfilling orders already on hand.

NOTES FROM THE NORTH

GLASGOW, Wednesday.

Scottish Steel Trade.—Active conditions continue to rule in the Scottish steel trade and all plant is running fully. Rearmament requirements are very large and everything possible is being done to speed up deliveries of all Government contracts. A considerable tonnage of steel is on demand for the Admiralty orders now in hand in this district, and with the recent heavy bookings of vessels for the mercantile service, the total output of the steelworks will be quickly absorbed for many months to come. The demands of other consumers are also exceedingly good, giving the indication that industry in general is much better. For light steel there is also a very steady demand, and the makers of black and galvanised sheets are working at full pressure to meet the requirements of a very general character. Orders in hand for the motor industry represent quite a fair proportion of the current output, while a very considerable tonnage is on demand for metal containers of different kinds. Prices are unchanged and are as follows :—Boiler plates, 11*l.* 8*s.* per ton ; ship plates 10*l.* 10*s.* 6*d.* per ton ; sections, 10*l.* 8*s.* per ton ; medium plates, 12*l.* 2*s.* 6*d.* per ton ; black-steel sheets, No. 24 gauge, 14*l.* 15*s.* per ton ; and galvanised corrugated sheets, No. 24 gauge, 17*l.* 5*s.* per ton, all delivered at Glasgow stations.

Malleable-Iron Trade.—In the West of Scotland malleable-iron trade a slight improvement falls to be recorded and more business is passing. The inquiry is better and, on the whole, the outlook is more encouraging. The re-rollers of steel bars are enjoying a very busy run at present, and with the demands of buyers amounting to a considerable tonnage, makers are all fully occupied. Their stock of raw material is none too heavy and they are keeping up a constant pressure for supplies to enable them to overtake the demands of their customers. The home market is the main source of the current business, but there is quite a fair inquiry for export lots. The following are to-day's quotations :—Crown bars, 12*l.* 5*s.* per ton for home delivery or export ; re-rolled steel bars 11*l.* 15*s.* per ton for home delivery and 11*l.* per ton for export ; No. 3 bars, 12*l.* per ton, and No. 4 bars, 12*l.* 5*s.* per ton, both for home delivery.

Scottish Pig-Iron Trade.—The demand for Scottish pig-iron is steadily increasing and the orders from the steel-works alone amount to a large tonnage. Hematite and basic iron are moving freely, while there has been an improvement in the demand for foundry grades. Production has been increased by the starting up of another furnace, making the number in blast 11. Prices are steady and are as follows :—Hematite, 6*l.* 0*s.* 6*d.* per ton, and basic iron, 5*l.* per ton, both delivered at the steelworks ; foundry iron, No. 1, 5*l.* 8*s.* per ton, and No. 3, 5*l.* 5*s.* 6*d.* per ton, on trucks on makers' yards.

THE JAMES ALFRED EWING MEDAL.—The second award of the James Alfred Ewing Medal has been made to Professor Arnold Hartley Gibson, D.Sc., M.Inst.C.E., of the University of Manchester, in recognition of his work in connection with hydraulic engineering. The Medal was founded in memory of Sir Alfred Ewing and is presented for specially meritorious contributions to the science of engineering. The first award of the Medal, it will be recalled, was made in 1938 to Mr. C. S. Franklin, for his work in connection with wireless development in England. Awards are made by the Council of the Institution of Civil Engineers, on the recommendation of the Presidents of the Institution of Civil Engineers and the Royal Society. The Medal was presented to Professor Gibson at the Institution of Civil Engineers, on May 2, by the President, Mr. W. J. E. Binnie, M.A.

NOTES FROM CLEVELAND AND THE NORTHERN COUNTIES.

MIDDLESBROUGH, Wednesday.

General Situation.—While conditions in the iron and allied trades change slowly, movement is in the direction desired. Commercial customers need supplies of most commodities and are returning to the market, but have difficulty in re-opening negotiations, iron and steel producers being still too busily engaged in supplying material for defence purposes to resume extensive discussion of ordinary business.

The Cleveland Iron Trade.—Slightly better account can be given of the state of the Cleveland pig branch of trade, which, however, is still very unsatisfactory. Founders have rather more work on hand than recently, and are booking orders, but their consumption of pig has not yet greatly increased and the intermittent output of the blast-furnace meets the additional demand for foundry iron. Makers have little Cleveland pig stored, but still see little prospect of conditions justifying early resumption of continuous production. Merchants have command of only moderate parcels of foundry iron. They report improvement in business with old home customers, but export trade still negligible. Stabilised quotations remain at the equivalent of No. 3 Cleveland at 99*s.* delivered within the Tees-side zone.

Hematite.—In the East Coast hematite department the statistical position is gradually changing in favour of sellers, but more rapid reduction of stocks would be welcome. While home buyers are taking up substantial tonnage, the bulk of the supply continues to pass into use at makers' own consuming works. Merchants are handling a fair amount of tonnage and are providing regular home customers with moderate supplies, but their efforts to put through business with firms abroad meet with little success. Recognised market values stand at the level of No. 1 grade of hematite at 120*s.* 6*d.* delivered to North of England areas.

Basic Iron.—Substantially enlarged make of basic iron is reserved for growing requirements of producers' adjoining steelworks, and the quotation of 92*s.* 6*d.* is nominal.

Foreign Ore.—There is no new feature in the foreign ore trade. Consumers are still much too overbought to enter into commitments for delivery over periods well ahead, but imports are on a scale that is steadily reducing tonnage overdue for acceptance. To date, this month, unloadings on Tees-side total 49,928 tons, compared with 55,703 tons for the corresponding part of April.

Blast-Furnace Coke.—Heavier local consumption of Durham blast-furnace coke is met by ample supply. Sellers continue to seek contracts on the basis of good medium qualities at 24*s.* 3*d.* at the ovens.

Manufactured Iron and Steel.—Aggregate output of semi-finished and finished iron and steel is exceptionally heavy and the vast tonnage production does not fully cope with delivery demand. Manufacturers of several commodities have still to concentrate on meeting Government requirements, but some expansion of general commercial negotiations can be reported. Re-rollers continue to complain of inadequate supply of home-made steel semies, and have to import Continental products to some extent. Sheet makers have as much work on hand as they can deal with, and producers of finished steel are very busily employed. Distribution of specifications for shipbuilding requisites are on quite a good scale, with the result that departments that have been slack for a considerable time, are becoming actively occupied, Principal quotations for home trade : Common iron bars, 12*l.* 5*s.* ; steel bars, 11*l.* ; soft steel billets, 7*l.* 7*s.* 6*d.* ; hard steel billets, 8*l.* 10*s.* ; steel ship, bridge and tank plates, 10*l.* 10*s.* 6*d.* ; steel ship rivets, 14*l.* ; iron ship rivets, 15*l.* ; steel constructional rivets, 15*l.* 5*s.* ; steel boiler plates, 11*l.* 8*s.* ; steel angles, 10*l.* 8*s.* ; steel joists, 10*l.* 8*s.* ; Tees, 11*l.* 8*s.* ; heavy sections of steel rails, 9*l.* 10*s.* ; fish plates, 13*l.* 10*s.* ; black sheets, No. 24 gauge, 14*l.* 15*s.* ; and galvanised corrugated sheets, No. 24 gauge, 17*l.* 5*s.*

Scrap.—As regards scrap, heavy steel is almost unobtainable, while cast-iron and machinery metal are inconveniently scarce.

EXHIBITION OF TURNERY.—An exhibition of the work of the Junior Technical Schools throughout the country was opened in the Guildhall, London, on Tuesday, May 9, and will close to-day, May 12. The exhibition is organised by the Worshipful Company of Turners and the work is divided into two classes, viz., work in wood and work in metal. Referring to the latter it may be said that the standard of craftsmanship attained is, making allowance for the youth of the students, very good. Naturally, since turning is specifically encouraged there are a number of examples of lathe work, particularly screw-cutting, while a group of aluminium pistons is worth attention from the point of view of finish. Some examples of tools and jigs are also shown and there is a turned air-cooled cylinder. Naturally small parts such as gauges, squares, scribing blocks, etc., are in evidence, but examples of more delicate work are not wanting, there being, for instance, some very well made planimeters, not, however, graduated, spherical micrometers, and so forth. The Company awards silver and bronze medals for individual work and challenge cups and trophies to schools, the most meritorious exhibitor being awarded free indentures of apprenticeship which carries with it, subject to continued proficiency and conduct, admission to the Freedom of the Company on completion of the apprenticeship.

NOTICES OF MEETINGS.

ROYAL SOCIETY OF ARTS.—Wednesday, May 17, 8.15 p.m., 18, John-street, Adelphi, W.C.2. Joint Meeting with the ROYAL PHOTOGRAPHIC SOCIETY. "The Centenary of Photography." Four papers, by Mr. P. A. Le Neve Foster, Mr. J. D. Johnston, Miss M. T. Talbot and Dr. A. J. Bull, and Dr. O. F. Bloch.

ROYAL INSTITUTION.—Friday, May 19, 9 p.m., 21, Albemarle-street, W.1. "New Phenomena in Liquid Helium," by Dr. J. D. Cockcroft.

NOTES FROM SOUTH YORKSHIRE.

SHEFFIELD, Wednesday.

Iron and Steel.—Further improvement is reported in several sections of the local staple trades. The flow of orders has been maintained, and most concerns are operating to capacity. The demand for raw and semi-finished materials reaches a high level. Furnaces that were damped down when the demand slackened towards the end of last year, have been re-lighted, and at some firms, additional melting plant is being installed. Both basic and acid steels are in strong request. An active run on cold-rolled strip is reported, while steelmaking alloys form a progressive section. A satisfactory state of affairs exists in the heavy-machinery and engineering branches. Messrs. Edgar Allen and Company, Limited, in their monthly report, state : "One of the most gratifying facts about the trade situation at our works has been the range and variety of orders received from overseas. Chile, for example, has ordered good quantities of small tools and high-speed steels ; Portugal is taking supplies of solid drill steel, and Finland twist drills. Lithuania has ordered files, while the Dominions continue to take big quantities of mining drill steel, small tools, and high-speed, and other steels." The machinery department of the firm has received some useful orders, including four tube mills, 6 ft. 6 in. in diameter by 20 ft. long, a scrubber and washer for India, and a rotary furnace for a British firm, while repeat orders have been for Aero vibrating screens, single roll crushers, crushing rolls and granulators for British users. There is an improving demand for railway rolling-stock. Producers are accounting for bigger outputs as compared with three months ago. Not only has the inland call developed, but heavier supplies are going to the Dominions. India continues to be Sheffield's best customer in buffers, while South Africa is taking wagons, carriages, axle wheels, springs, tyres, and buffers. Business is brisk in most types of colliery furnishings. Orders have been booked from South Yorkshire collieries for steel pit tubs, coal-cutting machines, pneumatic drills, haulage and winding gear, and steel pit props. Another progressive section is that devoted to the production of tramway and railway points and crossings made of manganese steel. During the past few weeks, several important consignments have left Sheffield works for different parts of the country. The demand for grinding and crushing plant has been maintained. Messrs. Edgar Allen and Company, Limited, have put on the market a new rotary coal crusher, designed for standard coking practice. The machine is of the high-speed type, and is normally driven direct from the motor through a flexible coupling. Usually, screens are not required, as the crusher is capable of reducing down to 80 per cent. through a one-eighth mesh without them, but if a greater reduction than this is required, say, 96 per cent. through a one-eighth mesh, it is recommended that screens should be fitted. The season in agricultural machinery and parts is flourishing, and producing works are operating to capacity. The special-steel branches are accounting for record outputs. Toolmakers are busy. Important inquiries have been received from abroad for a variety of tools.

South Yorkshire Coal Trade.—The export position shows further improvement. All grades of steams are in strong request. Orders are circulating for Best South Yorkshire hards. Cobbles and trebles are in better demand. Quotations of most types of fuel have been fully maintained. Shipments from the Humber ports last week totalled 75,400 tons, as compared with 53,000 tons in the corresponding week last year. The inland demand for industrial fuel shows expansion. Steams are in full request. Consumption of small coal has been maintained. Housecoal merchants have received notifications from numerous collieries of reductions of 1*s.* 8*d.* per ton in the pit-head price of most grades. The reductions become operative immediately. Blast-furnace coke moves steadily.

WATER SUPPLY AND DRAINAGE IN HYDERABAD CITY.—The extensive work of remodelling the whole water supply of Hyderabad City has now been completed. The recently-issued annual report of the Public Health Department of the State of Hyderabad records that the scheme included the enlargement of the filtration plant, the laying of extra 33-in. trunk mains from the filter beds, the provision of pumps and pumping mains, the construction of a service reservoir and the extension of the distribution system. Owing to the rapidly growing needs of the city, however, additional supplies and further new filter beds are under consideration. A sum of 37,500*l.* has been devoted to the improvement of the drainage of the City, the surface-drainage system requiring particular attention. Storm-water drains in about a quarter of the City's area have now either been rebuilt or remodelled, while an improvement scheme for cleansing the River Moosi, which flows through the heart of the City, is also nearing completion.

800-H.P. AND 400-H.P. VIMALERT MARINE ENGINES.

(*For Description, see Page* 565.)

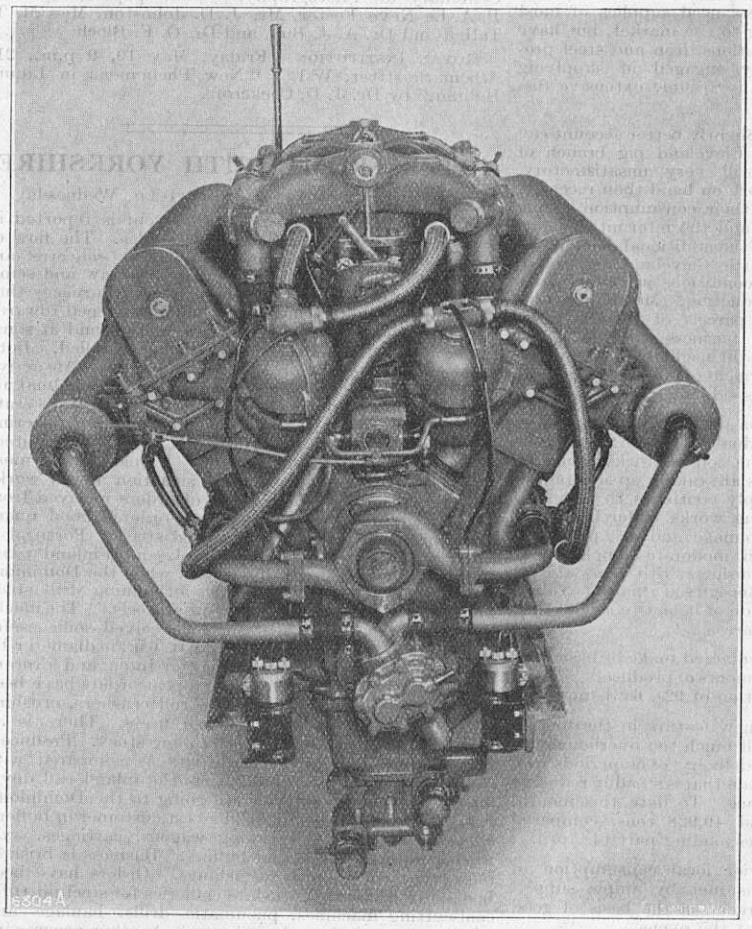


FIG. 1.

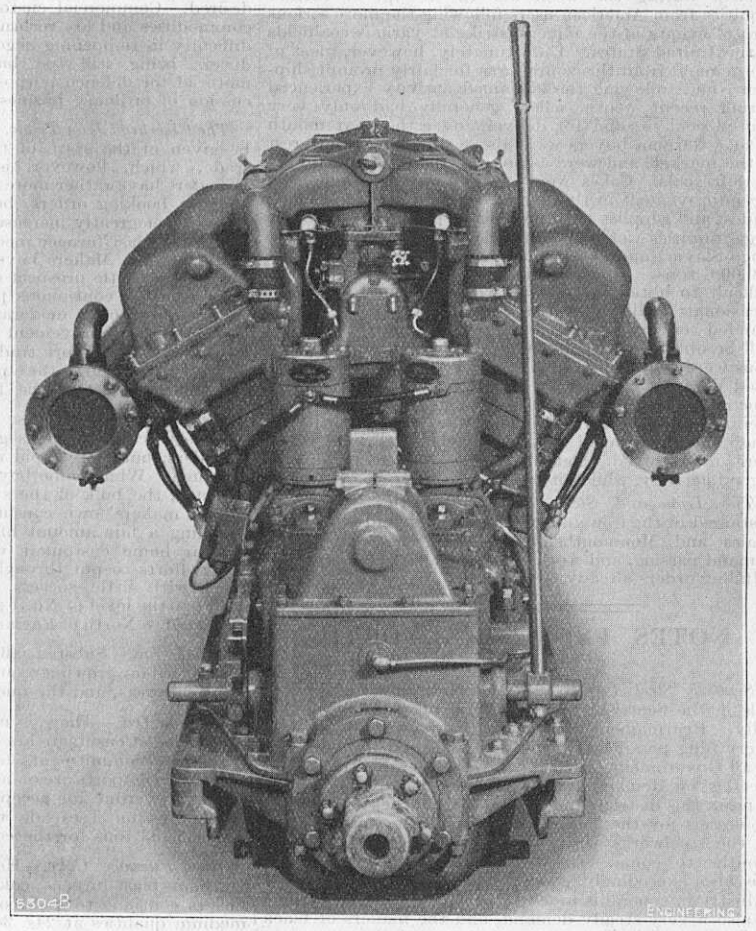


FIG. 2.

Fig. 3.

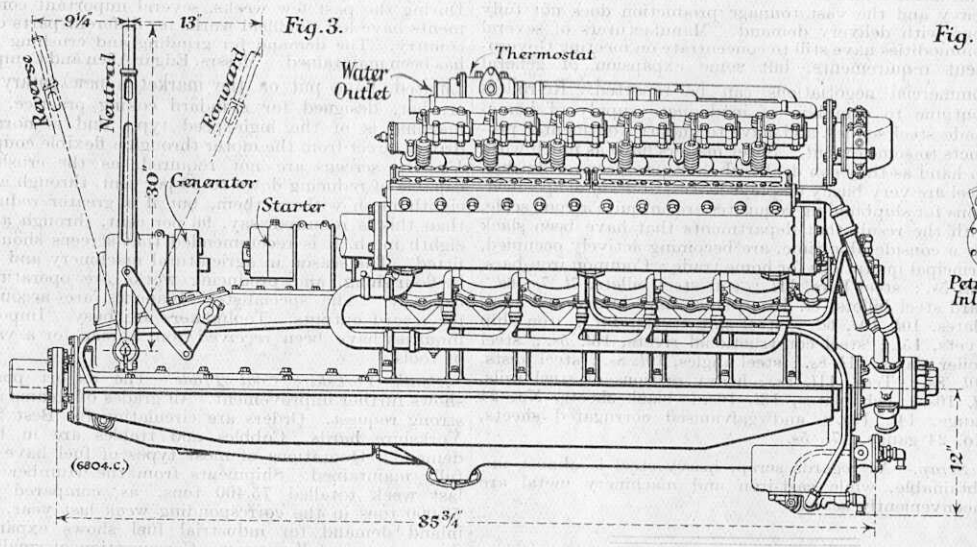
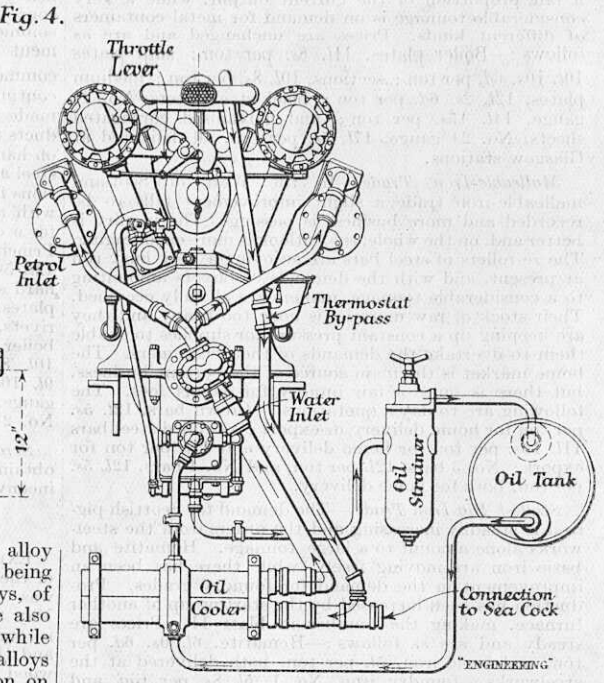


Fig. 4.



ANNUALS AND REFERENCE BOOKS.

D. A. Low's Pocket Book for Mechanical Engineers.—A characteristic feature of all the works of the late Professor David Allan Low is their essentially practical nature, and it is very pleasing to note that Mr. B. B. Low, in editing the new edition of *D. A. Low's Pocket Book for Mechanical Engineers* has inherited this tradition. This edition, which is dated October, 1938, has undergone both revision and addition, the former being only made where practice has changed since the compilation of the original work, the latter, of greater extent, recording processes and methods now common, but not in general use at that time. As examples of the latter, the succinct accounts of supercharging and Michell bearings may be cited, while there are sections on modern cutting tools, grinding, and sand blasting contributed by specialist firms. The tables provided in such sections are likely to be of real use, and the same may be said of such tables as those illustrating the properties of rolled-steel beams, in which the sections of the British Standards Institution are embodied. The chapters dealing with materials have been brought fully up to date, the newer alloy steels, for resistance to corrosion and heat, being adequately dealt with. Aluminium and its alloys, of the age-hardening and other modern types, are also dealt with, test results, etc., being included, while similar information is given for those magnesium alloys which are coming into increasing use. The section on boilers includes accounts of some of the latest types, and the current Lloyd's Rules for engines and boilers are drawn upon. The theoretical side of design has, for the most part, required little alteration, and the presentation of it is notable for the clearness of the diagrams provided. The whole of the illustrations, some 1,000 in number, are, indeed, excellent, and the printers, as well as the editor and publishers, are to be complimented on their reproduction. The common fault in pocket books of making the illustrations too small is not committed. There are in the 778 pages of the book, 28 different sections, and a sufficient index. It is of convenient size, and is not interleaved with advertising matter. The publishers are Messrs. Longmans, Green and Company, 39, Paternoster-row, London, E.C.4, and the price is 10*s.* 6*d.* net.

CALVERTS' MECHANICS' YEAR BOOK FOR 1939. That useful and practical little work known for long as *Calverts' Mechanics' Almanack*, is, as may be inferred, incorporated in *Calverts' Mechanics' Year Book* and, in consequence, it is correct to state that it enters its 64th year of publication with the issue for 1939. This long life, however, does not imply out-of-date matter, for, apart from standard tables, the matter in the book's 190 pages is as modern as it could well be. The plan of including illustrated workshop "tips" of an ingenious and time-saving nature is retained, and there are chapters containing a good deal of compressed information on such subjects as fuel combustion, welding, electric motors, mechanical handling appliances, rope driving, gearing, internal combustion engines, and so forth. Altogether, the book offers excellent value for the 6*d.* charged for it, 8*d.* post free. The publishers are Messrs. Sherratt and Hughes, Park-road, Timperley, Altrincham.

THE INNER GRAVING DOCK, COLOMBO HARBOUR.

MESSRS. COODE, WILSON, MITCHELL AND VAUGHAN-LEE, CONSULTING ENGINEERS, WESTMINSTER.

(*For Description, see Page* 549.)

Fig. 3.

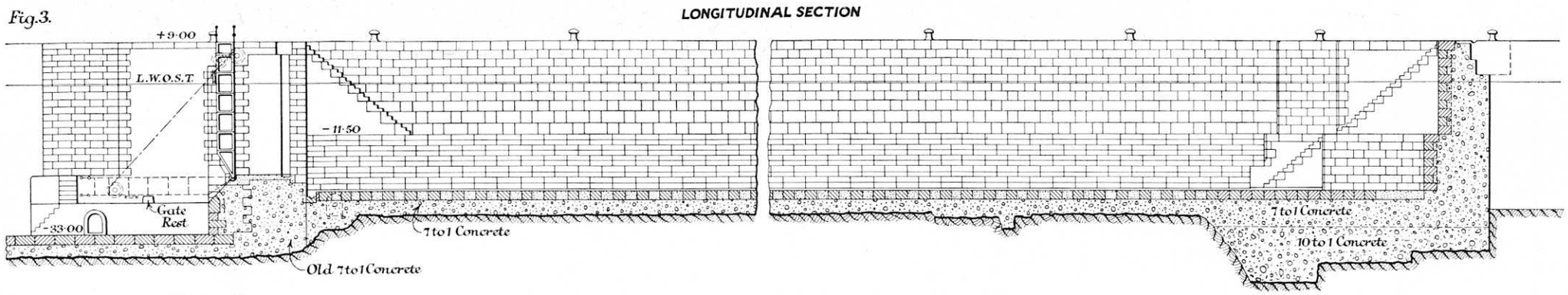


Fig. 4.

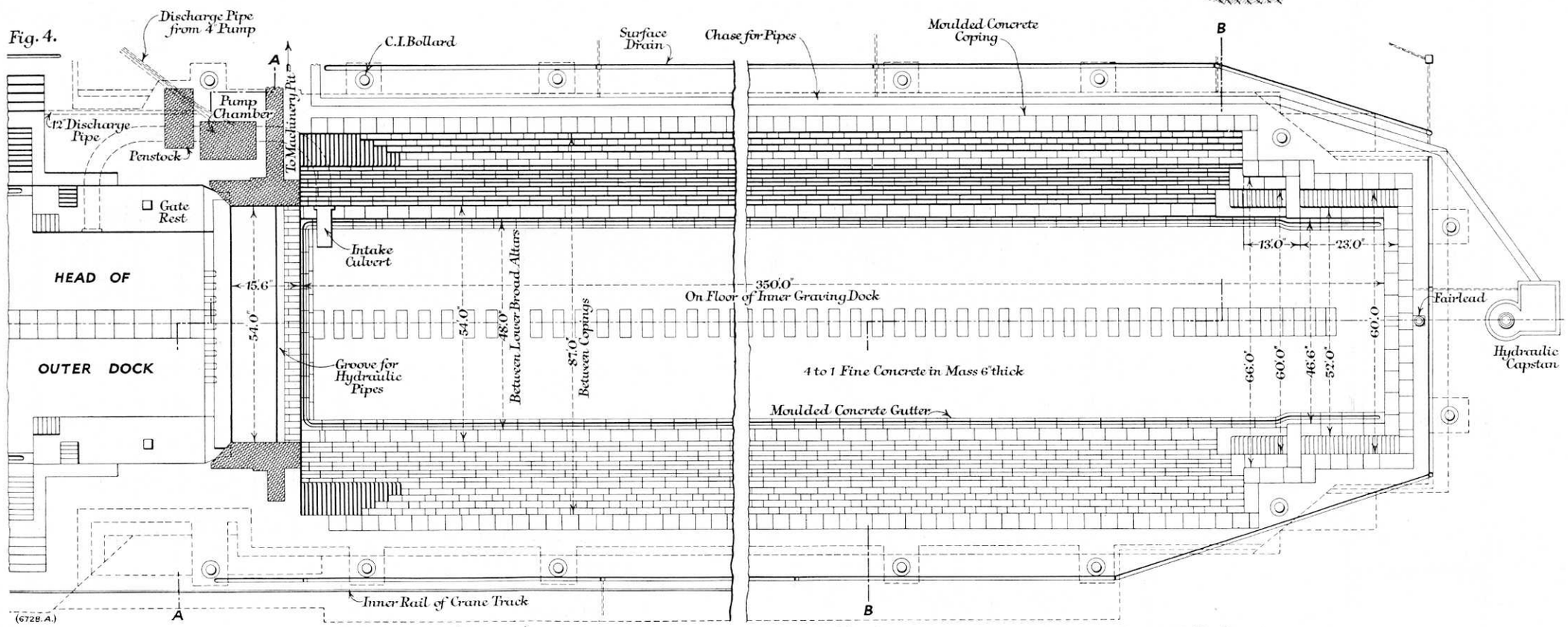


Fig. 5. **SECTION AA** (*See Fig. 2.*)

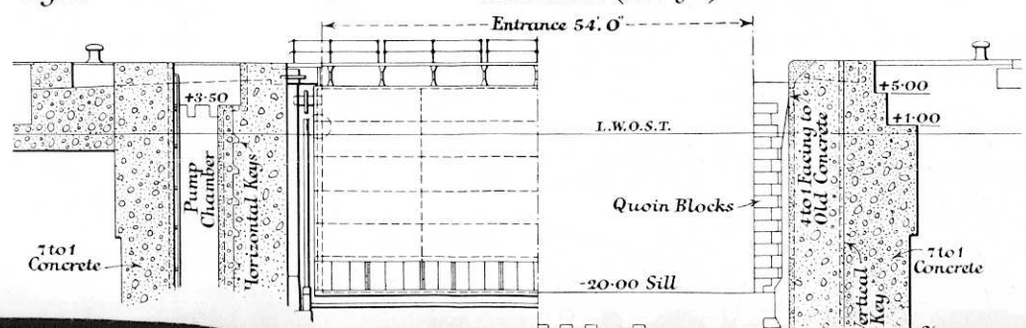
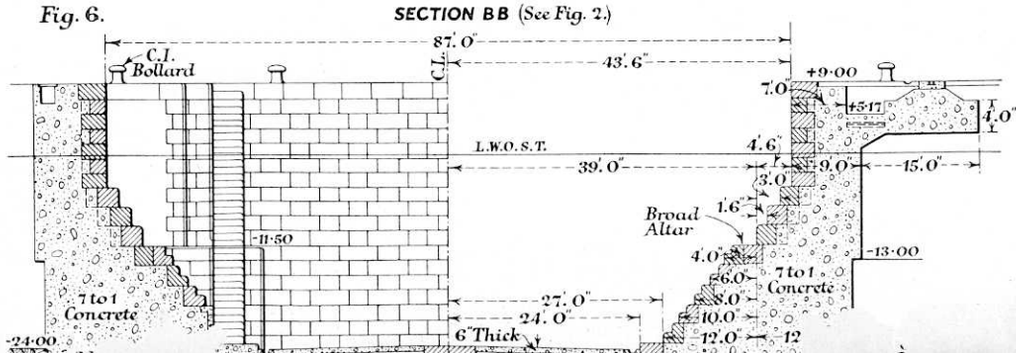
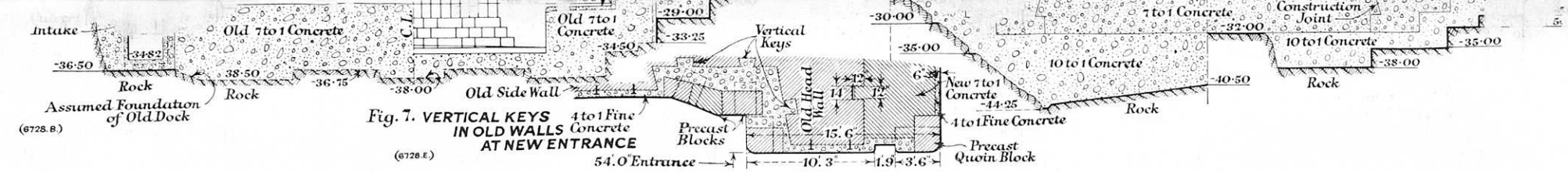


Fig. 6. **SECTION BB** (*See Fig. 2.*)





(6728.B.)

Fig. 7. VERTICAL KEYS IN OLD WALLS AT NEW ENTRANCE

(6728.E.)

Fig. 8. ELEVATION OF GATE

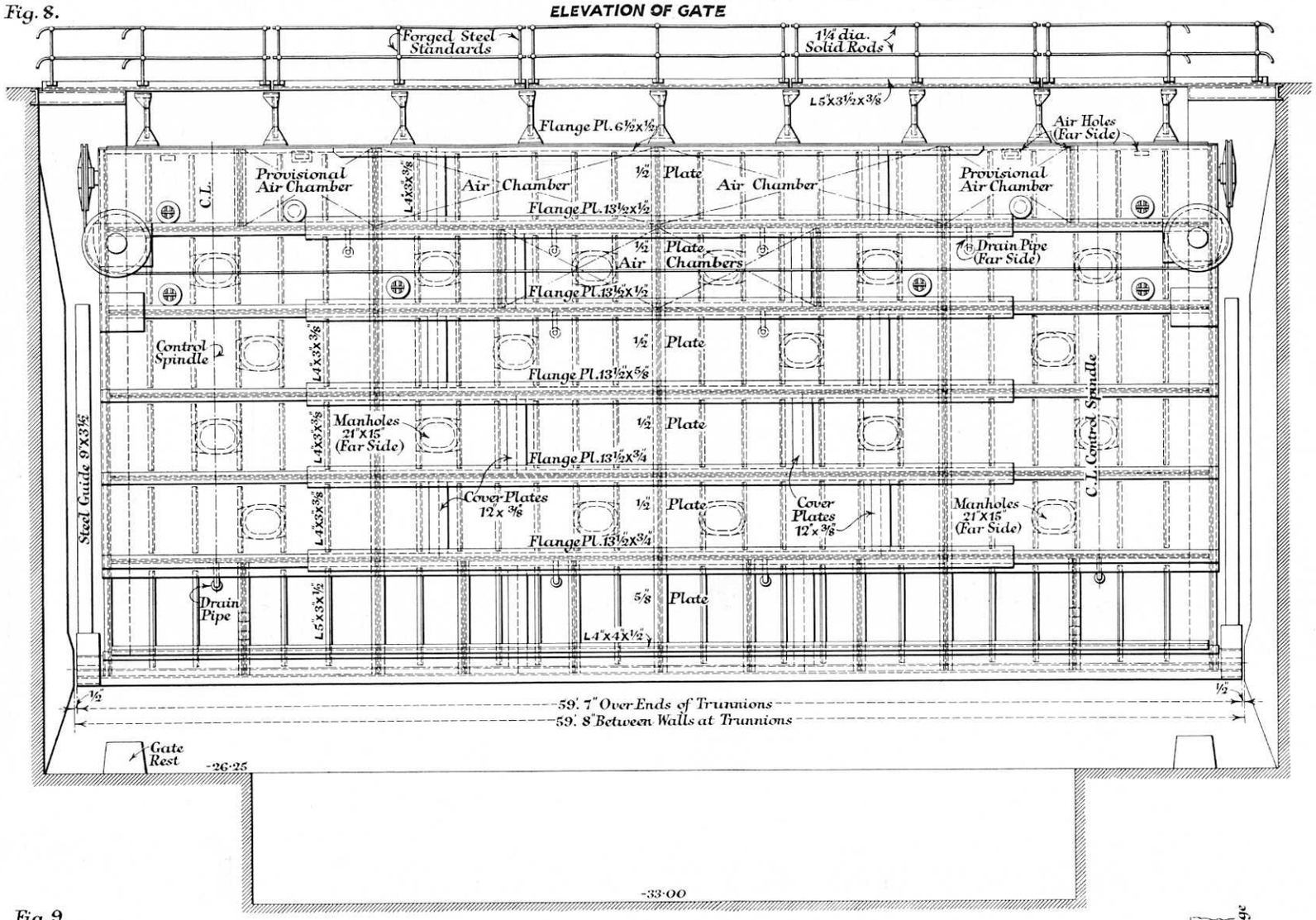
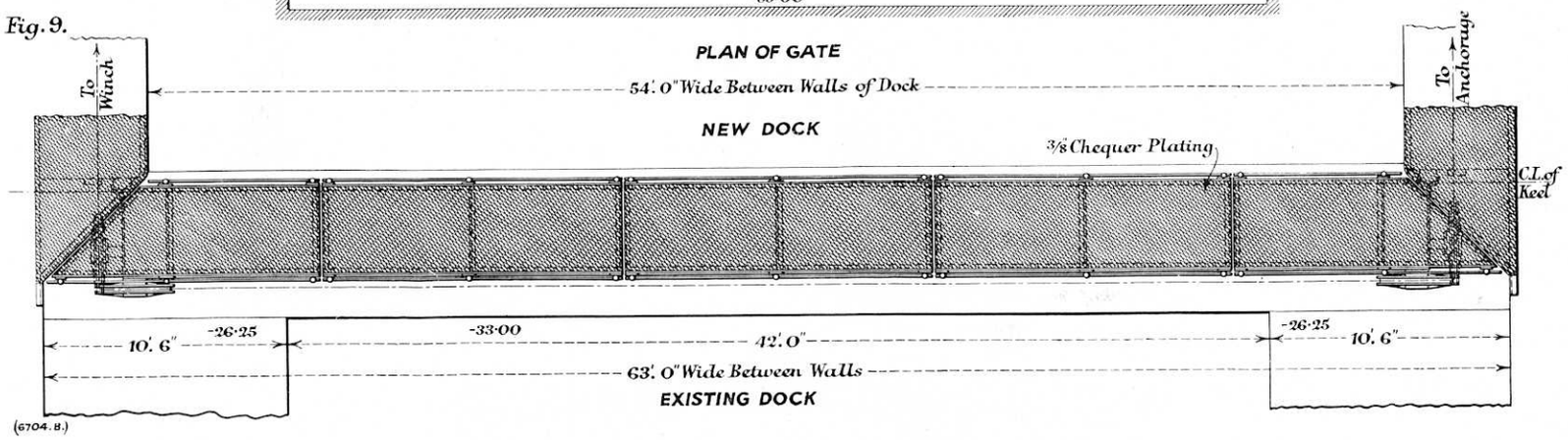
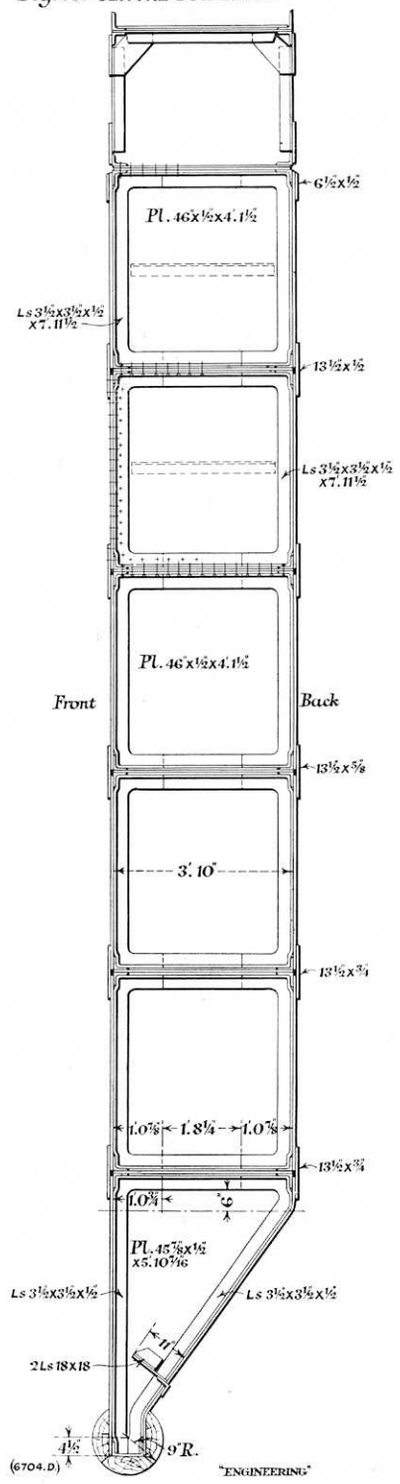


Fig. 9. PLAN OF GATE



(6704.B.)

Fig. 10. CENTRE BULKHEAD



(6704.D.)

"ENGINEERING"

ENGINEERING.

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Classified advertisements intended for insertion in the current week's issue must be delivered not later than first post on Wednesday. Alterations to standing advertisements must be received at least 10 days previous to the day of Publication. Passed proofs must be in our hands by Saturday morning, otherwise they will be taken as correct. The proprietors will not hold themselves responsible for blocks left in their possession for more than two years.

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ENGINEERING

FRIDAY, MAY 12, 1939.

Vol. CXLVII. No. 3826.

MARINE-ENGINE SHAFTING.

THE search for security in machinery design may be prosecuted in several directions, but inevitably with the same ultimate result ; whatever additional safety, or reduced probability of breakdown, is afforded by the strengthening of parts or the duplication of essential components, the strength of the chain is still that of the weakest link. The only escape from that *impasse* lies in the evolution of mechanism, possessing the impossibly uniform perfection of Oliver Wendell Holmes's "one-hoss shay" ; but, as yet, there is little reason to look for the consistent, or even the occasional, production of machines so equably resistant to the stresses imposed by normal working. It is sufficiently unusual to come across tensile-test specimens which have broken in two places at once, although this phenomenon is not unknown. Meanwhile, engineering design must continue to be based upon the general principles that either the mechanism must contain no single part which is indispensable to its continued functioning, or the design must ensure that failure shall not take place in the indispensable element.

The latter alternative represents the position of the marine propelling engine. Whatever precautions are taken, the power developed must pass through the shaft, and there can be only one output shaft per engine ; at least, for so long as present designs continue to be employed. One by one, other sources of weakness have been eliminated, but this crucial limitation remains, acquiring, with every advance in speed and power, a new significance analogous to that of a local bottle-neck in a trunk road. Some relief has been achieved by reducing the peak stresses, just as the carrying capacity of a road can be increased by distributing more evenly the flow of vehicles along it ; but such palliatives seldom amount to a cure, or even to an indefinite postponement of the need for a critical inquiry. Rather do they tend to intensify the average stress by encouraging the adoption of a higher load factor, as the ability to withstand existing conditions becomes more evident and assured.

The great interest that problems of shaft design have aroused in the last few years, as evidenced by the proceedings of various technical institutions, has been due directly and solely to the rapid growth of the marine heavy-oil engine. No conceivable increase in the working pressure or other operating conditions of reciprocating steam engines could have produced the crop of crankshaft failures which was part of the price paid by maritime commerce for the benefits of the new prime mover ; and it is improbable that the development of oil engines only for land purposes would have resulted in a comparable casualty list. The more rigid foundations of land oil engines are a considerable safeguard against such breakdowns, and this relative immunity must have suggested at an early stage that faulty alignment, possibly only momentary, was fundamental to the problems encountered with marine types.

In investigations of this order, the analytical process most briefly described as "of two things, one" may provide useful indications. On these lines it may be argued that, if a shaft fails, either the material is less resistant or the stresses are more severe than the designer anticipated. This method of elimination was followed by Dr. S. F. Dorey, the Chief Engineer Surveyor of Lloyd's Register of Shipping, in a paper entitled "Strength of Marine-Engine Shafting" which he read on March 24 before the North-East Coast Institution of Engineers and Shipbuilders. The paper was unusually comprehensive and does not readily lend itself to abridgment, but on the above lines a brief survey of its main theses may be attempted.

The first reaction to a broken shaft, as Dr. Dorey knew by experience, is to blame the material—which in this connection includes the workmanship ; and tests of crankshaft material consequently received prior attention. With the collaboration of the former Skoda Works, an extensive range of test-pieces was taken from two 80-ton crankshaft ingots and examined physically, chemically and microscopically. Broadly it may be said that the 28/32-ton mild-steel forgings, commonly used for crankshafts, left the court with no really indelible stain on their collective character. It was evident, therefore, that excessive stresses must be responsible, and an analysis of stress-producing conditions occupied a second, and large, portion of the paper. The stresses identified, it remained to determine their magnitude and, finally, to devise conveniently applicable methods of design to ensure that, in all normal circumstances, no more than the normal permissible stresses should be induced.

To this study, Dr. Dorey was able to bring an experience probably unique in modern engineering. His survey of the methods employed for a number of years by Lloyd's Register to predict and to measure the stresses in shafting was in itself material enough for a full-length paper, covering not only the stresses produced by torsional and axial vibrations, but also those resulting from lack of alignment and from rough-weather conditions. His definition of what may constitute a dangerous torsional-vibration stress was of particular interest, being supported by details of 19 investigations of crank and screw shafts. Of these, 17 related to motorships, the remaining vessels having respectively quadruple- and triple-expansion steam engines.

The conclusions reached were that stresses of the order of ± 9,400 lb. per square inch would definitely cause failure of screw shafts, but that ± 8,600 lb. per square inch might or might not do so ; that stresses of no more than ± 3,300 lb. might cause

failure of a shaft if the material were of coarse structure and weak in fatigue resistance; and that ± 4,000 lb. would fracture a tailshaft which had been subjected to the effect of sea water and consequent corrosion fatigue. In Dr. Dorey's opinion, the permissible vibration stress at service speed does not exceed ± 2,000 lb. per square inch. Failures of crankshafts have occurred with stresses varying from ± 3,700 lb. to ± 7,900 lb. per square inch, but a crankshaft of partly "built" construction has been known to withstand ± 8,000 lb. per square inch for more than 10 million cycles of stress. This may be taken as the approximate fatigue limit for an average crankshaft made from sound forgings. The requisite factor of safety must provide, however, for additional stresses due to wear of bearings and must cover also the possibility of undetected forging defects. To afford sufficient margin for these contingencies, the figure given for screw shafts, namely, ± 2,000 lb. per square inch, was recommended as the safe maximum for crankshafts also.

By correlating existing experimental data, a series of factors has been established, representing the ratio between the fatigue limits for small polished specimens not subjected to local stress concentrations and the limits for actual shafts, in which there are concentrations of stress due to holes, fillets, keyways, etc. These, taken in combination with the test results obtained from the ingots previously mentioned, give limiting values for the alternating stresses in the various parts of a large crankshaft. If, as Dr. Dorey stated, these values "at which a shaft will just not break" are exceeded for any reason, failure is only a question of time. The limiting alternating stresses, in ± tons per square inch, range in bending from a maximum of 9 tons at the journal to a minimum of 3·7 tons at the coupling recess, and in torsion from 5·5 tons to 2·2 tons at the same points.

A particularly valuable feature of the paper, however, was its examination of the effect of axial vibrations, on which Dr. Dorey has done a large amount of pioneer work. The use of clock gauges between crank webs is no new practice, but hitherto their readings have been taken only as indications of bending stresses, and the stressing likely to result from axial compression of the complete shaft as a complex spring has not been quantitatively determined. By loading shafts axially with hydraulic jacks, Dr. Dorey was able to obtain their spring constants and thence to calculate the axial natural frequency on the assumption that the thrust collar formed a node in the system. This assumption was supported by measurements of the movement of shafts when running. It was found, however, that the calculated frequencies were higher than the measured frequencies, probably as a result of simultaneous radial movements of the cranks and axial displacements of the bottom-end bearings on crank pins. Further examination of the observed results indicated that axial stiffness depended upon the angular relation of adjacent cranks.

The most important question in the study of axial vibrations was the source of the energy passing into the vibration. Assuming the thrust to be fixed, this energy could only come from the working cylinders, either directly or by an alteration of crankshaft length due to torsional vibration. If the whole shaft system participated in the axial vibration further accretions of energy might be traceable to periodic fluctuations of propeller thrust; but this aspect was not considered in the paper. Without reviewing in detail the arguments advanced by the author, it may be said that a definite shortening of the crankshaft, in both ahead and astern running, was found to be attributable to the mean transmission torque, from which it could be inferred that torsional vibrations would produce similar effects; and, at certain speeds, the axial-vibration load exceeded the propeller-thrust load. It may be noted that the foregoing summary of possible vibration problems assumes throughout that the shafting is in correct alignment and that the hull structure of the vessel is not "working." Alignment would appear, at first sight, to be the easier of the two to check and maintain, but in fact it is very difficult to ensure that all the bearings, or any particular bearing, of a crankshaft is supporting its fair share of the total load. Ordinary wear-down—a term which includes a possible spreading of the white-metal lining—is not the only factor contributing to poor alignment; bedding-down of engine chocks, and movement of the seatings or of the hull itself must also be considered.

Any or all of the above causes of stress, additional to the stress directly due to the power output of the engine, may be greatly accentuated in rough weather, and to obtain more precise information regarding the amount of this increment Dr. Dorey developed a high-speed stroboscopic equipment which enables direct stress readings to be made. The stroboscopic tube employed gives a flash lasting approximating $\frac{1}{10000}$ of a second. When the 18 in.-dia. disc carrying the electrical contacts is rotating at a peripheral speed of 1,200 ft. per minute, readings of the position of radial lines can be made to a quarter of a scale division, or $\frac{1}{200}$ in. Actual readings have shown that, although the maximum torque due to heavy weather was less than had been anticipated, the added fatigue loading was considerable. The same apparatus has been used to investigate the loading on the shafts and gearing of a White combination steam engine, measurements being taken on the turbine quill shaft of a 1,500-brake horse-power installation. These readings indicated that the loading was not excessive in the particular case, but, the author intimated, further attention is being given to stresses in gearing, for both turbine and oil-engine drives. In view of recent developments in oil-engine drives alone, it appears likely that the high-speed stroboscope will find an increasing sphere of usefulness in replacing more or less informed suspicion by definite quantitative knowledge.

SOME INCIDENTALS TO RAILWAY ELECTRIFICATION.

PROTAGONISTS of electric traction are able on request to produce a formidable list of advantages, which would follow a more or less extensive conversion of existing steam railways to electric traction. They are able in large part to justify their case in so far as this country is concerned by reference to the results that have been obtained on the Southern Railway; and, in general, by the argument that it is unknown, or at least very exceptional, for a line on which electric traction has once been adopted to return to the older system. On the other hand, supporters of the continued use of steam working are able to point with some emphasis to the enormous capital expenditure which the change demands and, more generally, to the fallacy of supposing that because electrification has been successful in certain cases it is a universal panacea for present ills. Both these views are, however, those of extremists. It is therefore a relief to turn to a paper by Mr. W. J. England, which was read before the Institute of Transport on Monday, April 3, under the title of "Some Incidentals of a Railway Electrification Scheme." The author is on the staff of the Southern Railway, and may therefore be regarded as a supporter of electric traction. Nevertheless, he is sufficiently unbiased to contend that the arrangements for the supply and distribution of energy, track equipment, sub-stations, rolling stock, and train services are not the only points that have to be considered in connection with the conversions of which his company has undertaken so many. Indeed, essential as all these matters are, there are certain incidentals which are of equal importance if the main object of the change, the securing of more traffic to the railway, is to be achieved.

The reason for this is simple. The improved services, which can economically be operated by electric traction, can, and frequently do, lead to such development of the districts served that a country station with a small passenger traffic may be changed almost overnight into a suburban or outer suburban one with heavy traffic and well-defined peaks. Bearing this in mind, the practice of the Southern Railway, when an electrification scheme is under consideration, is to conduct a "walk-over survey," during which not only are cable routes and substation sites selected, but a decision is reached on such points as track and signalling alterations, berthing accommodation, and platform lengthening. Mr. England gives an interesting example of how electrification may affect the station lay-out with consequent heavy structural works. In order that through services could be given from Waterloo to Reading and from Waterloo to Camberley via Ascot, the existing junction between the Reading and Camberley lines at the London end of Ascot station had to be moved to the Reading end, thus entailing a complete re-arrangement of the tracks and the reconstruction of a short spur line from the new junction to the Camberley line. This new junction has enabled a new and much more rapid system of working the up trains to be introduced. The portion from Camberley arrives at Ascot station and is followed 2½ min. afterwards by the portion from Reading, which runs right up behind it and is at once coupled to it. The combined train leaves 5 min. after the arrival of the Camberley portion. During the business period this method of working is extended, as a portion starting from Ascot is brought to the platform first and is followed in turn by the Camberley and Reading portions. In the down direction both Reading and Ascot portions run as one train as far as Ascot. It is possible for the former to leave Ascot 1½ min. after its arrival and to be followed 2 min. later by the Camberley portion. The heavy capital expenditure on civil engineering works has therefore, it is claimed, been justified by the greater facilities with which the public are provided. The junction is also being moved from one end of the station to the other at Swanley so as to enable electric trains from London to Gillingham and Maidstone to be run as one as far as that point and there divided in the same way as that just described. A similar procedure will be enforced for up trains when electric working is introduced in July next on this portion of the system.

Though such extensive alterations are not necessary at many points, there are, for the reasons given above, many stations where the platforms require lengthening or where improved accommodation of other kinds has to be provided. As pointed out by Mr. England, it is obviously desirable that the platforms should be long enough to accommodate the longest trains which will call at the station, though this ideal cannot always be attained, owing to the presence of over or under bridges which it would be very expensive to re-construct. In any event, cross-over roads and siding connections often have to be re-positioned and the location of signals changed. It is interesting to note that when such platform extensions are carried out on the Southern Railway, it is customary to employ pre-cast concrete sections, together with pre-cast wall blocks and coping stones, the space behind being filled in with rubble and spoil and the whole being then surfaced with tarmac. Incidental to such changes are the provision of footbridges, the modernisation of station buildings, often not before it is required, and the erection of stopping marks, in order that the station time allowance shall be reduced to a minimum.

A further problem of some importance in conjunction with a suburban electrification scheme, is the provision of berthing facilities and car sheds so placed that the car mileage shall be as low as possible. The traffic curve being what it is, the ideal arrangement is to have a proportion of the necessary berths actually at the London terminals, in order that the train may be divided at the conclusion of the morning rush hour and the part not required for mid-day working may be immediately available for the evening return load. Considerations of space, however, prevent this ideal from being fully attained, and some empty mileage is, therefore, necessary. This explains why depots, such as the one at Streatham Hill have been established. This comprises an inspection and cleaning shed with accommodation for 80 coaches and berthing sidings with cleaning stages; here a further 89 vehicles can be stabled. Such work as the changing of brake blocks and the maintenance of the control equipment and compressors, not to speak of light running repairs, can thus be carried out easily and without delay. Cleaning is also facilitated by vacuum and hydraulic plant.

As regards track problems, Mr. England points

out that electrification means that consideration has to be given in laying the conductor rails to such matters as suitable gaps for fog signalling, staff crossings and the protection of the public at level crossings. On the Southern Railway all existing direct-current track circuits have had to be altered to alternating-current, with the attendant work of installing impedance bonds. The running of a more intensive service has meant the re-positioning of existing signals, the introduction of intermediate block home signals and, even, as is well known, the installation of automatic signals. Telephone circuits also have to be reviewed, the problem of level crossings examined in order that the increased service shall not lead to any risk for those using them, while rather more minor, if still important, matters are the provision of coasting boards to assist motormen to maintain the schedule with a minimum consumption of energy, an increase in the number of staff refuges in tunnels and on bridges and viaducts, the insulation of gas and petrol pipes, the provision of sandbins on bridges with timber decking, and the issue of insulated tools to the permanent way staff.

Mr. England is careful to insist that he is dealing particularly with the electrification of a suburban passenger line on the third rail low-tension system, and that on other systems the "incidentals" may be different or require different treatment. This is, of course, true. At the same time he has done well to draw attention to matters which are too often overlooked when electrification schemes are being discussed, or if that is too strong a word, are considered to be more of a routine character than they actually are.

NOTES.

Coastal Shipping and Local Authorities.

The increasing competition of foreign vessels in the coastal trade of this country has for long given a great deal of anxiety to the shipowners concerned, and has been the cause of many representations in the lay and trade press. It has now attracted the attention of the Government, with the result that the Minister of Health has addressed a circular to local authorities, joint boards and port health authorities throughout the country indicating the desirability of securing that, as far as possible, heavy goods, such as coal, road and building materials, as well as materials used in civil engineering should, if brought coastwise, be carried in British ships. Actually, this matter was raised as long ago as 1934, when the County Councils' Association, the Association of Municipal Corporations and the Urban District Council Association all passed resolutions asking their constituent bodies to bear this matter in mind. There is, however, no harm in re-emphasising the importance of the subject with some vigour, especially at the present time. The British coasting trade is an essential element in the transport system of the country, and would be specially valuable in time of emergency, when other methods of communication might be subject to dislocation and foreign ships might be withdrawn. Any decrease in the use of British vessels tends to reduce tonnage which might be available in times of emergency, results in unemployment among seamen, and a reduced demand for British coal. Local authorities would, therefore, the Minister thinks, agree with him that practical steps should be taken to increase the use of British coastal shipping. It is therefore recommended that all authorities, if they have not already done so, should incorporate in their form of tender a stipulation that where materials intended for their use are carried coastwise, they should be conveyed only in British ships. This recommendation we may, perhaps, be permitted to endorse.

Young Engineers and Military Training.

Considerable discussion has been aroused in engineering circles by the apparent failure of the Government to recognise that their proposed arrangements for compulsory military service were likely to affect other kinds of students than those at Universities. Students in engineering colleges, and professional and trade apprentices (classes which overlap and interlock to a great extent) are at an important stage in their technical training at the age when they are now to be called upon to undergo initiation into military service; and training of that kind, to achieve its full value, must be continuous. No reasonable person would suggest, however, nor, we believe, would the majority of the students themselves desire, that the intention to follow an engineering career, in whatever grade, should absolve or debar them from the military obligations laid upon other young men of their age; but there has been a real fear that the demand of the War Office for its requisite numerical quota might cause large numbers of these potential technicians to be turned into infantry, to the permanent detriment of their technical development. We believe this fear to be unfounded, and to be the result merely of a very imperfect knowledge of the degree to which mechanisation now conditions the entire Army organisation. It is very necessary that the Army should recruit technically-trained men in proper proportion to the numbers of non-technical rank and file. The junior grades in the professional institutions, the youths engaged in courses at engineering colleges, and the craft apprentices are likely to find that there is every scope for their native or acquired engineering talent, provided that they make clear the fact that they possess it. To this end, we understand that the Institution of Civil Engineers and other institutions are advising their student members to make a point of informing the Interviewing Officers of their qualifications in such respects, so that they may be posted to suitable units when called up for their militia training. In the Royal Engineers, Royal Army Ordnance Corps, Royal Army Service Corps, Royal Armoured Corps (more popularly still the "Tanks"), and in Signals and Searchlight Section units, there is ample opportunity to apply and to extend any technical skill they may possess, quite as effectively as in any ordinary apprenticeship or pupilage.

400-B.H.P. AND 800-B.H.P. VIMALERT PETROL MARINE ENGINES.

The range of marine engines manufactured by Messrs. The Vimalert Company, Limited, Jersey City, N.J., is largely used in the United States for pleasure, commercial, and government boats. The range includes 400-b.h.p., 800-b.h.p., and 1,200-b.h.p. models, all three engines having twelve cylinders arranged in vee formation in two banks of six. The 800-b.h.p. engine is illustrated in Figs. 1 and 2, page 562. It is rated at 800 b.h.p. at 2100 r.p.m., the brake horse-power curve being almost linear from 550 b.h.p. at 1,400 r.p.m. to 800 b.h.p. at 2,100 r.p.m. The cylinder bore is $6\frac{3}{8}$ in. and the piston stroke is $6\frac{1}{2}$ in. The two banks of cylinders are set at an angle of 60 degrees. The total piston displacement is 2,539·55 in., and the compression ratio is 6 to 1. The total weight of the engine is 3,100 lb. The cylinder blocks are of alloy cast iron with inserted wet liners. The liners are forged from chrome-molybdenum steel, and are flanged at the upper end. There are two cylinder heads, each embracing three cylinders, on each block, the heads being heat-treated aluminium-alloy castings having a high tensile strength. The joint between the blocks and heads consists of a soft aluminium ring at the combustion chamber proper and a composition gasket for the water jacket. The sleeve packings at both ends consist of heat and oil-resisting rubber rings. The blocks are attached to the crankcase by five studs per cylinder extending in to the crankcase. The intake and exhaust-valve seat inserts are of alloy steel, while the camshaft bearings, cam follower guides and valve covers are of aluminium alloy. The pistons are also of high-tension aluminium alloy, but have cross-ribbing in iron on the underside of the head to improve cooling and increase the rigidity. There are five rings per piston, including two scraper rings, all located above the pin. The gudgeon-pins, of alloy steel, are of the fully-floating type, end movement being limited by aluminium plugs held in the bosses by a light driving fit. Both the master and link connecting-rods are of heat-treated alloy steel. The main big-end bearing is of steel-backed bronze, and the big-end bearing of the link rod, together with the gudgeon-pin bearings, of phosphor-bronze. The link pins are retained in place by a tapered draw bolt passing through a boss in the master rod. The crankshaft is of the conventional six-throw seven-bearing type, and is a heat-treated alloy-steel forging. The main bearings are $3\frac{1}{2}$ in. in diameter, and the crankpins are $3\frac{1}{4}$ in. in diameter.

The crankcase is of box-section type in aluminium alloy. The main bearing upper halves are supported in transverse webs in the upper portion of the crankcase, and the lower halves are supported in forged aluminium-alloy caps. The latter are attached by means of long alloy-steel through bolts, which pass through the cylinder heads at their upper ends. Long alloy-steel studs, referred to earlier, are used for attaching the cylinder blocks to the crankcase, the upper end of these studs also extending through the cylinder heads. This combination results in an extremely rigid structure. An oil sump of aluminium alloy is bolted to the crankcase and carries the oil pumps. The main bearings are of steel-backed bronze. The valve gear is of the overhead type, with two camshafts per block, one for the exhaust and the other for the inlet valves. The valves are operated by Tee-shaped cam followers, the latter being in direct contact with the cams. The valves are, therefore, not called upon to take side thrust. Each valve is provided with two springs, one within the other. The exhaust valves are of the tulip type, of special alloy-steel. They are sodium-filled to promote better cooling, and have stellite tips and seats. The inlet valves are nickel-chromium steel forgings, and are also of the tulip type. As regards the induction system, two Stromberg double-barrel carburettors are used, each being connected to a Tee, and each side of the latter feeding three cylinders. The Tees are water-jacketed. Both carburettor inlets are fitted with a large combination air filter and flame arrester. The crankcase breather outlets are connected by 1-in. tubing to the air-intake assembly, and screen-type fire arresters are provided at the breather connections. The fuel is fed to the carburettors through strainers from an engine-driven pump under pressure controlled by a relief valve. Battery ignition is employed, there being two Delco distributors driven by the camshaft driving shafts, each distributor firing one set of plugs. There are two plugs to each cylinder, giving two independent ignition systems. Complete radio shielding of the ignition system can be provided.

Due to the corrosive action of sea water, an indirect cooling system is used incorporating both fresh-water and sea-water cooling. A centrifugal pump provides fresh-water circulation to the cylinder and induction-pipe jackets, and a gear-type pump is fitted to circulate salt-water through the exhaust manifold only. The centrifugal pump is of the single-entry double-discharge type, one outlet discharging fresh water into each bank of cylinders. The gear-type pump is direct coupled to the crankshaft at the distributor end. The bronze body has two separate pumping spaces each having its own gears. There is a common inlet, and a double outlet on the discharge side. The hardened driving gears rotate in a separate compartment filled with grease, so that they do not come into contact with sea water. An oil slinger prevents oil in the crankcase creeping along the pump shaft, and a water slinger is placed on the shaft between the stuffing-box and the crankcase to reduce the possibility of water seeping into the latter.

The lubricating system is of the dry-sump type, with an external oil tank and oil cooler. A gear-type pump draws oil from the tank and forces it under pressure to the main bearings, connecting-rod bearings, camshafts, reverse gear, etc. The oil is scavenged by three gear pumps, which return it through the cooler to the tank. The oil cooler is of the tubular type, and is made of bronze. The engine is provided with twin starting motors and a generator. Both starting motors are mounted on the reverse gear housing, and are operated in unison by a magnetic starting switch, arranged for remote push-button control. The starters operate the Bendix drives through double gear reductions. The generator is gear-driven, and is also mounted on the reverse gear housing. It is a 12-volt model, with electro-magnetic voltage control and a reverse current cut-out. When the engine is running above 500 r.p.m., the generator supplies the current for the ignition and also keeps the battery fully charged. As it is driven by the reverse-gear steel shaft, it will not supply current with the clutch disengaged or when running in reverse.

The clutch is of the multiple-disc type. The driving discs are lined with a moulded composition, and the driven discs are of steel. The reverse gear has a ratio of 1 to 1, and is of the bevel type. The bevel gears and intermediate pinions are of hardened and ground alloy steel. The driving and driven bevels are mounted on large ball bearings. The four intermediate bevel pinions float on Timken taper roller bearings. The entire unit is lubricated by oil under pressure from the engine lubricating system. A heavy-duty duplex type ball bearing, mounted at the rear end of the reverse gear housing, takes both the forward and reverse propeller thrust.

The 400-b.h.p. engine is illustrated in Figs. 3 and 4. It has many features in common with the 800-b.h.p. model described. The cylinder bore is 4·993 in., and the piston stroke is 7 in. The two banks of cylinders are set at an angle of 45 deg., instead of at 60 deg., as in the larger model. The brake horse-power rises from 331 b.h.p. at 1,300 r.p.m., to a maximum of 424 b.h.p., at approximately 1,975 r.p.m. The total weight of the engine is approximately 2,180 lb. The

earlier models of this engine had separate forged-steel cylinders, but separate cylinders of nickel-chrome alloy cast iron are now fitted, the material having a high strength, with a relatively high resistance to wear and corrosion. Special provision has been made for wide clearances round the valve heads, and the ports are designed to give an easy flow for the gases. The arrangement of the water passages provides for ample cooling of the crown of the cylinder head and the exhaust valve seats. The incoming water to the jackets is divided into two streams, one passing to the lower end of the jacket, and the other being directed round the valve seats and plug bosses. The meeting of the two streams causes a high degree of turbulence, which assists in maintaining the heads and valve seats at a safe temperature. Large openings are provided at the sides to give ready access to the water-jackets, and the outlet is through a pipe screwed to the top of the jacket between the valve guides, where it covers a large hole through which the entire upper parts of the jacket can be cleaned. The barrel of the cylinder below the jacket is machined with a cam-controlled tool to leave heavy sections of metal between the bolts, while leaving the latter as close to the bore as possible. The interior of the cylinders is machined all over, including the valve head clearance pockets. The remaining features of the engine need not be described in detail, as they are generally similar to the larger model. The pistons, for example, are of aluminium alloy, but without the iron cross ribbing. The gudgeon-pins are of the fully-floating type, while the connecting-rods are of the forked type, the mating rod being arranged to oscillate on the outside of the crank-pin bearing. The crankshaft is of the six-throw seven-bearing type, as in the larger engine. The crankcase is again of box-section in aluminium alloy, but in the case of the smaller engine, the top and bottom halves each contain the corresponding halves of the main bearings. The valve gear in both engines is of similar design, and the arrangement of the induction system is also similar, two duplex Zenith carburettors being used for the smaller engine. The water-circulating system is somewhat different on the latter. In this case a thermostat in the outlet header by-passes a larger proportion of the water circulating through the engine and conducts it back to the inlet connection, where it is mixed with the incoming supply. Only enough water is pumped overboard to maintain the engine at the desired operating temperature. The water circulating pump is of the gear type, and, as shown in Fig. 4, this pump has a single inlet and dual outlet to the two banks of cylinders. The water first passes to the jackets of the exhaust manifolds, then to the cylinder jackets, and finally to the jackets of the inlet manifolds and the thermostatic control. As also shown in Fig. 4, the water supply to the pump passes through an oil cooler, and as the water returned by the thermostatic control also passes through this cooler, the oil supply is kept at a practically constant temperature. The control, therefore, ensures correct operating temperatures for both the water and oil. The remaining details of the smaller engine are all generally similar to the larger model. The sole selling agents for the British Isles for Vimalert engines are Messrs. J. Samuel White and Company, Limited, Cowes, Isle of Wight.

SOIL MECHANICS.*

By KARL VON TERZAGHI, Dr.-Ing., M.Inst.C.E.

LESS than ten years ago the Foundation committee of a well-known engineering society decided, at one of its meetings, that the word settlement should be avoided in public discussions, because it might disturb the peace of mind of those who are to be served by the engineering profession. Even to-day it is sometimes very difficult to learn the truth about foundations or dams which have developed into sources of trouble. These and many other dismal facts concerning the subsoil induced progressive engineers all over the world to turn the searchlights of scientific investigation from the superstructures into the dark spaces located beneath the towering products of structural engineering. The movement started simultaneously in several countries some twenty-five years ago, and the result of the concerted action was given the name "soil mechanics." Officially the christening of the newly-born science took place in 1936, at the First International Conference on Soil Mechanics and Foundation Engineering at Harvard University in Cambridge, Massachusetts.

Pressure of Earth on Lateral Supports.—During the last century and up to the present day the pressure of earth on lateral supports, such as retaining walls or the timbering of cuts, has been computed by means of one or two theories, known as Coulomb's theory and Rankine's theory. From experience and from experiment, we know that the conditions for the validity of Coulomb's theory are more often satisfied under practical conditions than are those for the validity of Rankine's theory. The following discussion will therefore be limited to the first of these theories applied to backfills with negligible cohesion, such as sands. Coulomb's theory, published as early as 1773, is based on the empirical fact that the failure of a laterally supported bank occurs as a result of the shearing resistance of the earth being exceeded along a surface of sliding, such as $a\,c$ in Fig. 1, herewith. If the wall yields away from the fill, as shown in Fig. 1 (*a*), the average slope of the surface of sliding is greater than 45 deg., and the corresponding lateral pressure is called the active pressure of the earth. If, on the other hand, the lateral support is forced towards the fill, the surface of sliding rises at an average angle of less than 45 deg., and the lateral force required for producing this type of failure is called the passive earth pressure. Coulomb's computation of the earth pressure was based on the following assumptions :—(1) That the shearing resistance s per unit of area, along any section through the earth, is given by

$$s = p \tan \phi \quad . \quad . \quad . \quad (1)$$

where p denotes the normal pressure per unit of area of the section and ϕ the angle of repose of the earth. (2) That the surface of sliding is perfectly plane. (3) That along the surface of sliding the shearing resistance of the earth is fully mobilised. These three assumptions make it possible to compute the total intensity of the lateral pressure, but they do not suffice to determine the location of the centre of pressure. In order to obtain information on this vital point, Coulomb was obliged to supplement his set of assumptions by a fourth :—(4) That in every point of the sliding wedge, $a\,b\,c$ in Fig. 1, the state of stress in the soil corresponds to what is known as a limiting state of equilibrium. If both the back of the lateral support and the surface of the backfill are plane, the state of homogeneous failure in the sliding wedge involves a hydrostatic distribution of the lateral pressure over the back of the support. The corresponding centre of pressure is located at one-third of the height of the wall.

Based on these four assumptions, Coulomb derived his well-known formula for the computation of the lateral pressure, which in practice fails to account for the effect of the compactness of the sand, the intensity of the lateral pressure, the conspicuous absence of the hydrostatic distribution of pressure over the timbered sides of cuts, and many other important phenomena familiar to the man who works in the field. Nevertheless, for more than a century, progress has been limited to the replacement of the numerical evaluation of Coulomb's formula by more expedient graphical methods, until careful examination during the last twenty years showed that the source of existing contradictions between theory and reality can only reside in the basic assumptions (1) to (4) in the preceding list. The subsequent investigation of the basic assumptions furnished the following results. By direct experiment it was found that the value ϕ in equation (1) is not identical with the angle of repose, except for dry sand in a loose state. In contrast to the angle of repose, which has always a value of about 34 deg., the angle of internal friction ϕ can assume any value between the angle of repose and an angle greater than 40 deg., depending on the degree of compactness of the sand. The influence of the presence of water on the stability and on the lateral pressure of sand was provided for by most engineers by the assumption that the water reduces the value of ϕ in equation (1) by 6 or more deg. In contrast to this widespread opinion, experiments established the fact beyond any doubt that the influence of water on the ϕ-value of sands is practically nil. The cause of the known effects of water on stability and pressure simply resides in the fact that the water carries one part, u_w, of the total normal pressure p acting on the potential surface of sliding. Since the water has no shearing resistance, its presence reduces the shearing resistance along an interface through a saturated sand from the value determined by the classical equation (1) to

$$s = (p - u_w) \tan \phi \quad . \quad . \quad (2)$$

Equation (1), as thus modified, eliminates the necessity for an assumption concerning the non-existing lubricating effect of water on sand. The value u_w was found to be equal to the unit weight γ_0 of the water, multiplied by the height h to which the water rises in a standpipe from the point to which equation (2) refers.

According to the second fundamental assumption of Coulomb's theory, the surface of sliding should be plane. It was already known in Coulomb's day that the surface of sliding is curved, but knowledge concerning the importance of the error due to disregarding the curvature remained limited to a few special cases having no practical importance, and no progress was made until von Kármán, Jáky, Ohde, and others published the results of their successful efforts during the last fifteen years. By means of advanced analytical methods and on the assumption that the soil is on the verge of failure at every point in the wedge, these investigators found that, in both the active and passive cases, the surface of sliding consists of a curved lower part and plane upper part. According to the third assumption the shearing resistance of the supported earth should be fully mobilised along the entire surface of sliding. In a natural bed of earth, or in a fill deposited behind a rigid obstacle, the shearing stresses are insignificant compared with those corresponding to the state of failure. Hence the third assumption of Coulomb's theory can only be satisfied if the sliding wedge, $a\,b\,c$ in Fig. 1 (*a*), is given an opportunity for lateral expansion corresponding to the deformation which precedes the failure of a solid body. For retaining walls this expansion can only be achieved in conjunction with a lateral yield of the wall, and in cuts by the exposure of the working face during excavation, combined with the compression of the struts and wedges.

The fourth and last condition for the validity of Coulomb's theory involves the breakdown of the equilibrium of the soil in the entire space $a\,b\,c$ (Fig. 1) between the sliding surface and the lateral support. This in turn represents the condition for the triangular distribution of lateral pressure over the back of the support, such as shown in the right-hand diagram in Fig. 1 (*a*). The corresponding centre of pressure is located at one-third of the height, H, of the support. For mechanical reasons, simultaneous breakdown in the entire wedge does not occur, unless the lateral support yields by tilting around its lower edge. In every other case—for example, that shown in Fig. 1 (*b*), involving a yield by tilting around the upper edge of the support—the failure starts with a disintegration of the lower (shaded) part of the wedge and is associated with a slip along the upper part of the surface of sliding. As a consequence, the condition for the hydrostatic-pressure distribution ceases to exist. Instead of trans-

Fig. 1.

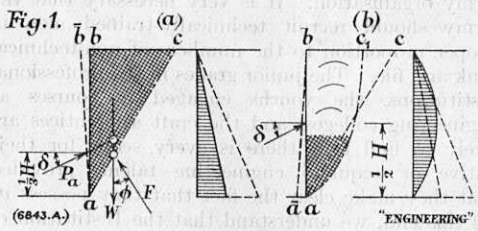


Fig. 7.

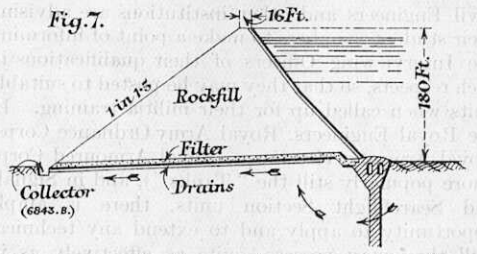


Fig. 9.

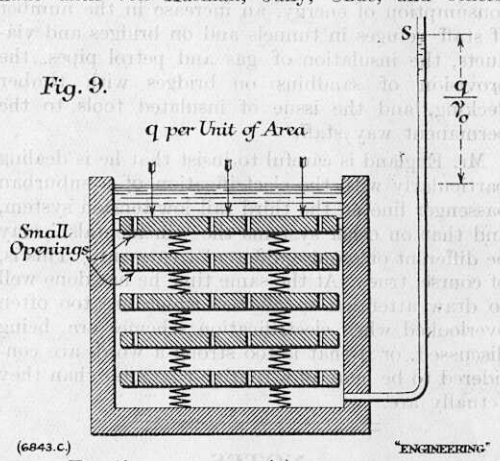
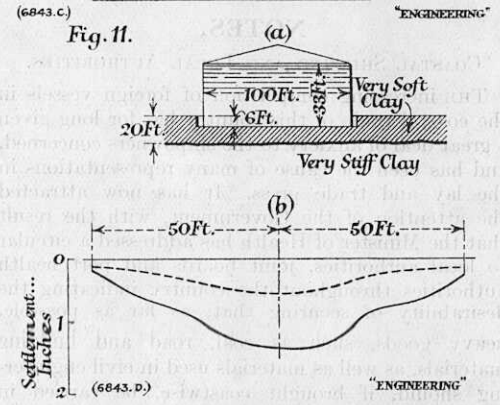


Fig. 11.



* The forty-fifth James Forrest Lecture, delivered before the Institution of Civil Engineers on Tuesday, May 2, 1939. Abridged.

mitting its weight on to the lower part of the wedge, the earth contained in the upper part arches between the surface of sliding and the back of the support, causing the lateral pressure on the upper part of the support to increase at the expense of the pressure on the lower part. The arching effect also influences the shape of the surface of sliding. Instead of being almost plane, the surface exhibits very marked curvature, shown as $a c_1$ in Fig. 1 (*b*). An understanding of this action leads to the conclusion that the pressure-distribution associated with the conditions shown in Fig. 1 (*b*) should be approximately parabolic, the centre of pressure being located in the vicinity of one-half of the depth of the cut. In engineering practice the closest approximation to this condition should be expected in timbered cuts in sands. In the case of clays we know that under practical conditions the fundamental requirement of an almost complete mobilisation of shearing resistance is not complied with. As a consequence, problems dealing with pressure exerted by clays under field conditions are for ever beyond the scope of earth-pressure theories in general. In our future treatment of these problems we must choose between maintaining our present state of ignorance and acquiring a stock of reliable experience by systematic measurements and identification tests in the field.

Stability of Slopes.—Closely related to the problems of earth pressure are those relating to the stability of slopes. In older textbooks on civil engineering this subject is not treated, being considered too simple. It was sufficient to prescribe that the slopes of fills and cuts should be established at an angle somewhat smaller than the angle of repose. The values of the angle of repose for different types of soils were assembled in tables, regardless of the fact that every cohesive soil—most of the soils in nature are cohesive—can stand in vertical banks at a height depending on the nature of the soil. Considering the arbitrary character of the data used as a basis for selecting a slope, it is not surprising that Nature occasionally protested against this violation of its laws. Such was, for instance, the case some twenty years ago, in southern Sweden. Within a relatively short period several serious slides occurred along the railways of that part of the country, one of which caused the loss of 41 lives. In order to avoid any further accidents of this type the railroad administration appointed a committee, including, among others, Messrs. W. Fellenius and J. Olsson, to investigate the degree of safety of the existing slopes and to propose measures for eliminating the danger. The report of that committee was published in 1922. It contained the most complete analysis of landslide phenomena and of soils subject to slides which had been published to that time. It disclosed the fact that it is economically impossible to establish slopes in difficult country to comply with the usual requirements for safety of structures, and that we must be content with precautions against the danger of slides wrecking trains. In their investigations he members of the committee also made extensive use for the first time of what is known as the Swedish method for determining the degree of stability of a slope. The method is based on the empirical fact that the profile of the surface of sliding always approaches the shape of a circular arc. In the case of earth structures or natural banks consisting of fine-grained soils having very little cohesion, the most dangerous conditions exist during rainstorms. In the case of embankments provided for the storage of water, the most critical conditions exist on the downstream side, when the reservoir is full.

The determination of the shearing resistance of typical clays is a difficult problem. The relation between the normal pressure and the shearing resistance is much more complicated than could have been anticipated ten years ago, and even to-day our knowledge of this subject is still in a somewhat controversial state. The most important recent contribution was made in 1936 by Mr. M. J. Hvorslev.* If a submerged body of soil having little or no cohesion is in a loose state, an insignificant external or internal disturbance, such as might be produced by a mild earthquake or by a spontaneous subsidence within the earth, is likely to transfer the soil temporarily into a liquid state, causing it to flow on a horizontal surface. This phenomenon is known as a flow-slide. In order that a material can flow upon suitable provocation, it must be loose enough to have a tendency to reduce to a denser state as a result of any type of deformation. If this requirement is fulfilled, a spontaneous subsidence transfers part of the weight of the solid constituents to the water, thus considerably increasing the pressure u_w which acts in the water, while the total pressure in the mass of earth remains unaltered. According to equation (2),

$$s = (p - u_w) \tan \phi,$$

an increase of the pressure u_w in the water, at unaltered total pressure p, reduces the shearing resistance s, which has the same effect as if the internal friction of the mass were diminished. If this reduction is sufficient, the mass assumes the characteristics of a viscous liquid and retains this consistency until the excess water has drained away.

Failure of Dams Due to Piping.—In 1910, Mr. W. P. Bligh published his well-known rules for the design of dams on a porous foundation. Considering the state of our knowledge in those days, his contribution was of outstanding importance, and for many years it did not occur to me that there could be any flaw in the procedure. In 1919, however, after I had begun a systematic search for neglected variables, I also included the phenomenon of piping in the programme of my investigations. After having acquired some experience with inverted filters on minor structures, I designed a filter 400,000 sq. ft. in area for a rock-fill dam in Algiers, a cross-section of which is shown in Fig. 7, opposite. The body of the dam covers the outcrops of several strata of fine sand which, after the reservoir is filled, will furnish channels for an appreciable flow of seepage towards the base of the dam. Since the discharge area will be covered with rockfill, incipient piping of the water in the sand cannot be detected until it is too late. The inverted filter serves to exclude the danger of underground erosion without inducing a dangerous concentration of flow lines at some other point, but in order to satisfy these requirements the filter material must be neither too coarse nor too fine. Assisted by the results of recent investigations, we are to-day in a position to eliminate the danger of piping at a moderate expense, simply by obstructing the escape routes for the solid soil constituents without interfering with the flow of seepage.

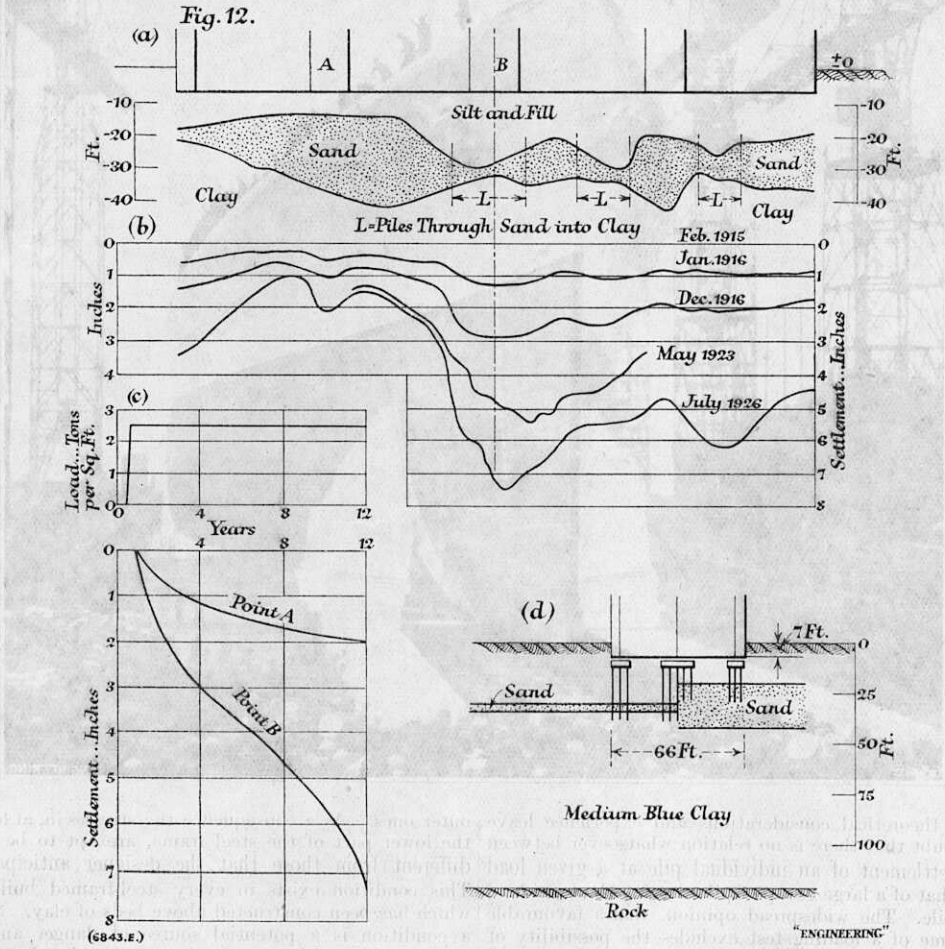
The Consolidation of Clays and its Practical Consequences.—One of the many factors which has passed unnoticed in spite of its obvious practical significance is the time element. From experience we know that the settlement of buildings or the pressure on the lining of tunnels may increase for many years, although external conditions remain unchanged; yet the older textbooks on engineering may be searched in vain for equations pertaining to earths and foundations which contain the time factor. The most conspicuous manifestation of the influence of time on the settlement corresponding to a practically constant load, is demonstrated by the settlement of buildings located above beds of medium or soft clays. The cause thereof was found to reside in the low permeability of clay soils. For clays, as well as for any other porous materials, an increase of load produces a decrease of porosity as well as a decrease of thickness of layer. The relation between the pressure q and the void-ratio e (ratio between the volume occupied by the voids and the solid) can be expressed with fairly close approximation by the equation

$$e = e_c - C_c \log \frac{q - u_w}{q_o} \quad . \quad . \quad (7)$$

where e_c denotes the initial void-ratio, u_w the hydrostatic pressure in the water content of the clay, and C_c and q_o are empirical constants. Since the voids of a clay in its natural state are almost or entirely filled with water, a decrease of the porosity of a clay is accompanied by an escape of a corresponding amount of water. Due to the low permeability of clay, this escape can only occur very slowly.

The mechanics of this time-lag of consolidation are illustrated by Fig. 9, opposite, which shows a cylinder with a system of perforated pistons maintained in their relative positions by two sets of spiral springs. The cylinder is considered to be completely filled with water. If a load q per unit area is applied to the uppermost piston, it cannot possibly descend to its ultimate position until the excess water has escaped from all of the various compartments. Hence, at an early stage of the process of compression, the springs located in the lowest compartments will be under no compression. As a consequence, the entire load q must be carried by the water in these compartments, and the water rises in the standpipe S to an elevation $\frac{q}{\gamma_o}$ above the position which it occupied before the application of load. As time goes on, the pressure in the springs increases, and a corresponding decrease in the pressure of the water takes place, as shown by a drop in the water level in the standpipe. A similar process occurs in a layer of clay after loading its surface. The mechanics of this process can be expressed by a partial differential equation of the second degree, which is known as the fundamental equation of the process of consolidation. In this equation one of the variables is represented by the factor "time." I was invited to co-operate in a case which proved to be a large-scale illustration of the theory of consolidation. The owners of a steam-power plant desired to open up a private water supply for their power-house. For this purpose a well was excavated through the clay, down to a layer of water-bearing gravel located between the base of the clay and the surface of the underlying rock. The owners were overjoyed with the abundant water supply which was obtained, but their joy was tempered by their simultaneous discovery that the time-rate of settlement of the power-house had increased tremendously. Within a few months the corner adjacent to the well had subsided more than 1 ft. In spite of the coincidence between the beginning of the pumping operations and the beginning of the increased rate of settlement, no one suspected a causative relation between the

Fig. 12.



"ENGINEERING"

(6843.E.)

* "Über die Festigkeitseigenschaften gestörter bindiger Böden." Ingeniorvidenskabelige skrifter A. Nr. 45.

phenomena, and the incident was considered mysterious. Hence the owners were surprised when the settlement practically ceased, after the well had been closed upon my suggestion.

Settlement of Footings and of Raft Foundations.—Settlement due to the lowering of the ground-water level is one of the many vital topics passed over in silence in the older printed sources of information for civil engineers. The settlement of footings and of raft foundations is another. The instructions which the reader finds for the design of such foundations are limited to simple rules for selecting the allowable bearing pressure, using as a guide either the general appearance of the soil (sand, stiff clay, etc.) or else the results of loading tests to be performed at the building site at the elevation of the base of the future foundation. The reader is free to believe that he need not worry about settlement if allowable bearing pressures are not exceeded. To say the least, he is most likely to believe that the settlement will be uniform, provided a uniform distribution of the pressure over all the loaded area is obtained. Unfortunately, neither of these two widespread opinions is justified except under certain very limited conditions. According to the results of a general survey conducted by Mr. L. Casagrande, in connection with bridge piers and abutments on German highways, the settlement of these structures ranged between the following limits :—

No. of Structures.	Description of Soil.	Average Soil Pressure. Tons per sq. ft.		Settlement. In.	
		From	To	From	To
21	Sand, gravel ..	1·5	3·0	0	0·4
31	Boulder clay, sand or gravel with clay	2·5	4·0	0	0·8
8	Clay, loess, loam, etc.	1·1	2·6	2	8
9	Silt	1·1	2·0	8	40

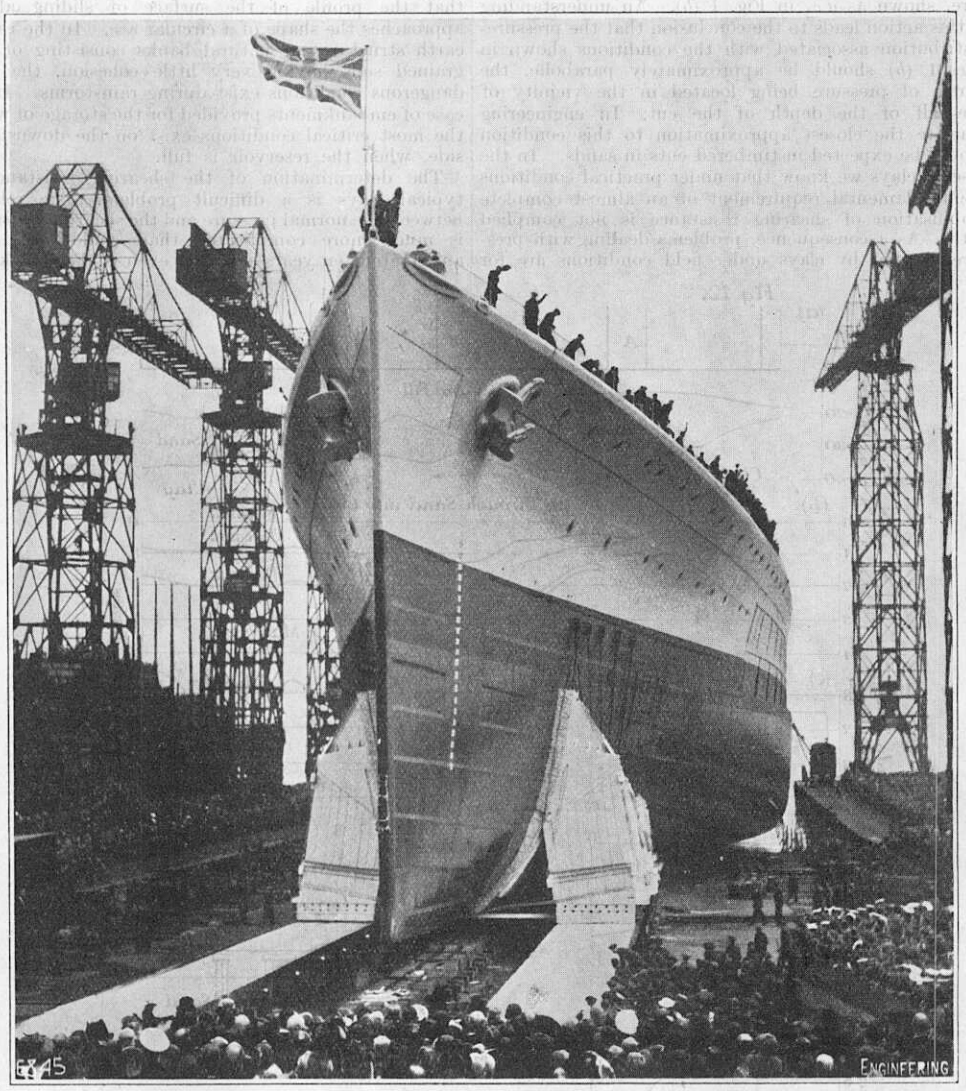
Since the conceptions regarding the admissible unit load for different types of soil are approximately the same all over the world, the above-quoted figures can claim more than a local interest. The assumption that a uniform load distribution also involves a uniform settlement is not only in contradiction to the theory of Boussinesq, published in 1885, but it is also in contradiction to practical experience. Some years ago I was called upon to design the foundation for the cylindrical tank in Fig. 11 (*a*), on page 567 to be built of welded-steel plates. Since I expected, in accordance with the theory of Boussinesq, a bowl-shaped settlement, I considered it necessary to provide a very flexible support for the bottom of the tank. As a consequence the bottom was placed on a feebly-reinforced concrete slab, 4 in. thick. Fig. 11 (*b*) shows a section through the bottom at two different periods after the tank was filled for the first time. In spite of a perfectly uniform distribution of load the settlement exhibited the anticipated characteristics of a shallow bowl. The design of foundations depending on allowable bearing-pressure methods is based on the tacit assumption that the settlement merely depends on the nature of the soil to a depth of 10 ft. below the base of the foundation. In reality, settlement depends on the character of the soil profile to a depth of at least $1\frac{1}{2}$ times the width of a building, on the size and spacing of the footings, on the depth of a foundation, and—last but not least—on the location of the footings or of the loaded section of a raft with reference to the outer boundaries of the area covered by a structure. If the subsoil contains beds of clay the settlement is also a function of time.

Settlement of Pile Foundations.—If the top strata of the subsoil are too soft to carry the weight of a building, the weight can be transferred to a lower stratum by means of piles. Textbooks prescribe either the use of pile-driving formulas or the making of loading tests for the purpose of estimating the bearing capacity of piles. Pile-driving formulas are based on Newton's theory of impact and represent the relation between the penetration produced by the blow of a hammer and the corresponding resistance Q_d counteracting the penetration of a pile. It is obvious that the quantity Q_d represents the dynamic resistance, *i.e.*, the resistance of the pile to a very rapid penetration. In 1925, I published the results of investigations which showed that there is no relation whatsoever between the dynamic and the static resistance of piles, except in the relatively rare case in which piles are entirely embedded in sand or in some other highly permeable material. Pile-driving formulas are dependable only in a few exceptional cases, and in general they can be considered to be only a crude means for estimating the relative bearing capacity of individual piles. Loading tests furnish information concerning the relation between load and settlement for an individual pile.

LAUNCH OF H.M.S. "PRINCE OF WALES."

MESSRS. CAMMELL LAIRD AND COMPANY, LIMITED, BIRKENHEAD.

(*For Description, see Opposite Page.*)



Both theoretical considerations and experience leave no doubt that there is no relation whatsoever between the settlement of an individual pile at a given load and that of a large group of piles having the same load per pile. The widespread opinion, that a favourable outcome of a loading test excludes the possibility of serious settlements of an entire pile foundation, ranks among the most incomprehensible and most detrimental prejudices in the field of civil engineering.

An impressive example of the practical consequences of this prejudice is illustrated by Fig. 12 on page 567. This monumental structure was intended to serve as an outstanding example of high-grade engineering. According to a statement published by the designers during the preliminary work, the foundation was designed so as to exclude the possibility of any settlement in excess of $\frac{1}{16}$ in. In order to be sure of this prediction, the site was explored by means of 21 test borings and three test shafts. In addition, 80 test piles were driven and 38 loading tests were performed. On the basis of the results of the loading tests and the pile-driving records, the designers modified the pile-driving formula so as to adapt it to the subsoil conditions in existence at the site of the building. Finally the piles were laid out in such a manner that every pile carried exactly the load required to produce a settlement of $\frac{1}{16}$ in. The results of these costly and painstaking efforts are shown in Fig. 12 (*b*) and (*c*): twelve years after construction was completed the maximum settlement was nearly 8 in. and the differential settlement exceeded 6 in. Even to-day, whenever I visit the building, I notice cracks which I have not observed before. According to the accepted rules for the design of steel-framed buildings, the members of the structure are designed on the assumption that the building rests on a perfectly rigid base. If the subsoil is compressible the base of the building tends to assume the shape of a shallow bowl, yet the stiffness of the walls resists this tendency to a certain extent. This brings about a transfer of part of the weight of the building from the inner columns to the outer ones. As a consequence the stresses in, at least, the lower part of the steel frame, are apt to be very different from those that the designer anticipated. This condition exists in every steel-framed building which has been constructed above beds of clay. Such a condition is a potential source of danger and is incompatible with the fundamental rule that the factor of safety for every member of a structure should be approximately the same. Thus far, nothing is known concerning the percentage of deviation of the stresses from the theoretical stresses. It would therefore seem worth while to secure some pertinent information.

Sampling and Testing.—The fundamental requirement for an adequate forecast of settlement is an intimate knowledge of the compressibility of all clay strata contained in the subsoil down to a depth equal to at least $1\frac{1}{2}$ times the width of the area covered by a building. More than twenty years ago, when engaged in the survey of landslides along their railroads, the members of the Swedish Geotechnic Commission noticed and described the softening influence of kneading a clay at unaltered water content. At a later date, Mr. A. Casagrande discovered a similar influence of kneading on the resistance of clays to compression while laterally confined. As a result o these discoveries it became necessary to develop methods for securing undisturbed samples, and to-day in many countries a 5-in. undisturbed sample can be ordered without any further comment and be obtained at a reasonable price. At present, Mr. J. Hvorslev is preparing a detailed report on the problems and current methods of sampling soils and the equipment employed. This report is being prepared for the Committee on Sampling and Testing, Soil Mechanics and Foundations Division of the American Society of Civil Engineers.

While discussing the different branches of applied soil-science I quoted numerous incidents involving damage to property. In all these cases damage was due to the fact that soil had behaved in a manner different to that which the designers had anticipated.

Perfect Example of the old

Such cases invariably result in the embarrassing question: Who is responsible? At the beginning of the century the engineer was entitled to consider the misbehaviour of his structure as a deplorable act of God, and he was able to justify his claim by producing textbooks containing the essence of the knowledge of contemporary authorities. This excuse, however, will certainly not hold for ever, and the time is approaching when the courts will decide against the designer who refuses to take notice of the existence of soil mechanics. Hence it is in the vital interest of all members of the profession to become familiar with the subject by active participation in the efforts to broaden our knowledge of this important science.

There is no doubt in my mind that the mastering of our youngest science will greatly increase the capacities of the experienced engineer. My opinion has repeatedly been confirmed by the statements of seasoned practitioners who were open-minded enough to appreciate and to digest the fruits of our labours. At the same time, I cannot help feeling deeply concerned about the self-confidence inspired in many members of the incoming generation of engineers by our knowledge, because, quoting from the first James Forrest lecture delivered by Dr. Anderson in 1893,* "There is a tendency among the young and inexperienced to put blind faith in formulas, forgetting that most of them are based upon premises which are not accurately reproduced in practice, and which, in any case, are frequently unable to take into account collateral disturbances, which only observation and experience can foresee, and common sense provide against." In 1893 this remark was aimed at the incoming tide of theoretically-trained structural engineers. To-day, in 1939, these golden words should be framed, to adorn the wall of every room in which research in soil mechanics is carried on. To accomplish its mission in engineering, science must be assigned the role of a partner and not that of a master.

H.M. BATTLESHIP "PRINCE OF WALES."

THE battleship Prince of Wales, the second vessel of the five constituting the new King George V class, was launched from the Tranmere shipyard of Messrs. Cammell Laird and Company, Limited, on May 3, the naming ceremony being performed by H.R.H. the Princess Royal. It will be recalled that Her Royal Highness launched H.M.S. Rodney from the same yard in 1926. The weather conditions were perfect, and although the slight breeze was against the tide, its force was not sufficient to delay the required rise in water level, the launch taking place precisely at the intended hour of 11.0 a.m. As will be seen from the illustration on the opposite page, the vessel was launched on two ways, unlike the Rodney, which was supported by additional bilge ways.

The Prince of Wales and her sister-ship, King George V, now completing at the Walker Naval Yard of Messrs. Vickers-Armstrongs, Limited, were ordered in July, 1936, and the keels of both were laid on January 1, 1937—the day after the expiry of the Washington Naval Treaty and also of the London Treaty of 1930. In view of the anticipated provisions of the London Naval Treaty of 1936, however, between Great Britain, France and the United States, the standard displacement of these two ships, and of the three further vessels of the class, was limited to 35,000 tons. The three additional vessels, Duke of York (originally named Anson), Jellicoe and Beatty, formed the battleship provision under the 1937 programme of new construction and were ordered, respectively, from Messrs. John Brown and Company, Limited, Messrs. Swan, Hunter and Wigham Richardson, Limited, and Messrs. Fairfield Shipbuilding and Engineering Company, Limited. Although, by programme, they were a year later than the Walker and Birkenhead ships, the keels of all three were laid within six months of the earlier pair. The main armament is to consist of ten 14-in. guns, and the secondary armament, of sixteen 5¼-in. guns, mounted in pairs in turrets. A powerful anti-aircraft armament will also be carried. At the luncheon which followed the launch, Mr. Geoffrey Shakespeare, M.P., Parliamentary Secretary to the Admiralty, stated that the weight of armour on the Prince of Wales would exceed the displacement tonnage of the earlier Prince of Wales, completed in 1904. The designed speed has not been disclosed, but it is stated to be higher than that of the Nelson and Rodney, which are 23-knot ships. The machinery will consist of the well-established combination of twin-screw geared turbines and water-tube boilers. The full complement will amount to about 1,500 officers and men, as the vessel is to be fitted as the flagship of a second-in-command. The Prince of Wales is expected to be commissioned in 1940.

* ENGINEERING, vol. lv., page 722 (1893).

CONSTRUCTIONAL METHODS ON GERMAN MOTOR ROADS.

MUCH interesting information bearing on the methods of construction employed on the new motor roads in Germany is contained in a report entitled "Concrete Road Construction on the Reichsautobahnen,"* compiled by Mr. F. G. Turner and recently published by the Ministry of Transport. The information was collected during the visit of a technical committee of the Roads Department to Germany in July, 1937. The report states that the new system of trunk roads is planned to have an ultimate length of 4,400 miles; up to the present, 650 miles have been completed. The main features of the system are that the roads are to be used by mechanically-propelled vehicles only; that there are no level crossings; that comparatively few other roads are connected to the system; that there are dual carriageways, each 24 ft. wide; and that vehicles are not allowed to stop on the roads, parking places being provided every 10 or 12 miles. The speed of vehicles on the system varies from about 45 miles to 75 miles an hour. Travelling between Berlin and Brunswick, the Committee estimated the average speed to be about 55 miles an hour. The riding qualities of the roads were found to be excellent.

All constructional work in progress which was inspected was on a sandy sub-soil. The formation was, in every case, compacted by a spreader, or levelling beam, followed by a tamping beam. The beams covered the full width of the carriageway. The tamping force used was approximately 3 tons per square foot. The specifications called for the earthwork to be formed within a limit of accuracy of 2 in. and the concreting contractor was required to finish the formation true within ⅜ in. before concreting began. The finished formations were observed to be very firm. A layer of tough paper, to reduce friction, was laid between the concrete slab and the earth. It was specified that the cement used should have a strength of 250 lb. per square inch after 7 days' water storage; 350 lb. per square inch after 28 days' water storage; and 420 lb. per square inch after 28 days' air and water storage. No limit for shrinkage was fixed. It is stated that only about 30 per cent. of German cement manufacturers could comply with the specification, but, as ample supplies of material were, none the less, available, the specification was maintained. Coarse and fine aggregates were carefully selected. For fines, two grades of sand were usually specified. There were three, four or five gradings of coarse aggregate.

Batching was effected by weight, usually at a railway siding which might be several miles from the construction site. The aggregates were delivered by rail to silos from which skips were charged with the correct mix. The cement was then added and the skips transported to the mixers on the construction site. The water ratio varied from 0·4 to 0·5 depending on the aggregate and the concrete was laid in two courses, usually with 7 per cent. more water in the top course than the lower. An example of a bottom-course concrete used on the Mannheim-Karlsruhe road is quoted as follows:—

Water-cement ratio	46 per cent.
Cement, per cub. m.	325 kg.
,, batch	300 kg.
Proportions of mix	300 : 1,800 kg.
Water needed per batch	138 litres.

The use of a low water content and, consequently, high-strength concrete, is made possible by employing consolidating and finishing machines. It is because it has been considered that such machines cannot satisfactorily compact 8 in. of concrete, which is the usual thickness, that two courses are laid. The bottom course is 6 in. thick and the upper 2 in. It is stated that the makers of the compacting machines claim that this idea is not correct and that the latest types of machine could satisfactorily compact 12 in. of concrete. In the earlier roads, steel reinforcement was used, but this practice has now been discontinued. The reason appears to be the shortage of steel, although the report quotes one view that was expressed to the Committee to the effect that "the small amount of steel that has been used could not possibly prevent cracks from occurring, and therefore it could be omitted."

The concrete is laid in slabs 12 ft. wide and 26 ft. long. The road slopes uniformly, with no camber, so that the longitudinal joints are simple butt joints. The transverse joints are all expansion joints ½ in. wide at the bottom and ¾ in. wide at the top. They are not staggered. The joints are formed with a wooden batten about 5 in. deep placed and left at the bottom of the slot. Above this a Wieland jointing strip, 2½ in. deep, is laid and the concrete is then laid continuously without regard to the joints, so that there is a thickness of about ½ in. of concrete at the top of the joint about the Wieland strip. This latter is a hollow steel form, 2½ in. deep and ¾ in. wide. It is made in lengths of about 12 ft. and before being placed in position is painted on the sides with bitumen. It fits over the wooden batten and lies above it, as already explained. Immediately after the finishing machine has left the surface of the concrete, a shelter on wheels, running on rails, with a platform a few inches clear of the concrete, is run into position. Men working in this shelter remove the concrete on top of the Wieland strip and finish off the arrises by hand. The Wieland strip is left in the concrete for three or four weeks, steam then being blown into it through a hole at one end and passing out through a hole at the other end. This procedure melts the bitumen and the strip is then withdrawn. The space, 3 in. deep, between the concrete slabs, above the wooden batten, is then filled with a bitumen and asbestos. The wooden batten remains in place. It is stated in the report that in every case inspected by the committee some of the mixture had been extruded and formed a protuberance on the surface at the joint. The material, however, did not seem sticky. Immediately behind the working shelter, mentioned above, a train of shelters long enough to cover one day's work, about 220 yards, is passed over the concrete. As these shelters pass forward the surface behind them is covered with plaited straw mats, or sand, kept wet for three weeks. Sometimes the concrete is watered every day for about a week after this protection has been removed. The road surface is required to be finished to an accuracy of 0·16 in. in 13 ft., any greater inaccuracy than this being removed by grinding. Such grinding was necessary in a number of places on the Berlin-Brunswick road, but it is stated that grinding is almost unknown on recent work.

The report states that the reputed cost of the concrete carriageway on the Reichsautobahnen was 10 marks per square metre. Taking 12 marks to the pound, this is equivalent to 13*s.* 4*d.* per square yard. The cost of the roads was given as 250,000 marks per kilometre, which, at the same rate of exchange, is 33,400*l.* per mile. It is stated that, comparatively speaking, the roads are carrying "very little traffic indeed." Rough counts on the road between Berlin and Brunswick and on the road between Heidelberg and Mannheim showed, in each case, about 150 vehicles per hour, or roughly nine vehicles per yard width per hour. The report concludes with various observations made as a result of inspection of the roads. The remarks all refer to roads within 70 miles of Berlin. It was noted that concrete constructed in 1934 and 1935 has not cracked as much as that constructed before 1934. In this connection it should be mentioned that machine finishing was introduced about 1934 or 1935. It was also noted that unreinforced concrete laid on a cambered road without a longitudinal joint had cracked at the centre of the carriageway where the width was 15 ft. or more, and that unreinforced slabs are likely to crack transversely if they are more than 30 ft. long. Several of the roads which have a considerable number of cracks carry very little traffic.

Our summary of various parts of this interesting report is necessarily selective and we have not attempted to deal with the important sections dealing with the road machinery. Mr. Turner has collected much valuable information and presented it in an informative way. The report should be in the hands of all who are concerned with road construction; in view of the very modest price at which it is published, there is no reason why it should not be purchased by the most junior members of surveyors' or contractors' staffs.

* H.M. Stationery Office. Price 3*d.*

THE FAMO DIESEL-ENGINED TRACTOR: ERRATUM.—In connection with the description of the Diesel-engine tractor shown by Messrs. Famo Fahrzeug und Motorenwerke, of Breslau, at the Leipzig Fair, which appeared in our issue of April 21, it was stated that the firm also built petrol tractors. We are now informed that this is not correct; they build Diesel tractors only. These have either an electric starting arrangement or a petrol hand-starting device. The rubber-tyred tractor shown in Fig. 8 of the Leipzig Fair article is spring-mounted on the front axle only.

PROPOSED BROADCASTING DEVELOPMENTS.—The British Broadcasting Corporation announces that, as the result of the re-allocation of wavelengths recently decided upon at the European Wavelength Conference at Montreux, certain changes will be made in the wavelengths of British broadcasting stations from March 4, 1940. It is also announced that the new transmitting stations at Slant Point and Clevedon will be opened on Monday, June 14. The stations at Washford, Bournemouth and Plymouth will then be closed down. The first of the new stations will use a power of 100 kW and a wavelength of 285·7 m., while that at Clevedon will use a power of 20 kW and a wavelength of 203·5 m. Further, a contract has been placed with Messrs. Marconi's Wireless Telegraph Company, Limited, for the supply of two 120-kW transmitters to replace the existing 70-kW regional transmitters at Brookman's Park and Moorside Edge.

LABOUR NOTES.

THE Ministry of Labour provisionally estimates that at April 17, the number of insured persons between the ages of 16 and 64 in employment in Great Britain was, approximately, 12,511,000. This was 108,000 more than the total for March 13. It is estimated that on a comparable basis there was an increase of approximately 270,000 compared with April 4, 1938. Employment improved between March 13 and April 17 in building, public-works contracting, agriculture and horticulture, shipbuilding and repairing, engineering, iron and steel manufacture, the motor-vehicle, cycle and aircraft industries, metal-goods manufacture, the cotton and tailoring industries, the distributive trades, the hotel and boarding-house service, and entertainments, sport, and railway and shipping services. On the other hand, employment declined in the wool, textile, and hosiery industries, and in boot and shoe manufacture.

At April 17, the numbers of unemployed persons on the registers of employment exchanges in Great Britain were 1,343,295 wholly unemployed, 238,729 temporarily stopped, and 62,370 normally in casual employment, making a total of 1,644,394. This was 82,535 less than the number on the registers at March 13, and 103,370 less than at April 4, 1938. The total on April 17 comprised 1,217,085 men, 48,935 boys, 327,116 women, and 51,258 girls.

The total of 1,644,394 registered unemployed included 1,492,971 persons who were applying for benefit or unemployment allowances. An analysis of these applicants according to the length of the last spell of registered unemployment is as follows:—283,000 (19 per cent.), 12 months or more; 1,026,000 (69 per cent.), less than six months; 815,000 (55 per cent.), less than three months; 629,000 (42 per cent.), less than six weeks. Of the persons on the registers at April 17, about 57 per cent. were applicants for insurance benefit and about 34 per cent. for unemployment allowances, while about 9 per cent. had no applications for benefit or unemployment allowances.

The report of the General Federation of Trade Unions for the first quarter of the current year states that the number of affiliated societies is now 91, of which 57 are on the higher scale, 32 on the lower scale and 2 on both scales. The membership on which contributions are based is 348,080, of which 226,777 is on the higher scale, 111,597 on the lower scale and 9,706 on both scales. The gross membership is 359,550. During the three months which ended on March 31, the sum of 6,544*l.* 11*s.* was received in contributions and 217*l.* 11*s.* 8*d.* paid out in benefits.

At a meeting in London last week, the General Council of the Trades Union Congress decided to call a meeting of executive representatives of affiliated organisations to consider the position arising out of the Government's introduction of conscription. The conference is to take place on May 19 in the Central Hall, Westminster.

The first ballot in the election of a successor to Mr. Little as president of the Amalgamated Engineering Union has resulted as follows:—B. Anderton (Plaistow) 1,419, R. Brierley (Oldham) 4,463, H. Bryson (Hartlepool) 3,497, J. Burnett (Brighouse) 2,320, A. J. Caddick (Portsmouth) 7,503, W. H. Hutchinson (Lambeth) 11,014, R. Openshaw (Crewe) 8,791, J. Tanner (Fleet Street) 13,961, W. F. Watson (London 3) 2,234, P. S. Wilde (Battersea) 698, L. D. Youd (High Wycombe) 1,720. A second ballot is now in progress, the two candidates being J. Tanner and W. H. Hutchinson. Mr. Tanner is a member of the executive council and Mr. Hutchinson one of the Union's national organisers.

An explanatory memorandum attached to a circular issued by the Japanese Minister of Social Welfare states that in view of the prevailing circumstances, the general organisation of work in shifts is strongly recommended as a means of raising industrial output to a maximum, strengthening the protective measures for labour employed in munition factories, and alleviating unemployment caused by the Government monopolisation of raw materials. As for the organisation of work in shifts, each factory should adopt its own methods with a view to securing an optimum output. In principle, daily hours of work should not exceed 12, and the hours worked by each shift should be as short as possible. A three-shift system should be preferred for dangerous and unhealthy operations, those which entail the handling of heavy objects or require concentrated attention or deep reflection, or operations performed by a large number of young persons under 16 years of age or women, to whom protective legislation applies.

The change-over of shifts, it is stated, should be effected in a period not exceeding ten days, at the end of which the employers should give the workers a holiday. At the same time a period not exceeding 15 days could be introduced, it is suggested, for shifts working less than ten hours a day. Special attention should be given to wages and allowances so as to ensure that they are not reduced by the restriction of working hours entailed by the adoption of the shift system. New hands with no experience should be given special training for a certain time before being incorporated in a shift, while the various operations and processes should be split up as far as possible with a view to their simplification.

The weekly organ of the International Labour Office at Geneva states that a Japanese Imperial Order has been promulgated relating to the registration of the vocational qualifications of seamen. The Order provides that persons belonging to certain groups, but not being in the service of the army or navy, or members of the medical, dental or pharmaceutical professions, must inform the Maritime Division of the Bureau of Communications in their district of residence, of all details relating to their vocational qualifications before July 15 each year. These groups are as follows: (*a*) persons holding seamen's certificates; (*b*) persons who have completed their training in one of the seamen's training institutes nominated by the Minister of Communications within the last three years, or who have landed within the last three years from a vessel on board which they have served after completing such training; (*c*) persons having more than a year's service on board a vessel covered by the Seamen's Act, which they had left within the last three years; persons on board such vessels are not covered by the obligation under this order, as they are already under administrative supervision in consequence of their being registered with the competent authorities.

The notification must indicate the name and date of birth of the seaman concerned; his present place of residence and place where his civil status is registered; military status; education; number on the Seamen's Register; number of his seamen's employment book and name of the administration which issued it, if he possesses such a book; the class and number of his seaman's certificate if he holds such a certificate; his occupational record; his present speciality; the amount of his wages or salary, if any; his state of health; civil status; number of his dependants; what kinds of service he would be willing to undertake, and any other information specified by the Minister concerned. The Bureau of Communications may instruct the competent officials to inquire into the occupational capacity of persons on the register, and to require the latter to submit the necessary papers to facilitate supervision.

In a recent case decided by the Superior Court of Pennsylvania, the meaning of the word "voluntarily" as used in the State Unemployment Compensation Act was determined. The Section provides that an employee is ineligible for compensation if his unemployment is due to his "voluntarily leaving work." The claims of two employees were involved in the decision. In one case, the employee resigned because his physician told him that continued employment in his occupation would endanger his health, while in the other case the employee was discharged, but left his employment prior to the effective date of the discharge in order to attempt to secure other work.

In discussing the two cases, the court pointed out that the word "voluntarily" might be used in a number of different ways, but with regard to the purpose and intent of the Act, the most appropriate definition was "of one's own motion," so that the expression, "he left work voluntarily" meant that the employee left of his own motion and was not discharged. It was observed also that voluntary leaving was the opposite of a discharge or other action by the employer severing relations with his employees, against which "the Act was mainly designed." Finally, the court declared that where the employee, without action by the employer, resigned or quitted his employment, that action amounted to voluntarily leaving work, "such as to render him ineligible for unemployment compensation under the Act." For these reasons, the court held that the employee who resigned because of his health was not entitled to compensation, as he quitted of his own motion and was not discharged, dismissed, or laid off by his employer.

The court said that it was not within the province of the board "to explore the reasons or mental processes which led the claimant to give up his employment." It was pointed out that this would result in too variable and uncertain results, and would be doing violence to the usual and ordinary meaning of the term "voluntarily leaving" in the light of the purpose of the enactment. In the case of the employee who was discharged, but left his employment a few days before the effective date of the discharge, the court held that he was entitled to unemployment compensation from the date the discharge became effective. After stating that the claimant's employment was broken or severed as a result of the act of the employer in notifying him that he would be laid off, the court declared that "his leaving a few days in advance of the time fixed for his lay-off, with the employer's full assent, cannot be construed as 'voluntarily leaving work' but only as anticipating by a few days, with the consent of the employer, the effective date of his dismissal."

On Monday this week the Ministry of Labour issued a booklet entitled "Holidays with Pay; Collective Agreements between Organisations of Employers and Workpeople." The report of the Amulree Committee on holidays with pay issued in April, 1938, recommended that the grant of such holidays under voluntary agreements between organisations of employers and workpeople should be extended to the utmost practicable extent and at the earliest possible date. The booklet now issued summarises the main provisions contained in the agreements at present in operation, and gives the text of a number of the principal agreements or of those which include features of special interest. It is pointed out that there is a wide diversity in the terms of the different agreements, and it is believed that the information given, as to the various ways in which the agreements have been framed on all the main points which arise for settlement, will be of assistance to those who are concerned in making or revising such agreements. In addition, there is an appendix in which is given a list of the industries or services in which collective agreements, providing for payment for annual holidays to wage earners, are known to be in operation. The price of the booklet is 9*d.*, and it may be obtained from H.M. Stationery Office.

The compilers of the booklet state in the course of an introduction that in their report to the Ministry of Labour, the Amulree Committee estimated that at the end of March, 1938, annual consecutive days of holiday with pay in some form were provided for about $7\frac{3}{4}$ million workpeople out of a total of about $18\frac{1}{2}$ million workpeople in the employment field. For the purpose of their estimate, the Committee interpreted the word "workpeople" as covering manual workers generally and non-manual workers in receipt of not more than 250*l.* a year, including unemployed workers. Of the total of $7\frac{3}{4}$ million, a large proportion were granted paid holidays under the provisions of collective agreements between employers or their organisations and the trade unions concerned, the total number of manual wage earners covered by such collective agreements being estimated at about 3 million in March, 1938, as compared with $1\frac{1}{2}$ million to $1\frac{3}{4}$ million when the Committee was appointed. Since the date of the Committee's report there has been a further extension of collective agreements providing for annual paid holidays, and the total number of workpeople now covered by such agreements is estimated at about 4 million.

In March, the Chilean Minister for Foreign Affairs promulgated a Decree suspending the issue of immigration permits until further notice. The preamble of the Decree explains that this measure has been found necessary largely for administrative reasons. With the present means at their disposal the immigration services are not in a position to ascertain whether persons authorised to immigrate do in fact engage in activities of value to the country, and whether the capital they bring with them is in fact converted into Chilean currency.

According to the weekly organ of the International Labour Office at Geneva, the President of the German National Institution for Employment Exchanges and Unemployment Insurance has issued a circular explaining how unemployed Jews may be placed. He states that the number of unemployed Jews has increased substantially, and points out that it is not in the interest of the State that Jewish labour which is capable of being used should not be found employment, instead of receiving benefits without giving any service in return. All Jews who are unemployed and capable of work should be placed, he says, as quickly as possible, so as to set German workers free to assist in urgent construction work for the State. The attention of heads of private undertakings is drawn to the necessity of engaging Jewish labour as quickly as possible. Jews should be employed, it is stated, in special undertakings on development and building work, etc. Contractors and undertakings will not be penalised, it is added, owing to the fact that they employ Jews.

PNEUMATIC CORES FOR CONCRETE FLOORS.

MESSRS. PNEUMATIC CORES, LIMITED, LONDON.

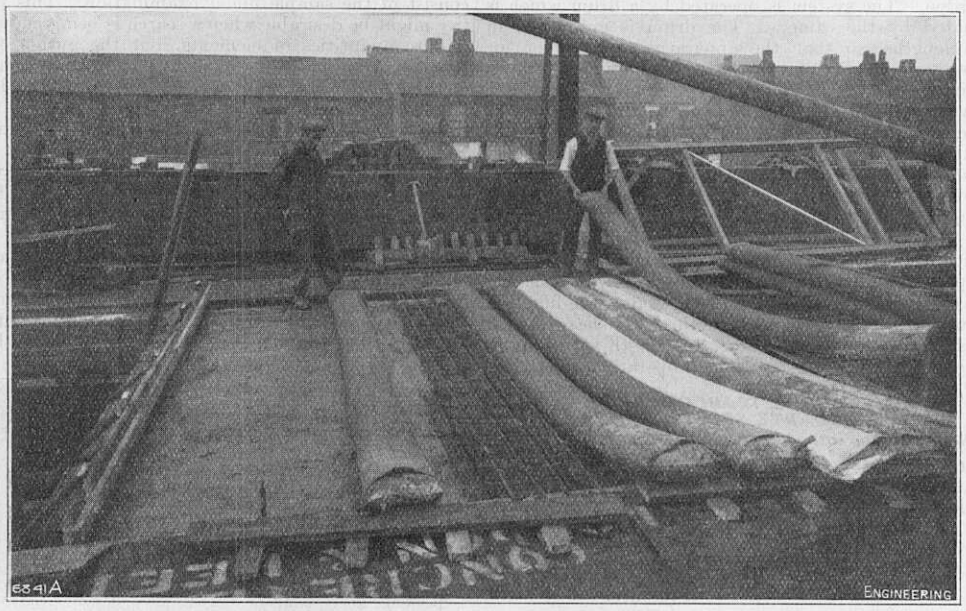


FIG. 1. PLACING PNEUMATIC CORES IN POSITION.



FIG. 2. CORES IN PLACE, READY FOR POURING CONCRETE.

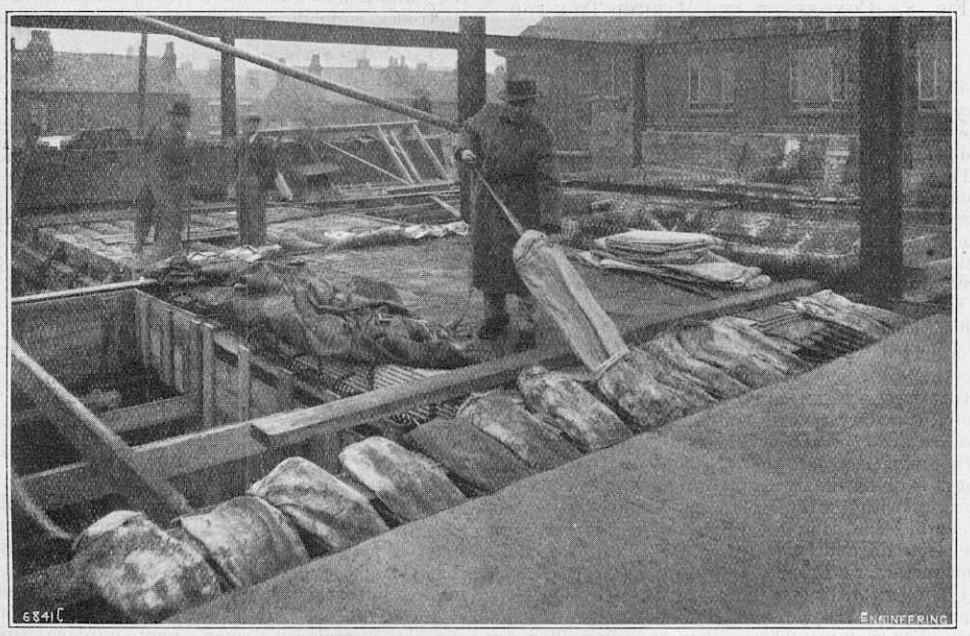


FIG. 3. WITHDRAWING CANVAS COVERS OF CORES.

PNEUMATIC CORES FOR CONCRETE FLOORS AND WALLS.

THE hollow concrete floor, generally reinforced, is now a well-known method of building construction, and is formed either as a whole *in situ*, or by interlocking pre-cast beams. In either case, some kind of shuttering has to be used in order to form the cavities. One of the most usual methods is to employ the so-called hollow tiles, that is rectangular hollow blocks of burnt clay, which are necessarily left in place. Clearly, shuttering of a type that can be withdrawn when the concrete is set represents a saving in material, and it is with such shuttering that the present account is concerned. The system has been developed by Messrs. Pneumatic Cores, Limited, Grand Buildings, Trafalgar-square, London, W.C.2, and is illustrated in Figs. 1 to 3, on this page. As may be inferred from the title of the firm, and as will be evident from the illustrations, the shuttering consists of air-inflated bags which are collapsed when their function is ended and withdrawn for further use. The same type of core is employed for both pre-cast floors and those laid *in situ*, the factors determining which kind of floor should be employed being, broadly speaking, those of high transport costs or spans longer than about 16 ft. Where the floor is to be laid in situations not too far from where the beams are made, the pre-cast floor is suitable, though even in such cases lengths over 16 ft. would be awkward to handle. The illustrations above referred to show successive stages in the laying of a long-span floor in place.

The appearance of the cores is best gathered from Fig. 1. They consist of long bolster-like bags of strong rubber with an inflating valve at one end. The bags are contained in canvas covers, so that the concrete does not come into direct contact with them. The first stage in constructing a continuous floor is to lay the concrete ceiling on temporary centring in the usual way. The inflated cores, of the full length of the span, are then laid on the ceiling at the required pitch. This operation is shown in Fig. 1. In Fig. 2 the reinforcement is being placed in position, after which the concrete is poured and rammed in the customary manner.

When the concrete is hard, that is, after about four hours, the cores are deflated, and can then be readily withdrawn from the canvas bag. It is necessary, of course, to leave the ends sufficiently exposed for access. The operation shown in Fig. 3 is not that of withdrawing the cores, but of withdrawing the canvas covers. These are made with a broad tape attached to the centre of the inside of the blind end. The tape lies on the surface of the core and projects from the open end of the bag. When the core has been removed, the tape is pulled, as shown in the illustration, with the result that the bag is peeled off the concrete from the blind end outwards. It is, of course, turned inside out during the process, and eventually comes out altogether, its front part being still in position in Fig. 3, and thus possibly giving an incorrect impression. The cores have all been removed and are seen folded and in a pile to the left of the man removing the bags. Concrete is being poured and rammed on the inflated cores in the part of the floor visible in the background. The intermediate length of floor, it may be mentioned, is of special construction, as this part of the building houses a safe deposit. When all the bags have been removed, the gap through which they have been pulled is filled up solid with concrete, the floor edges having been wetted and hacked where necessary. In this operation the cavities are stopped at the ends with the concrete filling.

In making units for pre-cast floors, the cores are inflated to a pressure of about 5 lb. per square inch, and wrapped in Kraft paper to protect them and to facilitate their withdrawal when the concrete has set. The moulds are then assembled and, with the cores placed in them, pushed on a roller conveyor to the vibrating table. Here the cores are folded back to allow concrete for the soffit, or bottom, to be poured in, rammed and levelled while being vibrated, the cores being held in position by timbers and holding-down bars. The top surface is then trowelled smooth. The moulds are next rolled along conveyors to the yards, where they are stacked for their initial set. Three or four hours later the cores are withdrawn for re-use. The time taken to produce a unit is about 20 minutes. A somewhat similar process is followed in making concrete cavity walling. The units in this case consist of two slabs of concrete, each 1½ in. thick, separated by a 2-in. cavity. The total thickness is thus 5 in., and the usual depth is 14 in., the length being as desired up to 15 ft. A layer of concrete is poured into the bottom of the mould, with suitable reinforcement, and is levelled to the required thickness. The pneumatic core is then placed on the bottom layer, and galvanised-steel ties are inserted vertically at intervals along the sides of the mould. A second layer of concrete is then poured and levelled, the core

following the line of the mould sides and ties, so that two distinct walls are formed. The completed units when built up on edge form a wall with an unbroken cavity. The pneumatic core is also employed in the manufacture of pre-cast reinforced-concrete hollow columns and beams.

Apart from the saving of tiles, the pneumatic core is stated to enable a floor to be laid more rapidly, as the core can be placed in position in much less time than it takes to lay a line of tiles. The cavity is larger than those in tile floors, as the thickness of the tiles decreases the cavity, and it is, of course, lighter by the weight of the tiles. The cavities can be made larger for special purposes by simply inflating the cores to a higher pressure. We understand that the pneumatic core method has been in successful use for about five years, and that it has been approved in a number of countries abroad. It is the invention of Mr. C. B. Matthews, M.Inst.C.E., and Mr. J. G. Ambrose, M.Inst.C.E.

SOME APPLICATIONS OF THE SPECTROGRAPH TO THE QUANTITATIVE ANALYSIS OF FERROUS AND NON-FERROUS METALS.*

By F. G. BARKER, F.I.C.

IT was not until recent years that the findings of the early pioneers of spectroscopy have been put to any important use in industry. As regards the application of the spectrograph to quantitative metallurgical analysis, the first systematic investigation in Great Britain appears to have been undertaken in 1925 by Twyman and Smith under the auspices of the British Non-Ferrous Metals Research Association. They first investigated its use as a means of estimating certain impurities in zinc, and in this connection they found, from an examination of a series of synthetically prepared samples, that cadmium could be determined satisfactorily when present in amounts between 0·001 per cent. and 0·10 per cent. They also found that the elements lead and iron could likewise be examined satisfactorily from the same spectrum. In view of the success which attended this initial work, the scope of the investigation was extended to cover other non-ferrous materials, with very satisfactory results. About five years ago, a survey was made of the work which had been done by the British Non-Ferrous Metals Research Association, and by one or two manufacturers of non-ferrous metals who had installed spectrographs in their laboratories for the routine examination of their products. It was evident from the results they had achieved that spectrographic methods were suitable not only for the rapid detection of constituents in a wide range of alloys, but also for the quantitative estimation of impurities and minor constituents. It was therefore decided to purchase a spectrograph for use in the Admiralty Naval Ordnance Laboratory at Sheffield†.

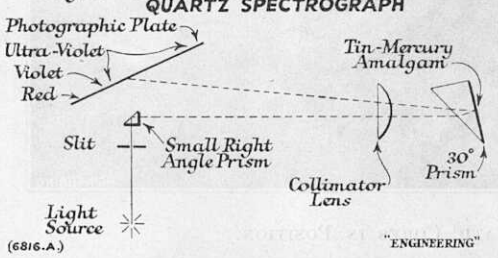
As spectrographs of three sizes, known as small, medium and large, were being made in Britain, it was necessary first to decide which would be most suitable for the type of work to be done. Each of the instruments embodies similar general principles in construction and covers the same range of wavelengths, namely, about 2,000 Å to 8,000 Å., but the length of the spectrum differs in each. It is about 3 in. long in the small instrument, 10 in. in the medium, and 30 in. in the large. For the analysis of most non-ferrous metals and alloys the medium size is generally satisfactory, but for the analysis of iron and steel the large instrument is essential on account of the great number of iron lines which appear in the spectrum. Although it was the intention at first to apply the spectrograph to the analysis of non-ferrous metals, the Laboratory also had in view its possible use in the field of ferrous analysis, and therefore decided to employ the large instrument.

Spectrographs for metal analysis are generally fitted with a quartz prism and optical train, because many of the spectrum lines which are best suited to this work lie in the ultra-violet range, and quartz does not absorb ultra-violet radiations, whereas glass does.

The spectrograph consists essentially of a heavy iron stand, on which the optical system and controls are mounted, enclosed by a metal dust-proof cover, and also an electrode stand, slit, and camera. The whole outfit is of robust construction and all parts are in permanent adjustment. As already mentioned, the apparatus covers a wave band of 2,000 Å. to 8,000 Å., and the dispersion is such that this would give a spectrum about 30 in. long. It would obviously be impracticable to use plates of such a length, and the instrument is, therefore, designed so that the complete spectrum can be examined in three sections. This is made possible by a system of controls by which the prism may be rotated and the plate-holder at the same time brought automatically into the correct focal position. The system is operated by a drum which is situated by the camera. The drum is graduated in wavelengths, so that the apparatus can be set for photographing any part of the spectrum which may be desired.

A diagram of the optical train of the large quartz spectrograph is shown in Fig. 2, on this page. The light from the slit is reflected by a small right-angled prism to the collimating lens and refracted by a 30-deg. Littrow prism, the back face of which is coated with a mercury-tin amalgam. This reflects the light back again through the collimator lens, which also serves as the camera lens, on to the photographic plate. In front of the slit is a wedge-shaped piece of metal known as a reducing wedge, the function of which is to control the length of the beam which falls on the slit. By keeping this length at the minimum necessary for the subsequent operations of reading

Fig. 2. OPTICAL TRAIN OF LARGE QUARTZ SPECTROGRAPH



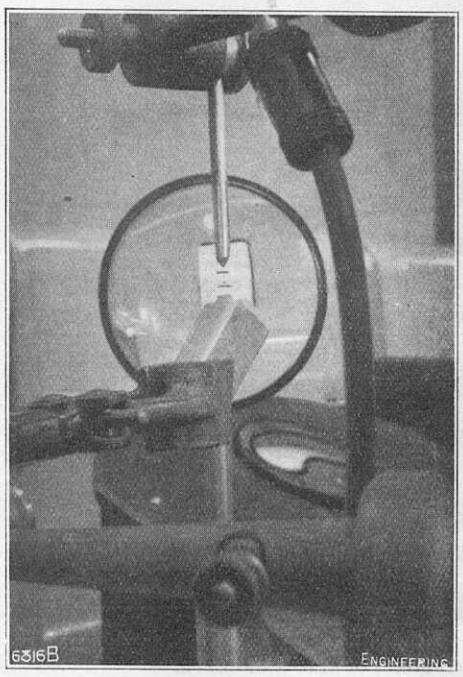


FIG. 8. CONDENSER AND MARKED TILE FOR ALIGNMENT OF LIGHT SOURCE.

or evaluating the spectra, it is possible to economise very consideraly in the use of photographic plates. The author generally employs a slit length of 2·5 mm., and is able to make 24 separate exposures on one plate.

The above-mentioned exposures on one plate are made possible by means of a plate-holder which can be raised or lowered by a special rack-and-pinion device. The first exposure is made at the bottom of the plate, and the latter is then moved downwards by the registered amount. The next exposure is then made, and so on until the plate is filled. In front of the plate-holder is a mechanically-operated shutter, which can be adjusted to suit the slit length chosen and thus prevent extraneous light from reaching the plate during successive exposures. The electrodes are connected to a direct-current supply of about 120 volts, and the arc is struck by bringing them together and then separating them until an arc of the required length is obtained. A regulating resistance is inserted in series with the arc to obtain a standard current strength. The sample under examination serves as one electrode, and for the other a machined rod of the same metal, or a rod of graphite, or any spectroscopically pure metal can be employed, the selection being dependent on the type of metal or alloy under examination. For example, when copper or copper alloys are being examined, a rod of pure copper is used as the other electrode. Similarly for steels examined by the arc method, a rod of pure iron is used. Rods of various metals and graphite of great purity can be obtained for this purpose from the manufacturers of spectrographic equipment. Some workers claim that the greatest sensitivity is obtained when both electrodes consist of the sample under examination. This practice might be desirable when a search is being made for minute quantities of elements, but the author finds that for most purposes any slight advantage which the method might have is more than offset by the large amount of work involved in machining. The rods employed for electrodes have a diameter of about 5 mm., and are shaped at the end to a cone of 80 deg. In order to avoid contamination, the point is cleaned with a file or a shaping tool after each exposure. This, however, is not inconvenient, as several rods are in use and can be cleaned and re-shaped at one time.

The polarity of the sample is of some importance. D. M. Smith, after carrying out numerous tests, concluded that the alloy under examination should be made the negative pole, because the impurity lines have then an intensity approximating to that obtained when both

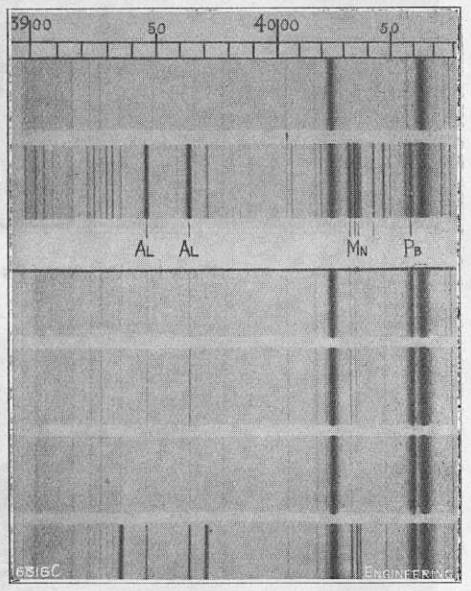


FIG. 11. SPECTROGRAMS VIEWED BY JUDD LEWIS COMPARATOR

electrodes are of the same material. Brownsdon and Van Someren also investigated this question and arrived at the same conclusion. Although the author has not carried out a systematic investigation into this matter, he has obtained evidence in support of their view and has adopted this practice. If a sample is too small or of too low a melting point to be used as an electrode itself, it is placed in a crater freshly prepared in a graphite rod; this is commonly known as a "globule" test. The alignment of the light source is carried out by opening the spectrograph slit and focusing the spectrum on a piece of ground glass which is held at the back of the camera in the position that the plate would occupy. When in correct alignment the stand is fixed, and the correct positioning of fresh electrodes is made possible by utilising the simple

TABLE I.—*Standard Conditions of Arc Excitation.*
Arc gap, 4·0 mm. Slit width, in all cases, 0·015 mm.

Material.	Positive Electrode.	Current. Amperes.	Wave-band. Å.	Exposure. Seconds.
Copper	Copper	4·0	3,000–5,800	23
Brasses	,,	4·0	2,800–4,800	30
Bronzes	,,	4·0	2,320–3,000	45
Cupro-nickels ..	,,	2·5	3,000–5,800	23
,, ...	,,	2·5	2,800–4,800	30
Monels	,,	2·5	2,320–3,000	45
Aluminium and alloys	Graphite	4·0	2,800–4,800	60
Globule on all metals ..	Copper or Graphite	4·0	3,000–5,800	15
		4·0	2,800–4,800	20
		4·0	2,320–3,000	30
Iron	Iron	2·5	3,000–5,800	5
Steel	,,	2·5	2,800–4,800	7
,, ...	,,	2·5	2,320–3,000	10

device shown in Fig. 8, on this page. A white tile is fixed on the cover of the spectrograph, and on it two lines are marked. Between the tile and the electrode stand is placed a condensing lens, in such a position that the image of the electrodes is focused between the two lines when the spectrum from the same source is in focus at the back of the camera. The period of exposure employed when photographing spectra depends on the nature of the material under examination, the elements sought, and the technique employed,

* Communication from the Spectrographical Section of the Naval Ordnance Inspection Laboratory, Sheffield, read before the Iron and Steel Institute on Thursday, May 4, 1939. Abridged.

† See pages 104 and 199, *ante*.

but exposures generally are of less than one-minute duration.

Standard Conditions for the Arc Spectra.—The conditions which have been standardised by the author for taking arc spectrograms are shown in Table I, on the opposite page. The material, shown in the first column and constituting the sample, is always made the negative electrode. The differences in current and exposure shown are found necessary in order to obtain spectrograms of suitable intensity for evaluation.

It is evident, from an examination of a spectrum, that there are a large number of lines of variable density and an apparent lack of regularity in their arrangement. In places, however, small groups of lines, or pairs of similar intensity are seen lying close to each other. The latter are known as "doublets," and as their position in the spectrum is always constant they soon become familiar to the operator, and are of great assistance when evaluating spectrograms. In spite of the apparent irregularity of the lines, it has been shown, with certain elements which give less complex spectra, that there is some order in their grouping, and that they conform to formulæ which have been evolved mathematically. In complex spectra, however, such as those now under discussion, the problem of such grouping is extremely involved and beyond the scope of this paper. A point of the greatest importance, however, is that, in spite of the fact that over 14,000 lines given by different elements have been found and logged between wavelengths of 2,000 Å. and 6,000 Å., no two elements have been discovered to give a line in exactly the same position. In many instances, however, they may be very close together.

The positions of the lines given by any element are, therefore, characteristic of that element, and serve as a means of identifying it. The most convenient and accurate method of describing the position of a spectrum line is to give the value of its wavelength. Tables for all the principal lines in spectra for all the elements are available in publications such as H. Kayser's handbook and Twyman and Smith's *Wave-Length Tables for Spectrum Analysis.*

Judd Lewis Comparator.—This identification of lines in a spectrum is made fairly simple by the use of an instrument known as the Judd Lewis comparator. It consists of a two-way microscope, by which objects placed beneath the two objectives may be viewed through one eye-piece. The stage is an open frame divided into sections, each of which will carry a spectrum plate. The plates can be moved parallel to either their major or minor axes, so that an unknown spectrum may be compared with a standard spectrum on which several lines are marked with the symbols of the elements that they represent. In lining up the plates, "doublets" and other distinctive groups of lines, which have already been mentioned, are found most useful. An example of what is seen when looking through the eye-piece of the comparator is given in Fig. 11, on the opposite page. The upper half of the picture is a standard spectrum. The figures at the top represent wavelengths and the symbols lower down indicate the elements corresponding with the lines immediately above them. The lower plate, which contains the unknowns, shows the spectra of three different samples. It will be seen that the first contains a trace of aluminium, the second a little more, and the third a little less. The manganese content, which is indicated by the strength of the three lines which lie close together under the symbol "Mn," also falls in the same order as for aluminium. All the samples contain an appreciable quantity of lead. Fig. 14, on this page, affords another example of how increasing amounts of an impurity are readily detected in the spectrum. The alloy in this instance is brass, and the impurity bismuth.

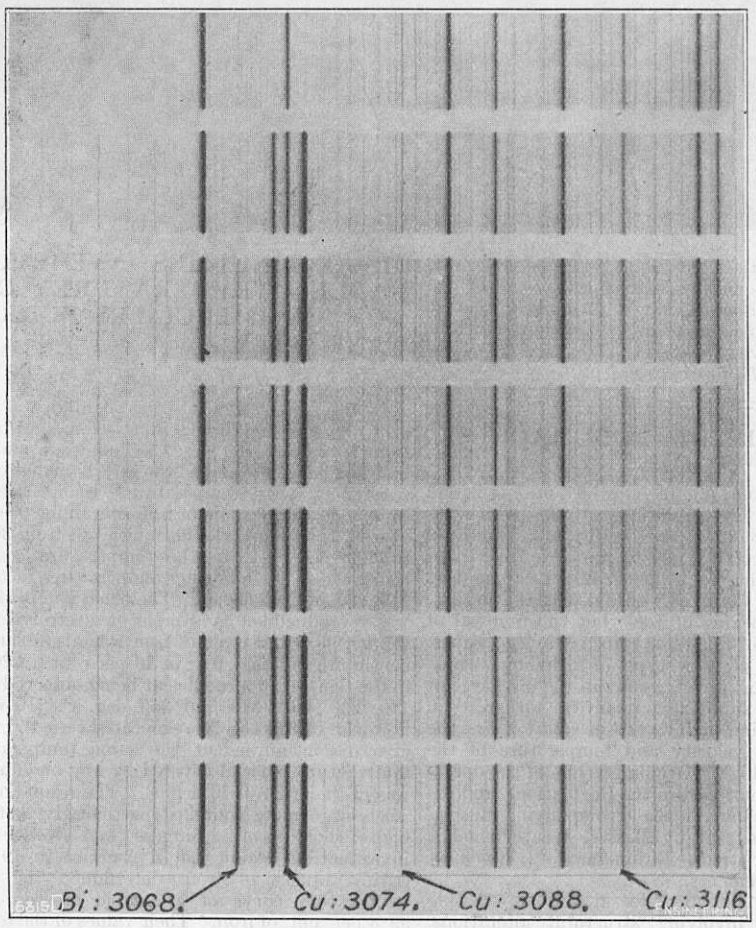


FIG. 14. SPECTROGRAMS OF BRASS CONTAINING BISMUTH.

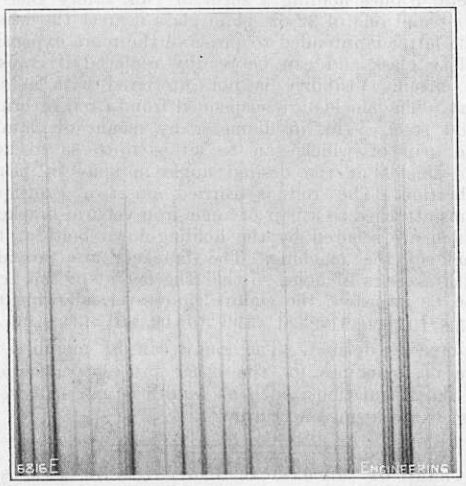


FIG. 16. SPECTROGRAM OF NI-CR-V STEEL OBTAINED BY LOG-SECTOR WEDGE METHOD.

Quantitative Examination of Spectra.—From the spectra already examined it will probably be evident that if one had a series of standard spectra of a metal or alloy containing impurities in known and increasing amounts, it should be possible by comparison with them to estimate the impurities in a similar metal of unknown purity, provided that all the spectra were taken under the same conditions. This method has been employed for the quantitative examination of metals and is known as the "external comparison" method. Such comparisons are conveniently made in the Judd Lewis comparator. For accurate work this method requires a very rigid adherence to standard conditions in the preparation of the spectra, and even then the accuracy obtainable is not of a satisfactory order for accurate quantitative work. A very extensive collection of standard plates is also required if the range of material to be examined is wide.

The foregoing objections are largely overcome by another method known as the "internal comparison" method, which was originally proposed by Gerlach and Schweitzer. They suggested that the densities of lines due to the element being evaluated could be compared with the densities of lines of a major alloying element within the same spectrum. As an apparatus such as the Judd Lewis comparator is usually employed for making such comparisons, it is necessary that the two lines to be compared shall be sufficiently close to appear together when viewed through the eye-piece. To see how this principle is applied the spectra shown in Fig. 14 may be examined again. It is known that one of the most sensitive lines for bismuth has a wavelength of 3,068 Å., so that to determine whether bismuth is present one first looks for this line. If no line is present it can be said immediately that the bismuth content of the metal is less than a certain amount. This amount is dependent on the conditions under which the spectrum was taken, but is generally very small. Under the conditions employed in the author's laboratory for the analysis of brass the smallest amount that can be detected is 0·0003 per cent. By varying the conditions of arcing and exposure, however, it is possible to detect much smaller amounts. To draw up data for the quantitative determination of bismuth in brass one first looks for copper lines which have an intensity similar to that of the bismuth line to be examined. As the field covered by the comparator is similar to that shown in Fig. 14, any suitable copper line which appears there can be chosen. It will be seen that the copper line marked 3088 resembles in intensity the fainter of the 3068 bismuth lines. On closer examination it will be seen that the line is of about the same intensity as the bismuth line corresponding to 0·0007 per cent. of that element. This gives the first standard. Lines used for such comparisons are known as "line pairs." On the last spectrum but one it will be seen that the 3116 copper line is about equal in intensity to the bismuth line corresponding with 0·002 per cent. of bismuth, which gives another standard. Similarly, when the bismuth content is 0·007 per cent., the 3068 bismuth line is comparable with the 3074 copper line, which is of equal intensity, but for quantities between 0·002 per cent. and 0·007 per cent. of bismuth it is necessary to search for other comparison lines. In this manner a table is compiled to cover any desired range of composition which is capable of estimation by such a method.

As the Admiralty specification for brass permits 0·005 per cent. of bismuth, it will be evident that, since as little as 0·0003 per cent. can be detected and a distinction made between amounts that differ by as little as 0·0005 per cent., the method is sufficiently sensitive for the purpose.

TABLE II.—*Section of Table for Determination of Bismuth in Brass by "Internal Comparison" Method.*

Bismuth. Per cent.	Bi Line 3068.	Bi Line 2898.
0·0007	= Cu 3088	—
0·002	= Cu 3116	—
0·005	—	= Cu 2892
0·007	= Cu 3074	—

Comparison Tables.—A table, which was compiled partly from the spectrograms just examined, and is typical of all tables for internal comparison when made by visual examination, is shown in Table II. At the head of the table are seen the bismuth lines that are used for comparisons, and in the columns below are seen the copper lines which are used in conjunction with them. In the first column is shown the amount of bismuth which is present when the two lines under examination are equal in intensity. For example, when the 3068 bismuth line is equal in intensity to the 3088 copper line, the bismuth content is 0·0007 per cent., and when the 2898 bismuth line is equal in intensity to the 2892 copper line the bismuth content is 0·005 per cent., and so on.

Tables on a basis similar to that described have been drawn up to cover many non-ferrous metals and alloys of the type and purity called for in the Admiralty specifications.

Log-Sector Wedge.—Before leaving the subject of non-ferrous analysis, reference should be made to

another method which has been examined by the author for the determination of elements present in much larger amounts than can be estimated by the methods already described. It is known as the "log-sector wedge" method. The apparatus is employed while the spectrum is being photographed, to vary the exposure along the slit of the spectrograph, so that at one end of the slit a very much longer time is given than at the other. This variation is produced by the rotation of a disc, called the log sector, the periphery of which is cut to a logarithmic curve so that photographic exposures along the length of the slit are proportional to the "cut-out." The disc is driven by a small geared motor, and is placed close to and lined up with the slit of the spectrograph. The image has the form of a tapered line graded from thick and dense at one end to thin and vanishing at the other, as shown in Fig. 16, on page 573. The length of the line is proportional to the quantity of element present in the sample, and the standard for comparison is the length of a similar line given by the main constituent of the alloy. It will be evident from an examination of this spectrogram that one of the difficulties attendant on the use of this method is the determination of the exact point at which the tip disappears. The author and his colleagues carried out many tests in which different operators read the same spectra, and the differences between the readings were so great that the method was abandoned. The reading of this type of spectrogram was also found to be a very fatiguing operation.

Steel.—The utility of spectrochemical methods for the analysis of steel will next be examined. Although a considerable amount of work has been done in Britain on the analysis of non-ferrous metals by means of the spectrograph, relatively little work has been done with steel. Some years ago Twyman and Fitch* made some tests by the log sector method and claimed to be able to determine silicon up to 0·8 per cent. with an accuracy of 10 per cent. of the content, also chromium up to 4 per cent., nickel up to 5 per cent., and copper up to 1 per cent., each with an accuracy of 5 per cent. of the content. Later, Twyman and Harvey† carried out some experiments with the same steels but with a modified technique, and recorded accuracies of an order of 10 per cent. of the element on determinations

TABLE IV.—*Tables for the Spectroscopical Determination of Nickel and Copper in Steel.*

Nickel. Per cent.	Ni Line 3414·7.	Ni Line 3515·1.	Ni Line 3050·8.	Ni Line 3393.
0·01	Visible	—	—	—
0·05	= Fe 3415·5	—	—	—
0·10	—	= Fe 3516·4	= Fe 3053·1	—
0·20	—	—	—	= Fe 3392·3

Copper. Per cent.	Cu Line 3247·5.	Cu Line 3274.
0·01	= Fe 3248·2	—
0·03	= Fe 3244·2	—
0·05	—	= Fe 3271
0·10	—	= Fe 3286·8

of nickel, manganese and chromium. Preliminary tests upon the lines of the previous investigators which were made in the author's laboratory failed to confirm the adequacy of their methods and the accuracies claimed for them. Furthermore, it was not considered economic, nor always possible, to machine the shapes and sizes of samples which require analysis to the dimensions used by them. It was decided to attack the problem on other lines, and build up a new technique.

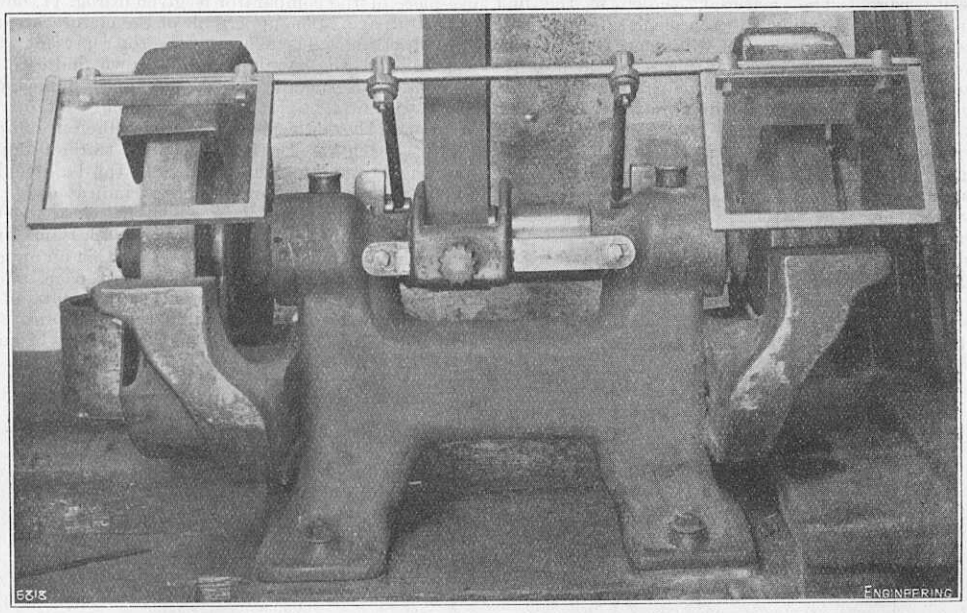
Early experiments showed that the elements present in steel in very small amounts could be estimated with a fair degree of accuracy by the methods already described for non-ferrous metals, subject to slight modification, but it was evident that the determination of elements present in larger amounts was a very much more difficult problem. The detection and estimation of small amounts were therefore attempted first. The greatest handicap in this work was the lack of material which gave a graduated range of composition, such as is essential for the preparation of standard tables or curves. Suitable material was, however, ultimately obtained, and standard spectra and tables were prepared for small amounts of several of the elements which are commonly present in steel. Table IV is read in precisely the same manner as Table II, for bismuth in brass. For example, when the 3413·9 nickel line is equal in intensity to the 3415·5 iron line, the nickel content of the steel is 0·05 per cent., and so on. This, and other tables have been constructed from the most suitable lines that have so far been found. Further search may reveal other lines which might be preferable and might permit somewhat higher percentages of the elements to be estimated, but it is unlikely that it would be possible to estimate by eye amounts much in excess of those shown.

(*To be continued.*)

* See ENGINEERING, vol. cxxx, page 635 (1930).
† *Loc. cit.*, vol. cxxxvi, page 487 (1932).

SAFETY GUARDS FOR GRINDING MACHINE.

MESSRS. WEATHERSHIELDS, LIMITED, BIRMINGHAM.



SAFETY SHIELDS FOR MACHINE TOOLS.

THE recent Factory Act includes a section entitled "Protection of Eyes Regulations, 1938," which, as may be inferred, requires the occupants of factories where processes involving risk to the eyes are carried on to make provision for safeguarding the operators concerned. One of these risky occupations is grinding; not the mere sharpening of tools but the removal of unwanted masses of metal, as in fettling castings. The very nature of this type of grinding, which does not involve fine finish, results in the discharge of coarse particles. Moreover, quantity rather than quality being the aim, high speeds of rotation are the rule and both the velocity and temperature of the flying particles are high. Grinding is one of the operations specifically mentioned in the Regulations, and the new safety shields shown in the accompanying illustration have been designed by Messrs. Weathershields, Limited, 48, Moor-street, Birmingham, 4, to meet the statutory requirements.

The shields are intended for fitting to existing machines without involving structural alterations. In the example illustrated, there is a shield measuring 8 in. by 6 in. over each wheel. The shields consist of metal frames holding a sheet of ¼-in. safety glass in front and one of 32-oz. plain glass nearest the wheel. The latter is intended to preserve the more expensive safety glass and can be readily replaced if cracked or pitted. Visibility is not interfered with in any way. The shields are suspended from a rod of bright mild steel, ½ in. in diameter by means of clamps, the grip of which can be adjusted so as to hold the shields at the desired angle in spite of heavy vibration. The rod is carried on two cantilever arms attached to a pair of angle-iron vertical brackets, which are secured by the holding-down bolts at the back of the machine. The brackets are provided with a series of holes so that the height of the arms can be adjusted, the clamps, moreover, allowing the arms to be swivelled, and to be advanced or retracted as desired. The guard can be modified for use on machines for the other processes instanced in the Regulations, such as sand-blasting, spot-welding, band-sawing and turning.

CHART OF MECHANICAL PROPERTIES OF STEELS.—Messrs. Aircraft Materials, Limited, Midland-road, London, N.W.1, have issued a wall card showing, on one side, the mechanical properties and chemical analyses of a range of 28 carbon and alloy steels, and, on the other, a table of Brinell hardness numbers and the corresponding Vickers, Rockwell (C scale) and Scleroscope hardness numbers, with a corresponding tensile strength value in both tons per square inch and kilogrammes per square millimetre. A table of recommended heat-treatments, for various typical steels, is also included.

DISCONTINUITIES IN THE RESISTANCE - TEMPERATURE CURVES OF COMMERCIALLY-PURE IRON AND STEEL.*

By C. SYKES, D.Sc., and F. W. JONES, Ph.D.

IN an investigation into the possibility of changes in iron and steel occurring in the temperature interval from 50 deg. to 400 deg. C., Thompson and his collaborators have determined the rate of change of electrical resistance with temperature. Using an annealed sample of American ingot iron containing 99·9 per cent. of iron, they found discontinuities of from 30 per cent. to 100 per cent. in the temperature coefficient of resistance at the following temperatures: 55, 100, 120, 140, 220 and 245 deg. C. The behaviour of the material was reproducible. A sample of electrolytic iron containing 99·9 per cent. of iron was also examined, discontinuities of the order of 10 per cent. to 20 per cent. in the temperature coefficient being observed at 70, 120, 170, 230, 290, 310 and 350 deg. C. It was found, however, in this case that repeated tests did not always give discontinuities at the same temperature. The temperature interval covered by any one discontinuity was of the order of 10 deg. C. The results obtained on steels were more complex, particularly in the case of high-carbon steels. Burgess and Kellberg, in an investigation, conducted in America in 1914, on the critical ranges of iron, determined the resistance-temperature curve of a sample of iron containing 99·8 per cent. of iron. Their values of the temperature coefficient from 300 deg. C. upwards show no discontinuities. The method used to determine the temperature coefficient from the experimental measurements is not given, and as it appeared possible that it may have been estimated over temperature intervals so large that the discontinuities had been averaged out, the present authors have calculated a new set of values from their experimental data, using temperature intervals of about 2 deg. C. The maximum variations found in the temperature coefficient are ± 3 per cent. in the temperature interval 300 deg. to 500 deg. C. The accuracy of the measurements permitted a maximum estimated error of ± 3 per cent., and one would conclude therefore that the discontinuities, if any exist, are at least five times smaller than those observed by Thompson.

It has been suggested that discontinuities are associated with transformations taking place in the iron or steel. The evidence for such low-temperature transformations has been summarised,† and it is true to say that discontinuities in a large number of the physical properties have been reported from time to time. Various hypotheses have been put forward suggesting that modifications take place in the temperature interval 50 deg. to 450 deg. C. in the iron lattice or electronic configuration of the iron atom or both, and that these modifications or transformations give rise to the observed discontinuities in physical properties. In this way changes in mechanical properties

* Paper presented at the Annual Meeting of the Iron and Steel Institute, May 3-5, 1939. Abridged.
† See *Jl. Iron and Steel Inst.*, vol. cxxxviii, page 125 P (1938).

have been correlated with anomalies in specific heat, electrical resistance, etc. It appears, however, that the specific-heat/temperature curve of annealed iron from 100 deg. to 450 deg. C. is reasonably continuous, *i.e.*, the material is free from transformations in this temperature interval. This conclusion is in agreement with the work of Burgess and Kellberg, but not with that of Thompson, and it appeared desirable that further measurements of the variation of the temperature coefficient of electrical resistance as a function of temperature should be made. The matter is of practical importance, since if it can be shown that structure-insensitive properties such as specific heat and electrical resistance vary continuously with temperature, then the reasons for the anomalous changes in mechanical properties can be sought from a consideration of such factors as grain boundaries, grain size, precipitation effects, etc.

Experimental Arrangements.—Thompson and Whitehead made their resistance measurements on a wire specimen immersed in a gas-heated oil-bath which was kept well stirred. The temperature was measured by means of a mercury thermometer. Goffey and Thompson made further measurements in an electric furnace which had a uniform temperature zone extending over 6 in. The specimen, in the form of a spiral, was mounted in this zone, and stout copper connections were brazed to the ends of the spiral. Current and potential leads were fastened to the stout copper connections outside the furnace. A current of about 2 amperes was passed through the spiral, and the e.m.f. generated was applied to the terminals of a galvanometer through a suitable resistance. The galvanometer reading, therefore, was roughly proportional to the resistance of the spiral. The temperature was measured by means of either a nitrogen-filled mercury thermometer or a thermocouple placed inside the spiral. The e.m.f. of the thermocouple was used to deflect a moving-coil galvanometer. The heating rate of the furnace was kept fairly constant by means of a number of resistances in series with the furnace winding. Readings of the galvanometer deflection recording the resistance were made at 2 deg. C. intervals as recorded on the thermometer. The increase in deflection was about $2\frac{1}{2}$ mm. per deg. C. and the deflection could be readily measured to $\frac{1}{2}$ mm. The change in galvanometer deflection per deg. C., $\frac{\Delta\,\delta}{\Delta\,\theta}$, was plotted against temperature and the resulting curves showed discontinuities. The present authors estimate that errors of $\pm$ 20 per cent. in $\frac{\Delta\,\delta}{\Delta\,\theta}$ are possible with this arrangement owing to incorrect readings. Any change in heating rate will produce some discontinuity in the apparent-resistance/temperature curve unless the thermal capacity divided by the rate of heat absorption is identical for both the specimen and the temperature-measuring device. The actual magnitude of these extraneous effects may be negligible, and Thompson found in certain check tests on copper that a substantially smooth curve was obtained.

Burgess and Kellberg used a fine spiral of iron wire and a fine spiral of platinum wire. These were heated *in vacuo* and the resistance of both spirals was measured alternately (to an accuracy of about 5 parts in 10^6), using a sensitive potentiometer. The time at which the resistance of each spiral attained a definite value could be ascertained to 0·1 second. The platinum spiral served as a temperature indicator, and by interpolation the resistance of the iron spiral was determined as a function of temperature. This method is practically ideal for testing whether real discontinuities exist, since the thermal capacities of the spirals are very similar. The heat transfer *in vacuo* is very low, and this helps to minimise fluctuations in the heating rate of the spirals.

In the present experimental work the specimens, in the form of 1-mm. diameter wire, were prepared from some of the materials used in a previous investigation of the change in specific heat of iron with temperature. After drawing, the wires were annealed at 750 deg. C. for $3\frac{1}{2}$ hours *in vacuo*, and then slowly cooled (60 deg. C. per hour) to room temperature. X-ray examination showed that the wires were free from any lattice distortion produced by the drawing operation. The composition of the materials used is shown in Table I.

TABLE I.

Material.	C. Per cent.	Mn. Per cent.	Si. Per cent.	P. Per cent.	S. Per cent.
Armco iron ..	0·018	0·02	0·008	—	—
Swedish Lancashire iron ..	0·01	0·01	0·008	—	—
Steel No. 6 ..	0·43	0·73	0·20	0·037	0·038

Resistance measurements were carried out in air in an electric furnace. The wire specimen, insulated by two thin sheets of mica, was tightly clamped between two blocks of copper. This arrangement prevents heat flow along the leads into the specimen and has the additional advantage that the temperature difference between the copper and specimen is very small (< 1 deg. C.) at normal heating rates. Thermocouple wires for temperature measurement were fastened by grub screws into the copper blocks. The assembly was placed inside two concentric copper tubes thermally insulated from one another and from a surrounding tubular resistance furnace. The temperature of the furnace winding was raised at a constant rate of 1·5 deg. C. per minute; a thermocouple placed between the furnace wall and the outer copper cylinder actuated

Fig. 1.

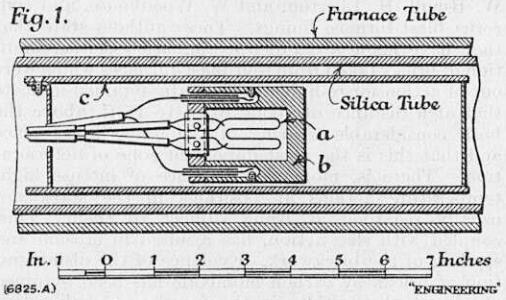
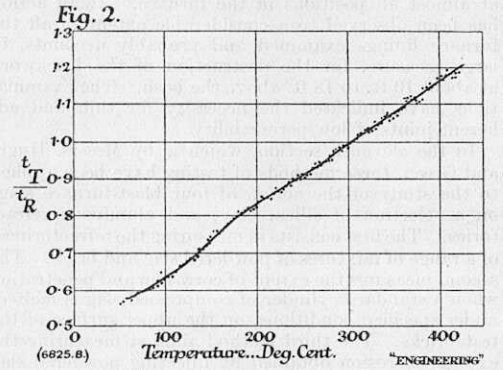


Fig. 2.



the automatic furnace control. It was hoped that this arrangement would raise the temperature of the copper blocks and specimen at a uniform rate. Actually, large variations in heating rate, $\pm$ 10 per cent., were observed which could not have been due to errors in measurement and which are ascribed to uncontrollable factors such as variable air convection, etc.

The above arrangement was therefore abandoned and an apparatus was constructed in which the specimen could be heated *in vacuo*. This is shown in Fig. 1, herewith. The wire specimen *a* was mounted inside a hollow copper cylinder *b*, closed at both ends, which formed a uniform temperature enclosure. The current and potential leads to the specimen were made of the same material as the specimen to minimise spurious e.m.f.'s and were clamped tightly between mica sheets where they entered the copper cylinder. The heat transfer to the specimen was governed entirely by the temperature of the surrounding cylinder, which was measured by using thermocouple wires fastened into holes in the walls of the cylinder. The interior of the cylinder and the wire specimen were blackened. At the heating rates used, the temperature difference between the wire and the cylinder was small (1 deg. C.) and has been neglected. The cylinder *c* was placed inside a larger hollow cylinder *d*, also of copper, and the whole arrangement fitted inside a silica tube which was evacuated to a pressure of 10^{-3} mm. or less. The cold junctions for the thermocouple were *in vacuo* inside a glass tube which was surrounded by a thermos flask filled with ice. All leads were brought out of the vacuum through a multiple glass seal.

A thermocouple was welded directly on to the winding of the furnace used to heat the silica tube, and this was used to actuate the automatic arrangement previously mentioned. The rate of rise of temperature of the block and therefore of the specimen was obtained by means of a potentiometer and sensitive galvanometer. The time was recorded at which the e.m.f. of the thermocouple passed through 0·1-mV intervals; the time intervals t_T per 0·1 mV (2·3 deg. C.) were free from variations greater than those likely to be introduced by the method of measurement. An approximately constant current of 0·3 ampere was passed through the specimen, a large-capacity 6-V battery being used as a source of e.m.f. Care was taken to eliminate the possibility of bad contacts, *e.g.*, no sliding resistances were used in the circuit, so that the only change in the current through the specimen was a gradual decrease of not more than 0·5 per cent. during the course of the experiment. The rate of increase of resistance was determined as follows:—The e.m.f. across the specimen was measured using a potentiometer and sensitive galvanometer, and the time, t_R, taken for the e.m.f. across the specimen to increase 0·1 mV was recorded. This increase corresponded to an increase in resistance of the specimen equal to 2 per cent. of its resistance at room temperature, and was produced by an increase in temperature of 3 deg. C. The potential difference across a standard resistance in series with the specimen was measured at intervals, to check the current through the specimen.

Results.—If R_0 is the resistance of the specimen at 0 deg. C. and R_T the resistance at T deg. C., then:—

$$R_T = R_0 \left(1 + \int_0^T \alpha\, d\,T\right),$$

where α is the temperature coefficient, and

$$\frac{d\,R_T}{d\,T} = \alpha\, R_0.$$

Experimentally two time intervals are determined: t_T, the interval in seconds for the e.m.f. of the thermocouple to rise 0·1 mV, and t_R, the interval in seconds during which the e.m.f. across the specimen, produced by a current i, rises 0·1 mV:—

$$t_T = \frac{\delta\,t}{\delta\,V} = \frac{\delta\,t}{\delta\,T} \cdot \frac{\delta\,T}{\delta\,V}$$

where V is the e.m.f. of the thermocouple;

$$t_R = \frac{1}{i} \cdot \frac{\delta\,t}{\delta\,R},$$

consequently

$$\frac{t_T}{t_R} = i\,\frac{\delta\,T}{\delta\,V} \cdot \frac{\delta\,R}{\delta\,T} = i\,R_0\,\frac{\delta\,T}{\delta\,V} \cdot \alpha.$$

The current i and R_0 are constant, $\frac{\delta\,V}{\delta\,T}$, which is the e.m.f. per deg. C. of the thermocouple, varies slightly with temperature but in a uniform manner, and therefore any discontinuities in $\frac{t_T}{t_R}$ can be ascribed to discontinuities in α. Absolute measurements of α have not been made, as they have no particular advantage for this particular problem.

Fig. 2, on this page, shows values of $\frac{t_T}{t_R}$ plotted against temperature, the specimen being a sample of Swedish Lancashire iron, and is typical of the type of result obtained. A smooth curve has been drawn through the points, and the percentage deviation of each point from the smooth curve has been ascertained. This, plotted against temperature, indicated that the deviations are generally less than 2 per cent., and that there appears to be no correlation between the deviations on different curves taken on the same specimen. In calculating the above data the authors have assumed that the heating rate of the copper block surrounding the specimen is free from discontinuities. In view of the experimental arrangement this assumption is justifiable. The deviations found can be accounted for by experimental error, since the value of t_R is 100 seconds, and can only be measured to $\pm$ 2 seconds. The increase in e.m.f. in 0·1-mV stages is liable to an error of $\pm$ 1 per cent. in setting; consequently, maximum errors of $\pm$ 3 per cent. may be introduced.

The above results confirm the work of Burgess and Kellberg, and show that the changes in temperature coefficient of the present authors' samples over temperature intervals of the same magnitude as those chosen by Thompson are quite small, *i.e.*, at least 5 times smaller than those recorded by Thompson. The results of the present preliminary experiments indicate the difficulty of eliminating spurious effects, and the authors think it probable that the residual discontinuities obtained with the final apparatus are also spurious and could be eliminated with improved technique.

REFRACTORY MATERIALS FOR STEELWORKS AND BLAST FURNACES.

THE First Report on Refractory Materials, prepared by the Joint Refractories Research Committee of the Iron and Steel Industrial Research Council and the British Refractories Research Association, was presented for discussion during the annual general meeting of the Iron and Steel Institute, on Thursday, May 4. The report, which contains 478 pages, is divided into two main sections, respectively dealing with steelworks refractories and with blast-furnace refractories. Each main section contains a number of contributions describing investigations carried out by well-known authorities on various aspects of the problems under consideration. In a foreword, it is explained that, while problems closely associated with the use of refractories in the steel industry have been studied by the British Refractories Research Association since its inception in 1920, it was recently considered that this work would be facilitated and rendered more productive by a closer liaison between the Iron and Steel Industrial Research Council and the Association. A Joint Panel was therefore formed in 1937. A similar

Blast-Furnace Refractories Joint Panel had been formed in 1930, and in order to co-ordinate all investigations on refractory materials for the iron and steel industry as a whole the Joint Refractories Research Committee was appointed under the chairmanship of Dr. T. Swinden.

After an introduction by Dr. Swinden, on the general programme adopted by the Committee, Messrs. A. E. Dodd and A. T. Green give a critical review of the literature and of certain hitherto unpublished work on the refractories employed in the basic open-hearth process. The survey, they point out, shows that both the concrete results of past research and the gaps in our present knowledge stand out fairly clearly. The conditions leading to the breakdown of silica, magnesite, and chrome-magnesite products in different parts of the steel furnace have received close attention and are now tolerably well known, but the influence of the furnace design on the life of refractory materials is still largely an unknown quantity, and the systematic collection of data on this question is urgently required. The skill of the furnace operator appears to play an important part in determining the life given by a particular lining. The greatest diversity of opinion exists as to the requirements of casting-pit refractories, however, and the amount of precise experimental data published is exceedingly small. This contribution is followed by an account of a research on composite chrome refractories, by Messrs. W. J. Rees and T. R. Lynam. These authors state that laboratory slag tests reveal that the addition of more than 12 per cent. of silica to a chrome batch seriously reduces the resistance to basic slags, and the chrome-silica bricks proved less durable in the back wall and gas slopes of the open-hearth furnace than ordinary chrome refractories. On the other hand, preliminary tests on the chrome-alumina series indicate that the alumina addition is beneficial in increasing the refractoriness-under-load without detracting from the slag resistance of the chrome ore when used alone. Microscopical work suggests that the increased strength of chrome products, to which magnesite has been added, is due to combination of the silica present in the chrome ore with part of the magnesia to form forsterite, which has a fusion point of 1,890 deg. C.

Some experiments on chrome-magnesite-dolomite mixtures, by Messrs. A. A. Chadeyron and W. J. Rees, are detailed in the fourth contribution. The results obtained from hydration tests had certain interesting features. Thus, the resistance to hydration of a 100 per cent. dolomite test-piece was not markedly less than that of dolomite to which 10 per cent. of chrome ore or magnesite had been added, or than that of dolomite to which 20 per cent. or even 30 per cent. of the other components had been added. This would suggest that the hydration tendency is not necessarily proportional to the dolomite content. Some factors influencing the durability of chrome-magnesite bricks in basic open-hearth furnaces are discussed by Messrs. W. Hugill and A. T. Green, in the fifth section of the report. They state that the former hot face of chrome-magnesite bricks taken from an all-basic steel furnace was found to be covered with a loose, granular, blue-black layer, which readily fell away and appeared to be quite free from bond. There were no signs of fusion in this surface layer, but, from 1 in. to 1½ in. behind this zone spalling had occurred with the formation of cavities, which showed definite signs of fusion and were brown, in contrast to the blue-black working face. Analysis of these zones revealed a marked increase of iron oxide at the former hot face, a smaller increase in lime, and a decrease in magnesia. As great a quantity as 128 parts of iron oxide and seven parts of lime were, in one instance, taken up by 100 parts of brick. The microscope reveals that this absorption apparently causes the chromite grains to grow, squeezing the matrix further into the brick and obliterating the pores. The grains showed laminations, and it appeared that further absorption of magnetic oxide in solid solution would have caused fracture.

Section 6, by Mr. W. Hugill, describes the methods employed to prepare samples of synthetic spinels from chemically-pure materials, for use in the elucidation of some of the problems associated with the behaviour of chrome-magnesite bricks. Some of the properties of these synthetic spinels were determined and further work is in progress. The seventh contribution, by Messrs. A. A. Chadeyron and W. J. Rees, deals with the tridymitisation of silica bricks, the authors pointing out that many attempts have been made to produce a high proportion of tridymite in silica bricks by the introduction of a small amount of a "mineraliser" which will induce the silica to crystallise out from the glassy matrix as tridymite and not as cristobalite. In the present investigation experiments were conducted using sodium metaphosphate, and it was found that the addition of 0·5 per cent. of this salt lowers the specific gravity and the apparent porosity of a silica-brick batch to a slight extent. The thermal-expansion curve shows that complete conversion to cristobalite and tridymite has taken place, the proportion of the latter being slightly greater than in the normal brick. The mechanical strength at high temperatures is only slightly affected by the addition of sodium metaphosphate. Micro-examination of the experimental and normal bricks indicated that the tridymite crystals, in those bricks to which the metaphosphate had been added, were better formed and somewhat larger than in the normal brick. The seventh and eighth sections of the report have been contributed by the Open-Hearth Refractories Joint Panel. The latter is a brief summary of the current investigations, while in the former a nomenclature is drawn up for sections of the open-hearth furnace.

The tenth section, and the first which deals with blast-furnace refractories, is by Messrs. A. T. Green, W. Hugill, H. Ellerton, and W. Woodhouse, and concerns blast-furnace linings. These authors state that they have made a detailed examination of the condition of bricks taken from four blast-furnaces which were out of action for re-lining. The data obtained indicate that at a distance of about 10 ft. to 15 ft. above the bosh considerable wearing of the lining takes place and that this is the most important zone of deterioration. There is, moreover, evidence of intense high-temperature actions at positions in the stack not usually regarded as being subject to them. This, coupled with slag action, has resulted in erosion and spalling of the brickwork. Evidence of the disintegration of bricks by carbon monoxide has been obtained at almost all positions in the furnace. Alkali action has been observed to a considerable extent in all the furnace linings examined and probably accounts, in large measure, for the destruction of the brickwork at about 10 ft. to 18 ft. above the bosh. The examinations have indicated the necessity for thin and adherent joints of low permeability.

In the eleventh section, which is by Messrs. Hugill and Green, three methods of testing have been applied to the study of the action of four blast-furnace slags on a selection of silica, clay, and aluminous refractories. The first consists in measuring the refractoriness of a range of mixtures of powdered slag and brick. The second measures the extent of corrosion and penetration when a standard cylinder of compressed slag is melted, under specified conditions, on the upper surface of the test bricks. The third method aims at measuring the extent of erosion obtained by injecting powdered slag into a blast flame impinging at 45 deg. on the test bricks under standard conditions. A marked feature in all the refractoriness brick-slag composition curves is a relatively low minimum temperature of softening, varying only from 1,140 deg. to 1,200 deg. C., despite a wide variation in the composition of the bricks. From measurements of the depth of corrosion and of penetration, indications of an order of merit in the fireclay and aluminous bricks have been obtained. As a result of the third test, the bricks could be made to fall into two classes—the silica bricks and the remainder—and tentative orders of merit were assigned in each class.

The twelfth section of the report, by Messrs. F. H. Clews, H. M. Richardson and A. T. Green, deals with the action of alkalies on refractory materials. Among other results obtained, it has been found that, in the presence of dry air at 1,000 deg. C., potassium-chloride vapour reacts more readily with fireclay products than with silica, but this distinction is not so marked when moisture is also present. A feature of the reaction with alkali chlorides is the tendency of the materials to expand without loss of shape. Linear expansions of as much as 4 per cent. have been recorded. The action of the vapour from sodium carbonate has shown some analogy with that of alkali chlorides in being absorbed more readily by the fireclay products than by the silica materials. Expansions, such as occurred with the alkali chlorides, however, have not been observed. The same three authors present section 13, which deals with jointing cement. Of the silica cements tested, they found that the most generally satisfactory contained graded ganister and graded silica brick with a total lime content of about 3 per cent. and about 3 per cent. of clay. Finally, Messrs. Clews and Green discuss, in Section 14, the relative merits of the three recognised variants of the refractoriness-under-load test. Using the increasing-temperature constant-load form of the test, considerable differences in the temperature of failure were noted, reaching as much as 100 deg. C. for fireclay and 60 deg. C. for the silica—when employing the fastest and slowest rates. These results are attributed to an appreciable temperature gradient within the specimen. Secondly, investigations, using the maintained-temperature constant-load form of the test, have indicated that the results obtained during the period of constant temperature are a reasonably accurate index of the behaviour of the test-piece. The third form of the test, namely, the maintained-temperature increasing-load procedure, was examined first for materials which show plastic deformation at high temperature, and subsequently for materials which fail by shearing. The deformation-load-time curves, obtained for different rates of loading, have indicated the necessity of standardising this part of the procedure if the test is to pass into general use.

COAL RESOURCES AND THE GAS INDUSTRY.

IN a lecture delivered before the twenty-seventh Annual Conference of the British Commercial Gas Association at Brighton, on Monday, April 24, Sir Harold Hartley, C.B.E., F.R.S., gave a survey of the contribution which the gas industry was making to the problem of the conservation of the nation's resources. Coal, he said, was much more than a mere source of heat units. It was a complex chemical substance, which by suitable treatment would yield gas, a smokeless fuel of great flexibility and almost universal applicability to heating problems; coke, a smokeless solid fuel with many diverse uses from the blast-furnace to the open domestic fire; and, in addition, a variety of chemicals with a wide range of uses, such as motor spirit, wood preservatives and raw materials for the manufacture of tar macadam, dye-stuffs, plastics and high explosives.

Since 1920, when the essential modern function of the gas industry as the producer and supplier of smokeless gaseous and solid fuels had been recognised by the introduction of the therm as a basis for the sale of gas, the efficiency of carbonisation had been increased from 70 per cent. to 80 per cent., representing a saving of over 4,000,000 tons of coal per annum. Improved refractories and methods of construction had greatly increased the lives of retorts and reduced leakage. Mechanical handling had reduced the labour employed in carbonising by 75 per cent. Similar progress had been made with water-gas plant. Purification had become a matter of outstanding importance in relation both to cost, amenities and the effect on the efficiency and life of gas-burning appliances. Research into the principles underlying condensation and gas washing was showing its results in economies, in both cost and space. The drying of gas was eliminating difficulties due to water and rust, while the problems connected with the removal of sulphur, nitric oxide and gum were being steadily solved. Thus on the manufacturing side the steady application of scientific research and control over the wide range of problems had led to great technical progress.

The problem of commercial distribution over longer distances had been solved by the use of high-pressure feeder mains and, as a result of the extensions of the areas of supply, it was estimated that 95 per cent. of the houses in the country were now using gas for one purpose or another. The annual output of gas-burning appliances for domestic purposes was about 2,000,000, more than half of which were cookers. This was due to the introduction of modern designs, while a new range of uses for gas had been found in refrigerators, water heaters, wash boilers, irons and drying cabinets. Automatic ignition, time and remote controls, thermostats and thermo cut-offs all contributed to the effectiveness of the apparatus. The efficiency of cookers had been increased by 15 per cent., of water heaters by 40 per cent., and of gas fires by 30 per cent., which for the average household produced at least 20 per cent. extra service, or 20 per cent. decreased gas consumption for the same service. Thus, the carbonising industries had not only promoted the conservation of coal by more efficient treatment, but had added to its uses by developing novel as well as substitute services. Gas had also made remarkable progress in recent years in the field of industrial heating. Modern designs of equipment based on studies of heat transfer, insulation and recovery gave higher efficiencies than the older solid-fuel appliances and had the advantages of automatic control, convenience, cleanliness and reduced labour and wastage costs.

Considerable advances had been made in the production and utilisation of coke, including the effect of carbonising conditions in different types of retorts and ovens on the characteristics of the output. Blending, moreover, had not only yielded improved cokes, but had enlarged the range of coals from which they could be produced. Improvements in coke quenching, sizing and grading had had an increasing influence on the popularity of coke as a clean and smokeless fuel in the domestic market. Similarly, the redesign of furnaces with automatic gravity-feed stokers, thermostatic control and increased efficiencies had helped to establish coke as a fuel for large central-heating plants and for a variety of industrial heating purposes.

Improvements in the efficiency of the recovery of the chemical by-products had contributed to the increase in the overall thermal efficiency of carbonisation, but it was seriously underrating these by-products to think of them purely on a thermal basis. Benzole and tar represented the only indigenous source of benzene hydrocarbons and their derivatives and were therefore of great national significance, both in peace and war. Phenol was not only the basis of picric acid, but one of the most important raw materials in the plastic industry. Toluene was not only the parent of T.N.T., but the raw material for the preparation of dye-stuffs. In fact, it was true to say that if gas and

coal were no longer required, coal would have to be carbonised to supply the industries that required tar. In addition to tar there was ammonia, which yielded ammonium sulphate for use as a fertiliser. The sulphur that accumulated in the oxide purifiers not only gave a purer atmosphere, but could be converted into sulphuric acid. There were still, however, plenty of problems to be solved, including the widening of the range of coals for carbonisation, complete gasification and improved methods of purification and by-product recovery.

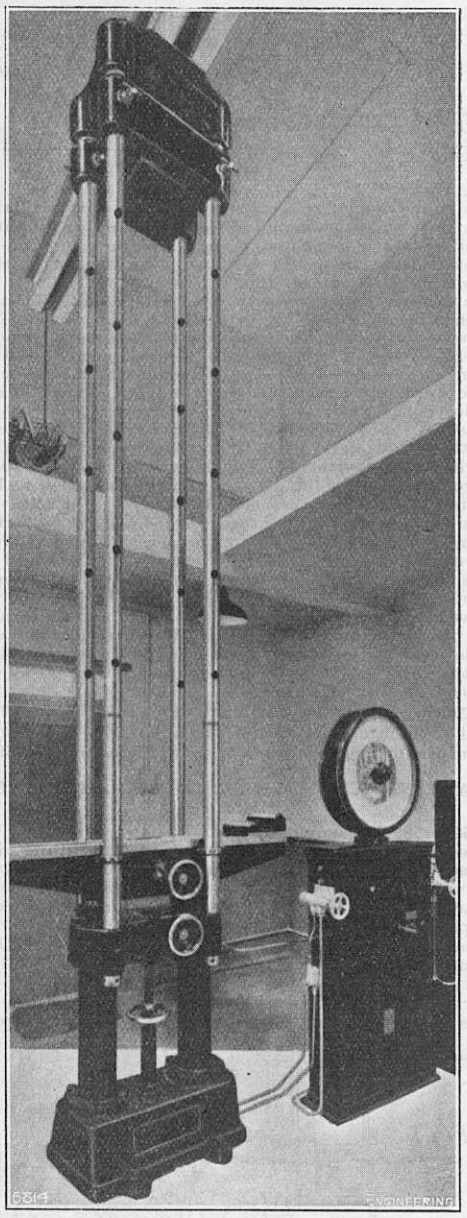
TESTING MACHINE FOR AEROPLANE STRUTS.

THE machine shown in the accompanying illustration has been recently installed in the aircraft factory, at Rochester, of Messrs. Short Brothers (Rochester and Bedford), Limited, by Messrs. W. and T. Avery, Limited, Soho Foundry, Birmingham. It is described as a self-indicating universal testing machine, designed for conducting compression tests on aeroplane struts having a maximum length of 10 ft. It is stated that, while the majority of the specimens will be tested to destruction, proof-load tests will also be carried out. Moreover, tension and transverse testing can be performed, should these be required. We are informed that the machine, which has a capacity of 50 tons, is particularly suitable for rapid testing, but the speed is readily controllable and the rate of straining can be made very slow. The machine consists of a straining unit, shown on the left in the illustration; a pumping unit, partly seen on the right; and a load-indicating cabinet shown in the centre. Oil is employed as the pressure medium and it is delivered from the pump, through the load-indicating cabinet, to the two single-acting cylinders of the straining unit. As is seen in the illustration, these cylinders are arranged side by side upon a base-plate and are connected at the top by a cross-head, which ensures rigidity. Both the cylinders and the rams are machined and ground to very fine limits; packing is not used and a small quantity of oil is permitted to force its way between each cylinder and its ram, thus providing lubrication. This oil is collected in a recess arranged at the top of each straining cylinder and gravitates back to the pump suction tank. The recesses are fitted with wipers to prevent the entry of foreign matter.

The pressure-oil operating upon the rams, within the two straining cylinders, forces the middle cross-head upwards, thus enabling the compression tests to be conducted on specimens inserted between the middle and the upper crossheads. The pump supplying the pressure oil is motor driven and is of the reciprocating ram type. It is fitted with three rams and positively seated valves. The main shaft, which is the only rotating part of the pump, is carried throughout on ball bearings in a rigid cast-iron housing. The latter is bored to receive the main bearings and end cover, and machined to carry the pump body. The pump body consists of a forged alloy-steel block and into this are fitted phosphor-bronze liners in which the three rams work. The rams are of case-hardened alloy steel and are ground and lapped to a fine sliding fit in the phosphor-bronze liners. A cast-iron suction bonnet is bolted to the top of the pump body.

The load-indicating cabinet embodies a cam-resistant type weighing mechanism, a small cylinder, and the requisite reduction levers. The weighing mechanism is in direct connection with the ram of the small cylinder, which is also in communication with the straining cylinders. The cross-sectional area of the ram of the small cylinder bears a definite ratio to that of the main rams of the straining cylinders. The load applied at the main rams is thus proportionately reduced at the small ram and is transferred through the reduction levers to the dial mechanism, to be indicated on the dial seen in the illustration. In order to eliminate friction, the ram of the small cylinder travels in a phosphor-bronze liner, which is steadily rotated, during a test, by worm gearing driven by a flexible shaft geared with the motor driving the pump. Provision is made to ensure the absence of shock after a test by a dashpot and capillary valve. The supply of pressure oil to the testing machine is controlled by valves situated at the sides of the load-indicating cabinet. The delivery from the pump is led to a connection on the control valve at the right-hand side of the cabinet and the supply to the cylinders of the testing machine is regulated by the handwheel shown in the illustration. Any excess delivery from the pump is by-passed, through the control valve, back to the pump suction tank. To avoid pulsations in the transition of pressure to the small cylinder, a separate pipe is taken from the main cylinders to the small cylinder. Hence, any slight pulsation which might remain in the pressure supply is damped out within the main cylinders.

The valve at the left-hand side of the indicating cabinet controls the exhaust from the testing-machine cylinders. The maximum speed the main rams attain, on the return stroke from the upper position, is approximately 2 ft. per minute. This valve also serves to control the pressure oil, from the main cylinders to the small cylinder, in connection with the lever system of the load-indicating cabinet. The pressure on the specimen is maintained or relieved by the operation of the handwheel on this valve. The main dial of the indicating cabinet is of the "shadowless" type, and is relieved to receive the indicating pointer. The dial is double faced to enable load indications to be observed from the front or rear of the machine. Another feature is that two sets of graduations are provided, namely, a major, reading up to 50 tons by 0·1-ton divisions, and a minor, reading up to 20 tons by 0·05-ton divisions.



The change from the one set of graduations to the other is made by turning, through 180 deg., a small handle on the front of the cabinet, when the handle is automatically secured in position. To register the maximum load attained during a test, a second pointer is provided which is carried in frictionless bearings in a small housing secured to the glass of the dial. This second pointer is carried round the dial by the main load-indicating pointer and the contact thus made is employed to pass an electric current to a solenoid in the small housing which, when energised, releases a friction pad positioned adjacent to the loose pointer, leaving it free to rotate. Immediately the main load-indicating pointer moves in a backward direction, the electric circuit is broken and the solenoid de-energised, allowing the friction pad to retain the loose pointer in the maximum position reached during the test. The loose pointer is subsequently returned to its original position by turning a knob on its spindle by hand. To indicate that the electric circuit is functioning during a test, a signal lamp is provided.

ITALIAN IMPORTS OF COAL.—During 1938 Italy imported 11·8 million metric tons of coal, Germany supplying 6·9 million tons, the United Kingdom 2·2 million tons, and Poland 1·6 million tons.

$\frac{3}{16}$-IN. PORTABLE ELECTRIC DRILL.

WE recently described and illustrated in ENGINEERING, vol. cxlvi, page 748 (1938), a $\frac{1}{4}$-in. portable electric drill made by Messrs. The Van Dorn Electric Tools, for which firm Messrs. Black and Decker, Limited, Slough, are distributors. This drill, known as the "Holgun," was notable for its light weight and compactness, and has now been followed by a $\frac{3}{16}$-in. drill, known as the "Hornet," designed generally on the same lines. The new tool is only 6 in. in length overall and weighs 2 lb. 2 oz., the size and weight enabling it to be comfortably manipulated by one hand. With a collet instead of a chuck, the weight is reduced to 1 lb. 14 oz. Ball-bearings are fitted throughout, except at the rear of the chuck spindle, where there is a strong needle-roller bearing. The chuck spindle is of high-grade alloy steel, heat-treated, and the gear wheel is mounted on it with splines, an arrangement which not only increases the strength of the transmission, but facilitates inspection and overhaul. The pinion meshing with the gear wheel is integral with the armature shaft, which is also of heat-treated alloy steel.

The motor is of the universal type, *i.e.*, it can be run on either alternating or direct current. It is adequately ventilated by a shrouded fan. Control is by an instant-release paddle-type switch conveniently actuated, whether the tool is held in the right or left hand. As with the larger drill, the "Hornet" can be used with either a flexible drive or a stiff angle drive. The former enables the drill to be used in situations where a spindle offset of only $\frac{3}{16}$ in. is available, while the latter is very useful in drilling, with one-hand control, holes which cannot be directly reached. All parts of the drill are readily accessible and the housing is so shaped that it fits naturally and comfortably in the palm of the operator's hand.

CATALOGUES.

Heat-Resisting Alloy Steels.—We have received from Messrs. Darwins, Limited, Fitzwilliam Works, Sheffield, data relating to heat-resisting steel and a chart showing the properties of the various alloy steels sold under the trade name of "Pireks."

Non-Ferrous Materials.—We have received a copy of the first issue of *The Tandem News*, published by Messrs. The Eyre Smelting Company, Limited, Merton Abbey, S.W.19, who claim to have the largest and best-equipped white-metal works in Europe.

Hot-Wire Vacuum Switches.—Messrs. Sunvic Controls, Limited, Stanhope House, Kean-street, Aldwych, London, W.C.2, have sent us a booklet describing hot-wire vacuum switches used in conjunction with toluene regulators and other thermostats.

Profile Projector.—Messrs. Taylor, Taylor and Hobson, Limited, Leicester and London, have sent us a booklet describing their 200-in. profile projector, which was illustrated and described in ENGINEERING, vol. cxlviii, page 174 (1935), and illustrating its applications.

High-Duty Castings.—Messrs. Ashmore, Benson, Pease and Company, Limited, Parkfield Works, Stockton-on-Tees, who are licensees of the International Meehanite Metal Company, Limited, have sent us a leaflet giving technical data on the properties of their castings.

Crushing and Screening Machinery.—We have received a catalogue describing the crushing and screening plant for mines and quarries, manufactured at the Fraser and Chalmers works of Messrs. The General Electric Company, Limited, Magnet House, Kingsway, London, W.C.2.

Cables.—We have received from Messrs. British Insulated Cables, Limited, Prescot, Lancashire, a pamphlet giving particulars of conveyor and drill cables for use in coal mines, and complying in all respects with the regulations of the Mines Department of the Board of Trade.

A.R.P. Material.—"Ribmet" reinforcing units, for permanent concrete trench lining, made by Messrs. The Expanded Metal Company, Limited, Burwood House, Caxton-street, London, S.W.1, are described in a pamphlet recently received. The design is stated to have the approval of the Home Office.

Heavy-Oil Engines.—Messrs. The National Gas and Oil Engine Company, Limited, Ashton-under-Lyne, have sent us a leaflet describing a new range of Diesel engines developing 50 to 55 brake horse-power per cylinder at 500 to 550 r.p.m. and, when pressure-charged, capable of a 50 per cent. increase in power.

Fireproof Panelling.—In addition to protected-metal roofing, Messrs. Cellactit and British Uralite, Limited, Lincoln House, 296 to 302, High Holborn, W.C.1, manufacture "Kimpoloboard," a panelling intended for use in extreme cases of fire hazard. A brochure to hand describes a series of tests showing that this material is completely resistant to the action of thermit.

Pulsator Jigs and Classifiers.—From Messrs. The General Electric Company, Limited, Magnet House, Kingsway, London, W.C.2, we have received a leaflet describing the "Richards" pulsator jigs and classifiers, manufactured at their Fraser and Chalmers Engineering Works, for dealing with mining products. It is claimed that, as the pulsations occur in an upward direction only, a larger tonnage of mineral can be handled per unit of space occupied.

"ENGINEERING" ILLUSTRATED PATENT RECORD.

SELECTED ABSTRACTS OF RECENT PUBLISHED SPECIFICATIONS UNDER THE ACTS OF 1907 TO 1938.

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, W.C.2, at the uniform price of 1*s.*

The date of the advertisement of the acceptance of a Complete Specification is, in each case, given after the abstract, 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.

HYDRAULIC MACHINERY.

501,454. The English Electric Company, Limited, of London, and P. W. Seewer, of Rugby. Sluice Valves for Dams. (3 *Figs.*) August 31, 1937.—The sluice valve is intended for application in cases where use is made for power purposes of water passing through some of the sluices of an existing dam designed primarily for irrigation. The necessary conduits and valves can be put in place with the minimum alteration to the existing sluices and the forces on the dam are unaltered both in magnitude and in directions and points of application. Furthermore, a space is maintained above and around the sluice valve extending vertically through and right down to the bottom of the dam which is sealed off from the upstream side of the dam, the flow being in the direction of the arrow. Before the addition of the sluice valve, a channel-shaped iron casting 1 extending up each side of the culvert served as the guide for a sluice gate. The operating gear for the gate extended up through a well 6 passing vertically through the dam. The gate when closed served to seal off the well 6 from the culvert and to seal off a space 7 at each side between the gate and the casting 1 which space forms a continuation of the well down to the bottom of the dam. In applying the present sluice valve, the casing 8 is inserted in the culvert so that it is sealed to the channel casting 1 and top and bottom linings of the culvert around the whole of its front edge by

Fig. 1.

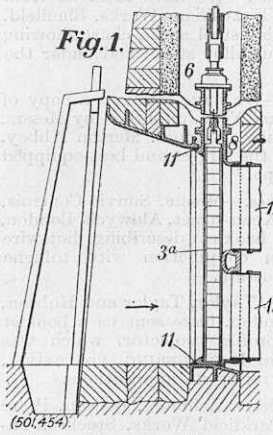
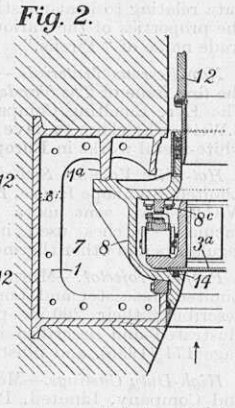


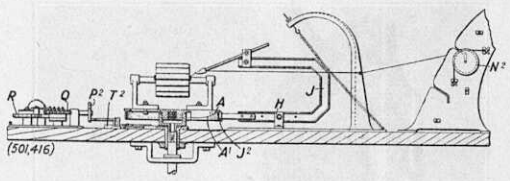
Fig. 2.



gutta-percha rings 11. The casing is tightly held by wedge strips between the channel casting 1 and the front of the casing. A backward extension from each side of the casing also bears tightly against that part 1*a* of each channel casting 1 which previously received the thrust of the sluice gate. Tubular conduits 12, one above the other, are secured to the back of the casing 8 by expansion joints. The existing sluice gate, modified by the reduction of its width, runs within the casing on rollers which run on a track plate carried by the ridge 8*c* mounted on the back inner wall of the casing 8 and serves as the valve to close the entrance of each of the conduits 12. The pressure on the face 3*a* of the gate is transmitted to the casing 8 by way of the ridge 8*c* and thence to the existing channel castings 1 at the points 1*a* at which the forces due to the pressure on the existing gate were previously applied, and thus the same forces are applied to the dam at the same places. In the front inner wall of the casing 8 is a continuous groove of trapezoidal cross-section within which lies a rubber strip 14 urged outwards by fluid pressure applied to the back of the groove and bearing against the front plate 3*a* to form the sealing packing. To leave the gate free for operation the pressure behind the rubber is relieved by opening an exhaust valve. The top of the casing 8 is open to permit the gate and its operating gear to pass through into the well 6, a cover being detachably secured and sealed to the top of the casing to form the chamber which receives the gate when the valve is fully open. The operating gear passes through this cover and through a gland at the top. The detachable cover of the casing is smaller than the interior of the well 6 so as to leave the inner surfaces of the latter accessible for inspection and repair.—(*Accepted February* 28, 1939.)

ELECTRICAL APPARATUS.

501,416. F. Nolten, of Nottingham. Armature-Winding Machine. (4 *Figs.*) August 27, 1937.—A circular table A rotates in a horizontal plane, being driven by a variable-speed electric motor. The rotating table is mounted just above the level of a bench and carries on its upper face two brackets set diametrically opposite to each other. These brackets are secured in radial slots in the table so that the distance between them can be adjusted. Their upper ends carry bearings for the axle of the armature to be wound, the adjustment of the brackets providing for varying lengths of armature. On the bench at the side of the table is a fixed plate carrying a bracket H which can be adjusted at varying distances from the edge of the table. A lever J is mounted on a horizontal pivot in the bracket H and a roller J^2 on its inner end bears upon cam surfaces A^1 on the edge of the rotating table A. To vary the amplitude of the oscillations of this lever its pivot can be moved nearer to or away from its inner end when the bracket H is moved nearer to or away from the edge of the table. The inner end of the lever J is pressed against the cam surfaces on the table by a spring connected to its outer end. The action of this spring is checked by another spring which is opposed to it and the tension of which can be adjusted. A finger carrying a guide for the wire is attached to the free end of the lever by a universal joint.



The guide can be set in any position relatively to the armature and the amplitude of its rising and falling motion can be regulated to suit armatures of various sizes and also to lay the wire in the correct slots in the armature for a two- or four-pole winding. The wire is drawn from a spool secured on an axle mounted in end standards. The axle is fitted with brake drums N^2 to which adjustable brakes are applied so that the tension on the wire can be regulated. A star wheel P^2 and a worm are mounted on a shaft of a counting mechanism. The worm gears with a worm wheel Q mounted on an independent bedplate which also carries a ratchet wheel R. The star wheel P^2 has five arms and is intermittently advanced by a bell-crank lever pivoted on a spring-returned slide T^2 which is projected once per revolution of the table by a cam on the axle of the latter. One end of the bell-crank lever is held between two fixed pins while its other free end engages with the arms of the star wheel P^2 and advances it one-fifth of a revolution at each revolution of the table. The wheel Q has an arm which advances the ratchet wheel R one tooth at each revolution. Both of the wheels Q and R have the same number of holes as teeth, and a pin can be placed in any of the holes in the wheel Q, while an axle which carries a lever can be placed in any of the holes in the wheel R. When the table A has made the predetermined number of revolutions, the end of the lever is engaged by the pin and oscillated so that its other end trips an electric switch which cuts the current off from the driving motor. (*Accepted February* 27, 1939.)

MACHINE AND OTHER TOOLS, SHAFTING, etc.

501,458. Greenwood and Batley, Limited, of Leeds. J. C. M. Maclagan and W. B. Pilling, of Leeds. Bolt-Head Trimming Machine. (4 *Figs.*) September 6, 1937.—The machine consists of a bedplate on which is mounted a shaft carrying a flywheel. A pitman mounted on the eccentric 6 of the shaft reciprocates a trimmer slide, and the forward end of the trimmer slide carries a holder for the shearing tool 10. In axial alignment with the shearing tool is the supporting die 11, to which the bolts are fed in turn, and this supporting die is mounted in a holder and backed

Fig. 1.

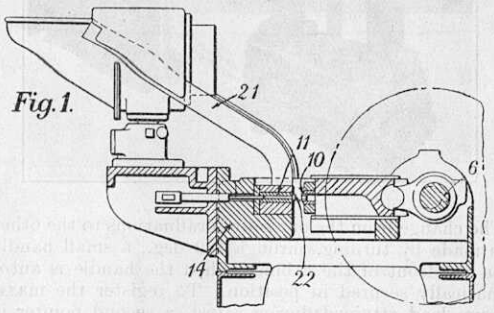
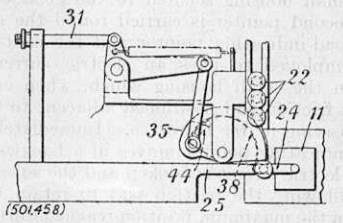


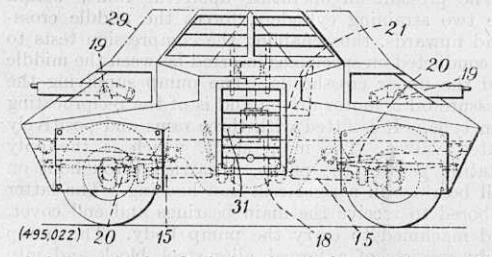
Fig. 2.



by a thrust plate supported by a heavy casting forming a part of the body of the machine. An ejector pin passes through a hole in the back thrust plate. On the heavy casting is mounted a hopper for the cheese-headed bolts to be trimmed. The untrimmed bolts are fed from the hopper in turn to a transfer position alongside the supporting die by a chute consisting of side bars 21, between which the untrimmed bolts 22 are supported by their heads, a cover bar retaining the bolts in position. The supporting die is formed with a lateral slot 24, which extends through the die 11 from front to back, while the holder has a lateral extension the upper surface of which is aligned with the underside of the slot in the die 11. Each bolt 22 is delivered to the transfer position in front of the transfer plate 25 by a feeding mechanism, and is pushed along the upper surface of the holder extension by the transfer plate until it is in axial alignment with the shearing tool. The inner end of the slot in the die and the pushing end of the transfer plate which enters the slot grip the shank of the bolt, while the forward edge of the transfer plate is flush with the forward face of the die, so that when fully home in the slot it completes the support for the bolt head. The feeding mechanism consists of a stop bracket carried on the transfer slide. A bell-crank lever is pivoted to the bedplate, and a stop rod 31 connected to the bell-crank lever slides in a bore in the bracket. A stop nut on the rod is adjustable as required. A link connects the bell-crank lever to the rocking feed-quadrant 35, which partially encloses an inner support-quadrant 38, and both are carried on the same fulcrum pin. A tension spring retains the quadrants in the up or open position ready to receive a bolt from the chute bars. After a bolt has been trimmed and ejected the transfer slide recedes, and the bracket meets the stop nut when the slide is almost at the back of its stroke and rocks the feed-quadrant 35. This sweeps the next bolt, 22, round into position in front of the transfer plate 25. The inner support-quadrant 38 is rocked back by a peg secured to the outer quadrant 35 and engaging a slot 44 in the inner quadrant 38, which allows the latter to move back when the bolt has been carried round into the transfer position. In the top, or open, position the bolt 22 is held between the inner quadrant 38 and the die block. By feeding the bolt laterally into the supporting die the length of stroke of the shearing tool is considerably reduced, so that the machine can be made shorter and more rigid. Variation in the length of the bolt shanks does not affect the setting of the trimming slide. (*Accepted February* 28, 1939.)

MOTOR ROAD VEHICLES.

495,022. Commer Cars, Limited, of Luton, and A. H. Glasspole, of Luton. Armoured Car. (2 *Figs.*) April 1, 1937.—The invention is an armoured car which can be readily driven in either direction and yet is capable of rapid and inexpensive production. The chassis essentially consists of two longitudinals cross-braced at intervals and supported by semi-elliptic springs from a pair of axles. These carry, adjacent to one longitudinal, differential mechanisms driven from a pair of aligned propeller shafts 15 connected with opposite sides of a gearbox mounted centrally and transversely in the chassis. A transverse cradle on the chassis supports a power unit 18 and clutch between which and the gearbox is a reversing gear. In front of and behind the power unit are gun mountings 19 with seats 20 for the gunners,



each below the level of the chassis longitudinals. The seat 21 for the driver is rotatably mounted on a vertical pillar, the axis of which passes through the centre of the chassis. The pillar carries within it a steering shaft operated by either of two steering wheels, one in front of the pillar and one behind, each being so geared to the shaft as to preserve uniform direction of rotation. The steering shaft is connected to all four wheels. A single control for the gearbox and reversing mechanism can be operated by the driver in whichever position his seat is, but clutch and brake pedal controls are provided fore and aft of the pillar. The whole is armour-cased, the driver's housing being raised above the gun mountings to provide good visibility. The top portion of the driver's housing can be slid fore and aft, as shown at 29, to improve the driver's visibility, hinged covers being provided to fill in the gaps left when the slidable portion is moved. The casing extends outside the road wheels, having a louvre inlet 31 where the radiator of the power unit is mounted. A spare wheel is carried vertically opposite the radiator, while a space between the spare wheel and the adjacent chassis longitudinal houses fuel tanks, batteries and other accessories. Fore and aft of the driver's position there is space for ammunition and crew. The vehicle can be driven in either direction through all the gear ratios, while by steering all four wheels each wheel may have a smaller lock, for a given turning circle, than if only two wheels are steerable, and this facilitates the enclosing of the wheels in the armour-casing. Each gun has a traverse of slightly more than 180 deg., so that the zones of firing can overlap. As both axles, the wheel hub assemblies and numerous other parts are the same at both ends of the vehicle, there is considerable economy in the manufacture and assembly of such parts, and in this way the car is one which admits of being rapidly produced when necessary. It can tow from either end without having to manœuvre into position, and is effectively controlled in awkward positions, as the driver can always face the direction in which he desires to travel. The total tractive effort available at the ground is a percentage of the total vehicle weight. Moreover, the gearbox can be designed to provide a suitable drive for a winch to move disabled or ditched vehicles or guns where the tractor cannot approach for towing purposes.—(*Sealed.*)