

ARTIFICIAL-FERTILISER FACTORY AT SINDRI, INDIA.

THE new artificial-fertiliser factory of Sindri Fertilizers and Chemicals, Limited, which was opened by the Prime Minister of India (Pandit Nehru) at Sindri on Sunday, March 2, is the outcome of advice, given by the Foodgrains Policy Committee in July, 1943, that immediate steps should be taken to increase the production of nitrogenous fertilisers in that country to 350,000 tons per annum. A mission of experts from Imperial Chemical Industries, Limited, and the Power-Gas Corporation was therefore appointed to examine the position. After close investigation, they recommended the establishment of one large factory either at Harduaganj, near Aligarh, or at Sindri, in Bihar, on the banks of the Damodar river, about 14 miles downstream from Dhanbad. Although the cost of erecting the factory was more, the second of these two sites was eventually chosen, owing to the fact that the railway wagons carrying coal to the North Punjab could be used on their return journey for the transport of the gypsum required for fertiliser manufacture. The Chemical Construction Corporation of New York were appointed to prepare designs for

In spite of many difficulties, particularly those associated with the supply of materials and transport, good progress was made; the first boiler was lighted in December, 1950, and the first turbo-alternator was commissioned in February, 1951. The first part of the gas plant was commissioned two months later and the first ammonia converter in July, 1951. Pure anhydrous ammonia was made for the first time on August 28, 1951, and ammonium sulphate was delivered to the silo on October 30, 1951.

The factory proper is divided into four main groups: power plant, gas plant, ammonia synthesis plant, and sulphate plant, with which are associated common facilities for maintenance, handling materials and supplying water and process steam. As an indication of the size of the establishment it may be mentioned that about 800 tons of coal, 500 to 600 tons of coke and 1,800 to 2,000 tons of gypsum are being handled daily, as well as 20 to 30 tons of miscellaneous stores. When coke ovens are installed, 900 additional tons of coal will have to be dealt with. The daily outgoing products will consist of 1,000 tons of ammonium sulphate and 600 tons of cement (when the cement factory is built), as well as 300 to 400 tons of ashes and other waste products.



FIG. 1. SEMI-WATER-GAS PLANT AND GASHOLDER.

the factory, and the Power-Gas Corporation, Limited, Stockton-on-Tees, were employed to construct the factory, to supply certain specialist plant of their own manufacture, and also to act as agents for the remaining equipment, as much as possible of which was to be made in India. The agreement with the Power-Gas Corporation was signed on June 2, 1947. Brigadier M. H. Cox, C.I.E., O.B.E., M.I.Mech.E., chief technical adviser to the Government of India, directed the project.

Work on the 350-acre site was begun by the Central Public Works Department early in 1945 and included the removal of some 1,200,000 cub. yards of earth and the use of 91,000 cub. yards of reinforced concrete for the foundations of the buildings and plant. About four miles of deep sewers and $1\frac{1}{4}$ miles of cable trench were also laid, as well as formation work for 8 miles of railway sidings. In addition, a metalled road, about 6 miles long, and including two substantial bridges across nullahs, was constructed to link the factory area with the district road system near Pathardihi. This work was carried out by the Bihar Public Works Department. The connection of the factory with the main East Indian Railway system involved the construction of a branch line about 6 miles long with embankments up to 50 ft. high and a number of bridges.

The problem of handling these great quantities has been complicated by the fact that while some of the incoming raw materials can be carried in open trucks, the finished products must be loaded into covered wagons, so that a considerable interchange of empties will be necessary.

The incoming raw materials are handled by three separate electrically-operated tippler-belt conveyor systems, one for coal, one for coke and the third for gypsum. The tipplers, which were constructed by Messrs. Strachan and Henshaw, Limited, Bristol, have been specially designed to deal with both open and closed wagons. After being run on to these tipplers the side doors of the wagons are opened and the platform, which is mounted on a three-point suspension, is tilted to an angle of 40 deg. As a result, the material in the centre of the wagon is discharged into underground hoppers. The system is then rocked so as to clear first one end of the wagon and then the other, and finally the wagon is lowered to track level and run off. Up to 12 wagons per hour can be dealt with in this way on each system.

The materials are next taken from the hoppers by Sherwin electromagnetic vibrating feeders on to one of several conveyor-belt systems, the total length of which in the factory is 10,700 ft. The feeders and conveyors were supplied by Fraser and

Chalmers Engineering Works, Erith, and are electrically driven. Mimic diagrams are installed, where necessary, to indicate the parts of them that are in use, and interlocks and limit switches are provided so that any part of the system is shut down in case of a fault. The incoming coal can be delivered either to the boiler-house bunkers or to a stockyard. In the former case, it is passed through ring-type crushing mills, made by the American Pulverizer Company, St. Louis. It is recovered from the store by 8-cub. yard scrapers, which are operated by crawler tractors.

As most of the mines in the Bihar coalfields were supplied with electric power from local generating plant, the Government had intended for some time to modernise the arrangements by erecting a central thermal station and installing a grid distribution system. The site selected for the new station was actually at Sindri. After the plans for establishing the fertiliser factory at that place had taken shape, however, it was decided to build a single 80-MW station, for the supply of power both to the grid and to the factory, as well as to provide process steam for the latter. A description of this station was given on page 44, *ante*, but it may be recalled that it is capable of dealing with a factory load of 45 MW and a grid load of 13 MW, as well as supplying 300,000 lb. of process steam per hour at a pressure of 25 lb. per square inch gauge to the factory and 23,000 lb. of boiler feed water per hour to the jackets of the generators in the gas plant. Electricity is distributed from it to 12 factory substations on the three-phase system at 11 kV through about 5 miles of cables, which were made by British Insulated and Callender's Cables, Limited, Norfolk-street, London, W.C.2. These substations are equipped with 38 transformers, made by the English Electric Company, Limited, Kingsway, London, W.C.2, the total capacity of which is 79.5 MVA. The voltage is stepped down in these stations to 3.3 kV, at which value motors with individual outputs of 200 h.p. or more are supplied. Motors of lower output down to $\frac{1}{2}$ h.p. are supplied through other transformers at either 400 or 230 volts, depending on their size. There are 510 motors with an aggregate output of 15,000 h.p. in the factory, in addition to those which form an integral part of the plant they drive, such as the compressors and recirculators. The lighting throughout the factory, which was installed by the General Electric Company, Limited, Kingsway, London, W.C.2, is supplied at 230 volts. Control of the feeders and the medium and low-pressure equipment is effected by switchgear made by Messrs. A. Reyrolle and Company, Limited, Hebburn, Co. Durham, some 140 oil circuit-breakers being supplied for this purpose.

Nitrogenous fertilisers are produced by the fixation of atmospheric nitrogen by combining it with hydrogen to form ammonia. At Sindri, the semi-water-gas process is used for this purpose; it involves the daily consumption of 500 to 600 tons of high-grade metallurgical coke, which is handled by a Strachan and Henshaw tippler and Fraser and Chalmers conveyor-belt system, similar to that described in connection with the power plant. This system delivers the coke either directly to the gas plant or to stock. As it will be necessary to store considerable quantities of coke until the coke ovens are built, two runs of elevated gantry, each 1,040 ft. long, have been installed; they are equipped with conveyors and trippers so that four parallel banks of coke, some 20 ft. high and containing 30,000 tons, can be built up. Coke from this stockyard, or direct from the tippler, is delivered through crushers, where it is reduced to a size of 3 or 4 in., to bunkers on the roof of the gas plant.

The gas plant, the building of which is shown in Fig. 1, was supplied by the Power-Gas Corporation. It consists of eight water-gas generators and is capable of producing 33 million cub. ft. of gas per day with seven units working. The generators are supplied with coke from automatic cyclic chargers; each is in the form of a cylindrical steel vessel, the upper portion of which is brick-lined, while the lower portion is boiler-jacketed. Each generator is provided with a revolving base-plate, which supports a grate and ash boxes. Blast is forced through the grate to the fuel bed and the ash is extracted into railway wagons. Steam is generated in the

THE SINDRI ARTIFICIAL-FERTILISER FACTORY.

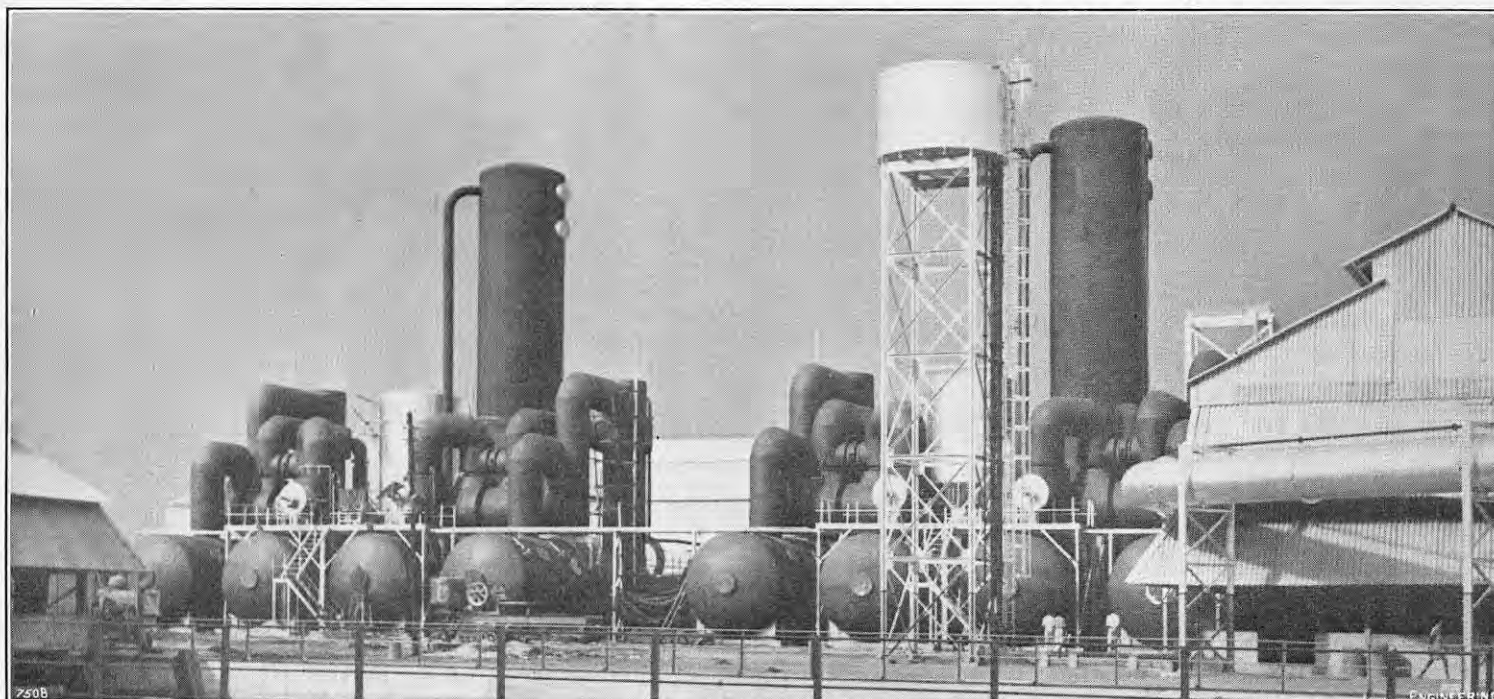


FIG. 2. CARBON-MONOXIDE CONVERSION PLANT.

boiler jackets at a pressure of 20 lb. per square inch and is available for use in the gasification process, the arrangement of which is shown diagrammatically in Fig. 4. The gas-making cycle consists essentially of blow and run periods lasting in all three to four minutes, during which the fuel bed is alternately heated up by the introduction of air alone and cooled during gasification. Automatic control is effected by a hydraulic controller working at 1,000 lb. per square inch, interlocks being provided to prevent a dangerous sequence or combination of valve operations. Each generator can be run continuously except or the short period during each shift which is necessary for emptying the ash boxes and examining the fuel bed. The cycles of the various generators are staggered to ensure continuity of output.

The gas, which consists of 36 per cent. of carbon monoxide, 34 per cent. of hydrogen, 22.9 per cent. of nitrogen, and 6.5 per cent. of carbon dioxide, is delivered to three washing and cooling towers, which can also be seen in Fig. 1. It flows through these towers in an upward direction and meets a downward stream of water as it flows. This water flows over a number of alternate cones and discs to ensure intimate contact with the gas. Nearly 200,000 gallons of water per hour are used in this system and are re-circulated by pumps through a settling tank, so that the amount of make-up is small. Equipment for adding a solution of soda ash to the system is installed, so that the sulphuretted hydrogen will be partially removed. The cooled washed gas is delivered to a raw-gas holder with a capacity of 500,000 cub. ft., which acts as a buffer to balance any variation between the rates of gas production and of delivery through the subsequent processes. This gas-holder, which is of the spirally-guided type, is 100 ft. in diameter and 100 ft. high when fully extended. It is fitted with alarm and shut-down equipment which operates when its contents have reached about 90 per cent. of the full capacity, or have fallen to about 10 per cent. of that amount.

Gas will be delivered from the new gas-holder by boosters through purifier filter boxes, which are filled with over 1,000 tons of iron oxide and are designed to remove solid impurities as well as the remaining sulphuretted hydrogen. The gas then passes to the carbon-monoxide conversion plant, a view of which is given in Fig. 2. In this plant, it is first saturated with warm water and, after further steam has been added, the mixture is passed through heat exchangers, so that conversion is carried out in two stages under the most efficient temperature conditions. Much of the heat of

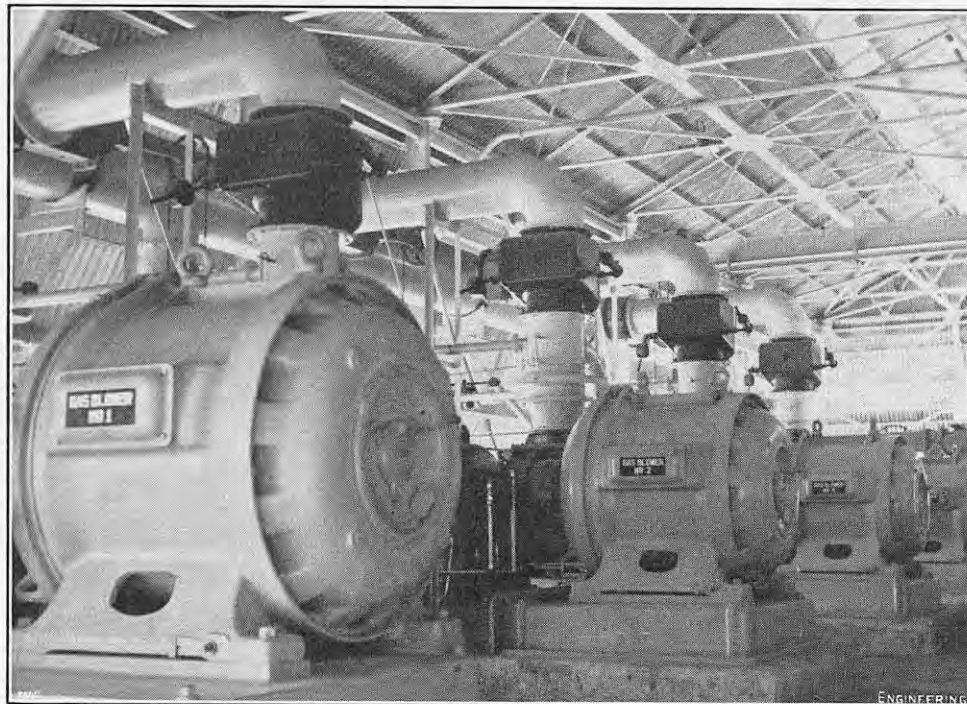


FIG. 3. GAS BOOSTERS.

reaction generated in the process is transferred from the converted gas to the incoming gases in these heat exchangers, after which the outgoing gas is further cooled in a saturator and condenser. The plant comprises two main circuits, each of which consists of a water heater saturator, two sets of primary and secondary heat exchangers, two sets of primary and secondary converters and a final condenser, as shown in Fig. 4. The water-circulating and cooling system is common to both circuits. A view of the gas boosters used to supply gas at the required pressure to this part of the plant is given in Fig. 3.

The converted gas is delivered to a second holder from which it is withdrawn subsequently for compression to a pressure of 20 atmospheres before it is delivered to the carbon-dioxide removal plant. This plant consists of towers, of which an illustration is given in Fig. 7, Plate XIII. Water is delivered to the top of the towers by electrically-driven pumps and flows down it against the upward stream of gas. The motors driving these pumps are mounted on the same shaft as turbines which

are operated by the descending water, thus saving a considerable amount of power. The carbon dioxide is released in two stages in de-gasifying tanks the greater part of it being afterwards stored for use in the carbonating section of the ammonium sulphate plant. Most of this gas plant, with the exception of the heat exchangers, was fabricated in India.

The ammonia synthesis plant, the arrangement of which is shown diagrammatically in Fig. 5, consists of six main sections, which are housed in a U-shaped steel-frame building with asbestos-cement panelling. The first section consists of eight horizontally-opposed staggered-cylinder six-stage compressors with a 14-in. stroke, which were manufactured by the Cooper Bessemer Company, Limited, Mount Vernon, U.S.A., and are directly driven by 2,750-h.p. 3.3-kV synchronous motors running at a speed of 300 r.p.m. A view of these compressors appears in Fig. 8, Plate XIII. The composition of the gas, by volume, at the intake to this section of the plant is: hydrogen, 39 per cent.; carbon monoxide,

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Fig. 4. GAS-PRODUCTION FLOW DIAGRAM.

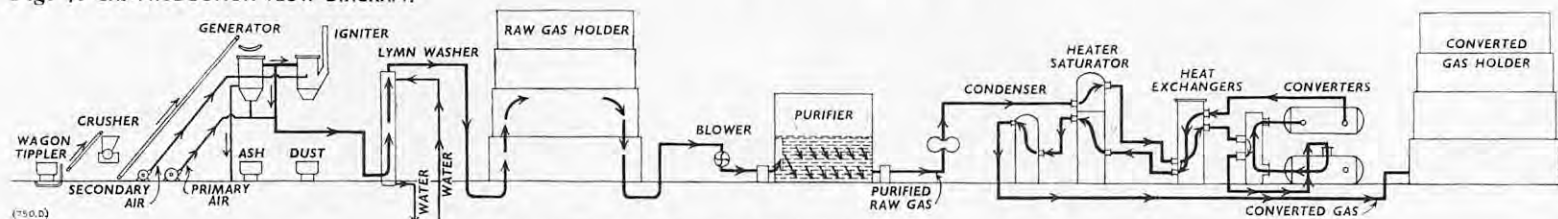


Fig. 5. AMMONIA-SYNTHESIS FLOW DIAGRAM.

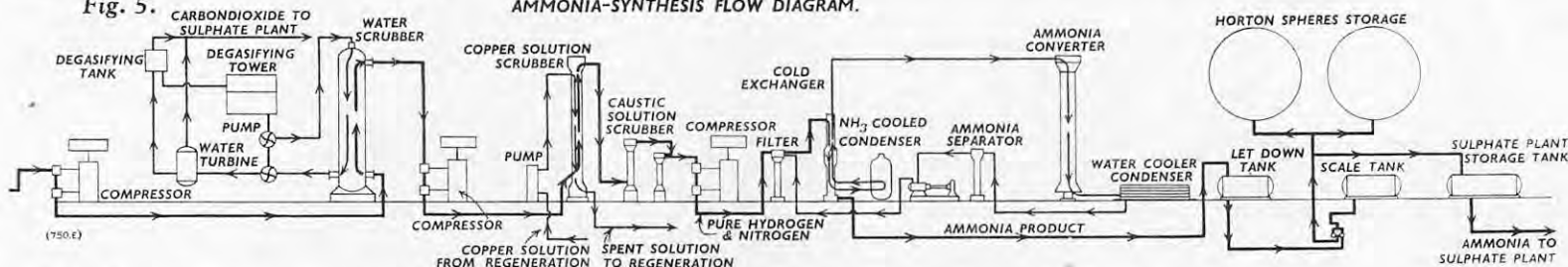
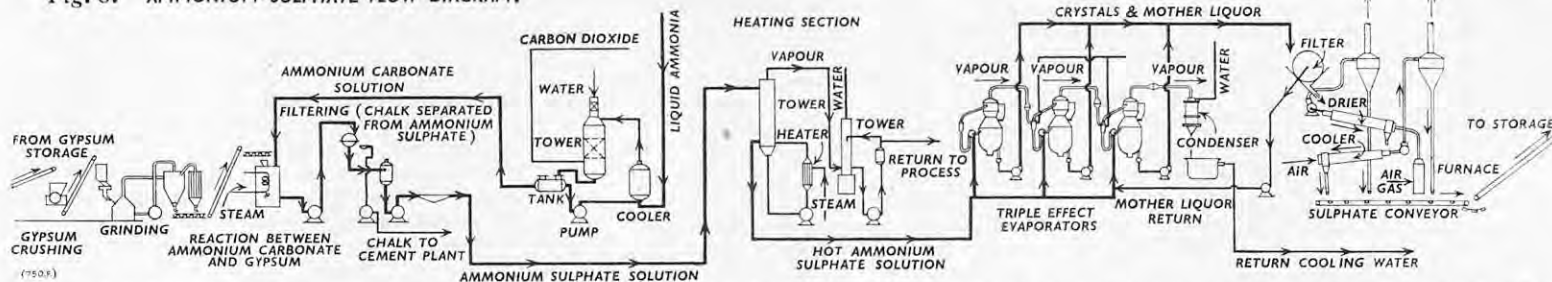


Fig. 6. AMMONIUM-SULPHATE FLOW DIAGRAM.



31 per cent.; nitrogen, 22 per cent.; and carbon dioxide, 8 per cent. There are also traces of argon and methane. All these gases, with the exception of the hydrogen and nitrogen, are removed as the mixture passes through the six stages of compression. During the first three of these stages, the incoming gas is successively compressed to a pressure of 280 lb. per square inch and the carbon dioxide is extracted from it by passing it through welded scrubbing towers, which were constructed by Messrs. John Thompson, Limited, Wolverhampton. An illustration of these towers, which are 75 ft. high, is given in Fig. 7, Plate XIII. The circulation of water through these towers is effected by centrifugal pumps, manufactured by the Harland Engineering Company, Limited, Alloa, which are coupled both to a 1,450-h.p. motor and a 575-h.p. Francis turbine, the latter being driven by the falling water as explained above. After further compression to 1,800 lb. per square inch, the gas is washed with ammoniacal copper solution to remove the carbon monoxide and some of the carbon dioxide. The rest of the carbon dioxide is extracted with caustic solution. During the sixth stage of compression, the gas is compressed to 5,200 lb. per square inch and is then passed to the ammonia synthesis section.

In this section, the leading features of which are high pressure, elevated temperature and catalytic action, liquid anhydrous ammonia is produced by the N.E.C. process. The equipment installed for this purpose, which has a total output of 270 tons per day, consists of four independent converters, each comprising a circulating compressor, an oil filter, an ammonia-cooled condenser and cold exchanger, a converter holding a charge of catalyst and a water-cooled condenser. The catalyst charge is maintained at a temperature of from 500 to 550 deg. C. by heat exchange between the incoming and outgoing gases. The purified and compressed nitrogen-hydrogen mixture is delivered to the synthesis system and is mixed with gases at the circulator outlets, where the greater part of the ammonia has already been condensed from the gas. After any oil has been removed the gas mixture is passed through a condenser and cooled so that the ammonia is condensed. Water and acidic compounds, which would poison the catalyst, are also removed, owing to the great affinity of the condensing ammonia for them. The scrubbing towers in the purification section are hollow-forged vessels,

machined all over and were manufactured by the English Steel Corporation, Limited, Sheffield. After leaving the condenser the gas mixture enters the ammonia converter and is then passed to coolers where the greater part of its ammonia content is removed as liquid anhydrous ammonia. The uncondensed gases are led to the circulator for re-circulation through the system. The refrigeration section contains all the equipment necessary for supplying refrigerant, both to the regenerated copper solution in the purification section and to the ammonia-cooled condensers in the synthesis section. It includes five electrically-driven ammonia compressors with their condensers and associated equipment, as well as the same number of recirculating compressors, all of which were supplied by the Worthington Pump and Machinery Corporation, Harrison, New Jersey.

The anhydrous ammonia, produced in the synthesis section, is passed through two horizontal measuring tanks and thence to spherical vessels for bulk storage. These vessels, an illustration of which appears in Fig. 9, Plate XIII, are used owing to the reduction in the amount of steel required in their construction. They were supplied by the Whessoe Foundry and Engineering Company, Darlington, and are 45 ft. 8 in. in diameter with a wall thickness of $\frac{7}{8}$ in. The shaped plates, of which they are formed, were delivered ready for welding at Sindri and were completed on site. Each sphere weighs 145 tons and has a capacity of 800 tons of liquid ammonia. They are lagged with cork, so that a storage temperature of 30 deg. F. is maintained. The internal maximum working pressure is 50 lb. per square inch, which is generated by a re-compression system. The compressors in this section of the plant were supplied by Messrs. Peter Brotherhood and Company, Limited, Peterborough.

The ammonium-sulphate plant consists of eight main sections, shown diagrammatically in Fig. 6. In the first of these the incoming gypsum is handled by a tippler and conveyor system, similar to that used in other parts of the plant; and is then taken either direct to the crushing mills or to a covered stockpile with a capacity of 90,000 tons, equal to about seven week's requirements. The crushing equipment comprises two Pennsylvania Impact hammer mills manufactured by Fraser and Chalmers Engineering Works, Erith. After passing through these mills the gypsum is taken to eight grinding mills of the Lopulco type, which were supplied

by International Combustion, Limited, Derby. Each of these mills is capable of producing 11 tons of ground gypsum per hour from raw material, which can pass through a screen of 1-in. mesh. The ground gypsum is then taken by conveyors to the inlet of the reaction and filtration plant, where it is fed into ammonium-carbonate solution in the presence of excess of carbon dioxide. As a result, double decomposition takes place in a series of steam-heated reactors, ammonium sulphate being produced in the form of liquor and calcium carbonate as an insoluble precipitate, which is subsequently separated from the solution in the Endflow filters, which are shown in Fig. 10, Plate XIV. The filtered-liquid which still contains some particles of chalk, is next settled out in stainless-steel tanks, which are fitted with equipment for automatically drawing off the liquor and removing the deposit. The pumps employed in connection with this part of the plant were manufactured by Messrs. Mather and Platt and Company, Limited, Manchester, and the British Labour Pump Company, Holloway, London, N.7.

The clear liquor from the settling tanks still contains some free ammonia and carbon dioxide. These impurities are, however, removed in a decomposition section, an illustration of which appears in Fig. 11, Plate XIV, and are sent back to be recycled in the carbonation section. The purified ammonium-sulphate liquor is next passed through a series of multi-effect Krystal evaporators, manufactured by Messrs. Ashmore, Benson, Pease and Company, Limited, Stockton-on-Tees, in which the excess water is driven off and crystals of ammonium sulphate are formed. These evaporators, a view of which appears in Fig. 12, Plate XIV, have an annual output of 350,000 tons of sulphate crystals, to produce which a daily consumption of 3,000 tons of feed solution, 600 tons of exhaust steam, 5,350,000 gallons of cooling water and 7,200 kW of power for driving the circulating and regulating pumps, are necessary. The installation consists of nine stainless-steel vessels, each with an external heat exchanger and liquor circulating pumps. The upper part of the vessel, in which evaporation takes place, is 12 ft. 6 in. diameter, and the lower, where the crystals form and grow, is 14 ft. 6 in., the combined height of the two being 40 ft. The internal surface of the lower vessel is of stainless steel to eliminate the caking of the crystals and inside it is a central pipe, which carries

supersaturated liquor from the upper part. This liquor causes the dense suspension of crystals, which is already in the lower container, to grow so that they sink to the bottom of the vessel and are removed. The pumps, by means of which the liquor in the vessels is circulated, are designed so that they do not crush the crystals.

The wet crystals are fed to rotary driers, manufactured by Messrs. Edgar Allen and Company, Limited, Sheffield. Here they are dried by hot inert gas and are subsequently cooled by air in equipment of similar design. Any sulphate dust, which is carried over in the air stream, is separated out and returned to the belt conveyor. The sulphate is transferred from the outlets of the coolers to a conveyor system, which delivers it either to a storage silo or direct to the bagging plant. The silo, of which an illustration appears in Fig. 13, Plate XIV, is a reinforced-concrete building 660 ft. long. It comprises 22 independent arch sections, each 30 ft. long, which have a span of 143 ft. between abutments and a rise of 82 ft. to the crown. Each arch consists of a 6-in. reinforced-concrete slab, which is thickened to 24 in. at the springings and crown and incorporates four heavily-reinforced stiffening ribs, 4 ft. 6 in. high and spaced at 7 ft. 6 in. centres. The gable ends of the building consist of 5-in. panel walls framed between the columns and beams. These walls are not rigidly connected to the building, but are provided with sliding joists between the heads of the columns and the adjacent arch ribs. Free deflection of the end arches under load is thus possible without setting up the stresses which would arise if rigid ties to the gables were used.

Below the floor of the silo is a 9 ft. by 7 ft. conveyor tunnel, and there is also a 90-ft. elevator tower with an area of 34 ft. by 28 ft. 6 in. in one gable end. The sulphate to be stored is delivered by an inclined conveyor to the top floor of this tower and is discharged on to a second conveyor, which is suspended from the crown of the arch and extends the full length of the building. Sulphate can be discharged from both sides of this second conveyor on to the floor of the silo at any point throughout its length. It can be recovered from stock by a third conveyor running in a tunnel under the building and delivered to the bagging plant. This last conveyor is supplied with material by an electrically-operated scraper, which runs on a broad-gauge track and is equipped with a swivelling and elevating boom so that the full width of the silo can be covered. The silo was designed and constructed by the Cementation Company Limited, Doncaster, while the scraper was supplied by Messrs. Stothert and Pitt, Limited, Bath.

The bagging and dispatch section of the factory is designed to deal with 1,000 tons of ammonium sulphate per day, which involves handling 10,000 2-cwt. bags. The sulphate is delivered by the conveyor system just described to a Fraser and Chalmers conveyor in the roof of the section, whence it falls by gravity through one of eight automatic weighing and filling machines into a bag which rests in an upright position on a "start and stop" conveyor. When the bag has received the weighed quantity of material it is moved along to the closing machine, where it is sewn up and finally tipped down a chute on to a rail wagon.

LITERATURE.

Lens and Prism Making: A Text-book for Optical Glassworkers.

By F. TWYMAN, F.R.S. Second edition. Hilger and Watts, Hilger Division, 98, St. Pancras-way, London, N.W.1. [Price 58s. net.]

THE first edition of this book was published during the war and was reviewed in *ENGINEERING*, vol. 155, page 302 (1943). It described the methods used by Adam Hilger, Limited, in the production of prisms and lenses of the high quality for which they achieved world-wide reputation. At the time of its appearance, the optical industry was expanding rapidly to meet the great demand for optical instruments and components required for the prosecution of the war and to meet this demand a considerable number of unskilled persons had to be absorbed into the industry. One of the objects of

the book was to help such persons to produce optical work of first quality after a short period of training under competent supervision, and that it achieved this object may be inferred from the fact that second and third impressions were produced in a little over a year from the date of the first publication.

The methods of optical production described in the first edition were those for which the author, as managing director of Adam Hilger, Limited, had been largely responsible for many years. In the second edition, the wide scope of the first has been extended to include information on the manufacture of spectacle lenses, fine dividing, and the production of large object glasses and mirrors for astronomical telescopes, with which work, we gather, the author has not been personally concerned. Moreover, since the first edition appeared, Adam Hilger, Limited, have been combined with other optical instrument-making firms to form Hilger and Watts, Limited, and some of the work in which these firms have specialised is described in the new volume.

Apart from such additions, of which the making of artificial crystals and the production of non-spherical surfaces are examples, the ground covered and the method of treatment are similar to, but usually fuller than, those in the first edition. There is evidence throughout of a happy combination of theoretical and practical experience which renders the book interesting and informative to others besides the optical glassworkers for whom it is particularly intended. To give an idea of the scope of the work, it may be stated that the first four chapters, dealing with the history of the subject, the making of single prisms and lenses, grinding and polishing tools and materials, are followed by an important one on dioptric substances, in which the properties and production of optical glasses, crystals, optical plastics, etc., are considered. Subsequent chapters are devoted to the methods of producing lenses and prisms in quantity, non-spherical optical surfaces, including corrector plates and Schmidt cameras, the testing of optical glass and optical components, silvering and blooming, and the making of gratings. The remaining chapter deals with the working of large object glasses and mirrors, among the latter being the 200-in. mirror for the Mount Palomar telescope. There are four appendices, one of which is a glossary of terms used in the optical industry, a bibliography and a subject-matter index. Although some of the material from the first edition is included in the second, the fact that the latter contains 629 pages as compared with 178 pages in the former suggests that it may well rank as a new book. It is certainly the most comprehensive publication of its class that has come to our notice and will be indispensable to those for whom it is intended.

Leben und Schaffen der Reichsbahn—Brückenbauer Schwedler, Zimmermann, Labes, Schaper.

By PROFESSOR AUGUST HERTWIG. Wilhelm Ernst und Sohn, Hohenzollerndamm 169, Berlin-Wilmersdorf, Germany [Price D.M. 15 in paper covers or D.M. 17.50 bound]; and Lange, Maxwell and Springer, Limited, 41-45, Neal-street, London, W.C.2. [Price 26s. 3d. in paper covers or 30s. 8d. bound.]

EVER since Caesar bridged the Rhine at Mainz in seven days—as great a feat, perhaps, as any of the war-time works of the Bailey-bridge builders of the present day—the bridge has been accredited as the highest achievement of the constructional engineer. This is not so much because a great bridge, unlike a tunnel, stands for all to see as a manifest token of the builder's art and ingenuity, but because the spans which are thrown from pier to pier and strand to strand demand the continuing conquest of the relentless force of gravity. In Britain, the great estuaries still provide the opportunity and the challenge, but German bridge-builders have been fortunate in having the Rhine and other great rivers to test their skill while the British have been driven to India and the Colonies in the search for rivers as great, and greater, to span. German railway bridges therefore provide a much more varied and impressive display of the art than is available in this country, and, though the Forth Bridge still stands after nearly 60 years

as the unrivalled masterpiece of Western Europe, unquestionably there is profit in studying the work of the bridge-builders of the Reichsbahn.

Professor Hertwig gives short biographical sketches of the four engineers, Johann Wilhelm Schwedler, Hermann Zimmermann, John Labes and Gottwalt Schaper, who held the principal responsibility for the planning and construction of bridges on the German State Railways in the latter half of the Nineteenth Century and the first decades of the Twentieth. Each sketch is profusely illustrated and includes a complete bibliography of the technical papers of each subject; moreover, in each case one or more of these technical papers is reproduced in full. The book is therefore of far greater value than the typical English biography of an engineer, which is so often written as a pot-boiling "success story" by a professional biographer and so rarely by a trained engineer.

It is an every-day experience to read a technical paper which re-discovers a proposition formulated years ago or discusses a well-worn theme from a familiar angle, and these impressive bibliographies, and the papers reproduced as examples of their contents, cannot be lightly dismissed as ancient history. The first paper reproduced is by Schwedler, on the design of riveted joints. Much has since been written on this subject, especially after Batho's publication of an elastic theory of longitudinal joints in the *Journal of the Franklin Institute* in 1916, but no one interested in rivets can afford to overlook this paper, though it appeared in 1867. At the other end of the time scale is Schaper, who was writing right up to 1942. His work is less analytical than that of his predecessors, but the half-dozen examples of it which occupy the last 40 pages of the book, including articles on rust-prevention, welding, and high-duty steel as a building material, show a wide range of interest and a substantial depth of application.

The book is abundantly and excellently illustrated. It includes, of course, the well-known Rhine bridge at Remagen, a design of artistic and functional perfection, which seems to have inspired the winner of a recent competition in the United States as well as the famous bridge at Sydney. It well deserves a fine translation, for the benefit of the many engineers who lack the mastery of German necessary for a full appreciation of the original.

THE POTENTIAL FLOW TANK.

By E. MARKLAND and N. HAY.

THE electrolytic or potential flow tank has been used to solve many problems arising in engineering practice. The merit of the method is that, with simple apparatus, solutions may be found in cases where a mathematical solution, other than by the relaxation method, is unknown. For instance, the seepage of water through earth dams,* the estimation of the critical Mach number of an aircraft-spinner and engine-cowling combination,† and the elastic torsion of non-circular shafts‡ have all been investigated by this method. In fact, any plane field problem may be solved if it involves a potential function ϕ which satisfies Laplace's equation

$$\nabla^2 \phi = \frac{\partial^2 \phi}{\partial x^2} + \frac{\partial^2 \phi}{\partial y^2} = 0.$$

The first use of an electrolytic tank was made by Relf§ in 1924, to trace the streamlines of potential flow past an obstacle. The equations for steady two-dimensional irrotational flow of a perfect fluid may be shown to be analogous in two ways to those for the flow of electric current in a uniform plane-conducting sheet. If solid boundaries in the fluid flow are represented by geometrically similar non-conducting boundaries in the sheet, then streamlines and equipotentials in the former are represented by similar current lines and equipotentials

* B. Gentilini, *L'Energia Elettrica*, May, 1946, pages 177-186.

† W. T. O. Lewis and E. J. Newman, Bristol Aero-plane Company. Report No. KR.66/44.

‡ J. Peres and L. Malavard, *Comptes Rendus, Académie des Sciences*, vol. 211, pages 131-133 (1940).

§ E. F. Relf, Aeronautical Research Committee Reports and Memoranda No. 905 (1924).

THE SINDRI ARTIFICIAL-FERTILISER FACTORY.

(For Description, see Page 289.)



FIG. 10. VACUUM PUMPS.

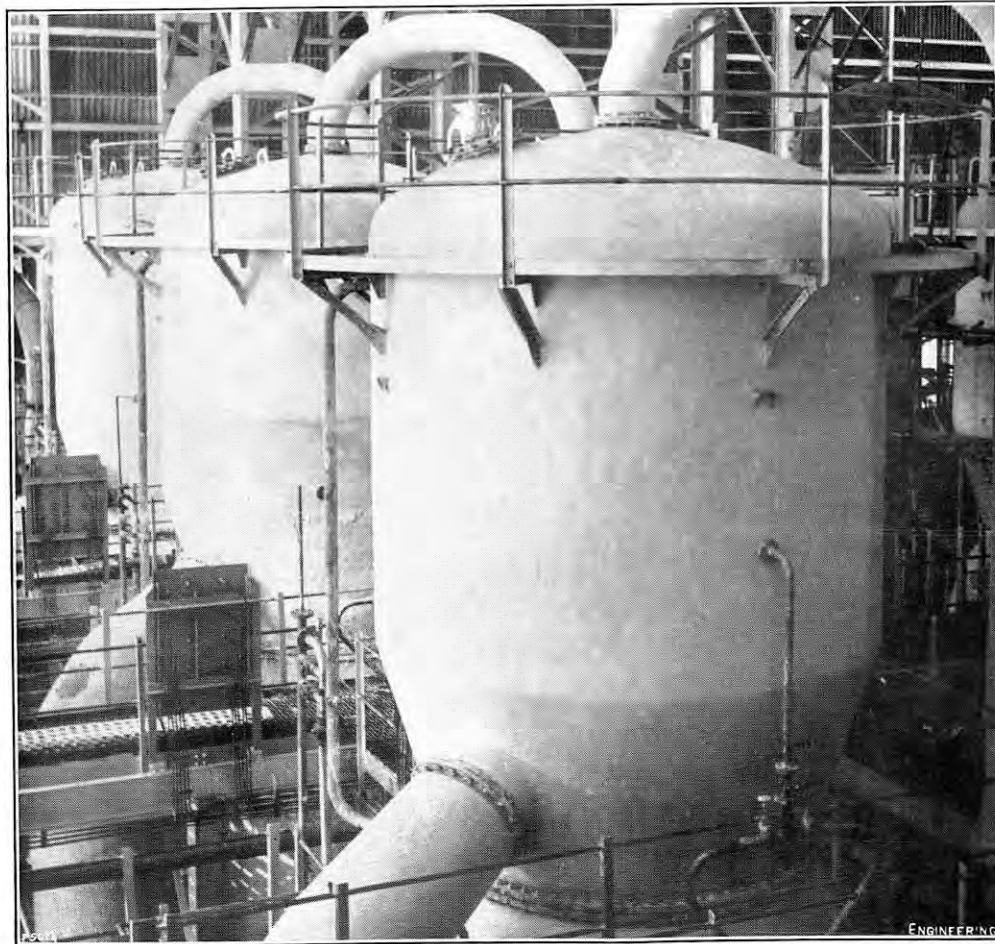


FIG. 12. "KRYSTAL" EVAPORATORS FOR CRYSTALLISING AMMONIUM SULPHATE.

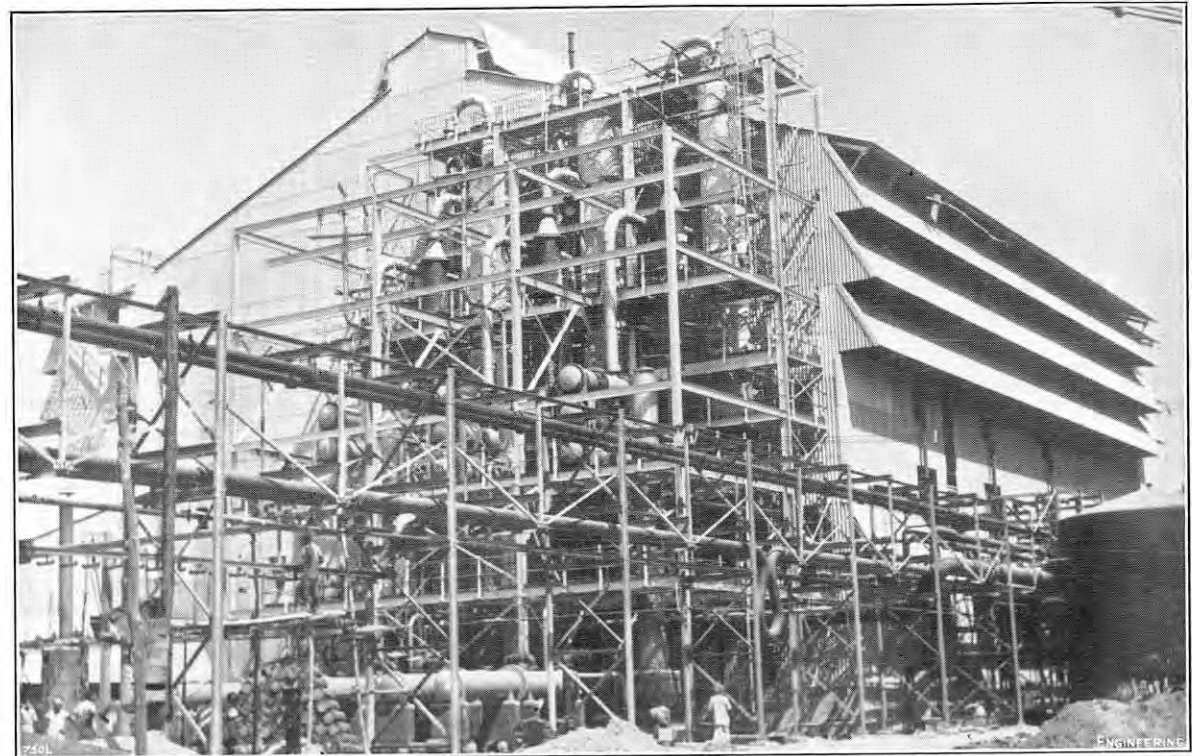


FIG. 11. DECOMPOSITION PLANT FOR RECOVERING EXCESS AMMONIA AND CARBON DIOXIDE.

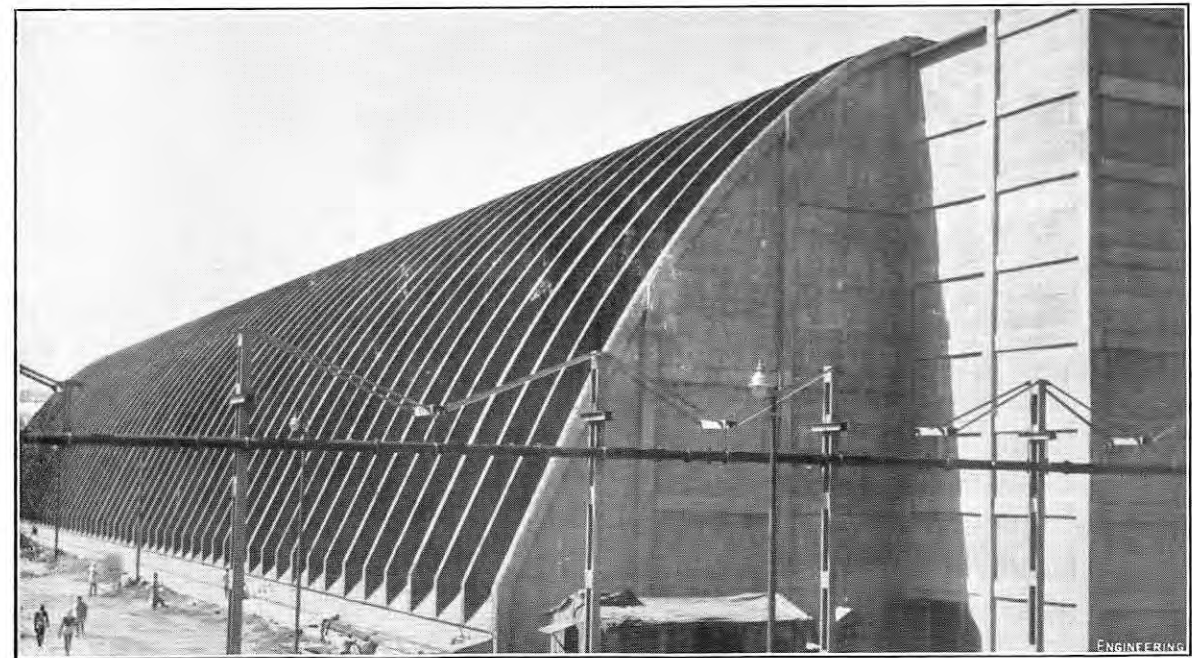


FIG. 13. 90,000-TON AMMONIUM SULPHATE SILO.

THE SINDRI ARTIFICIAL-FERTILISER FACTORY.

(For Description, see Page 289.)



FIG. 7. 75-FT. CARBON DIOXIDE SCRUBBERS.

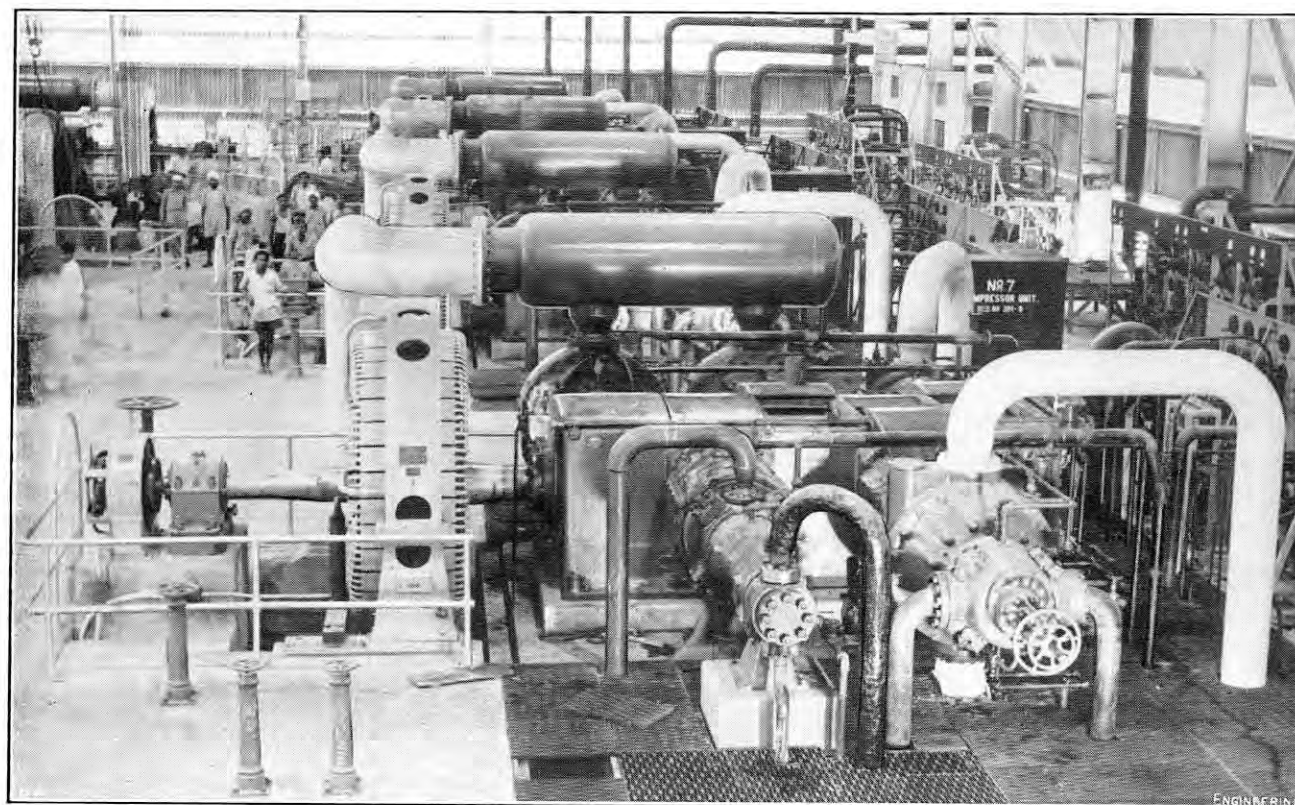


FIG. 8. MULTI-STAGE GAS COMPRESSORS IN SYNTHESIS SECTION.

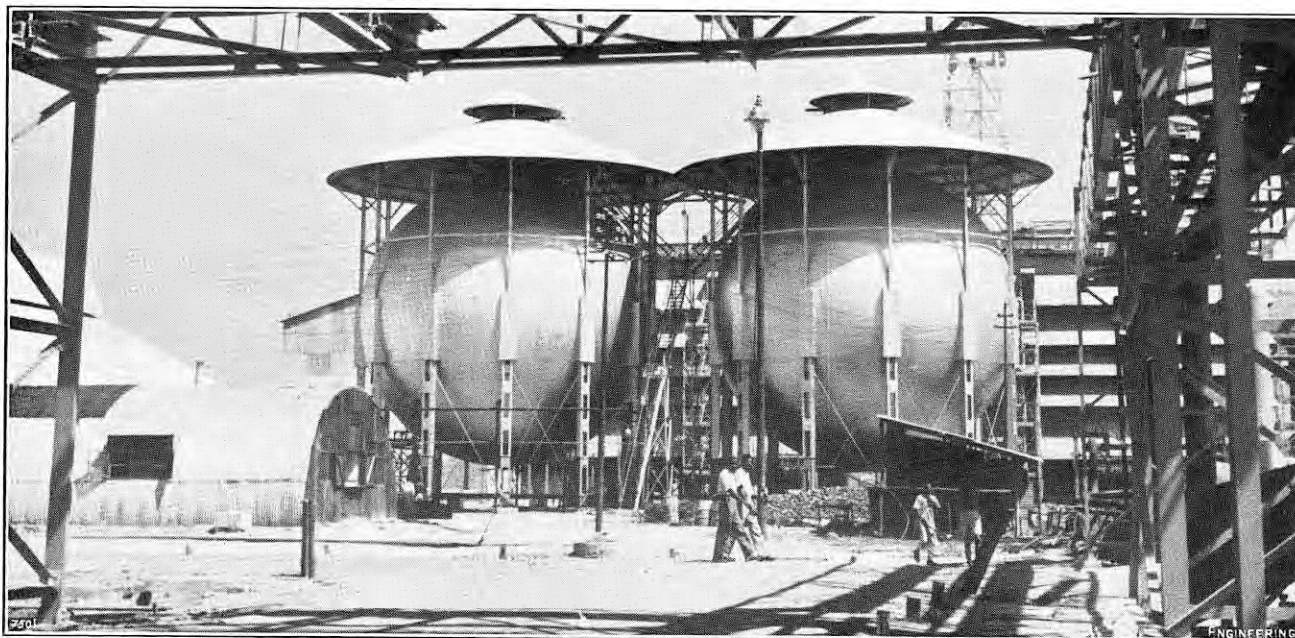


FIG. 9. LIQUID-AMMONIA STORAGE TANKS.

THE POTENTIAL FLOW TANK.

Fig. 1. Analogy A

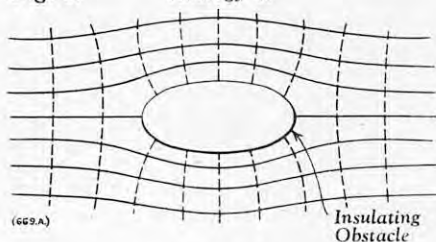


Fig. 2. Analogy B

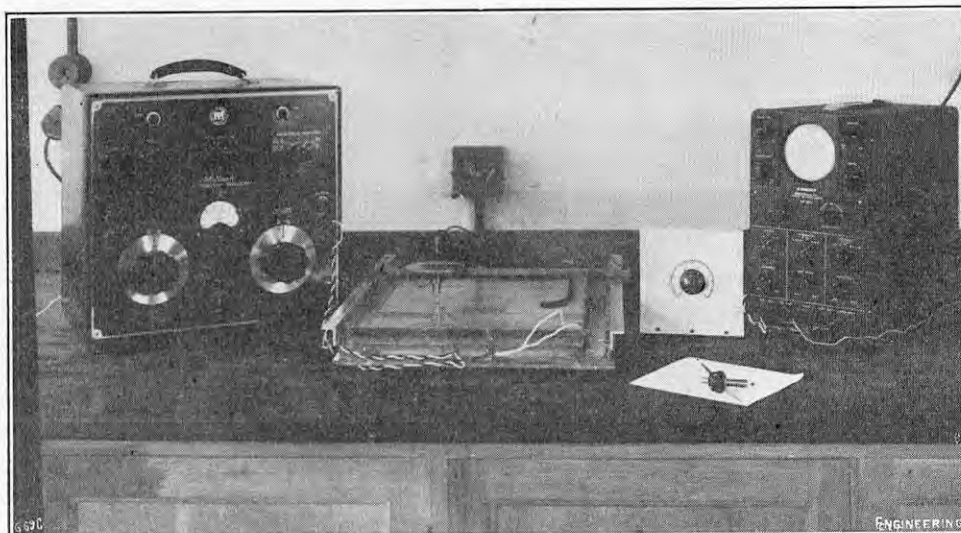
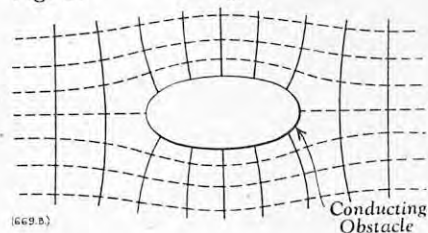


FIG. 3.

Fig. 4.

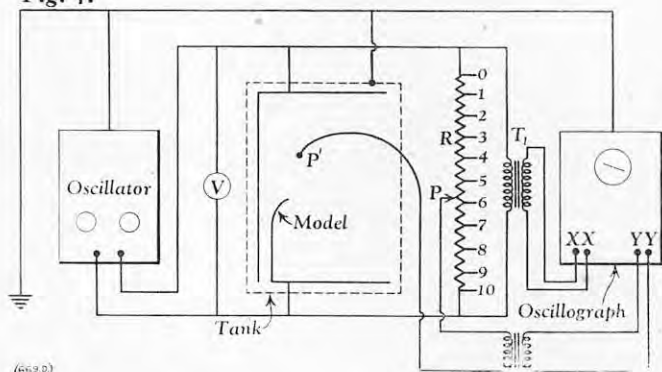


Fig. 5.

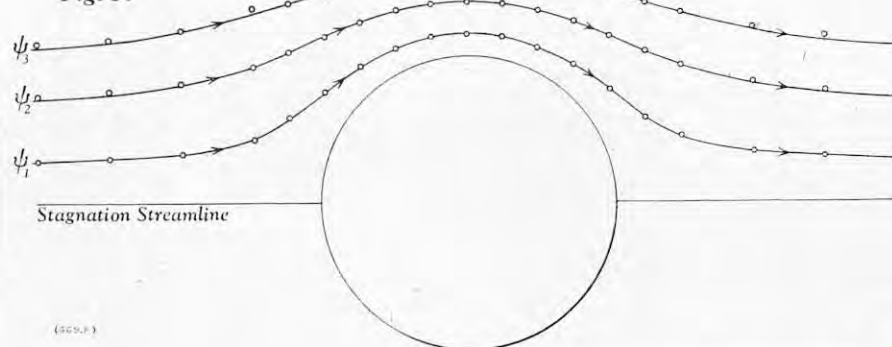


Fig. 6.

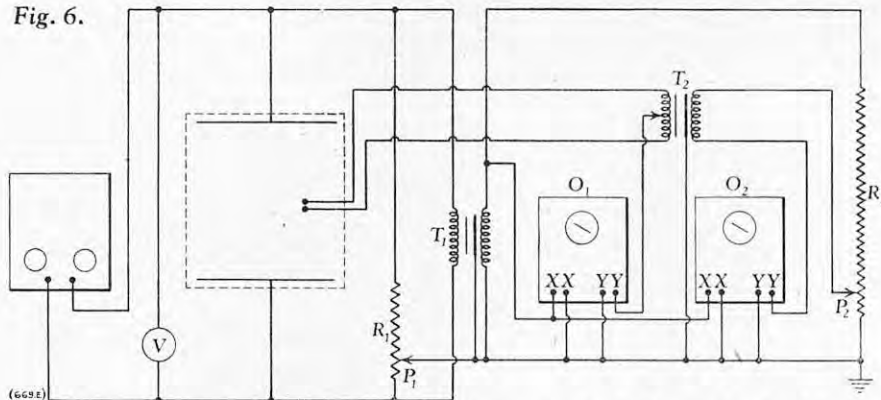
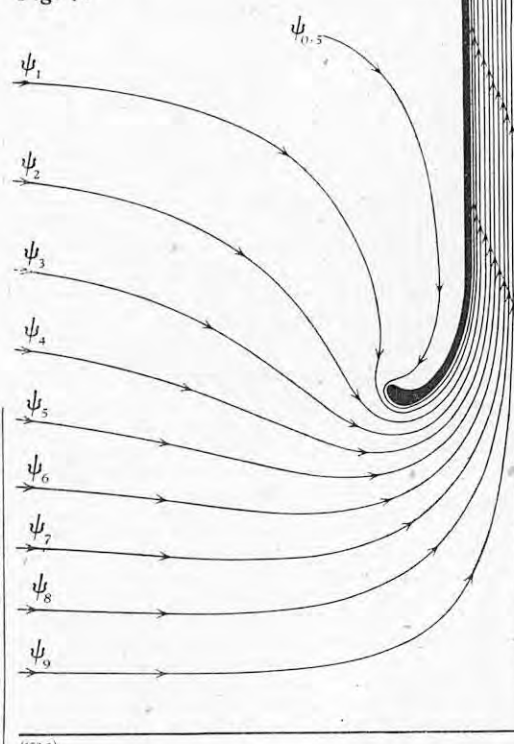


Fig. 7.



in the latter. If, however, solid boundaries in the fluid flow are represented by conducting boundaries in the sheet, the converse is true, and streamlines and equipotentials in the fluid flow are represented by equipotentials and current lines in the sheet. The two analogies may be referred to as A and B, respectively, and are illustrated in Figs. 1 and 2, respectively. Similar analogies may be drawn for many other physical problems.

The potential flow tank provides the uniform plane conducting sheet, required in these analogies, in the form of an electrolyte of uniform depth. Suppose it is desired to obtain the solution to the problem of two-dimensional flow of a perfect fluid round a given obstacle. If a model of the obstacle is made in a conducting material, such as graphite, and placed in the tank, then the streamlines of the flow may be found simply by plotting equipotential lines in the tank. If, however, it is desired to measure the velocity at points in the fluid flow, a model is made in an insulating material, such as wax, and the velocity at any point may be found by measuring the potential gradient at the corresponding point in the tank. Details of the electric circuits required are given below.

An extension of the analogy to flow of a compressible inviscid fluid, where the effect of density

changes in the fluid was simulated by varying the depth of the electrolyte, was made by Taylor and Sharman.* Ferrari† showed how cases of axially symmetrical flows could be treated, provided analogy A was used, by tilting the bottom of the tank so that a cross-section through the electrolyte is wedge-shaped, the apex of the wedge representing the axis of the flow. Malavard‡ has developed a "wing calculator" specially for the study of lift of wings under various conditions, and de Haller§ and Hargest|| have investigated flow through cascades. Rouse and Hassan¶ have described a tank built to investigate the pressure distribution on the walls of pipe inlets and contractions with a view to improving their cavitation performance.

Fig. 3 shows a tank constructed recently, and suitable for general small-scale use. For use with

* G. I. Taylor and C. F. Sharman, *Proc. Royal Society Series A*, vol. 121, pages 194-217 (1928).

† C. Ferrari, *Aerotechnica*, vol. 10, pages 453-469 (1930).

‡ L. Malavard, *Pub. Scient. et Techn. du Ministère de l'Air*, No. 153 (1939).

§ P. de Haller, *Sulzer Technical Review* No. 314 (1947).

|| T. J. Hargest, *National Gas Turbine Research Establishment Memo*, No. M.48 (1949).

¶ H. Rouse and M. M. Hassan, *Mechanical Engineering*, vol. 71, pages 213-216 (1949).

analogy B, the circuit shown in Fig. 4 is used. The oscillator feeds alternating current at about 2 kilocycles and 60 volts to the tank, to the potential divider T_1 , and through transformer T_2 to the X-X plates of the oscilloscope. Probe P' consists of a platinum wire of about 0.02 in. in diameter which may be moved about the tank on the T-square with graduated scales to record its position. The potential difference between the probe and a chosen point P of the potential divider is transferred through transformer T_2 to the Y-Y plates of the oscilloscope. A point equal in potential to the chosen point of R

may be found by adjusting the position of the probe to obtain a horizontal line on the screen. An equipotential line is determined by finding a series of such points for the chosen point of R, and results obtained in this manner for ideal flow past a cylinder are shown in Fig. 5. The lines shown have been calculated by potential-flow theory and Fig. 5 therefore gives an indication of the accuracy of the apparatus.

Errors may arise in practice from the capacitance between the probe and the electrodes, which produces an elliptical trace on the screen and thus reduces the accuracy in finding the null point, and from the contact potential between the probe and electrolyte. These problems are discussed by de Haller.* The capacitance effect may be reduced to negligible proportions by raising the frequency or by incorporating a capacitance bridge into the circuit. The magnitude of the contact potential depends largely on the material chosen for the electrodes, and de Haller gives a qualitative table of merit, in which platinum is quoted as having a very low contact potential. Graphite electrodes have practically none, and have the advantage of being readily worked to any desired profile.

Fig. 6 shows the circuit used in analogy A. A double probe mounted on a rotating head is used to measure the direction and intensity of current, giving the velocity in the analogous fluid flow. Provision is made for bringing the average potential of the probes, picked off the centre tapping of the primary winding of transformer T_2 , to the earth potential of the circuit to avoid stray capacitance to earth. This is indicated when a point P_1 of potential divider R_1 is chosen so that oscilloscope O_1 shows a horizontal trace. The direction of the equipotential at any point of the tank is found by setting P_2 to earth and rotating the head carrying the probes until no signal is received on oscilloscope O_2 . The head is now rotated through 90 deg. and the potential gradient at the probes is measured by finding the point P_2 of resistance R_2 for which oscilloscope O_2 again shows no signal. The velocity in the fluid flow is proportional to the resistance between P_2 and earth under this condition. It will be noted that no current is taken by the probes when measurements are made, so that the electric field is not disturbed.

A typical result obtained by analogy B, showing the streamlines of flow into a two-dimensional pipe entry, is shown in Fig. 7. The model was constructed and the readings recorded and plotted within a week. This is one example of the rapid solutions that may be obtained with the tank; problems in many other fields may be solved in a similar manner.

The apparatus described was constructed in the workshop of the Engineering Department of Nottingham University, of which Professor J. A. Pope, D.Sc., is the head. Acknowledgment is made to Mr. L. Malavard for permission to publish the circuit shown in Fig. 6.

THE FERRARIS DISC.—Professor P. Harmegnies, Professor of Industrial Electricity at the Faculté Polytechnique de Mons, will deliver two lectures on the properties of the Ferraris disc at King's College, Strand, W.C.2, on Monday, March 10, and Thursday, March 13, respectively, commencing at 5.30 p.m. in each case. The course has been arranged under a scheme for the interchange of British and Belgian lecturers. Admission will be free and no tickets will be required.

EXPORTS OF MOTOR VEHICLES.—The Society of Motor Manufacturers and Traders have announced that, during January of this year, 38,000 cars, worth more than 13,000,000*l.*, were shipped overseas, the largest number ever exported in one month. The exports of commercial vehicles during the same month totalled nearly 14,200 units, with a record value of nearly 8,000,000*l.* The manufacturers of agricultural tractors also broke all previous records for monthly shipments, both in numbers and value, nearly 12,300 tractors, worth almost 4,500,000*l.*, having been sent overseas. These remarkable figures have been made possible by the chartering of tramp steamers, nearly 50 such vessels having been chartered since last spring to supplement the deliveries to Australia alone. The actual number of units exported to Australia by this means was in the region of 70,000, this figure including cars, commercial vehicles and agricultural tractors.

* P. de Haller, *Sulzer Technical Review*, No. 314 (1947).

THE ENGINEERING OUTLOOK.

X.—THE RAILWAY ROLLING-STOCK INDUSTRIES.

THE private manufacturers of rolling stock have few grounds for dissatisfaction and much cause for pride in the achievements of their industry in 1951. From Table I, herewith, taken from the *Monthly Digest of Statistics*, it will be seen that, though the total output of locomotives of all types was somewhat lower in 1951 than in 1950, this was almost entirely due to reduced output at the nationalised railway workshops. The private builders, who now rely entirely on overseas orders where main-line locomotives are concerned, succeeded in maintain-

340,000*l.* less than in the corresponding period of 1950.

A report on the locomotive industry, published in December by Political and Economic Planning, drew attention to the insecure position of the private builder of steam locomotives in the United Kingdom. With no home market to fall back on, he is faced with a prospect of falling sales as a result of the growth of locomotive industries in his principal markets, the buying out of railways formerly in British hands and the rise of the Diesel locomotive. The demand for locomotives, moreover, has always been subject to severe fluctuations. In 1921, the exports of locomotives and parts were valued at 9.6*l.* millions, but this figure was not reached again between the wars, and after 1930 the exports never

TABLE I.—PRODUCTION OF LOCOMOTIVES.*

	Steam.				Diesel and Diesel-Electric.				Electric.
	Total.	For Main-line Railways in the United Kingdom.	For other United Kingdom Users.†	For Export.	Total.	For Main-line Railways in the United Kingdom.	For other United Kingdom Users.†	For Export.	For Main-line Railways in the United Kingdom.
Annual totals :									
1935	717	—	—	137‡	—	—	—	—	—
1948	779	397	62	320	—	—	—	—	1
1949	826	370	67	389	—	—	—	—	—
1950	808	380	73	355	515	25	123	367	3
Quarterly :									
1949—3rd Qr.	204	88	21	95	140	15	46	79	—
4th Qr.	241	139	9	93	172	11	59	102	—
1950—1st Qr.	215	96	21	98	100	2	22	76	—
2nd Qr.	174	82	13	79	144	3	29	112	—
3rd Qr.	185	82	18	85	116	7	30	79	—
4th Qr.	234	120	21	93	155	13	42	100	3
1951—1st Qr.	162	51	16	95	108	1	35	72	8
2nd Qr.	205	74	16	115	139	4	32	103	4
3rd Qr.	178	79	10	89	112	7	36	69	8

* Production by British Railways and by private builders.

† Industrial locomotives.

‡ Number exported.

TABLE II.—UNITED KINGDOM : EXPORTS OF LOCOMOTIVES AND PARTS.

	Number.			Value (£1,000).		
	1949.	1950.	1951.	1949.	1950.	1951.
Complete locomotives :						
British West Africa	71	38	58	878	407	745
Union of South Africa	203	100	148	2,435	218	359
Southern Rhodesia	23	35	19	608	906	17
British East Africa	113	70	71	1,136	230	217
India	129	235	170	1,174	3,346	2,298
Australia	33	114	204	228	1,867	3,835
Other Commonwealth countries and Irish Republic	69	71	111	191	274	876
Egypt	34	33	12	743	401	26
Other foreign countries	391	233	180	1,899	1,728	1,184
Steam	401	354	349	7,631	7,496	7,140
Other	665	575	624	1,661	1,882	2,417
Total	1,066	929	973	9,292	9,377	9,557
Railcars	326	409	157	675	1,465	1,211
Parts :*						
British West Africa	—	—	—	432	322	218
Union of South Africa	—	—	—	473	372	434
India	—	—	—	565	913	1,600
Australia	—	—	—	149	221	325
Other Commonwealth countries and Irish Republic	—	—	—	866	733	595
Foreign countries	—	—	—	873	994	1,352
Boilers	—	—	—	517	464	660
Other	—	—	—	2,840	3,091	3,864
Total	—	—	—	3,358	3,555	4,524

* Except internal-combustion engines, axles, tyres and wheels.

ing their output at about the 1950 level, despite a growing tightness in the supply of steel and components. As will be seen from Table II, taken from the *Trade and Navigation Accounts*, the exports of locomotives in 1951, at 9.6*l.* millions, were 180,000*l.* higher than in 1950. Recurring economic crises since the war have never permitted really adequate capital outlay on the railways in Britain, which have suffered again as a result of re-armament. It is, however, of the utmost importance that the stock of passenger and freight vehicles should be maintained. Table III, taken from the *Monthly Digest of Statistics*, shows that the output of carriages in 1951 was 13 per cent. higher than in 1950, and the output of wagons, despite a fall in exports of 48 per cent., was 8 per cent. higher. The restrictions in capital outlay, however, affected the output of brake and signalling equipment, which, in the first eleven months of 1951, was valued at 5.1*l.* millions,

exceeded 3*l.* millions. In the five years 1930 to 1934, the output of the private builders averaged 180 locomotives and 142 boilers per annum, whereas the yearly capacity was 800 locomotives and 650 boilers.

From 1935 to 1939, the industry was still working at less than 50 per cent. of capacity. In the boom conditions following the war, high output was again achieved, though this is difficult to relate to capacity because of the wide range of types produced. The capacity at present would probably be about 800 locomotives a year only if every plant were to concentrate on one type of locomotive. The output in 1950 reached 524 locomotives, of which 354 were exported; and, in 1951, 484 locomotives, of which 349 were exported. Though the number produced in 1951 was thus 7½ per cent. below the 1950 figure, the total tonnage of the output was approximately the same. British

Railways have placed no orders with the private builders for the past two years. They are concentrating on the production of standard locomotives in their own workshops and have stated that, as policy stands at present, they are unlikely to give any orders to the private builders for five years. This policy is, of course, always liable to revision. Because of the high level of exports, the private builders have suffered remarkably little from the lack of orders from British Railways, and order books are still fairly full.

The North British Locomotive Company recently received a large order, valued at 4l. millions, from South Africa for 100 steam locomotives for heavy shunting and main-line duties. This was all the more welcome after the loss in 1950 of a contract valued at 1.75l. millions for 100 shunting locomotives for South African Railways, which went to Krupp's, in Germany. In this instance, the British tender was 250,000l. higher than the German and a scheme put forward by the North British Locomotive Company for the building of the loco-

own type of condensing equipment. Inadequate water supplies in South Africa raise serious problems in the operation of steam locomotives, but these are being overcome by the use of condensers, the development of which has been the special province of Henschel und Sohn.

There are still important orders in hand for locomotives in East and West Africa. The number of locomotives exported to those regions in 1951 was slightly higher than in 1950, but much less than in 1949. Exports to Southern Rhodesia, which were valued at 900,000l. in 1950, were very small in 1951, and this was only partly offset by increased exports to other Commonwealth countries. Approval of a loan of up to 5l. millions from the Economic Co-operation Administration to assist the Governments of Southern and Northern Rhodesia to improve their railways was, however, announced in July by Mr. William L. Batt, the Minister in charge of the Economic Co-operation Administration, and this should mean increased demand for locomotives and rolling stock. The possibility of large-scale American loans to undeveloped territories is, however, a source of potential danger to British manufacturers. On the conclusion of the re-armament programme, the United States may be expected to have large funds available for investment overseas. Since the United Kingdom, on the other hand, cannot hope to grant credits on any great scale, British manufacturers may be seriously handicapped in their most promising markets. British builders of steam locomotives are, perhaps, less likely to suffer than other manufacturers in the heavy engineering industry, since steam locomotives are now manufactured on a very small scale in the United States. There is, of course, no guarantee that builders in the United States would not again undertake their manufacture if sufficient inducement offered.

India is still the largest market for steam locomotives, but only 170 locomotives were exported to that country in 1951, compared with 235 in 1950. The downward trend must continue. The capacity of the workshops which the Indian Government are operating with the assistance of the British Locomotive Manufacturers' Association is increasing rapidly and by the end of 1954, when the L.M.A. technical-aid agreement expires, it is hoped that they will be able to supply a large part of the steam locomotives required by the Indian railways. It is not suggested, of course, that all the difficulties attending locomotive production in India will have been overcome by that time. In the meantime, however, British builders, in return for their assistance, are assured of a high level of orders from India, though under the terms of their agreement this is dependent upon satisfactory progress being made with the development of the Indian locomotive industry and does not entirely exclude competition from other manufacturers in the Indian market. The Tata locomotive works, which are being operated with assistance from the German firm of Krauss Maffei, have also been making good progress.

Exports to foreign countries, as well as to the Dominions, have been declining. One welcome feature, however, was the clearing of the arrears due from Argentina in payment for several large consignments of rolling stock supplied to the Argentinian railways while they were still British-owned. The satisfactory settlement of this debt, which was estimated in 1948 to be 2l. millions, most of which was owed to the Vulcan Foundry, Limited, has made possible the resumption of normal commercial relations, and orders are again being executed for Argentina. In their fight to maintain exports, builders have the benefit of the co-operative strength they enjoy through the Locomotive Manufacturers' Association, which employs its own representative, Mr. K. Cantlie, who supplements the work of the agents of the individual builders, and visits railways officials and users of industrial locomotives on behalf of them all.

On the whole, the industry is optimistic about future orders, though seriously concerned about the availability of steel; any reduction in supplies would seriously handicap the efforts to keep down costs and remain competitive. All private builders of steam locomotives have, nevertheless, found it advisable to diversify their production. The North

British Locomotive Company are manufacturing machine tools on a large scale, as well as excavators, under licence from the United States. They have received important orders for electric, Diesel-electric and also for the North British-Voith range of Diesel hydraulic locomotives. Metropolitan-Vickers-Beyer Peacock, Limited, who were formed by the parent companies to undertake production of gas-turbine as well as Diesel-electric locomotives, have sufficient orders on hand to ensure full activity for some years. The Vulcan Foundry, Limited, who are co-operating with the English Electric Company, exhibited one of the 660 brake horsepower Diesel-electric locomotives made for the Tasmanian Government at the Festival of Britain South Bank Exhibition.

The upward trend of exports of Diesel and Diesel-electric locomotives continued in 1952; valued at 2.4l. millions, they accounted for 25 per cent. of the total exports of locomotives, compared with 18 per cent. in 1949. Orders in hand include 31 Diesel-electric locomotives of 1,500 h.p., being built by the English Electric Company for the New Zealand Government Railways. The English Electric Company also received in 1951 orders for 13 Diesel-electric locomotives of 1,000 h.p. for the North Western Railway of Brazil, ten of 1,500 h.p. for the Queensland Government Railways, and three of 350 h.p. for the Victoria Government. The Birmingham Railway Carriage and Wagon Company, Limited, have an order for three Diesel-electric locomotives for 3 ft. 6 in. gauge lines from the Sierra Leone Development Company. The 1,000 h.p. engines are to be supplied by Sulzer Brothers (London), Limited, and the electric equipment by Crompton Parkinson Limited. The Commonwealth Railways of Australia have also placed an order with the Birmingham Railway Carriage and Wagon Company for locomotives valued at 500,000l., for the 3 ft. 6 in. gauge South Australian Railway. Crompton Parkinson Limited and Sulzer Brothers (London), Limited, are again sub-contractors. The Metropolitan-Vickers Electrical Company are to deliver in 1952 part of an order valued at 2.25l. millions for 48 Diesel-electric locomotives, ordered at the end of 1950 by the Government of Western Australia. Australia is now the largest market for British locomotives (steam as well as Diesel-electric), accounting in 1951 for 40 per cent. of the value of total exports. Large orders on hand at present guarantee the continuance of high exports, but the production of Diesel-electric locomotives is now being undertaken in Australia (though the engines still have to be imported) and this venture, if successful, must eventually cause a fall in British exports. The production of steam locomotives has already been attempted, but was found to be not very satisfactory under Australian conditions. The Diesel-electric locomotives at present being built are of a standard United States design.

Impressive evidence of the lower running costs of Diesel and Diesel-electric compared with steam locomotives has been collected in the past few years, and locomotives of this type have been supplanting steam locomotives on many railways throughout the world, though in backward countries, where the low first cost of steam locomotives is of great importance or where there are special conditions such as plentiful cheap coal, steam locomotives have been holding their own. On railways in the United States, steam traction is being steadily superseded and, though the number of steam locomotives produced has been increasing, it is still very small. In the first nine months of 1951, 14 steam, 1,850 Diesel and Diesel-electric, and two electric locomotives were put into service. This compares with eight steam locomotives, 1,681 Diesel and Diesel-electric and four electric locomotives in the corresponding period of 1950. Of the 1,827 locomotives on order towards the end of 1951, 23 were steam and two were electric. The locomotive requirements of the Canadian Pacific Railway comprise 50 of the Diesel-electric type. The Canadian Locomotive Company, of Kingston, Ontario, are to supply six of this type, of 1,600 h.p. each, and General Motors Diesel, Limited, are building 20 of 1,500 h.p. each.

Diesel and Diesel-electric traction is also making some headway on British Railways. It has been

TABLE III.—Production of Railway Rolling Stock and Other Equipment.

	Coaching Vehicles including Rail Motor Vehicles.*		Wagons.*		Railway Brakes and Signals, and Telegraph and Track Accessories.†	
	Total.	For Export.	Total.	For Export.	Total.	For Export.
	Number.				Value (£1,000)	
<i>Annual totals.</i>						
1935 ..	2,043	—	29,328	—	—	—
1949 ..	2,089	262	38,379	6,333	6,079	2,619
1950 ..	3,320	373	33,155	4,604	5,786	2,782
1951 ..						
<i>Monthly.</i>						
1950—Oct.	300	36	3,502	367	502	278
Nov.	325	45	3,931	442	489	226
Dec.	270	30	3,173	324	508	232
1951—Jan.	204	43	2,799	343	400	161
Feb.	144	18	3,133	274	456	198
Mar.	178	17	3,415	328	508	244
April	187	28	3,886	275	520	229
May	238	41	3,612	300	468	204
June	243	53	3,803	168	514	252
July	183	34	3,490	171	574	270
Aug.	166	22	2,929	192	461	209
Sept.	156	33	3,405	253	645	284
Oct.	200	29	4,075	249	591	244
Nov.	268	36	3,811	186		
Dec.						

* Production by British Railways, by Royal Ordnance Factories and by private builders.

† Deliveries by private builders only.

motives in South Africa proved unacceptable to the Government of that country because it was too costly. Price competition from Germany has been less keen of late because of rising wage and material costs. In many German heavy industries, including locomotive manufacture, wages have advanced considerably and the working week has been reduced from 55 to 45 hours. Iron and steel, which account for 92 per cent. of the weight of a steam locomotive and, with other materials, for 50 per cent. of the total cost, have also been rising rapidly in price, as they have done in this country.

The total German building costs are at present thought to be about equal to the British. Labour costs are still somewhat less, but this is offset by the much higher rate of bank credit—11 or 12 per cent. in Germany. Since the end of the war, German builders have had very little work from the Federal Railways, but it has been announced recently that they are to receive important orders which will give them greater stability. Competition between British and German builders in overseas markets is now on a very healthy basis, which does not preclude co-operation in special circumstances. The firm of Krupp report that substantial subcontracts have been placed in the United Kingdom in connection with their South African order (though these are understood to affect only certain instruments and equipment specified in the original contract); and the German firm of Henschel und Sohn have been collaborating in the fitting of 90 of the locomotives for South Africa with their

estimated that the 15 million tons of coal consumed annually by steam locomotives could be replaced by about 3 million tons of Diesel oil and, with the rapid development of oil-refining capacity in this country, this may seem a more desirable proposition than hitherto. Nevertheless, it is unlikely that Diesel traction will be used as extensively in Britain as in many other countries for a very long time—if, indeed, ever. British Railways' plan for the construction of Diesel locomotives, as announced in December, concerns so far only shunting engines, for which the Diesel engine has obvious advantages in being easily started and in consuming no fuel when temporarily idle; these factors counter-balance the high initial cost, which is about four times that of a steam locomotive. The decision to adopt Diesel-electric traction for shunting was probably also influenced by the findings of the committee set up by the Railway and London Transport Executives in 1948 to examine the question of railway electrification. This committee, which reported in March, pointed out that, in an electrified area, the necessity for electrifying all the tracks in a marshalling yard could be avoided by the use of Diesel traction; and recommended that, in preparing electrification schemes, the complementary use of Diesel power should be the subject of economic assessment as an alternative to the complete electrification of marshalling yards and the retention of steam locomotives.

Under the new programme, British Railways are to add 573 Diesel and Diesel-electric locomotives to their stock of shunting locomotives. At present, they possess only 130, though a further 84 have already been authorised. Of the 573 locomotives to be built, 432 are to be Diesel-electric, of 350 h.p., and 141 Diesel-mechanical, of 150/200 h.p. As a first instalment, 57 of the Diesel-electric locomotives and 12 Diesel-mechanical are to be included in the 1953 locomotive renewal programme; but the progress of the plan will depend upon the permissible level of investment expenditure, steel supplies, and the ability of manufacturers to provide Diesel engines and transmission equipment. It is not yet known to what extent the private builders will participate in the programme, but, as things stand, it appears that the railway workshops will build main frames, wheels, cabin structures and mechanical parts, and that the engines and transmission equipment will be contracted out. The decision to include a high proportion of Diesel-mechanical locomotives in the new programme is of great importance to the future of Diesel traction in Great Britain. Shunting locomotives of this sort are still in the experimental stage, and the experience gained under traffic conditions with the first 12 will decide whether or not the remainder are to be built. If successful, they are likely to have a much greater field of application than Diesel-electric locomotives, because of their much lower capital and maintenance costs. British Railways are by no means disregarding the possibility of using Diesel traction for main-line work. A 1,600 h.p. Diesel-electric locomotive has been making two return trips daily on the Waterloo to Exeter run since October. Altogether, four 1,600-h.p. Diesel-electric main-line express passenger and freight locomotives are undergoing extensive trials, as well as one of 800 h.p. for secondary passenger and freight services. Experiments are also being carried out with two Diesel-mechanical locomotives, one of 1,600 h.p. for main-line and freight services and one of 500 h.p. for local freight trips. It is still too early to predict the outcome of these trials, though there is every indication that the intensive utilisation necessary for the economic employment of Diesel locomotives can be scheduled on British main lines.

While the work of the Committee on electrification has been very valuable, the question of further electrification on British Railways is somewhat unreal at present in view of the need to restrict capital expenditure. The execution of several electrification schemes, including that on the London-Tilbury-Southend line, has already been held up. British manufacturers, however, have had large overseas orders for electric locomotives and traction equipment. Thirty-two lightweight 700-h.p. 1,500-volt direct-current motor coaches, built by the Metropolitan-Cammell Carriage and Wagon Company and the English Electric Company,

went into service on the Great Indian Peninsular Railway in 1951. The Gloucester Railway Carriage and Wagon Company announced in November that they had received an order valued at 2.6l. millions from the Toronto Transport Commission for 104 cars for the Toronto subway system, now being completed.

Further developments have taken place in the field of gas-turbine traction. British Railways, who have now had an experimental gas-turbine locomotive, built by Brown Boveri and Company, for some time, have now received delivery of a second, completed by the Metropolitan-Vickers Electrical Company at Trafford Park. This locomotive, which is being employed in the Western Region, weighs 120 tons and develops 3,000 brake horse-power. The Ministry of Fuel and Power is now interesting itself in gas-turbine locomotives and has placed an order for a coal-burning gas-turbine engine with the North British Locomotive Com-

successive cuts, which have all been made at short notice, have made rational forward planning difficult. In 1950, only 68l. millions of the reduced allocation of 81l. millions could be used, because of the impossibility of reformulating plans satisfactorily and because deliveries of rolling stock fell behind.

The present rate of construction is hardly sufficient to keep intact the present stock and yet the volume of freight to be carried is constantly increasing. It was planned to build 39,975 wagons for the British Railways in 1951, compared with 29,531 in 1950; since 35,600 wagons were produced up to the end of November, it seems that the programme was fairly well fulfilled. British Railways' operating stock, however, increased by only 7,000 to 1,109,000, in the year to December 2, 1951. An immense amount, moreover, requires to be done in replacing old rolling stock with up-to-date types. A committee of the Railway Executive recently reviewed the wagon situation and recommended

TABLE IV.—UNITED KINGDOM: EXPORTS OF RAILWAY WAGONS AND PARTS.

	Weight, Tons.			Value (£1,000).		
	1949.	1950.	1951.	1949.	1950.	1951.
<i>Wagons and trucks:</i>						
British West Africa	10,573	7,276	2,406	1,112	901	370
Union of South Africa	21,730	12,183	639	1,409	802	57
Southern Rhodesia	20,381	10,419	850	1,733	947	89
India	4,621	6,576	4,151	353	668	418
Malaya	1,371	972	805	158	103	85
New Zealand	211	2,481	3,002	23	238	314
Other Commonwealth countries and Irish Republic	7,883	26,537	24,527	682	2,735	2,878
Egypt	7,443	439	329	530	41	32
Burma	1,343	497	—	136	67	—
Brazil	4,858	769	105	443	82	12
Argentine Republic	10,105	7,964	2,553	970	832	295
Other foreign countries	2,773	8,622	5,305	410	932	572
<i>Exceeding 3 ft. gauge:</i>						
Complete	45,824	48,809	25,787	4,100	5,107	3,064
Parts, except axles, tyres and wheels	38,935	27,415	13,489	3,172	2,529	1,601
<i>Not exceeding 3 ft. gauge:</i>						
Complete	6,275	7,580	4,524	466	622	359
Parts, except axles, tyres and wheels	1,758	931	872	170	90	98
Total	92,792	84,735	44,672	7,909	8,348	5,122
<i>Axles, tyres and wheels for rail vehicles:</i>						
Wheels and axles, exported in complete sets	43,168	23,348	16,781	2,411	1,414	1,125
Other	49,774	67,744	63,909	2,575	3,317	3,837
Total	92,942	91,092	80,690	4,986	4,731	4,462
Grand total	185,734	175,827	125,362	12,895	13,079	9,584

TABLE V.—UNITED KINGDOM: EXPORTS OF RAILWAY CARRIAGES AND PARTS.

	Weight, Tons.			Value (£1,000).		
	1949.	1950.	1951.	1949.	1950.	1951.
<i>Railway carriages:</i>						
British West Africa	1,635	997	484	271	283	192
Union of South Africa	5,285	6,101	3,667	1,826	2,336	1,284
New Zealand	1,102	1,055	246	452	433	103
Other Commonwealth countries and Irish Republic	1,452	2,084	6,331	254	574	2,704
Egypt	1,239	1,203	544	275	303	134
Iraq	492	311	—	206	136	—
Other foreign countries	1,552	925	715	404	292	271
Complete carriages	7,048	8,215	10,649	2,283	2,730	4,181
Parts except axles, tyres, wheels and motors	5,709	4,461	1,338	1,405	1,627	507
Total	12,757	12,676	11,987	3,688	4,357	4,688

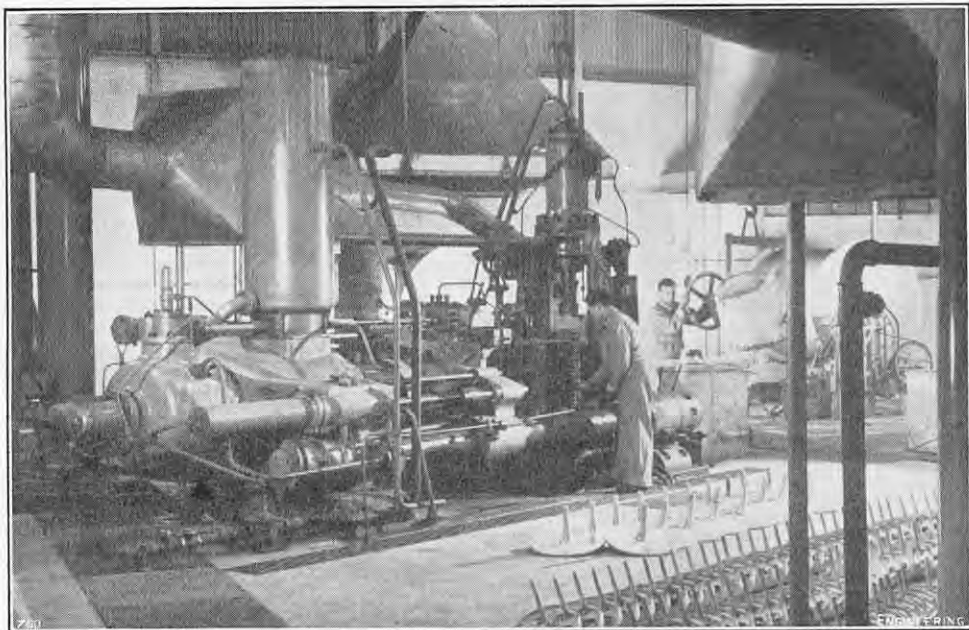
pany, who are to build it in collaboration with C. A. Parsons and Company.

It was the intention of British Railways to build 400 locomotives in 1951, including 51 Diesel-electric and four Diesel-mechanical; largely because of the shortage of steel and components, it was not possible to carry out this programme. As will be seen from Table I, only 216 were constructed in the last three quarters of 1951, and the final year's figures are not likely to have exceeded 350. In view of the continuing shortages and the restrictions on investment, British Railways have not committed themselves to a fixed programme for 1952. The British Transport Commission, however, in their annual report published in July, express grave concern at the "serious arrears" in capital investment, which will be difficult to make good, and consider that a more adequate allocation out of total national capital investment is necessary "if a large part of the transport system is not to stagnate or even decay." British Railways, moreover, have not even been able to use the whole of their existing allocation of funds for capital investment. The

that the 480 different types of wagons in use at present should be reduced to 150, and that all wagons with grease-lubricated axleboxes, which need much attention and frequent maintenance stops, should be abolished. Designs have been produced for 34 different types of standard wagons, but as yet only a few are in service.

The latest development in wagon design is a type for conveying iron ore. Thirty wagons, designed to carry up to 56 tons of ore, the largest mineral wagons ever to be built by British Railways, are under construction and when complete will carry 1.25 million tons of ore per annum from Tyne Dock to the steel works at Consett, County Durham. Pneumatic doors have been fitted (for the first time on British Railways' wagons) to facilitate loading and unloading, and the 30 new wagons will be able to replace 600 of the older type. British Railways have been paying considerable attention to the design of iron ore and mineral wagons. The 1951 building programme included the construction of 1,500 27-ton iron-ore wagons with a tipper discharge system. It was announced in May that

PRESSURE DIE-CASTING FOUNDRY AT SLOUGH.



the Butterley Company, of Derby, had been awarded a contract to build 1,200 all-welded mineral wagons, valued at 500,000/. The large quantity of steel required by the new type of wagons is a serious handicap in present circumstances—it was estimated, for example, that the wagons ordered from the Butterley Company would require 9,000 tons—and wagon builders have had to cut production drastically in the past few months. The three Scottish builders claim to have suffered a cut of 40 per cent. in their steel supplies.

As will be seen from Table IV, on page 296, taken from the *Trade and Navigation Accounts*, exports of wagons were seriously reduced in 1951. This was partly due to the inevitable irregularity of railway construction programmes, a factor which accounts for some of the decline in the Dominion and Colonial Markets. Even there, however, competition from foreign manufacturers has been intensifying, while the growth of local manufacture in South Africa and to a lesser extent in India has been so great that exports of wagons have been drastically reduced. The fall in exports to foreign countries has been severe; in 1949, they accounted for 31 per cent. of the total value of British exports of wagons, but in 1951 for only 18 per cent. The main reason is increased competition from European and Japanese builders, but this in turn is partly due to the fact that the latter have been faced with declining demand in their own countries. As was pointed out by the compilers of the *General Survey of the European Engineering Industry*, published by the United Nations Economic Commission for Europe, the decline in demand in Europe is due to the difficult financial position of most railways, which frequently makes it no longer profitable to increase their capital investment. Moreover, the general need to limit public expenditure, coupled with the fact that most European railways are under public ownership or control, make railways a comparatively easy target for reductions in investment programmes.

The tendency towards self-sufficiency in rolling-stock production (which is by no means confined to European countries) has been increasing since the war, and each country is now capable of satisfying numerically its wagon requirements and of virtually satisfying its requirements of passenger rolling-stock and locomotives. The United Kingdom has the greatest capacity for rolling-stock production of any country outside the Soviet Union, though Western Germany is a close second with a capacity of 37,000 wagons and 1,800 carriages per annum, compared with 45,000 wagons and 1,800 carriages in the United Kingdom. Belgium, France and Italy have capacities of 30,500, 28,000 and 25,000 wagons, respectively. No capacity figures have been issued for the Soviet Union, but the output planned for 1950 comprised 146,000 wagons, 2,600

carriages and 2,750 locomotives. Japanese capacity, which is estimated at 13,470 wagons and 2,000 carriages, is comparatively small by European standards, but, though the output is far below capacity, a high proportion is being exported. By the summer of 1950, Japanese builders were exporting about 150 wagons a month, which compares with 39 a month in 1937 and 98 in 1938.

British supremacy has been better maintained in the field of passenger coaches. As will be seen from Table V, opposite, taken from the *Trade and Navigation Accounts*, exports of complete carriages, at 4.2l. millions, were 52 per cent. higher than in 1950. The number of carriages supplied to British Railways also increased, though it is unlikely that the programme for 2,440 carriages was completed. Up to the end of November, 1,813 carriages have been built for British Railways and 354 for export, compared with 1,908 and 240, respectively, in the first eleven months of 1950. The trend towards all-steel construction has made the shortage of steel all the more serious for the carriage builders, and the production of the new standard carriages for British Railways has suffered greatly in the past few months. It now seems ironic that one of the reasons for adopting the all-steel carriage was the shortage of suitable kinds of timber. The steel carriage, however, has also many technical advantages, and recent improvements in design have considerably reduced their weight. Steel coaches now being built for the Bombay electrified suburban services by two British manufacturers are 26 per cent. lighter than similar coaches supplied 25 years ago. Another advance in lightness has been achieved by one builder, who is supplying cars having aluminium bodies for the surface lines of the London Transport Executive. These are said to be 37 per cent. lighter than steel cars previously built for the same service.

The outlook for the rolling-stock industries depends very much on the availability of steel. There is now hope that supplies will be fairly adequate by the second quarter of 1952. In spite of the need to restrict capital investment, the Government can hardly afford to permit a fall in building for British Railways. Overseas demand for wagons cannot be expected to increase, but manufacturers should be fully occupied in building for the home market. The overseas demand for locomotives and passenger carriages is still at a high level, and is likely to continue so for at least the next year or two.

"THE ENGINEERING OUTLOOK." ERRATA.—We regret that, on page 169, *ante*, we inadvertently described the journal *Teamwork* as being "the works magazine of the Austin Motor Company," whereas it is that of the Nuffield Organisation; and that, on page 264, *ante*, the Wenvoe television station of the British Broadcasting Corporation was incorrectly referred to as "Wivenoe."

LIGHT-ALLOY PRESSURE DIE-CASTING FOUNDRY.

DURING the past few years Messrs. High Duty Alloys, Limited, have experienced a rapidly increasing demand for light-alloy pressure die castings and, in order to be in a position to deal adequately with the orders received, the erection and equipment of a new shop at their Slough Works, Buckinghamshire, was decided upon. The new shop, which has now been completed and was officially opened on February 27, has an area of 7,600 sq. ft., and is 20 ft. high to the roof truss. The High-level lighting is furnished over the whole area. The pressure die-casting machines are hydraulically-operated and are Polak machines manufactured in Czechoslovakia. Four types, namely Nos. 600, 900, 2255 and 5065, are employed and some particulars of these are given in the Table. These data comprise the pressure applied to the metal in tons per square inch; the die-closing power, or locking power as it is sometimes called; the maximum weight of die-casting which can be produced; and the maximum area of casting, or, in other words, the maximum sectional area of a casting at the die "split line." The largest machine installed in the new foundry, which is of type No. 5065, is shown in the accompanying illustration, together with some examples of the aluminium-alloy pressure die castings it is capable of producing. These are seen on the floor in front of the machine. The firm state that with the aid of the new machines they can now produce pressure die-castings in weights ranging from 1 oz. to 30 lb.

Type of Machine.	Pressure Applied to Metal.	Die-Closing or Locking Power.	Maximum Weight of Casting.	Maximum Area of Casting.
No.	Tons per sq. in.	Tons.	Lb.	Sq. in.
600	3-16	70	2	31
900	6-30	120	4	62
2,255	10-55	220	18	140
5,065	11-70	519	30	310

The metal used in the new foundry is melted in oil-fired semi-rotary bulk furnaces and is then conveyed by overhead cranes to individual gas-fired furnaces, each situated in close proximity to a pressure die-casting machine so as to reduce to a minimum the movements required in subsequent operations. Throughout melting and casting the metal is under strict control by mechanical and analytical tests. Much thought has also been given to the question of maintenance to ensure that production continues in the event of individual breakdowns. All services such as gas and compressed-air mains, temperature-recording circuits, and inlet and return hydraulic pipes, each of which is painted in a contrasting colour, are arranged in trenches. For changing the dies and for maintenance and other work on the pressure die-casting machines, remotely-controlled travelling cranes running the entire length of the shop are provided. Each die-casting machine is also equipped with a fume extractor. The hydraulic power for each machine is furnished by individual electrically-operated pumps, housed in a pump room adjacent to the foundry.

ENGINEERING AT CAMBRIDGE UNIVERSITY.

THE report of the head of the Engineering Department of Cambridge University, Professor J. F. Baker, for the academic year 1950-51, was issued recently. It records that, during the period under review, 597 students—a slightly smaller number than in the previous year—were reading for degrees in engineering. Of these, 516 were taking honours courses. Although appreciably lower than in the peak year, 1947-48, these numbers are considerably higher than the pre-war totals, and, in consequence, the department is still somewhat congested. Work continued, however, throughout the year on a new five-storey building which will contain offices and lecture rooms, and it is hoped that this accommodation will be available in the near future. The list of research work completed, or in progress, is a lengthy one, and covers many branches of engineering. In the Aeronautics Department, the flight research undertaken on behalf of the Ministry of Supply to determine the value of distributed suction over an aerofoil, as a means of maintaining laminar flow in the boundary layer, has been completed. Other researches on boundary-layer suction are in progress in the wind tunnels, and a new method of calculating the thickness of the turbulent boundary-layer on the surface of an aerofoil, which is stated to be simpler and more accurate than those in use hitherto, has been devised.

In the Heat Engines laboratory, an investigation of secondary flows in axial-flow compressors is in progress,

and the effect of turbulence on the flow of air through cascades of compressor blades has been studied. The turbulence was measured by means of a hot-wire apparatus made by the department and described briefly in *ENGINEERING*, vol. 171, page 680 (1951). An investigation into the combustion of liquid fuels, which is supported by the Department of Scientific and Industrial Research, continued throughout the year. Progress was made also with the study of scavenge flow in two-stroke engines, this work being sponsored by the Mechanical Engineering Research Organisation. Coloured water was employed to represent the scavenge charge and to show the extent of the mixing region. A chemically-reacting dye was used to study the central core in which there is no mixing, and by means of a newly-developed multi-colour technique, the extent of the core, as well as the rapidly changing regime in the mixing region, could be observed simultaneously, a transparent cylinder being employed. A theoretical and experimental investigation of circulation in steam boilers has been completed, but some additional work is in progress in which the pressure drop and heat transfer in a pipe conveying a mixture of water and steam are being investigated. This work is sponsored by the Water-Tube Boilermakers' Association.

With the aid of a further grant from the Mechanical Engineering Research Organisation, work has continued in the Hydraulics Laboratory on swirling flow through a conical nozzle. The nozzle was made of Perspex and, as a result of the introduction of more refined methods of measurement, the causes of the discrepancies found between the observed and predicted results have been examined in more detail. The British Shipbuilding Research Association has renewed its support of experiments in an open water-channel, which were undertaken to determine whether stationary ship models can be tested in such a channel with moving water. A larger channel is under construction, in which the Froude number will normally be less than unity.

In the Materials Laboratory, research supported by the Ministry of Supply has been started to ascertain the effects of welding and notching on the strength of light-rolled sections of certain steels at temperatures down to -60°C . Mild steel and two high-tensile structural steels are being tested. Work has also begun on the preparation and testing of iron crystals at low temperatures. In the Mechanics Laboratory, an investigation of dynamic stresses in gear teeth by a photo-elastic method has been resumed. Improvements have been made to the loading frame of the photo-elastic apparatus to enable the effect of distributed loads on models to be simulated. In the Structures Laboratory, an analysis of stresses in flanged beams has been extended to the case in which loads are applied to the flange, and the experimental results have agreed well with theory. Research into non-infinitesimal deformations of thin plates has continued but theoretical and experimental work on the torsion of thin-walled prisms has been completed.

Investigations supported by the Department of Scientific and Industrial Research and the British Welding Research Association into the behaviour of structures in the plastic range have continued. These have included work on the behaviour of rigid-jointed plane frames and transversely-loaded square grids, the lateral instability of beams and stanchions, and the effects of variable repeated loads, shear forces, strain hardening and initial internal stresses on the plastic deformation of beams. The work on full-scale portal frames has been completed and analysed. A series of tests has been made of I-section stanchions subject to various combinations of end moment and restraint. In all cases, the moments were applied about the major axis of the stanchion and caused lateral instability, usually in the plastic range. Preliminary work, which has been completed, on the behaviour of elasto-plastic structures under repeated loads has confirmed that failure resulting from excessive plastic deformation can be caused by the repeated application of certain combinations of critical loads in a definite sequence. Several other research programmes are in progress in the Structures Laboratory.

The department's workshops continued to manufacture many items of equipment for internal use, but also, in increasing quantity, equipment for other departments of the university. The apprentice-training scheme, started in 1946, has now borne fruit and is considered to have justified itself. The year, however, was a difficult one for the workshops owing to the scarcity of engineering materials, delays in deliveries, rising prices and rationing of supplies. Certain plastics are said virtually to have disappeared from the market.

Substantial monetary gifts, amounting in all to 105,335*l.*, were received by the department during the period. One donation of 71,000*l.* came from the British Electrical and Allied Manufacturers' Association and is to be used for the permanent endowment of the Chair of Electrical Engineering. Some gifts in kind were also received.

ELECTRIC BOILER FOR AIRCRAFT HUMIDIFIER.

THE accompanying illustration shows a humidifying unit developed by the General Electric Company, Limited, Magnet House, Kingsway, London, W.C.2, for air-conditioning the pressure cabins of air liners flying at high altitudes. It is designed to be controlled by a humidistat, so as to come into operation when the relative humidity falls to 25 per cent., and to cut out when the humidity rises to between 60 and 70 per cent. Twenty such units have been ordered for installation in the Britannia air liners which are being constructed by the Bristol Aeroplane Company, Limited, Filton House, Bristol, and the first of them is expected to fly this year.

The humidifier comprises an electrically-heated boiler which supplies steam through a 2-in. diameter steam pipe to any convenient point in the cabin air-supply system. The water level in the boiler is maintained automatically at the correct level. Alternating or direct-current supplies at from 112 to 250 volts may be used. The boiler, which has a capacity of about 1½ gallons, is of 20-s.w.g. copper sheet and is enclosed in an outer casing of aluminium sheet with foil lagging between the inner and outer walls. It has ten closed-end tubes, each housing a 750-watt cartridge-type element, mounted in a removable

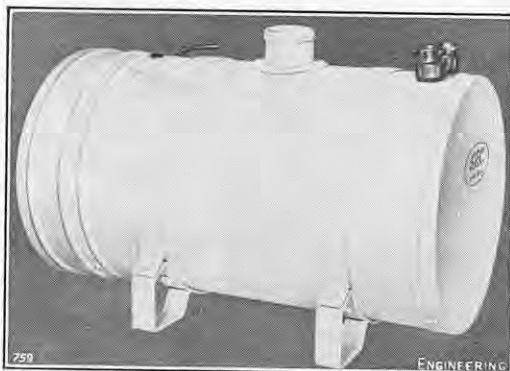


plate. By varying the number of heating elements, any desired loading up to 7.5 kW may be arranged, generating approximately 19½ lb. per hour of steam. With a unit of slightly greater overall length it is possible to increase the loading to 10 kW, and to generate approximately 26 lb. per hour of steam.

Water is fed into the boiler through a float chamber, the float controlling a micro-switch in the feed-pump circuit so that the level is kept constant. Should there be a failure in the feed, so that the level of water in the float chamber falls, a second microswitch is actuated to cut out the heating elements. The float chamber is insulated from the boiler by asbestos-sheet lagging. The complete unit weighs 32 lb. and is 18½ in. long by 10½ in. high.

ELECTRICITY SUPPLY IN ONTARIO: ERRATUM.—In our abstract, on page 19, *ante*, from the 1950 report of the Hydro-Electric Power Commission of Ontario, the new Sir Adam Beck Niagara generating station No. 2 was referred to as a 75-MW station, instead of a 525-MW station. When completed, it will contain seven generators, each of 75 MW capacity.

THE OLD CENTRALIANS.—The next monthly luncheon of the Old Centralians—the association of former students of the City and Guilds Engineering College—will be held on Friday, March 14, at 12.45 for 12.55 p.m., at the restaurant "Chez Auguste," 47, Frith-street, London, W.1. The after-luncheon address, on British Guiana and British Honduras, will be given by Sir Kenneth Mitchell, K.C.I.E., F.C.G.I., a vice-president of the association.

NEGRETTI AND ZAMBRA, LIMITED.—We have received from Messrs. Negretti and Zambra, Ltd., 122, Regent-street, London, W.1, a copy of a brochure outlining the history of the firm since its foundation in 1850 by Enrico Negretti and Joseph Warren Zambra. Negretti had been in business since 1843 in Old Leather-lane, London, but the business of the partnership began in Hatton-garden. They moved into new premises at the end of Holborn Viaduct about 1868, remaining there until 1941, when their building was destroyed by enemy action. During the war, they operated factories at Chesterfield and at Chobham, Surrey, and have recently acquired new premises of 50,000 sq. ft. area at Aylesbury. In June, 1946, the business was converted into a private limited company and in September, 1948, into a public company, the present chairman of which is Mr. P. E. Negretti. Two other members of the Negretti family—Mr. P. A. Negretti and Mr. P. N. Negretti—are members of the board of directors.

THE BIRMINGHAM MUSEUM OF SCIENCE AND INDUSTRY.

THE first section of the Museum of Science and Industry at Birmingham was opened officially by the then Lord Mayor, Alderman A. Paddon Smith, in May, 1951. We mentioned at the time that considerable accommodation was available and that the first display, of a part of the City's firearms collection, occupied only a small part of it. Since then it has been the policy to open further sections as the materials and labour situations permitted. The first extension, which was opened a few months ago, shows items illustrating the work of Matthew Boulton and James Watt in Birmingham in the Eighteenth Century. Both the first and second sections of the Museum are of purely historical interest, however, and, as it is an important part of the Museum's work to deal with the present-day application of science and technology, the latest addition to the rooms open to the public has been designed to contain items of scientific and general interest.

The new section was opened yesterday, March 6. The exhibits have been chosen more or less at random, to illustrate many different aspects of science, and will be changed from time to time. As at present arranged, the new science room contains a considerable proportion of electrical apparatus, but the exhibits cater for many tastes, and range from telephone-exchange equipment to shipboard instruments, scale models of various kinds, demonstrations of some of the principles of physics, and a working hot-air engine. The whole series of displays has been designed on the assumption that the visitor is not possessed of technical knowledge of the particular subject, and is based on the maximum use of visual or audible illustrations. The methods employed to provide visual demonstrations of the functions of some of the electrical apparatus have required considerable ingenuity; ingenious simplicity is the keynote.

As a rule, one subject occupies the whole of one show-case, but in some of the simpler displays several similar or related items are grouped together. There is, for example, a simple apparatus which shows the elementary principle of repulsion between like poles of permanent magnets. In the same case, the repulsion effect of electro-magnets is demonstrated, a typical industrial use of the principle being represented by an electrical indicating instrument. Again, in the same group there is a display of the measurement of electric current by means of an ammeter and a voltmeter, with an electric bulb to show the effect on the filament as the current varies.

From simple demonstrations of elementary principles such as these the visitor can proceed to study such items as radio-frequency oscillators, thyratrons and ignitrons, which, in all cases, give some visual or audible signal to make clear what happens when the controls are operated. A special display, provided by the British Thomson-Houston Company, Limited, shows phase control of a 150-watt and a 1,000-watt bulb by means of an ignitron and a thyatron valve. Like other displays, this is illustrated by a typical industrial application; in this instance, a photograph of a printing machine is mounted in the showcase. The demonstration equipment is mounted so that the actual valves and other items appear against a background on which is painted the wiring diagram, a principle which is applied to other displays as far as possible. Control of the display is by means of switches and knobs brought through the glass at the front of the case to a position where they can easily be reached by a visitor, and clear instructions are given on a showcard in the case for his guidance.

The principle of placing the controls of the display in the hands of the visitor is, of course, the general practice in museums to-day, but a useful feature of the new science section at Birmingham is the degree of uniformity in controls which has been achieved. All push-buttons, for example, are of a standard type, and are clearly mounted within a yellow border. Attention has also been given to the question of making the apparatus foolproof, and to ensuring that the exhibits cannot be damaged by careless operation of the controls. An obvious potential source of damage is the sudden rotation or reversal of a control knob, and this has been guarded against by providing every one with a slipping member lubricated with Ragosine grease. Normal rotation of the control knob operates the display as designed, but a sudden movement or reversal overcomes the "stiction" of the grease and the control slips, so that the apparatus is not harmed.

In some cases, more elaborate apparatus has been incorporated to prevent damage. This is well exemplified by a demonstration display of automatic telephone dials and selector mechanisms, provided by the Automatic Telephone and Electric Company, Limited, which consists of two of their standard dials and selectors. One shows simple vertical and horizontal movement by the selector when the dial is operated; the other demonstrates vertical movement and horizontal "hunting" for a vacant line. Operation according to the instructions, by pressing the

appropriate buttons and dialling, causes the selectors to function normally; but, if the controls are pressed violently and repeatedly, a thermal overload cut-out comes into operation, and cuts off the mains supply. An illuminated sign then shows that the machine is out of action, and it remains so until an attendant resets it. Another display of telephone equipment, by the General Electric Company, Limited, has two telephone hand-sets, one on each side of a switchboard, which is in a glazed cabinet with the whole of the equipment visible. It is possible to dial either of the telephones from the other, and to see exactly what happens in getting a connection, an engaged signal, or even a wrong number. To make the sequence of events understandable, an explanation of each step is given automatically on illuminated screens.

There are other working exhibits, such as that showing the continuous electrolysis of water, and a diagrammatic model illustrating by coloured lighting the cycle of events in a four-stroke petrol engine; also several static displays, including a magnetic ship's compass, a barometer, clinometer and a Walker's patent log. A wire model, which rotates slowly, and can be stopped by means of a push-button, shows the five regular geometric solids. Of the scale models, two are particularly interesting. They are both the work of two Birmingham amateur model-makers, and are fine examples of craftsmanship. One is of a Marshall overtype steam engine, of about 1890, and the other is of a 6 n.h.p. agricultural and general-purpose traction engine. The latter has an added interest in the fact that it was made from the original detail drawings, provided by the makers of the prototype, Messrs. Ransomes Sims and Jefferies, Limited, Ipswich. Both models are to a scale of 1 in. to 1 ft.

Perhaps the most novel of all the displays is one provided by Ericsson Telephones, Limited, which is designed to demonstrate the versatility of the telephone-type relay. It is based on a game played on a draught-board, and enables a visitor to play a piece against the machine. A choice of three opening moves is available, by pressing one of three buttons, and the game is then played by moving a piece mounted on the front of the machine. This causes a red light to appear under the chosen square on the draughtboard, and the machine then makes its own move, which is indicated in green. The time allowed to the player is automatically limited by the machine, and ten seconds before the time limit expires an illuminated sign gives warning. If the warning is ignored, the machine automatically cancels the game and resets itself. The game can continue until either the player breaks through the line set by the machine, or the machine-set line traps the player. The result is shown by illuminated signs.

SCHOLARSHIPS IN PRODUCTION TECHNOLOGY AND MANAGEMENT.

THE Ministry of Education has announced that 75 scholarships are to be awarded this year for the study of production technology and management in selected universities and technological institutes and in industrial undertakings in the United States. The principal aim of the scheme is to promote industrial productivity in this country. The Mutual Security Agency (formerly the Economic Co-operation Administration) is to supply the dollar equivalent to meet tuition fees, travelling expenses in the United States and suitable maintenance allowances. The approximate total cost of the scholarships will be 250,000 dols. Return passages to the United States will be paid from public funds. It is pointed out that in previous years most of the candidates qualifying for these awards have been employees of the larger firms and organisations in the United Kingdom and it is hoped that, this year, employees of the smaller firms, will be more numerous.

The awards will be made in two groups. In the first of these, 40 awards, available for the study of management and normally tenable for a period of nine months, will be open to persons between the ages of 23 and 35 of adequate educational standard, who are potential managers or occupy positions of responsibility in industry, or who propose to teach management subjects in educational establishments. A minimum of three years of industrial experience will be a condition of entry. In the second group, 35 awards, available for the study of production technology combined with management and normally tenable for a period of one year, will be open to students who hold good honours degrees in either pure science or technology. These candidates should have had at least two years of industrial experience and should now be working in industry or research associations or teaching in universities or technical colleges.

Successful candidates will be expected to leave for the United States early in September, 1952. The closing dates for applications are April 16 and 30 for the technological and management awards respectively. Further particulars regarding the scheme may be obtained on application to the Ministry of Education (F.E. Division 1), Curzon-street, London, W.1.

AERODYNAMIC INVESTIGATION OF THE PROPOSED SEVERN SUSPENSION BRIDGE.

THE National Physical Laboratory's investigation of the aerodynamic aspects of suspension-bridge design, with particular reference to the design of the proposed Severn bridge, has recently been completed, and the final report,* by Dr. R. A. Frazer, F.R.S., and Mr. C. Scruton, B.Sc., A.F.R.Ae.S., has been submitted to the Minister of Transport. The principal conclusion relating to the Severn bridge is that a bridge built to the proposed design† will be free from unstable aerodynamic oscillations. Though the investigation did not include a study of the way in which wind action excites unstable oscillations, the investigators found that the liability of a suspension bridge to unstable oscillations in wind can be predicted, once the critical values of the "reduced velocities" and the natural frequencies are known. "Reduced velocity" is a non-dimensional parameter $\frac{V}{NB}$, where V denotes the wind speed, N the actual oscillation frequency at that speed, and B the bridge width. The primary purpose of tests of model bridges in wind tunnels is the determination of the values of the reduced velocities.

The investigators also developed a method of calculating the stiffnesses and natural oscillations, which is important both for normal static structural design and for predicting aerodynamic instability. The "introduction" to the report is, in fact, a summary of the report, including the main conclusions, and it is reprinted, slightly abridged, below.

Objective Requirements of the Investigation.—The investigation was carried out on behalf of the Ministry of Transport by the National Physical Laboratory during the years 1946 to 1951. The main purposes were outlined in a preliminary letter from the Ministry of War Transport, which stated that the construction of a new roadway crossing of the River Severn estuary was proposed by means of a suspension bridge with a main span of 3,000 ft. and anchor spans of 1,100 ft. Since several bridges of this type had in varying degrees been subject to peculiar aerodynamic effects, resulting in some cases in complete failure of the bridge, the consulting engineers advising the Ministry of Transport had asked for an investigation of the problem, so that as satisfactory and economical a design as possible might be evolved. A note prepared by the consulting engineers briefly reviewed the main features of the problem. This note laid down that the purpose of the research was "to ascertain reliable and economical forms of deck and stiffening-truss structures and the effects of other features of the structure which may react on the tendency to oscillate." A number of design features were suggested as having a possible influence on the aerodynamic oscillations. These included the type of stiffening truss, the separation of the roads by open gaps, the ratio of the bridge width to the span length, and the level of the deck with respect to the stiffening girders. The note included suggestions for tests of complete bridge models and also for tests on models representing only a short length of the suspended structure. It was considered that if this latter method could be shown to be reliable, it could be used to establish the superiority of one or two forms of suspended structure. When the best form of structure had been decided it would be necessary to make final model tests to confirm the aerodynamic stability and to obtain information on the static wind forces for use in the calculation of wind stresses.

Main Features of Suspension Bridges.—The main components of a normal long-span suspension bridge are the end anchorages for the cables, the towers, the cables with flexible hangers or suspenders to carry the suspended structure, the suspended structure, and the deck or decks, each comprising one or several roads. Most modern suspension bridges have their side-spans suspended, and the centre-span and side-spans are separately supported at the towers. The vertical stiffening system may consist either of girders with solid webs or of Warren-type or lattice-type trusses, usually having parallel chords. Lateral stiffening to resist wind forces acting at right-angles to the span is effected by diagonal bracing in one or more horizontal planes. Bearings, consisting of slotted guides or rocker-arms in conjunction with vertical pins, are used at the towers and anchorages to take up expansion and longitudinal movements of the suspended structure, and to relieve lateral deformations.

There may be a single road, or several roads separated by gaps, at each deck level. If gaps are present they may be either covered by gratings or left completely open. For the Severn Bridge investigation, attention was restricted to bridges containing only a single deck. Such a bridge will be said to be of top-deck form or

bottom-deck form accordingly as its roads lie approximately level with the tops or the bottoms of the stiffening girders. It will be of mid-deck form if the roads are placed at about the central level.

Historical Background.—In the past, many suspension bridges have been damaged or wrecked by aerodynamic oscillations. Early examples are provided by Telford's timber-floored bridge over the Menai Straits and by the Chain Pier at Brighton, which was broken by torsional oscillations in wind in 1836. During the Nineteenth Century, bridges were designed more and more robustly until in some, such as the Williamsburg Bridge, the proportions became ungainly and uneconomical. A reversal of the trend then followed. In some cases the attempt to achieve both grace and economy with long spans, without the essential basic aerodynamic information, was pushed too far. The extreme was reached when narrow ribbon-like bridges, adequately designed to withstand static wind loads, were found to oscillate in wind. The Bronx-Whitestone Bridge at New York, and the original Tacoma Narrows Bridge, which was wrecked by torsional oscillations in wind in 1940, provided examples. Both of these were stiffened against local loading by plate-web girders. The Bronx-Whitestone Bridge was completed one year before the bridge over the Tacoma Narrows, and was found to be subject to small vertical oscillations. These movements are said to have occurred usually in moderate winds blowing at inclinations of less than 45 deg. to the spanwise direction. The most pronounced oscillations showed a single node near the centre of the span, but oscillations showing no nodes and two nodes were also observed. In stronger winds the bridge tended to become more steady. In the summer of 1940, friction dampers at the towers, as well as centre ties bonding the cables to the top flanges of the stiffening girders, were installed, and these reduced the movements. However, as the bridge continued to cause anxiety, stiffening trusses were fitted above the top flanges of the existing plate girders. They are believed to be satisfactory.

The history of the first Tacoma Narrows Bridge is widely known through the cine-film showing the oscillations and the failure. The film has a unique scientific value since it has allowed comparisons to be made between the recorded behaviour of an actual bridge and the behaviour of model representations of the same bridge in wind tunnels. The bridge was fitted with dampers at the towers and with diagonal stay ropes connecting the cables and the suspended floor at mid-span. This device is said to have been helpful in reducing longitudinal oscillations of the floor, though not very effective in reducing vertical oscillations. During the four months the bridge was in service, and even during the erection, vertical bending oscillations were observed. These movements occurred in a variety of different modes, and often had a considerable amplitude even at low wind speeds. On the day of the failure, in a recorded wind of about 42 miles an hour, a violent torsional oscillation with a node at mid-span developed, and this caused the collapse of the bridge in one hour. In the reports on this disaster the primary failure is attributed to the slipping under fatigue of the cable-band to which the north centre-tie was attached. The collapse of this modern bridge attracted wide attention and was followed by extensive researches in America. At the University of Washington, where some preliminary work had already been carried out, a wind-tunnel was built, with a working section 100 ft. wide, for testing model bridges. The first complete model bridge tested in this tunnel represented the original Tacoma Narrows Bridge, and it showed aerodynamic oscillations similar to those which had been observed on the actual bridge. This good correlation gave confidence in the experimental methods, which were then used to determine a safe re-design for the bridge. The new Tacoma Narrows Bridge was completed at the end of 1950. High winds have since been experienced at the site on several occasions, but the bridge has remained satisfactorily steady.

At the Golden Gate Bridge, very high wind speeds have been encountered on several occasions. Some years ago a slight movement with an estimated amplitude of up to one foot occurred in a wind of 75 miles an hour. Recently, rather more pronounced oscillatory movements, believed to contain a torsional component, were observed during a storm from the south-west with gusty winds up to 72 miles an hour. The structure of the wind at the bridge site is said to be influenced greatly by the hilly local topography, and wind speeds and wind directions may differ markedly at different positions along the span. Only slight oscillations have been recorded with the George Washington Bridge. Recently the original open gap separating the two roads was covered over to provide more accommodation for traffic. The San Francisco-Oakland Bay Bridge was heavily stiffened as a box structure, and has shown no unusual movements.

Main Types of Deformation of Suspension Bridges.—The main types of deformation which the suspended structure can take up under conditions of practical loading are vertical bending, lateral (or horizontal)

* Department of Scientific and Industrial Research, National Physical Laboratory. A Summarised Account of the Severn Bridge Aerodynamic Investigation. By R. A. Frazer, D.Sc., F.R.S., and C. Scruton, B.Sc., A.F.R.Ae.S.

† See ENGINEERING, vol. 171, page 270 (1951).

FULHAM POWER STATION.

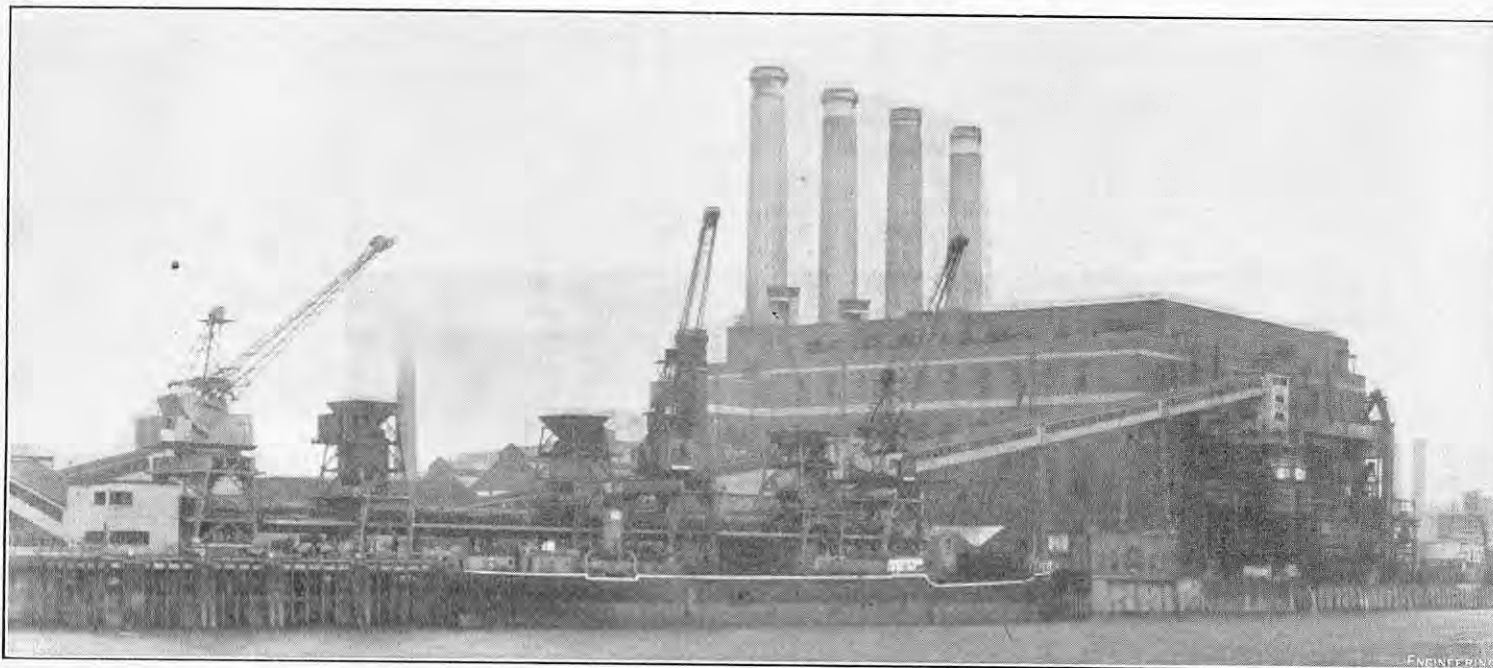


FIG. 1. VIEW OF STATION FROM RIVER THAMES.

bending, and torsion. With vertical bending the displacements which are of primary importance in relation to bridge oscillations are the vertical translations of the cross-girders, and the tilting of the cross-girders from their vertical planes. With lateral bending the corresponding translations are lateral, and the angular movements are about the vertical centre-lines of the girders. In the case of torsion, the cross-girders turn round the neutral axis of the structure and also warp. By warp is meant the twisting of the cross-girder planes themselves, and it is characterised by equal but opposite-handed tilting of the pairs of cross-girder posts concerned. Any vertical movements of the cross-girder posts that occur will be transmitted to the cable-bands through the suspenders. This will cause the cable-bands to displace also horizontally along the span, since the links of cable connecting them can extend only very slightly. The suspenders therefore become inclined. Suspender inclination arises also from the angular movements of the cross-girder posts when (as is normally the case) the suspension points are offset from the neutral plane of the suspended structure.

In the case of torsion the effects are rather complicated, since the suspenders become inclined both laterally (i.e., in vertical planes normal to the spar) and longitudinally (i.e., in vertical planes parallel to the span). The lateral inclinations are due to the turning of the cross-girder planes about the neutral axis, and they introduce forces tending to disturb the cables from their vertical planes and also to bend the suspended structure laterally. The longitudinal inclinations are due partly to the cable behaviour and partly to the warp of the cross-girders, and are opposite-handed for the two posts of any cross-girder. The two corresponding inclined suspenders then pull the cross-girder posts spanwise in opposite senses and so contribute a movement tending to bend the structure laterally. It is seen then, that with torsional loading, lateral bending can be induced in two ways: lateral forces can result from the twisting of the structure, and lateral bending movements from the cross-girder warp and from the cable geometry.

When a bridge is oscillating the live loading arises effectively from inertia. With torsional oscillations some lateral movements can be induced by the effects just referred to and also by any offset of the centre of mass of the suspended structure from the horizontal neutral plane. This inertial coupling will evidently be most pronounced for bridges possessing a single road deck placed either at the top or at the bottom of the structure. With natural torsional oscillations, the presence of a lateral component of motion will offset the effective centres of rotation of the cross-girders to positions above or below the neutral axis which will vary along the span. A knowledge of these effects is important in relation to the production of torsional aerodynamic oscillations from wind-tunnel tests of the pitching oscillation of sectional models. To provide the most complete information the range of practical positions for the centre of rotation should be covered by such tests. In the experimental investigations, allowances for a variation of the axis position were made, but the position was in all cases assumed to fall within the depth of the stiffening truss. Some justification for this limitation was provided by observa-

tions of the torsional oscillations of a full model of a mid-deck form of bridge. In this case the twisting at all cross-girders was very closely about the roadway centre-line. More precise information on the coupling effects between torsion and lateral-flexure is certainly desirable, but unfortunately it is beyond the scope of any existing theory. Illustrations of the effects are seen in the Tacoma Narrows Bridge film. Some of the very large torsional oscillations which preceded the first collapse of the bridge show appreciable lateral movements of the cables and deck platform.

Natural Oscillations of Suspension Bridges.—Before aerodynamic oscillations are considered, it will be necessary to understand how a suspension bridge would respond to a casual disturbance if all the damping forces due to the structure and to the surrounding air were removed. Under these idealised conditions, the free oscillations following a quite general disturbance would appear very complex and irregular. They would, of course, persist for an indefinitely long time. However, with special simple disturbances the oscillations would be of the simple harmonic type, and all points of the bridge would move regularly and in step. With any given bridge design there are numerous possible varieties of these so-called natural oscillations, and they have different frequencies and different modes of displacement according to the special simple (natural) disturbance. A general disturbance is mathematically equivalent to a combination of the natural disturbances taken in suitable proportions. Hence, also, the most general free oscillation, though apparently very irregular, is only some superposition of the regular natural constituents.

Since a suspension bridge has constructional symmetry about the vertical plane through its span-wise centre-line, the natural oscillations can be of two types. With one type the movements on the opposite sides of that plane are equal and in the same phase, and the deformation occurring is vertical bending. With the other type the movements are equal but oppositely phased, and are characterised by torsion and lateral bending. In this case the torsion or the lateral bending will predominate, according to the frequency. A further classification depends on the fact that the bridge also has constructional symmetry about the vertical plane which bisects the span at right-angles. The two halves of the total span can therefore move equally, either in the same phase or in opposite phases. In the first case the oscillations are said to be symmetric, and in the second case anti-symmetric. With symmetric oscillations movements must take place at mid-span, so the total number of nodes contained in the span is even; with anti-symmetric oscillations a node is present at mid-span, and the total number of nodes in the span is odd. Vertical bending oscillations and torsional oscillations will be accompanied by substantial vertical movements of the cable, and, in some cases, by movements of the towers and side-spans. With symmetric oscillations of these types the cables displace only vertically at mid-span, but can have marked horizontal movements at the towers. With anti-symmetric oscillations the horizontal movements of the cables can be marked at mid-span, but will in general be small at the towers.

(To be continued.)

THE 360-MW FULHAM POWER STATION OF THE BRITISH ELECTRICITY AUTHORITY.

THE British Electricity Authority's power station at Fulham, London, was completed on Wednesday, March 5, when No. 6 turbo-alternator set was formally commissioned by the Mayor (Councillor P. E. Fenne). The station was first put into operation in 1936 and was fully described in *ENGINEERING** at the time. It was designed for an ultimate capacity of 300 MW, consisting of five 60-MW sets, exclusive of house service generators, and the associated steam-raising plant. At that time two sets were in operation, while a third was in course of erection. Subsequently, two others have been added. The station, which was transferred to the London Division of the British Electricity Authority in 1948, was of greater capacity than was required by local needs, but it was intended that most of its output should be transmitted to other areas where the site conditions were not so favourable. It was one of the few British power stations to be seriously damaged by enemy bombing, the whole of the then capacity of 190 MW being put out of action on September 9, 1940. The station was, however, in service again with 60 MW of plant within nine weeks. This was increased to 130 MW within 15 weeks, and to 190 MW in 28 weeks.

The station occupies a site of 12½ acres on the north bank of the River Thames and has a river frontage, shown in Fig. 1, of 1,300 ft. The coaling jetty is 350 ft. long and the fuel is brought to it in 2,000-ton colliers owned by the Authority. Unloading is effected by three portal cranes at the rate of 175 tons per hour, and the coal is then taken by duplicate belt conveyors, with a capacity of 200 to 300 tons per hour, either to two silos with a combined storage capacity of 80,000 tons or direct to the boiler-house bunkers.

The steam-raising plant consists of 16 Stirling boilers, which are installed in two boiler houses. Eight of these boilers have a maximum continuous rating of 260,000 lb. per hour, while that of the other eight is 315,000 lb. per hour, the steam conditions, in all cases, being 625 lb. per square inch and 850 deg. F. The furnaces are water-cooled with Bailey walls and firing is by Taylor stokers. Eleven of the units are fitted with the Hagan compressed-air system of automatic control and the remaining five with controllers incorporating Selsyns and George Kent thermostats. The superheaters are of the Melesco type, while the smaller boilers have Foster Green and the larger Senior economisers. There are two Howden-Ljungstrom air heaters to each boiler, as well as two forced-draught, two induced-draught and two secondary-air fans, the output of which is controlled by Howden-Tate vanes or hydraulic couplings. A view of the boiler house firing aisle is given in Fig. 4, on page 304.

The generating sets consist of five Metropolitan-Vickers turbo-alternators, each with a maximum continuous rating of 60 MW when running at 1,500 r.p.m., and one English Electric set of the same output but running at 3,000 r.p.m. Three of the Metropolitan-Vickers alternators were designed to generate at 11 kV

* See *ENGINEERING*, vol. 142, page 353 *et seq.* (1936).

FULHAM POWER STATION.

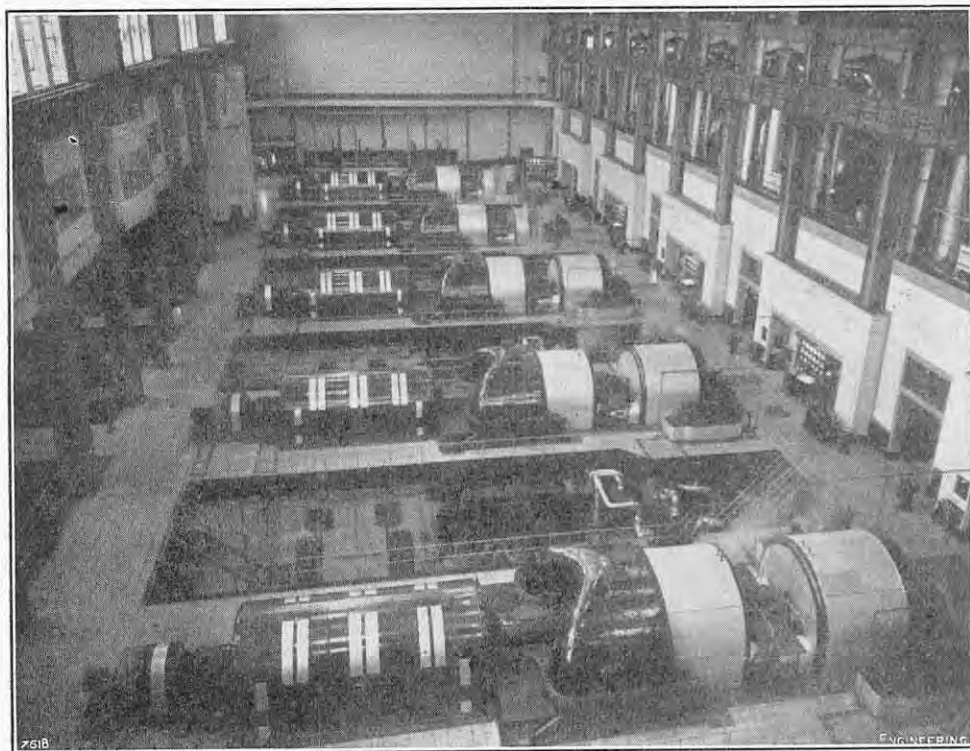


FIG. 2. TURBINE ROOM.

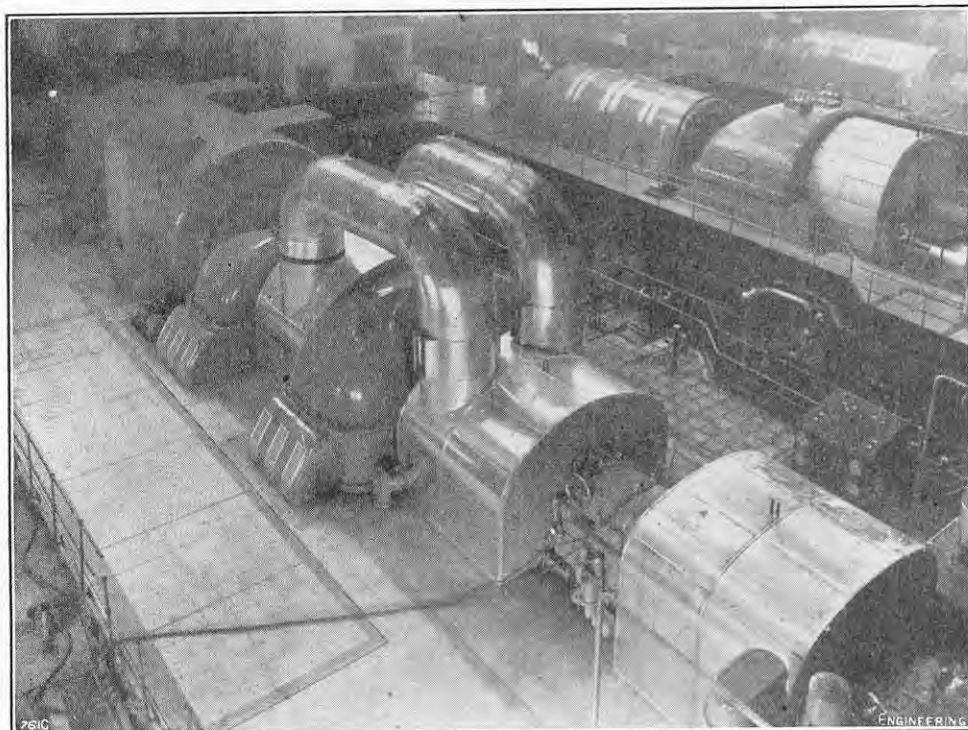


FIG. 3. NEW 60-MW TURBO-ALTERNATOR SET.

with a power factor of 0.8 and the other two at 0.9 power factor. They are directly connected to 75-MVA transformers, which step the voltage up from 11 to 66 kV. Switching is carried out at this voltage by metalclad equipment which is controlled from the room shown in Fig. 7, on page 304. The exciters have quick response features with a ceiling voltage 200 per cent. of normal, and their fields are supplied from overhung shunt-wound pilot exciters. Should the alternator voltage fall to 80 per cent. of normal under fault conditions, its excitation is automatically boosted to 150 per cent. of normal until the voltage has been restored to 95 per cent.

The turbines of these five sets, which are illustrated in Fig. 2, exhaust into Vickers-Armstrongs regenerative condensers with a cooling surface of 54,000 sq. ft., cooled by river water. The condensate is dealt with in a low-pressure heater, a gland heater, and a de-aerating heater and is then delivered by two electrically-driven lift pumps through three high-pressure heaters to the suctions of Mather and Platt feed

pumps, which can deliver 630,000 lb. of water per hour at a temperature of 358 deg. F. and against a pressure of 800 lb. per square inch to the boilers. Turbine-driven pumps are also installed for emergency use. A view in the feed-pump bay is given in Fig. 5, on page 304, and of the circulating-water pumps in Fig. 6.

The sixth 60-MW turbo-alternator set, which was formally inaugurated this week, is illustrated in Fig. 3, on this page. As its speed is 3,000 instead of 1,500 r.p.m., the exciter is driven through reduction gearing. As, moreover, the steam conditions may be altered from 600 lb. per square inch and 800 deg. F. to 900 lb. per square inch and 900 deg. F. the set has three instead of two cylinders, and the alternator is hydrogen-cooled. To accommodate the new set, the original 10-MW house generator, which had been largely redundant under present-day conditions, has been removed. It has also been necessary to increase the circulating-water capacity by constructing a new screen house at the intake, while a separate 54-in. discharge pipe has been run from the condenser to the river outfall.

GEAR-TOOTH STRESSES AND RATING FORMULÆ.

In presenting a paper to the Institution of Mechanical Engineers on "Gear-Tooth Stresses and Rating Formulæ," at the meeting held on February 29, Dr. H. E. Merritt, M.B.E., M.I.Mech.E., challenged the standardised rating formulæ of the three British Standards (436-1940; 545-1949; and 721-1937), and proposed new computations of the strength and zone factors used in those formulæ. By so doing he invited the comment that there were so many "missing links" in the theory of gear design that it might be better to revert to a simple method of computation until such time as there is a much fuller understanding of the subject. When that point was brought out in the discussion, he was not unsympathetic towards it, and towards those who, though not leaders in the theory of gear design, nevertheless have to design gears. His aim, however, is to make gear design more exact and thereby, perhaps, to save something on the 100,000,000% which is spent annually on the production of gears in Great Britain. As one who took part in formulating B.S. 436, he was free to criticise its basis.

Dr. Merritt gave first a brief statement of two systems of gear design—that in B.S. 436 and Dr. Harry Walker's system of controlled profile modification for precision gears—to provide a basis for the re-computed strength and zone factors described in his paper. With precision gears, he said, the load on a tooth, from the moment it made contact to the end of contact, increased uniformly, was then constant for a period, and then decreased uniformly. With "commercial" gears, according to B.S. 436, however, the load diagram was rectangular, i.e., the application and release of load were instantaneous. The load-point that was most unfavourable to wear of a pinion occurred at the beginning of the path of contact, and that most unfavourable to strength occurred at the end of the path of contact. The strength factors originally determined for 20-deg. spur gears, and incorporated in B.S. 436, were based on load-points coinciding with the change-points (i.e., corresponding to "precision" gears) and on the resultant compressive stress. But gear teeth, when they broke, nearly always failed by a fatigue crack which started on the tensile side. Strength factors determined by a graphical method given in the paper for commercial gears, on a basis of maximum tensile stress, would therefore be more consistent with experience and with the tooth form defined in B.S. 436. This had been done, and a new chart of strength factors was given in the paper. Two consequences were that a corresponding change was needed in permissible stresses (since the actual strength of a tooth was not changed by a new method of calculation), and the new strength factor of a "commercial" tooth was constant for a given addendum coefficient and independent of the number of teeth in the mating gear. In precision gears, however, the strength factor depended on the number of teeth in the mating gear and values could be charted only with defined addendum modifications. Dr. Merritt gave a chart for the case where both addendum modifications were 0.5.

The simple criterion he used for "surface stress" was $S_c = \frac{F_c}{R_r}$, where S_c was the surface stress, F_c the normal tooth reaction per inch of length of contact line, and R_r the relative radius of curvature of the teeth. The index 0.8 which was applied to R_r in the British Standards could now be abandoned, and he gave revised charts of zone factors for precision and commercial spur gears. Though the British Standards used a speed factor which was a function of the speed of the gears in revolutions per minute, it was now desirable to base it on pitch-circle velocity. Dr. Merritt therefore converted the wear formulæ to accord with this. He also considered the effect of intermittent and variable loading, suggesting that gears should be rated for strength on the maximum load assumed to act continuously.

SCHEME FOR REPAIRING WAR-DAMAGED FACTORIES.—Industrial representatives in areas containing a number of important war factories are being invited by the Ministry of Supply to form "self-help panels" to assist each other with labour, materials, plant, etc., in the event of damage occurring in war-time. The main task of carrying out repair work to factories damaged in war would fall upon the Works and Building Emergency Organisation, as part of the National Civil Defence arrangements. It is considered, however, that factories engaged on important war work should themselves introduce and operate a voluntary system of self-help and should be able to provide immediate first-aid from their own resources to restore factories to production as quickly as possible. Where repairs could not be undertaken by the panels, the matter would be referred immediately to the Works and Building Emergency Organisation. The regional controllers of the Ministry of Supply are preparing to set up panels in their Regions.

NOTES FROM THE INDUSTRIAL CENTRES.

SCOTLAND.

NEW STEEL PRICES.—As a result of the increase in steel prices, the following are some of the charges now operative in the central zone of Scotland:—Steel ship plates, $\frac{3}{8}$ in. basis, 29l. 14s.; boiler plates, $\frac{3}{8}$ in. basis, 31l. 1s. 6d.; joists, 27l. 18s.; plates and medium plates rolled in a sheet mill, $\frac{3}{8}$ in. and thicker, 38l.; similar plates, ranging from under $\frac{3}{8}$ in. to $\frac{1}{2}$ in., 38l. 15s.; steel angles and tees, untested, 31l. 5s. 6d.; the same, tested, 31l. 14s. 6d.; black steel sheets, Nos. 17 to 20 gauge, 40l. 12s. 6d.; galvanised corrugated sheets, Nos. 17 to 20 gauge, 57l. 5s. 6d. per ton.

EXTENSIONS TO FACTORIES.—Two Scottish companies of American origin, which began production only recently in the Vale of Leven industrial estate, 16 miles from Glasgow, are making preparations to extend their activities. Westclox, Ltd., who moved in in 1948 to occupy 58,000 sq. ft. of factory space, are now completing extensions, amounting to a further 43,000 sq. ft. Burroughs Adding Machine, Ltd., who started with 155,000 sq. ft. in 1950, are about to build an equally large factory.

LANARKSHIRE INDUSTRIAL ESTATES.—Mr. Henry Hopkinson, Secretary for Overseas Trade, has informed Mr. John Timmons, M.P. for Bothwell, that, in the next few months, a number of firms will begin production at the Carfin, Chapelhall, and Newhouse Industrial Estates, Lanarkshire. There were 8,968 unemployed persons in the county last month, an increase of 933 on the December total.

CLOSING OF TYPE FOUNDRY.—The only printers' type foundry in Scotland—that of Messrs. Miller and Richard, Edinburgh—has closed because of a steady decline in business as a result of the spread of automatic type-founding machines. The firm was founded over 140 years ago.

EXTENSION OF RUNWAYS AT PRESTWICK AIRPORT.—Work has now begun on the construction of the 1,000-ft. compacted-grass over-run which, as announced by the Minister of Civil Aviation last month, is to be added to the main runway at Prestwick Airport. This runway has recently been extended from 6,600 ft. to 7,000 ft. of paved length.

CLEVELAND AND THE NORTHERN COUNTIES.

THE IRON AND STEEL POSITION.—Disturbing features in the North of England iron and allied trades continue to confine transactions to very narrow limits. Market quotations have reached record levels, but little heed is paid to the rise in prices of Tees-side products. Last year, 24 per cent. of the total British output of pig iron and over 20 per cent. of the production of steel came from the North-East Coast. The demand, especially for steel, continues vastly in excess of the supply and the extremely stringent situation threatens to continue for some months. Less unsatisfactory conditions, however, are looked for later in the year and, in fact, there is a growing belief that the total home deliveries for 1952 will at least equal those for 1951. The promised supplies from the United States are expected to arrive in substantial quantities a month or two hence.

SCRAP FROM WRECKED SHIP.—The 4,000-ton Greek steamer, Taxiarchis, which has been aground on the rocks off Redcar, North Yorkshire, since January 14, has been purchased for scrap, as attempts to refloat her and tow her into port have not been successful. Efforts are being made to haul her on to the sands close in shore so that the work of breaking up may proceed. It is anticipated that the wreck will provide a total of 2,500 tons of scrap, which will go to Tees-side steelworks.

THE NORTH-EAST ENGINEERING BUREAU.—The annual report of the North-East Engineering Bureau, 109, Pilgrim-street, Newcastle-on-Tyne, states that northern firms have not received the volume of work expected under the defence programme. Some firms in the district, however, have obtained sub-contracts from main contractors in the southern and Midland areas. Referring to the Bureau's work during the year, the report states that 634 routine inquiries were received concerning contracts valued at over 700,000l., and that orders worth 190,000l. were obtained by member firms as a result. Had it not been for the shortage of materials, the value of these orders would have been greatly increased. The North-East Engineering Bureau is an organisation formed after the war to help in the expansion of the light engineering industry. During the past year, its membership increased by 15 per cent.

AVOIDANCE OF POWER CUTS.—As a result of the introduction of organised load-shedding last October, not a single hour's work has been lost on the North-East Coast during the winter due to power cuts. Firms were asked to adjust their working hours so as to cut down the electricity load in the mornings and from 4 p.m. to 5.30 p.m. each day. In most cases, firms arranged to work one shift each week from noon to 9.30 p.m. This method was carried out on a rota system and caused a considerable reduction in electricity consumption at peak periods. It is expected that normal working will be resumed after March 7.

LANCASHIRE AND SOUTH YORKSHIRE.

ROSSINGTON COLLIERS' PLEDGE.—Miners at Rossington Colliery, near Doncaster, have pledged themselves to the task of making up the output of 60,000 tons of coal, lost during the three weeks that the pit was idle owing to a failure of the compressed-air installation at the pit shaft. The repairs were delayed by some difficulty in obtaining promptly some of the material required.

STOWAGE OF PIT-WASTE UNDERGROUND.—Experiments on a large scale in the stowage of pit-waste underground have been extended, in South Yorkshire, from the original two pits—Bullcroft and Markham Main—to Upton, Barnsley Main, Hatfield, Bentley and Wharmcliffe Silkstone collieries. The pit waste is brought to the surface to be crushed and mixed with water to provide a material of the right consistency for handling. The mixture is then taken back underground to be driven into old workings by a special stowing machine.

UNREST IN COALFIELD.—In the Yorkshire coalfield there is growing unrest which has been expressed in the loss of more coal, through strikes and disputes, in the first eight weeks of the year than in any comparable period since the mines were nationalised. It is attributed to communist influence. There has been a decline in Saturday production but, so far, there has been no indication that Yorkshire miners are likely to follow the South Wales lead in a protest against Health Service economies.

AMERICAN INGOTS.—Mr. H. E. Wright, general manager and a director of Steel, Peech and Tozer, Ltd., in a speech made when opening an amenities centre, stated that he hopes that increased supplies of the American steel ingots now being used at their works would enable them to operate the finishing mills to an increasing extent.

TRAMWAYS OR OMNIBUSES.—The first step taken in the proposed complete change-over in Sheffield from electric tramways to motor omnibuses has aroused so much protest that a motion has been tabled for the next meeting of the City Council for the restoration of the Malin Bridge tramway service.

THE MIDLANDS.

THE EFFECT OF THE NOTIFICATION OF VACANCIES ORDER.—The Notification of Vacancies Order, which came into force on February 25, will have little effect on the distribution of labour in the Midlands, particularly in the Black Country. In that area, which lies between Birmingham and Wolverhampton, the priority lists at the employment exchanges are headed by the basic trades of the district. Foundry work, iron and steel production and finishing, engineering, drop-forging, and other steel-using trades are prominent. If there is to be movement of labour, it would appear that it will involve merely a change in the product being made by the individual, and not a transfer to different work. Much of this change of product will be brought about, of course, by the placing of defence contracts in the Midlands, and this will involve no movement of labour at all.

THE DROP-FORGING INDUSTRY AND THE PROPOSED STEEL BOARD.—Mr. W. E. A. Redfern, retiring president of the National Association of Drop Forgers and Stampers, speaking at the annual meeting of the Association in Birmingham on February 27, referred to a proposal that the drop-forging industry should be placed under the control of a new Iron and Steel Board. Mr. Redfern said that it had come to the Association's notice that such a development was likely when the steel industry was de-nationalised, and that the Association had already protested to the Minister of Supply. Another deputation is to see the Minister shortly.

THE TALYLLYN RAILWAY.—A meeting of members of the Talyllyn Railway Preservation Society, which was formed in Birmingham, was held in that city on February 23. The Earl of Northesk, President of the Society, said that 3,000l. of the 5,000l. needed to restore the railway fully had been raised. The line was closed for the winter last September, since when members of the Society had continued the work of relaying the track.

TRADE-UNION SURVEY OF RAW MATERIALS.—The survey of the raw materials position in the Midlands, which was undertaken recently by the Transport and General Workers' Union, has now been concluded. Questionnaires were sent to 500 firms, in many different industries, and from the replies received by Mr. J. Leask, the union's regional trade group secretary, has been able to report that, in many cases, there was no serious complaint about materials shortage. There were, however, some firms who reported under-employment for this reason, while others attributed the slackening in employment to German and Japanese competition, which was scoring on both price and delivery.

THE INLAND WATERWAYS ASSOCIATION.—The Inland Waterways Association has abandoned its scheme to hold a rally of boats at Market Harborough, Leicestershire, which was proposed to be held in August of this year. Instead, the Association intends to organise a tour of the Midland canals during the four weeks beginning on August 16. The route proposed is from Wolverhampton to Burton-on-Trent and Leicester, returning to Birmingham via Leamington and Warwick.

COALPORT BRANCH RAILWAY.—The branch railway from Wellington to Coalport, Shropshire, operated by the London Midland Region of British Railways, was closed for passenger traffic on March 1. The line is $9\frac{1}{2}$ miles long, and has seven stations, including the termini. There had been, until the closure, six trains a day each way. No statement has been made about the future of the line, but as it serves a number of factories it is likely to be kept open for goods traffic.

SOUTH-WEST ENGLAND AND SOUTH WALES.

PIG IRON FOR STEEL MANUFACTURE.—More blast furnaces are coming into operation in Wales to produce pig iron for steel manufacture instead of relying upon scrap. Mr. W. S. Gray, Regional Controller of the Ministry of Supply, said at a meeting of the Welsh Board for Industry. He added that work was in progress on the biggest blast furnace in Wales, at the steelworks of John Summers, at Shotton, and a third furnace was being brought into operation at the Abbey Steelworks, Margam.

FELLING OF OLD CHIMNEY STACK.—A chimney stack 170 ft. high which had stood for more than 75 years at the old Glanyrafon tin-plate works at Clydach, was felled during the week in six minutes. The 11-acre site of the old tin-plate works has been taken over by Rees and Kirby, Ltd., engineering contractors, who are to start an engineering factory there which, initially, will find employment for 70 men.

DEVELOPMENTS AT LLANGYFELACH.—It has been reported during the week that the Government had decided to establish a large new works in South Wales, similar to that at Trostre, possibly at Llangyfelach. This is the location originally chosen for the cold-reduction steel plant subsequently established at Trostre and more than 80,000l. was spent in preparing the site of four requisitioned farms.

WORK ON RIVER DEE ESTUARY.—The Industrial Association of Wales and Monmouthshire have agreed to investigate the desirability for a scheme to make the silted estuary of the River Dee navigable again for ships of up to 2,000 tons so as to relieve the congestion at the Merseyside ports. Before the war the Dee Conservancy Board had agreed that such a scheme was technically possible by building retaining walls, the present-day cost of which would be about 1,500,000l.

THE LATE MR. C. G. R. ELDON.—We regret to learn of the death, on February 23, of Mr. Christopher George Robert Elsdon, A.M.I.Mech.E., F.C.I.P.A., for many years a member of the technical staff of Messrs. W. D. and H. O. Wills, Ltd., at their tobacco manufactory at Bristol. Mr. Elsdon, who was born on March 15, 1890, received his general education at Christ's Hospital, Horsham, where, in 1908, he obtained a mathematical scholarship of 100l. a year for five years, tenable at Hertford College, Oxford. In the following year he was elected an exhibitor of Christ's Hospital and proceeded to Hertford College, where he distinguished himself in mathematics and graduated in 1914 as B.A. in engineering science. From 1914 to 1918 he was employed at Woolwich Arsenal as an advanced workshop student. In 1918 and 1919, he was engaged as a plant draughtsman at the Dagenham works of the Sterling Telephone Company, and towards the close of 1919 as a draughtsman with Gwynnes, Ltd., at Hammersmith. In 1920 he entered the office of Messrs. Marks and Clerk, chartered patent agents, as technical assistant. He spent five years with them, followed by a short period with Messrs. White, Langner, Stevens and Parry, of Chancery-lane, London, before joining the staff of Messrs. Wills.

NOTICES OF MEETINGS.

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

INSTITUTION OF ELECTRICAL ENGINEERS.—Monday, March 10, 5.30 p.m., Savoy-place, Victoria-embankment, W.C.2. Discussion on "Remote Measurement and Instrumentation," opened by Mr. H. Horwood. *North-Eastern Centre*: Monday, March 10, 6.15 p.m., Neville Hall, Newcastle-upon-Tyne. "Economics of Low-Voltage Electricity Supplies to New Housing Estates," by Mr. F. G. Copland. Tuesday, March 11, 7 p.m., City Hall, Newcastle-upon-Tyne. Faraday Lecture on "Sound Recording: Home, Professional, Industrial and Scientific Applications," by Dr. G. F. Dutton. *Radio Section*: Wednesday, March 12, 5.30 p.m., Savoy-place, Victoria-embankment, W.C.2. "The Slot Aerial and its Application to Aircraft," and "External and Suppressed Aircraft Aerials for Use in the High-Frequency Band," by Mr. R. H. J. Cary. *Southern Centre*: Wednesday, March 12, 6.30 p.m., South Eastern Electricity Board Showrooms, Brighton. "Influence of Rectifier Harmonics in a Railway System on the Dielectric Stability of 33-kV Cables," by Mr. S. B. Warder, Dr. Ing. E. Friedlander and Dr. A. N. Arman. *North Midland Centre*: Wednesday, March 12, 7 p.m., Town Hall, Barnsley. "Research in the Electricity Supply Industry," by Mr. C. W. Marshall. Thursday, March 13, 7 p.m., Town Hall, Leeds. Faraday Lecture. *Scottish Centre*: Wednesday, March 12, 7 p.m., Heriot-Watt College, Edinburgh. "Dimming of Low-Pressure Discharge Lamps," by Mr. C. E. Williams. *Institution*: Thursday, March 13, 5.30 p.m., Victoria-embankment, W.C.2. "Electronic Telephone Exchanges," by Mr. T. H. Flowers.

INSTITUTE OF METALS.—*Scottish Local Section*: Monday, March 10, 6.30 p.m., 39, Elmbank-crescent, Glasgow, C.2. Annual Meeting. "Joining Metals," by Dr. J. C. Chaston.

INSTITUTE OF FUEL.—*North-Eastern Section*: Monday, March 10, 6.30 p.m., King's College, Newcastle-upon-Tyne. "The Heat Pump," by Mr. L. Nichols. *Midlands Section*: Tuesday, March 11, 7 p.m., Midlands Electricity Board's Hall, Kingsway, Stoke-on-Trent. "The Modern Outlook on Refractory Materials," by Dr. A. T. Green.

INSTITUTION OF CHEMICAL ENGINEERS.—*Midland Graduates' and Students' Section*: Monday, March 10, 6.30 p.m., The University, Edmund-street, Birmingham. "Life of a Chemical Engineer," by Mr. W. N. Hoyte. *Institution*: Tuesday, March 11, 5.30 p.m., Geological Society, Burlington House, Piccadilly, W.1. "The Control of Low-Temperature Gas-Separation Plants," by Dr. M. Ruhemann. *North-East Graduates' and Students' Section*: Friday, March 14, 6.15 p.m., Chemical Engineering Department, Stephenson Building, Claremont-road, Newcastle-upon-Tyne. Annual Meeting and Film Display.

INSTITUTION OF PRODUCTION ENGINEERS.—*Sheffield Section*: Monday, March 10, 6.30 p.m., Royal Victoria Station Hotel, Sheffield. Annual Meeting. *Yorkshire Section*: Monday, March 10, 7 p.m., Hotel Metropole, Leeds. Annual Meeting. "5-in. Sliding Surfacing and Screw-Cutting Lathes," by Mr. D. H. Turnbull. *Liverpool Section*: Tuesday, March 11, 6.30 p.m., Adelphi Hotel, Liverpool. Film on "Atomic Physics." *Dundee Section*: Tuesday, March 11, 7.45 p.m., Mathers Hotel, Whitehall-crescent, Dundee. "Modern Applied Metrology," by Mr. G. V. Stabler. *Western Section*: Wednesday, March 12, 7.15 p.m., Grand Hotel, Bristol. "Deep Drawing and Pressing," by Dr. J. D. Jevons. *Preston Section*: Wednesday, March 12, 7.15 p.m., Bull and Royal Hotel, Church-street, Preston. "Co-ordination of Production Engineering and Cost Accounting," by Mr. D. Mayman. *Nottingham Section*: Wednesday, March 12, 7.15 p.m., Welbeck Hotel, Nottingham. "Employee Remunerations and Incentives," by Mr. R. B. Simpson. *London Section*: Thursday, March 13, 6.45 p.m., Royal Empire Society, Northumberland-avenue, W.C.2. Annual Meeting. "Resistance Welding," by Mr. A. J. Hipperson.

ASSOCIATION OF SUPERVISING ELECTRICAL ENGINEERS.—*Central London Branch*: Monday, March 10, 7 p.m., St. Ermin's Hotel, Caxton-street, S.W.1. "Maintenance and Repair of Electric Motors," by Mr. D. R. Reekie. *Birmingham Branch*: Wednesday, March 12, 7 p.m., 95, New-street, Birmingham. "Installation Practice," by Mr. W. J. Parker.

WOMEN'S ENGINEERING SOCIETY.—*London Branch*: Monday, March 10, 7 p.m., 35, Grosvenor-place, S.W.1. Discussion on "Professional Institutions and Trade Unions." *Manchester Branch*: Thursday, March 13, 6.30 p.m., Engineers' Club, Manchester. "Lost-Wax Process of Precision Casting," by Mr. F. H. Davis.

INSTITUTE OF ROAD TRANSPORT ENGINEERS.—*Scottish Centre*: Monday, March 10, 7.30 p.m., North British Hotel, Edinburgh. "Servicing of Diesel Engines," by Mr. S. Parrish. *Western Group*: Tuesday, March 11,

7.30 p.m., Grand Hotel, Bristol. "Diesel-Engine Repair and Maintenance, and Workshop Practice," by Mr. R. M. May. *East Midlands Centre*: Wednesday, March 12, 7.30 p.m., Mechanics Institute, Nottingham. Discussion on "Electricity as Applied to Vehicles."

INCORPORATED PLANT ENGINEERS.—*Dundee Branch*: Monday, March 10, 7.30 p.m., Mathers Hotel, Dundee. Annual Meeting. *Glasgow Branch*: Tuesday, March 11, 7 p.m., 351, Sauchiehall-street, Glasgow. Annual Meeting. *East Lancashire Branch*: Tuesday, March 11, 7.15 p.m., Engineers' Club, Manchester. Annual Meeting. *South Wales Branch*: Tuesday, March 11, 7.15 p.m., South Wales Institute of Engineers, Park-place, Cardiff. Discussion on "Insulation Materials." *Edinburgh Branch*: Wednesday, March 12, 7 p.m., 25, Charlotte-square, Edinburgh. Annual Meeting.

ROYAL INSTITUTION.—Tuesday, March 11, 5.15 p.m., 21, Albemarle-street, W.1. "Dusts and Powders in Nature and Industry.—III. Industrial Applications of Particle Technology," by Dr. H. Heywood. Thursday, March 13, 5.15 p.m., "Interference and Diffraction as General Wave Properties. IV. Interference Phenomena in Radio Meteorology," by Professor Sir Lawrence Bragg, F.R.S.

INSTITUTE OF MARINE ENGINEERS.—Tuesday, March 11, 5.30 p.m., 85, The Minories, E.C.3. "Epicyclic Gears," by Mr. H. N. G. Allen and Mr. T. P. Jones.

ILLUMINATING ENGINEERING SOCIETY.—Tuesday, March 11, 6 p.m., 2, Savoy-hill, W.C.2. "Lighting of Shipyards," by Mr. J. S. McCulloch.

INSTITUTION OF MECHANICAL ENGINEERS.—*South Wales Branch*: Tuesday, March 11, 6 p.m., Mackworth Hotel, Swansea. Discussion on "Welding Report of Anglo-American Productivity Council." *Southern Branch*: Wednesday, March 12, 7 p.m., University College, Southampton. Thomas Lowe Gray Lecture on "Ship Research," by Dr. S. Livingston Smith. *North-Western Branch*: Thursday, March 13, 6.45 p.m., Engineers' Club, Manchester. Thomas Hawksley Lecture on "Fuel and Power Projects," by Dr. H. Roxbee Cox. *Yorkshire Branch*: Thursday, March 13, 7 p.m., The University, Leeds. "Boilers for the Catering Industry," by Lieut.-Col. C. W. Mustill. *Institution*: Friday, March 14, 5.30 p.m., Storey's-gate, St. James's Park, S.W.1. "Basic Engineering Standards and Their Place in Design," by Captain G. C. Adams. **AUTOMOBILE DIVISION.**—Tuesday, March 11, 5.30 p.m., Storey's-gate, S.W.1. "Shock Absorbers," by Mr. J. W. Kinchin and Mr. C. R. Stock.

INSTITUTION OF ENGINEERS AND SHIPBUILDERS IN SCOTLAND.—Tuesday, March 11, 6.30 p.m., 39, Elmbank-crescent, Glasgow. "Considering Dredging Craft," by Mr. D. W. Low.

INSTITUTION OF HEATING AND VENTILATING ENGINEERS.—*South Western Branch*: Tuesday, March 11, 6.30 p.m., General Electric Co.'s Building, Cathays Park, Cardiff. Annual Meeting. "Panel Heating," by Dipl. Ing. L. J. Fisher. *Liverpool Branch*: Tuesday, March 11, 6.30 p.m., Radiant House, Bold-street, Liverpool. "Industrial Radiant Heating," by Mr. F. R. L. White.

ROYAL SOCIETY OF ARTS.—Wednesday, March 12, 2.30 p.m., John Adam-street, W.C.2. "The Utilisation of Organic Waste Matter in Domestic Refuse and Sewage," by Mr. J. C. Wylie.

NEWCOMEN SOCIETY.—Wednesday, March 12, 5.30 p.m., Institution of Mechanical Engineers, Storey's-gate, St. James's Park, S.W.1. "Development of Postal Franking Machines," by Mr. A. R. J. Ramsey.

INSTITUTE OF PETROLEUM.—Wednesday, March 12, 5.30 p.m., 26, Portland-place, W.1. "Production and Use of Alcohol Motor Fuels," by Mr. S. J. W. Pleeth; and "Economic Aspects of Alcohol in Motor Fuels," by Mr. T. C. Owtram.

LIVERPOOL ENGINEERING SOCIETY.—Wednesday, March 12, 6 p.m., 24, Dale-street, Liverpool. Joint Meeting with the INSTITUTION OF STRUCTURAL ENGINEERS (*Lancashire and Cheshire Branch*): "The Britannia Tubular Bridge Over the Menai Straits," by Mr. J. Cunningham.

INSTITUTION OF CIVIL ENGINEERS.—*Association of London Students*: Wednesday, March 12, 6.30 p.m., Great George-street, S.W.1. Debate: "That Railways No Longer Fulfil the Transport Requirements of This Country and Must be Converted to Trunk Roads and Aerodromes." *Midlands Association*: Thursday, March 13, 6 p.m., James Watt Memorial Institute, Birmingham. "Structural Design of Modern Aircraft," by Professor S. C. Redshaw.

INSTITUTE OF BRITISH FOUNDRYMEN.—*Lancashire Branch*: Wednesday, March 12, 7 p.m., Engineers' Club, Manchester. "A System of Studying Castings Defects," by Mr. G. W. Nicholls and Mr. D. T. Kershaw.

INSTITUTION OF STRUCTURAL ENGINEERS.—Thursday, March 13, 6 p.m., 11, Upper Belgrave-street, S.W.1. "Faults in Concrete Structures," by Mr. P. G. Bowie.

ENGINEERS' GUILD.—*Metropolitan Branch*: Thursday, March 13, 6 p.m., Caxton Hall, S.W.1. "The Problem of the Over 40's," by Mr. L. N. Duguid.

PERSONAL.

THE BRITISH MOTOR CORPORATION LTD., Cowley, Oxford, is to be the name and address of the new holding company resulting from the merger between MORRIS MOTORS LTD., and the AUSTIN MOTOR CO. LTD. VISCOUNT NUFFIELD, G.B.E., F.R.S., chairman of Morris Motors Ltd. is to be chairman of the new Corporation and Mr. L. P. LORD, hitherto chairman and managing director of the Austin Motor Co., is to be deputy chairman and managing director of the corporation. The other directors are Mr. R. F. HANKS, formerly vice-chairman and managing director of Morris Motors and Mr. G. W. HARRIMAN, C.B.E., hitherto deputy managing director of the Austin Motor Co.

At their meeting on February 21, the Corporation of Glasgow decided to redesignate the post of general manager of their Water Department as chief engineer and general manager. This position is at present held by MR. STANLEY D. CANVIN, B.Sc. (Eng.), M.I.C.E., M.Inst.W.E.

MR. HAROLD ORMISTON, B.Sc., A.M.I.C.E., assistant district engineer, North Eastern Region, British Railways, York, has been made assistant engineer (permanent way), Civil Engineer's Department, North Eastern Region, York.

MR. G. W. J. BRADLEY, F.R.I.C., M.Inst.Gas.E., F.Inst.F., has been appointed divisional carbonisation general manager of the East Midlands Division of the National Coal Board.

An honorary Associateship of the College of Technology, Birmingham, has been conferred upon DR. DONALD PARKINSON, F.Inst.P., of the compounding research division of the Dunlop Rubber Co., Ltd.

MR. A. B. GRAHAM, who has been manager of the Zenith Works of Henry Wiggin & Co. Ltd., Thornliebank, Glasgow, for the past 18 years, has been elected to the delegate board of the company.

MR. R. W. FLUX, A.M.I.E.E., who is on the staff of the British Electricity Authority, London, has been appointed to the newly-created post of chief engineer of the transformer department of Bruce Peebles & Co., Ltd., Edinburgh, 5. Mr. Flux, who will take up his new duties shortly, will be responsible to MR. P. BUTLER, joint general manager, for decisions affecting the company's transformer business.

MR. R. P. WINGATE, lighting engineer for the British Thomson-Houston Co. Ltd., Newcastle-upon-Tyne, left to take up an appointment with the company's lighting department at Mazda House, Fitzroy-road, London, N.W.1. on March 1. Mr. J. S. SMITH has been appointed lighting engineer at the Newcastle office of the firm.

MR. L. E. MEEKS and Mr. H. R. WALTON, B.Sc., both previously directors of Electroflo Meters Co. Ltd., have joined Elliott Brothers (London) Ltd., Century Works, Lewisham, S.E.13. Mr. Meeks is closely identified with production and design, while Mr. Walton has taken charge of the sales of the products of the Fisher Governor Co., Ltd., a subsidiary of Elliott Brothers.

MR. W. G. HOLMES retired on February 29 after 38 years as manager of the Southampton branch of British Insulated Callender's Cables Ltd., and the former firm, Callender's Cable and Construction Co. Ltd. His successor is Mr. E. HITCHEN, who joined the firm at Leigh in 1920, subsequently served in Manchester, and, in 1946, was appointed sales representative in North-West London.

DR. R. S. NYHOLM has been awarded the Corday-Morgan Medal and Prize by the Council of the Chemical Society in recognition of his experimental work on co-ordination compounds and nickel complexes.

MR. C. E. CADWALLADER, F.R.I.C.S., has been appointed a principal executive assistant of the London Transport Executive, 55, Broadway, S.W.1. He will act as deputy of the estate agent and rating surveyor.

The proposal to change the names of LEVER BROTHERS and UNILEVER LTD., Unilever House, London, E.C.4, to UNILEVER LTD. and UNILEVER N.V., respectively, has now been approved by the members of the two companies and took effect on Monday, March 3.

VICKERS LTD., Vickers House, Broadway, London, S.W.1, have acquired a controlling interest in the firm of ONIONS AND SONS (LEVELLERS) LTD., Bilston, Staffordshire. MESSRS. J. A. AND C. H. ONIONS have resigned their directorships, but MESSRS. J. E. AND G. F. ONIONS remain on the board.

THE QUASI-ARC CO., LTD., Bilston, Staffordshire, announce that, as from April 1, sales and service of Unionmelt automatic welding plant, powder and wire will be transferred to their associated company, FUSARC LTD., Team Valley, Gateshead-on-Tyne, 11.

RUSTON AND HORNSBY, LTD., Lincoln, inform us that their Birmingham branch office is to be removed to Dilworth House, 190, Broad-street, Birmingham, 15, after March 18. New telephone: Midland 2811.

THE FULHAM POWER STATION OF THE BRITISH ELECTRICITY AUTHORITY.

(For Description, see Page 300.)

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ENGINEERING.

MARCH 7, 1952.

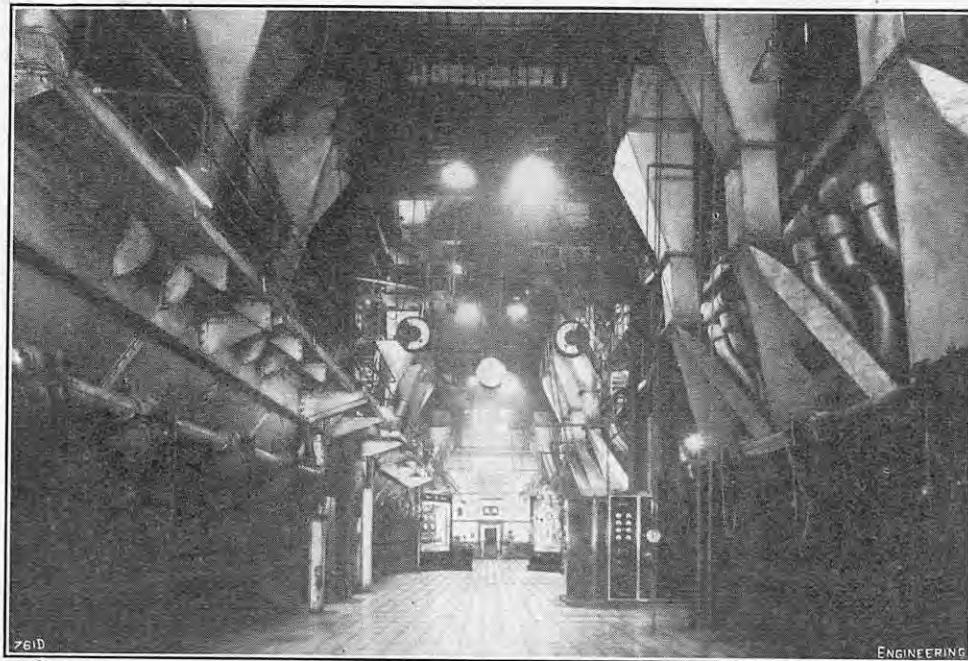


FIG. 4. BOILER-HOUSE FIRING AISLE.

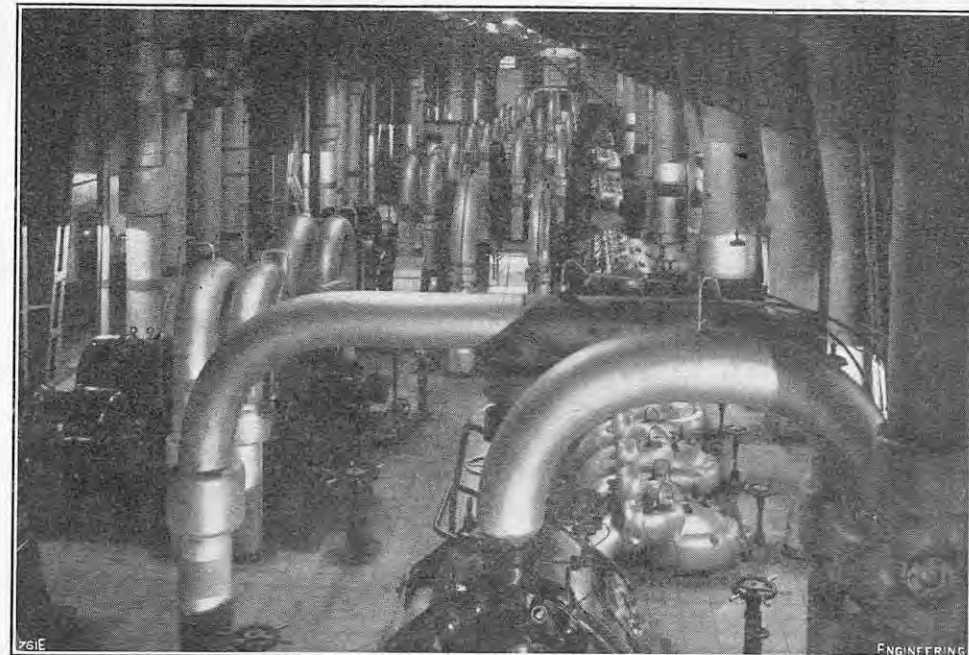


FIG. 5. FEED-PUMP BAY.

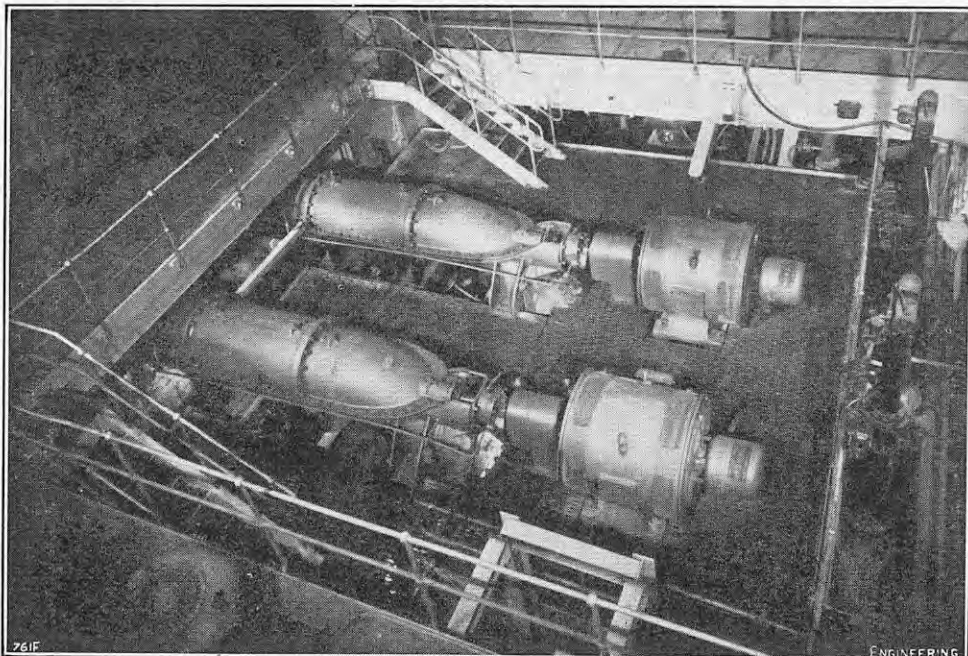


FIG. 6. CIRCULATING-WATER PUMPS.



FIG. 7. CONTROL ROOM.

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MAN-POWER AND PRODUCTIVITY.

To the ordinary man in the street, and especially to men who follow their normal courses through the streets of foreign countries, the ways of what Sir Owen Seaman, sometime editor of *Punch*, once described as "the Mummy of Parliaments" must appear rather more than strange. He might well wonder, for example, how it comes about that, if the House of Commons wants to debate the topical and highly significant subject of man-power and productivity, it must seize the opportunity to do so on a resolution "that a sum, not exceeding 918,376,000*l.*, be granted to Her Majesty, on account, for or towards defraying the charges for, among other things, Government hospitality, the Scottish Record Office, the National Maritime Museum, the White Fish Authority, administration of "certain African Territories," the Post Office (for which 70*l.* millions was sought) and tin (allotted 10*l.*, which, at the present price, will buy about 23 lb. of that metal). The answer, presumably, is that this vote included 72,000,000*l.* for the Ministry of Supply and 5,800,000*l.* for the Ministry of Defence, each vitally concerned with both man-power and productivity; though not more so, surely, than the Chancellor of the Exchequer will be next week when, in the usual phrase, he "opens" his Budget for the coming financial year. Be that as it may, the fact remains that, on the above-men-

tioned pretext, a debate on man-power and productivity was thus initiated at 3.39 p.m. on Monday, March 3, with a speech by the Rt. Hon. Alfred Robens, the Member for Blyth.

How many times Mr. Robens, in the course of his speech, declared that he had no wish to be controversial is, perhaps, of no great importance; it is always a little difficult, in reading the sedate reports of *Hansard*, to know whether a particular Member, at any given moment, had a twinkle in his eye or his tongue in his cheek. It may be that Mr. Robens had neither the one nor the other, but was speaking in sober earnest when he declared that "There is only one way in which we can get out of our difficulties and that is by hard, intensive work, increased productivity and great expansion of our industry." Not everyone would share his belief, perhaps, "that the general public in this country are better informed to-day on economic matters than they have ever been before"; and many may wonder why, if so, "there are very few people indeed who really realise how grave the situation is," after the serious warnings that have been given by the Prime Minister, the Chancellor of the Exchequer, and other members of the present Government. Mr. Robens himself provided a possible explanation in his artful selection of the figures that he adduced to show how industrial production had developed under the late Government. "From pre-war until we left office," he declared, "industrial production rose by 50 per cent., output per man by 26 per cent., and exports rose by 80 per cent." He did not say, however, whether he was computing these increases by weight, by volume or by cost; but it is not likely to have been by either weight or volume. The value of the cost criterion may be judged by the admission, on the same day, that, "measured over the whole field of consumers' goods and services, the purchasing power of a salary valued at 1,000*l.* in 1946 is now about 712*l.*"—and Mr. Robens's comparison was not with 1946, but with early 1939.

The more closely the speech of Mr. Robens is studied, the harder it is to accept his claim to be non-controversial. In the reports of the Anglo-American Productivity Council, he observed "one startling thing running through all of them." Admitting that "it is clear that there is a greater output per man in American than in comparable British industries"—greater in quantity, and not merely in value calculated in a depreciated currency, though he did not mention that small detail—he declared that "the thing that stands out a mile in all these reports is that it is not just machines that make the difference; it is new techniques and, in many cases, more efficient management." We do not believe that the secret of the greater American productivity per man lies in new techniques. It does result, to some extent, from more efficient management, because American managements are much more free to manage, according to their judgment, than are most of the hampered and restricted British managements. Even more, however, it results from the readiness of American labour to use machines to the utmost of their capacity, without either demanding the whole of the increased benefit for themselves or insisting that if a machine renders a man redundant, that man shall be paid to stand idly by, watching the machine work, instead of doing something useful elsewhere.

There are other points in Mr. Robens's speech on which comment might be made—for instance, his remark that, "in 1946 the total production [of coal] was 181 million tons," and that, "in 1951, under a policy of co-ordination and nationalisation, it had risen to 211 million tons," but his failure to mention that in 1913, without either co-ordination or nationalisation (and almost without mechanisation) it was 287 million tons; but some attention should be devoted to other speakers. Some, like Mr. Sydney Silverman, Member for Nelson and Colne,

confined themselves mainly to the immediate concerns of their own constituencies; others, like Mr. Charles Pannell (Leeds West)—who backed his argument by quoting *ENGINEERING*—spoke rather on behalf of a particular trade union. Mr. Pannell touched on a problem of considerable moment when he referred to the difficult position of redundant employees in a district like Oxford, where there is little alternative employment to be had; and must have had both sides of the House with him when he declared that the organisation of an armament drive is "not a matter of shipping people from this place to that place, but a matter of intelligence and the management of men where they are." In which connection the question arises, whether the greater output of the average American working man, by comparison with his British "opposite number," may not be due in part to the greater freedom that he enjoys to change his employment when he feels he would like to do so. It may not follow that he does, in fact, change more frequently; but it is certainly conceivable that he may derive a psychological incentive from the knowledge that he can if he wishes. By contrast, the British working man, contemplating the combined effect of trade-union restrictions, heavy taxation, and the housing shortage that prevails in all the industrial centres, may feel (without consciously putting his feeling into the words of the classic limerick) that he is merely "A creature that moves In determinate grooves—In fact, not a 'bus, but a tram"; a prospect hardly calculated to encourage initiative.

It cannot be alleged of the debate, considered as a whole, that it moved "in determinate grooves," for it ranged over a wide variety of topics; prominent among them the effect of restricted steel supplies, the operation of the Notification of Vacancies Order, the need for more scientists and technologists, and the employment (or continuation in employment) of older people in industry. If some of the contributions were a little vague, and occasionally inconsistent, that is hardly to be wondered at; for, in some respects, the Government have not been quite so informative about the detailed facts of the national situation as, we consider, they might have been. There is no doubt, for instance, that the cuts in steel allocations have been much more severe than most firms expected; and it is a great encouragement to a man to work steadily if he can see, in the shop, an ample supply of material waiting to be used. Mr. Frederick Lee, the Member for Newton, put the position in a sentence when he commented that "It is now expected that the engineering industry can carry the whole weight of re-armament and still maintain a high level of export goods." That, on the face of it, is much more a matter of ample material supplies and ample labour on the shop floor, than of an increased intake of university graduates.

Unquestionably, a higher proportion of the working population passes through university or technical college in the United States and in Switzerland—the two countries particularly cited—than in the United Kingdom; but it would be pertinent to inquire how they are used in the respective countries, on what scales they are remunerated by comparison with non-graduates, and whether, in the United States and in Switzerland, they are not a rather different species from the average British graduate. As in the case of the employment of older people, the utilisation of college-trained men in industry raises a number of questions. Is the failure to use them better the fault mainly of the potential employer or of the potential employee? Do the critics of either or both sufficiently realise the progressively changing nature of industry? So many men of intelligence and goodwill have been puzzling over such questions for so long, that Members of Parliament may be forgiven if, in a short debate, they fail to reach a satisfactory conclusion.

EXPORTS TO THE UNITED STATES.

MORE than twenty years ago, Judge Adamson said in the Court of Customs Appeals of the United States that "the intention of the American marking regulations is to make importation into the U.S.A. both expensive and difficult." The point of view underlying this remark has been somewhat modified in recent years, but the United States Customs regulations are still severe and are a serious handicap in attempts to market British goods in that country; essentially their purpose is to protect home manufacture. The United States is far from being alone in imposing tariffs and regulations tending to minimise, or even exclude, the importation of foreign goods, but in the present state of world finance, American action of this kind is of graver importance than similar activity by any other country. At the time when Great Britain was the financial centre of the world, this country traded freely with any other and offered no impediments to the mutual interchange of goods and services. The United States has built up a manufacturing industry of unparalleled magnitude behind high tariff walls and, no doubt partly for historical reasons, is not inclined to encourage free and unhampered trade with the rest of the world.

The present dollar crisis is partly a reflex from the impoverishment of western European countries as a result of two world wars. The contribution of the United States to both contests, in men, material and money, was magnificent, but in neither was American soil violated, nor American industry interfered with by the combatant armies. On the contrary, both events were of assistance in enabling the United States to expand manufacturing capacity to a point far surpassing that of any European country. It is natural, perhaps, to wish to retain the advantageous position thus secured, but the dollar shortage of Europe will not be overcome unless there is, on the part of the United States, a greater willingness to engage in two-way overseas trade. In view of the unexampled generosity repeatedly shown in furnishing financial assistance to other countries, criticism may seem out of place, but what, in effect, is charity is no effective substitute for proper trade relations. The United States contributes to the dollar holding of this country by purchasing tin and rubber, in both cases tending to impose somewhat severe conditions. Transactions in these two raw materials are a help, but they are not sufficient to supply Britain with the dollars necessary to buy all the American goods that British industry would wish to have. This country is not the only one which has recently had to restrict dollar purchases, and in the long view, the financial centre of the world cannot continue to be a seller without also becoming a buyer.

These long-term reflections are of little assistance to Great Britain at the present time. The immediate problem is to deal with the situation as it is, and to attempt to export all possible goods and materials to the United States in order to obtain dollars in return. The difficulties facing British manufacturers in attempts to establish a market for their products in the United States are by no means confined to questions of tariffs and customs regulations. The area in which they wish to sell is larger than Europe, embraces many different climates and types of people, and is already served by a highly-efficient industry with well-organised distribution and selling arrangements. To obtain a footing in this complicated market may well demand much preliminary study, and tentative and possibly non-productive experiment.

Considerable assistance has been afforded to British firms by the activities and publications of the Dollar Exports Board, a number of the reports of which have been reviewed in these columns.

A report* from another source which has just been published should be of particular value to firms who have little or no experience of American trade conditions, but are desirous of taking part in the export drive. This Roskill report is of a different type from those which have been issued by the Dollar Exports Board. Although it is essentially a collection of data, merely to say that is to give an incomplete idea of its contents. It is an extensive document of 228 pages and, in a first section, gives information about climate and population in nine regions into which the various States may conveniently be grouped. The geography and climate of the States in each group are relatively similar. This particular division into regions is employed by the Bureau of the Census of the United States. The value of information of this kind to the potential British exporter is that, as he cannot possibly plan a sales campaign to cover the whole of the country, he must have some information about climate and population density in the area he selects, on which to attempt to sell.

A section of the report gives detailed information about the United States Customs regulations, which are complex and may cause both difficulty and disappointment to British firms attempting to enter the American market unless they are carefully studied beforehand. Engineering and, particularly, electrical firms concerned with trade in the United States, will be well aware of the necessity of conforming with American standards, but manufacturers attempting to enter the market for the first time may find themselves in difficulty unless they study the conditions beforehand. Another matter which newcomers are not likely to foresee is that, while "all imported articles must be marked to indicate the country of origin," the adjectival form "British" will not be accepted. It is held to be too broad. Goods must be marked as having been made in Great Britain, England, Scotland, Wales, etc.

The longest section of the report reviews the market for various selected commodities. Many of these, such as textiles and pottery, are of great importance in the contribution they make to the export drive, but are not the concern of this journal. The engineering products which are dealt with are confined to motor vehicles, cycles, textile machinery and machine tools. The first of these was considered in detail in the "Engineering Outlook" article in our issue of February 8. Although, at the end of the section dealing with textile machinery it is stated that "there is little hope of British manufacturers competing successfully with the staple lines of spinning and weaving machinery" it is added that "the market for British textile machinery of specialised type is nevertheless considerable." Statistics of the importation of the various types of machine are given and it is stated that, in 1949, 58 per cent. of the imports of textile machinery were from the United Kingdom. This was apparently partly due to the absence of German competition, which may well reappear in the near future. In connection with machine tools, it is said that "there is considerable danger that the progress of re-armament in the United States will be held up by shortage of machine tools." As the same thing applies in this country, it might be supposed that the shortage is not likely to be met by British manufacturers, but as the official policy for many years has been to restrict home trade in favour of exports, there may possibly be some American business for British makers. Handicaps in the United States market are imposed by difficulties in connection with spare parts and adequate after-sales service.

* *The U.S. Market, Principal Features and Basic Statistics.* O. W. Roskill and Co. (Reports), Ltd., 14, Great College-street, London, S.W.1. [Price 2l. 2s. post free.]

NOTES.

ANNUAL DINNER OF THE INSTITUTION OF ELECTRICAL ENGINEERS.

The annual dinner of the Institution of Electrical Engineers was held at Grosvenor House, London, on Thursday, February 28, with the President (Sir John Hacking) in the chair. The toast of "The Institution of Electrical Engineers" was proposed by the Archbishop of Canterbury, who remarked that, like every other citizen, he benefited from their activities, although, with the one exception of the electric razor (for which he gave thanks to their profession), he was apt to take it all for granted. The profession of electrical engineering was regarded by those who practised it not merely as a job, but as an avocation. He was glad to learn that they abominated over-specialisation, because, although there was bound to be specialisation, it was a grave intellectual and moral danger to surrender to it. There was hardly a profession to-day which was not confronted with moral problems; and he would say bluntly that there were some things which science could do which it ought not to do in the interests of human nature. John Hopkinson had said: "What is wanted is not to depend on mathematics alone, but to have a general appreciation whether a thing looks about right." In that phrase he had opened the door to theology as the necessary complement to mathematics or electrical engineering. To determine whether a thing looked about right called into play judgment, wisdom, insight, vision, a sense of proportion and everything else that went to make up truth. He commended the Institution for the magnificent way in which it served the community in not losing sight of this. In reply, the President said that all branches of the electrical industry were growing at a rapid rate and one of the most important functions affecting their productivity was the maintenance of an adequate supply of suitably trained entrants to the profession. There were, however, indications that the number of entrants was materially less than had been hoped for and that the profession was not receiving an adequate share of the output of the universities and colleges. More effective use must be made of existing facilities. Colleges should therefore be encouraged to develop good technological courses covering theoretical matters and to work in close association with the industry as regards practical training. The toast of "Our Guests" was proposed by Mr. J. R. Beard. Field Marshal Sir William Slim, in responding, also called attention to the shortage of electrical engineers and electronic mechanics in the fighting Services and appealed to those who employed large numbers of such people in industry to spare some of them.

LEONARDO DA VINCI QUINCENTENARY.

The Diploma Gallery of the Royal Academy, Burlington House, Piccadilly, London, W.1, which has been closed to the public since 1939, reopened yesterday with an exhibition arranged to mark the quincentenary of the birth of Leonardo da Vinci, which falls on April 15. The chief feature of the exhibition is a magnificent collection of more than 250 original drawings by the master, most of which have been lent by the Queen from the Royal Collection at Windsor, acknowledged to be the finest of its kind in the world. There are a number of exhibits, however, from other sources also. Leonardo's genius for mechanical invention is well illustrated by a large number of facsimile reproductions from his notebooks and a number of models constructed according to his sketches and instructions. This part of the exhibition has been arranged by the Science Museum, South Kensington, and some of the exhibits, notably the models of flying machines, a parachute and weighing scales, will be familiar to some. Most of the models on show, however, are new and were made specially for the exhibition. They include a screw-cutting machine, which employs principles which are still in use for this purpose, a wood-boring machine with self-centering chucks, a file-cutting machine, machines for grinding plane and concave mirrors, a hygrometer, an anemometer, an N-type girder bridge, and a form of helicopter. In the same room are a number of reproductions of anatomical draw-

ings. The number of authentic paintings by Leonardo which have survived through the centuries is comparatively small, and the exhibition contains no examples. There are, however, a number of early copies of known works by Leonardo and of others attributed to him, including reproductions of such famous paintings as the "Mona Lisa" and "The Last Supper." The exhibition will remain open for about three months, the hours of admission being 10 a.m. to 5.30 p.m. on weekdays and 2 p.m. to 5.30 p.m. on Sundays. A series of evening lectures on various aspects of Leonardo's work will be given at weekly intervals throughout the period in the Senate House, University of London, W.C.1. The first lecture is on Thursday, March 13, at 7 p.m., when Professor L. H. Heydenreich will discuss "Leonardo and the Relation of Art to Science."

UNIVERSITY COLLEGE, LONDON.

The academic staff of University College London, including 66 honorary members, numbers some 470, of whom 46 are professors and 45 readers. The number of students attending the College is 3,493, which includes 731 post-graduate and research students, while the number of students from overseas totals 603, of whom 276 come from countries of the Commonwealth. These statistics were quoted by Sir David Pye, F.R.S., the former Provost, in the course of his annual report on the session 1950-51. It will be recalled that Sir David Pye retired on September 31, 1951, and was succeeded by Dr. B. Ifor Evans, an old student of the College, and previously Principal of Queen Mary College, London. In the course of a review of the work of the various faculties, it is stated that a new course on "Public Works" in the civil and municipal-engineering department has been attended by fourth-year undergraduates and that it includes special lectures on dock and harbour engineering, railway engineering and hygiene, as well as laboratory work on public-health engineering. In addition, a new course on soil mechanics has been instituted. In the mechanical-engineering department, a good start has been made in building up equipment for demonstrating the application of electronics to mechanical-engineering problems which will form the nucleus of apparatus for the study of vibrations. In the electrical-engineering department, the session has been marked by the introduction, for the first time, of the new Part III degree course. In electrical engineering, this brings into the final examination, as supplementary qualifying subjects: applied economics, law for engineers, and the presentation of technical information. In the chemical-engineering department researches have been conducted on electrostatic precipitation, the flow of solids through orifices, the catalytic oxidation of hydrocarbons, the electrostatic separation of minerals and other subjects. The summary of examination results indicates that 46 degrees were awarded in the Faculty of Engineering during the 1950-51 session, including five for the Ph.D., and three for the M.Sc. In addition, ten B.Sc. degrees and seven diplomas were awarded in the department of chemical engineering.

THE IDEAL HOME EXHIBITION.

The 29th *Daily Mail* Ideal Home Exhibition, which opened at Olympia on Tuesday, March 4, is the first large public exhibition to be held in the reign of Her Majesty Queen Elizabeth II. To mark the occasion, a feature entitled "Elizabeth Regina" is presented, depicting great personalities and scenes from the first Elizabethan era, and a "vista of the new reign." It is well known that the Ideal Home exhibition covers every phase of domestic life. Although no striking developments in domestic engineering are evident, there are many new products, and engineering industries are well represented with such goods as thermostatically-controlled boilers, washing machines, refrigerators, vacuum cleaners and polishers, food mixers and pulverisers, and radio and television sets. The British Electrical Development Association are demonstrating, on an electrically-operated revolving stage, how "electricity makes life easier." For the first time, there is a complete gas section, with exhibits of modern gas cookers, stoves, refrigerators, etc., by 13 firms. According to the Gas Council, if all the obsolete gas cookers now in service (esti-

mated at about 1½ millions) were replaced by modern equipment, over 500,000 tons of coal would be saved each year. Fuel economy is also the keynote of the Coal Utilisation Council's display of solid-fuel appliances for domestic heating and cooking. In the children's section, British Railways are showing a full-scale replica of the cab of the new standard 4-6-2 locomotive Britannia; a driver is present to explain the fittings. Sections of the new standard first-class and third-class passenger coaches are on view. Interesting packaging machinery can be seen in a demonstration of the manufacture of cigarettes by Messrs. J. Wix and Sons, Limited. The exhibition, which is open daily, except Sundays, from 9.30 a.m. till 9.30 p.m., will close on March 29.

EDUCATION AND PRODUCTIVITY.

The part to be played by the technical colleges in preparing young men for industry was the subject of the inaugural presidential address given by Sir Norman Kipping, Director-General of the Federation of British Industries, at the annual meeting of the Association of Technical Institutes in London on Friday, February 22. A good manager, said Sir Norman, must possess balanced judgment and leadership. Such qualities could rarely be assessed until a man was past 30 years of age, and it was at this age that supplementary educational facilities should be provided, by the universities and, possibly, by the technical colleges. The special responsibility of the technical colleges was in the field of technology. He suspected that the gap existing between the laboratory and the workshop was due to too great an attachment to conventional forms. It might be that teaching and textbooks had followed conventional channels too closely. The execution of unconventional designs needed a mind that had been trained to appreciate the possibilities of the many engineering production techniques, the teaching of which must form the solid core of the work of the technical colleges. They should provide the educational foundation on which the crafts could be built, and from which the best craftsmen could progress to designing methods of manufacture and of mechanisation. A wide range of other functions, however, played a vital role in industrial organisation—clerical processes, inspection, maintenance, mechanical handling and packaging. In order that the smaller firm, unable to employ many specialists, might gain advantage from new techniques in these specialised fields, there was a need for broadening all courses of technology. The technical colleges, the only channel of development for the majority of staffs employed in industry, had earned recognition for supplying industry with many of its middle ranks, some of whom might graduate to the higher ranks. There had been an enormous expansion in the numbers of full-time and part-time students. Rapid growth, however, had its dangers; human beings could not be mass-produced, and the development of the corporate life of the technical colleges would lead to a better "product." There was a growing desire in industry to foster closer links with education and training, and he suggested that the technical colleges and industry should co-operate in solving the problem of extending facilities for training young men for industry.

MAGNESIUM ADVISORY COMMITTEE.

The principal companies of the United Kingdom magnesium industry have formed a consultative and advisory body to be known as the Magnesium Advisory Committee, or M.A.C. The broad objective of the Committee will be to encourage expansion in the production and applications of magnesium and its alloys. The initial activities will be to hold regular discussions, between member companies, on general policy and technical matters, and to serve as the official liaison body for negotiations with the Ministry of Supply, the Ministry of Materials and other Government departments on all related subjects, at present with particular reference to the defence programme. Membership is open to all companies engaged in the production, casting or hot-working of magnesium or its alloys, with the provision of approval of applications by the Committee. The founder members of the M.A.C. are: Aeroplane and Motor Aluminium Castings, Limited; Birmetals Limited; Birmingham Aluminium Casting (1903) Company, Limited; James Booth and

Company, Limited; Bristol Aeroplane Company, Limited; High Duty Alloys, Limited; Kent Alloys Limited; Magnal Products Limited; Magnesium Castings and Products, Limited; Magnesium Elektron Limited; Rolls-Royce Limited; Sterling Metals Limited; J. Stone and Company (Charlton), Limited; and Stone-Fry Magnesium Limited. For the present, meetings are being held at Distillers House, St. James's-square, London, S.W.1, and Mr. H. G. Wilkinson, deputy chief metallurgist, Magnesium Elektron Limited, Bath House, 82, Piccadilly, London, W.1, is acting as honorary secretary, to whom all communications should be addressed.

THE BIRMINGHAM, TAME AND REA DRAINAGE BOARD.

The area in which the Birmingham, Tame and Rea Drainage Board are responsible includes the city of Birmingham, the county borough of Smethwick, the borough of Sutton Coldfield, part of the borough of Oldbury, the urban district of Solihull and parts of Bromsgrove and Aldridge, and parts of the rural district of Meriden—probably as varied an assortment of local authorities as are concerned in any sewerage district in the country. In that area of 104,372 acres, according to the report for the years 1949-51, which we have received from the clerk to the Board, there is an estimated population of 1,354,307. The daily dry-weather flow of sewage is stated to be 66,500,000 gallons—a figure which suggests that the daily water consumption *per capita* closely approaches that of London. The previous report described proposals that were under consideration for improving the purification plant at Minworth, to improve its efficiency and to enable it to deal with the greater volume of sewage which would be discharged through the new trunk sewer between Saltley and Minworth. The present report shows that considerable progress has been made with this scheme. The next instalment will comprise the construction of 16 deep circular primary digestion tanks, of reinforced concrete and 80 ft. in diameter; 12 of these tanks are to be fitted with floating steel gas-collectors, by means of which, it is expected, 300 million cubic ft. of sludge gas will be collected annually. The proposals cover the provision of plant for pumping the crude sludge, digested sludge, etc., and for circulating and heating the digesting sludge, the temperature of which, by utilising the sludge gas, will be kept down to 85 deg. F. The estimated cost of this plant at 1939 prices was 328,400*l.*; at present-day prices, it is 738,900*l.* Extensions are also proposed at Langley Heath, Sutton Coldfield, to meet the demand that is expected to result from local housing developments. The layout is so designed as to be readily extended to deal with a dry-weather flow of a million gallons daily. To meet developments at Castle Bromwich, where a light industrial centre is being established and a new housing scheme may follow, it is proposed by the Corporation of Birmingham to erect a pumping station and lay a rising main to discharge to the Board's sewage works at Tyburn. Extensions have become necessary at the Board's Yardley works, where the quantity of sewage has increased considerably and now contains an undesirably high proportion of trade wastes; it is expected that the cost will be 26,280*l.* An experimental plant has been erected at the Board's offices at Rookery Park, Erdington, for research on the treatment of gas liquor from the works of the West Midlands Gas Board.

AVRO-CANADA "ORENDA" ENGINE.—The production version of the Orenda axial-flow jet engine, designed and constructed by Messrs. A. V. Roe (Canada), Ltd., Malton, Ontario, Canada, has completed successfully the official military 150-hour type test.

EXHIBITION OF MODERN SWEDISH ARCHITECTURE.—On Friday, February 29, H.E. the Swedish Ambassador, M. Gunnar Hägglöf, opened an exhibition of modern Swedish architecture at the Building Centre, Store-street, Tottenham Court-road, London, W.C.1. The exhibition, which is mainly photographic, with a few samples of Swedish materials used in building construction, will be open from March 1 to 29, on weekdays between 9.30 a.m. and 5 p.m., and on Saturdays from 9.30 a.m. to 1 p.m.

OBITUARY.

MR. P. C. POPE.

It is with much regret that we record the death, which occurred very suddenly on March 1, of Mr. P. C. Pope, a founder member of the Institute of Fuel and secretary of the Institute from its foundation in 1927 until 1946. He was 80 years of age.

Philip Crosby Pope, who was born on January 26, 1872, was the son of a Tunbridge Wells doctor and received his general education at Tonbridge School. Part of his apprenticeship to engineering was served with Messrs. Richard Hornsby and Sons at Grantham, and the remainder in the marine engineering works of Messrs. Laird Brothers, at Birkenhead. He was employed subsequently by the British Westinghouse Company at Trafford Park, Manchester, and by the Lancashire Power Company. In this employment, he had been concerned largely with the application of mechanical and electrical power in collieries, mainly in Lancashire, in the course of which he was engaged on the installation of the first electric motors to use three-phase alter-



THE LATE MR. P. C. POPE.

nating current underground in this country. When in his early thirties, however, he decided to transfer to the commercial side of engineering and obtained the appointment of Manchester representative of Messrs. Siemens Brothers and Company. In this capacity, his activities extended over a very wide field, and before the 1914-18 war he travelled over much of Europe. On the outbreak of war in 1914, he joined the Department of Explosives Supply (afterwards merged in the Ministry of Munitions) and served as Director of Purchases throughout the war.

In the course of his pre-war occupations, Pope had had much to do with fuel problems, and on leaving the Government service in 1919 he took an active interest in the low-temperature carbonisation of coal, and, as a result, in the formation in 1925 of the Institution of Fuel Economy Engineers, of which the late Sir Alfred Mond (afterwards the first Lord Melchett) was President. Pope was elected chairman of the Council of the Institution. He was also a member of the Institution of Fuel Technologists, which likewise had Sir Alfred Mond as President, and of which Sir William Larke was the chairman of Council. The obvious overlapping of the purposes of the two institutions, and the fact that they both had the same President, led Pope to suggest to Sir Alfred Mond the desirability of a merger. This was accomplished in 1927 when the two societies united to form the Institute of Fuel, of which Pope was appointed secretary. He threw himself with characteristic enthusiasm and energy into the work of establishing the new Institute on a firm basis and extending its influence into every branch of

fuel utilisation, with a success that was self-evident; nor did he neglect the advantages of cultivating social activities, organising a series of well-attended conferences and special meetings, and being largely instrumental in founding the Fuel Luncheon Club, where the members could meet to hear short addresses, often "off the record," from leading figures in fuel supply and utilisation.

On retiring from his secretaryship at the end of February, 1946, when he was succeeded by the present secretary, Mr. R. W. Reynolds-Davies, B.Sc., Pope was made an honorary member of the Institute of Fuel—a somewhat rare distinction. For a while he was retained by the Council of the Institute in an advisory capacity; but a few years ago his eyesight began to fail and latterly he became almost completely blind. He continued, however, to keep in touch with the affairs of the Institute and to attend the meetings of the Fuel Luncheon Club, where he demonstrated to the end a keen appreciation of the latest developments in fuel technology.

COLONEL J. A. SANER, C.B.

For as long as most British civil engineers can remember, the name of Colonel J. A. Saner has been associated with river and canal training and maintenance work, more especially in connection with the River Weaver; and his death on February 20, at the age of 87, will be a matter of personal interest and concern to a large number of the present members of the Institution of Civil Engineers who were his pupils, assistants or associates at one time or another.

John Arthur Saner was born on August 11, 1864, and obtained his training in civil engineering as a pupil of Mr. R. A. Marillier, M.I.C.E., between 1882 and 1885, mainly in connection with dock construction and extensions at Hull. In March, 1885, he was appointed chief assistant to Mr. L. B. Wells, M.I.C.E., then the chief engineer to the River Weaver Trustees, under whom he obtained an extensive and varied experience in the construction, alteration and maintenance of embankments, locks, bridges, etc., during the progressive modernisation of the waterway to take barges of larger size. Mr. Wells retired in the latter part of 1887 and Saner, after a period as resident engineer, was appointed as his successor in December, 1888. He continued in that position for 45 years, eventually retiring in August, 1934. His original duties as chief engineer had been extended to include those of general manager, and he had filled both offices for many years. After his retirement, he was retained as consulting engineer until the River Weaver Navigation passed into the control of the British Transport Commission, and also carried on a private consulting practice. In addition to the ordinary duties of engineer and manager, he had acted as representative of the River Weaver Trustees in connection with the construction, by the Manchester Ship Canal Company, of the works at Weston Point, where the Weaver joins the Ship Canal, and also advised them when they had occasion to promote or oppose Parliamentary Bills affecting the navigation. He had been a corporate member of the Institution of Civil Engineers for rather more than 61 years and was advanced to the grade of member 55 years ago. He was awarded a Telford Medal in 1906 for a paper "On Waterways in Great Britain," and a Telford Premium in 1910 for a paper on the "Reconstruction of the Canal-Boat Lift on the River Weaver at Anderton." He delivered Vernon Harcourt Lectures to the student members of the Institution, in 1913, on "Canals and Canalised Rivers," and in 1934, on "Canals." He was also a past President of the Manchester Association of the Institution.

A keen supporter of the Volunteer movement, Colonel Saner served continuously in the Volunteers, the Territorial Army and the National Reserve from 1883 to 1921, and was probably one of the oldest wearers of the Volunteer Decoration. From 1904 to 1908, he commanded the 3rd (Volunteer) Battalion of the Cheshire Regiment, and the 5th Battalion from 1908 to 1912. In the 1914-18 war, he raised and commanded a war-time battalion of Volunteers, organised and managed a small munitions shop, and served as a member of the Canal Control Committee.

AERONAUTICAL RESEARCH IN AUSTRALIA.

ALTHOUGH much of the work of the Aeronautical Research Laboratories of the Department of Supply, Australia, is devoted to fundamental research, development work is becoming increasingly important, according to the annual report for 1950-51, recently issued by the Laboratories. An important development is the setting up of a new section, the High Speed Aerodynamics Division, at Salisbury, South Australia, near the Long Range Weapons Establishment; the Superintendent of the new Laboratory is Dr. D. M. Woods. At present the work of the high-speed division, which is being carried on in temporary premises, is on the design and construction of two large supersonic wind tunnels, on experiments with rocket-boosted models, and on theoretical supersonic aerodynamics. Later, flight experiments with manned or radio-controlled aircraft will be undertaken. A design for a 15-in. square variable-pressure continuous-flow supersonic tunnel is almost completed and the electric motor and compressor required have been ordered. The other high-speed tunnel is to be intermittent, and will have a much larger working section; a small pilot version will be constructed in the near future.

Ground-launched rocket model tests have already commenced. For drag measurements on wings, etc., the model is propelled by a 3-in. rocket, the results being measured by ground observation of the trajectory; but it has been found difficult to attain the desired accuracy over the required range. For measuring the pressure recovery, etc., in models of engine air intakes, a 5-in. rocket has been developed which will carry a pressure recorder, to be released with the model head and recovered by parachute. Investigations of flutter, roll and stability have been planned.

As a result of a recommendation by the Commonwealth Advisory Aeronautical Research Council, which met in Canada in September, 1950, that boundary-layer control research should be devoted to thin wings rather than to the thick-section wing developed by the Laboratories, no further flight tests have been carried out, although some wind-tunnel model work is still in hand to determine the effects of a nose slot in overcoming leading-edge contamination, and on the effects of different suction-slot arrangements. Other tests have shown that the thick-section wing is considerably less susceptible to surface waviness than conventional thin low-drag sections. The use of suction control in ducting is being investigated. Other work by the Aerodynamics Division includes a flight-testing programme for a radio-controlled tailless model aircraft; the design of free-oscillation equipment to measure damping in roll, pitch and yaw in the 9-ft. by 7-ft. wind tunnel; tests for the aircraft industry in this tunnel, for which two easily-interchangeable working sections are to be constructed in order to save time in setting up the models; and the design of a six-component wind-tunnel balance. The Merlin engine drive for the variable-pressure tunnel, mentioned in the previous annual report and on page 72 of our 172nd volume (1951), has been working for some months; the cooling system is to be redesigned. The flight section is preparing a Mustang aircraft with irreversible elevator control for flight tests. Theoretical work on certain fluid-motion problems, in which the quantity sought changes almost discontinuously in some narrow region of the flow field, has yielded some useful results. Extra-mural work has been carried out at Sydney University on measurements in a turbulent boundary-layer near the separation point, on a radio-controlled delta-wing glider for meteorological research, and on the scale effect on spinning models.

One of the principal subjects for study by the Structures and Materials Division is the life of aircraft structures; they are analysing a considerable amount of velocity-load data recorded on Australian civil-transport aircraft during normal operations. Full-scale repeated-load tests to destruction have been carried out on 26 identical wings at load ranges varying from 1 g to 6 g. A significant increase in endurance was observed in four wings which had been subjected to a static

pre-loading up to 80 per cent. of the full design load; this procedure reduced the stress concentrations initially present by plastic deformation. Strain-gauge measurements have indicated that, during the course of repeated loading, there is a steady increase of the mean strain, but not of the strain range; it is concluded from this that changes are occurring in the wing structure causing a continuous adjustment of the stress distribution.

Fundamental fatigue tests, in tension only, and in alternating tension and compression, are also being carried out on copper test-pieces to determine their dynamic stress-strain curve with a loading period of 40 milliseconds, and to determine the effect of the speed of loading on their life. The latter tests are being extended to aluminium-alloy specimens. Rotating-cantilever tests on aluminium-alloy specimens with various circumferential notches have shown that, as the root radius of the notch is decreased to 0.0005 in., the strength reduction factor is progressively increased. Root radii less than 0.0005 in., however, showed a less severe stress-concentration effect. An investigation on the effect on the fatigue strength of steel of surface profile, deformation, and internal stress, is in hand. A satisfactory hardening treatment for the steel has been developed, which does not cause any visible chemical alteration at the surface when examined at a magnification of $\times 20,000$, but it has not yet been possible to provide a reproducible tempering cycle in the induction heater. Theoretical work carried out in the Division includes the structural analysis of swept-back and tapered shell structures and non-rectangular skin panels, and investigation of the effect on structure weight of using elliptical fuselage frames instead of circular frames in a pressure cabin.

The Physical Metallurgy Division have completed the determination of the binary phase diagrams of alloys of chromium with beryllium, manganese, titanium, tungsten and zirconium, this being the first stage in an investigation of their high-temperature properties. To continue the work, a hot-hardness tester has been built, and three compression-creep machines are being constructed. Scaling tests on chromium and its alloys at 900 deg. C. have been continued for more than 300 hours, and have shown that the rate of surface deterioration decreases markedly with time; the total depth of the affected surface layer is less than 0.002 in. Slow deformation tests on aluminium at high temperature have shown that a substructure is produced, the size of which increases with the temperature of deformation; the finer the grain, the more difficult it is to form the sub-structure. Among other work carried out on the deformation of metals, fundamental studies of the creep of zinc-aluminium alloys are to be undertaken.

The Engines and Fuels Division are continuing systematic studies of flame speeds and of the performance of gas-turbine combustion chambers. For the latter, a test rig, consisting of a heavy outer casing enclosing a flame tube simulating the one to be tested, is divided by baffles into five separately-fed sections; an additional independent air supply can be introduced close to the fuel atomiser, various types of which have been tested. The work completed so far on this rig has indicated that it is mainly at weak-mixture conditions that combustion and performance can be improved. The object of the flame-speed studies is to reduce combustion-chamber dimensions by increasing combustion intensity. Large-scale eddies introduced by ordered arrangements of entry ports had a direct effect on flame propagation, but in the rig used the pilot flame was affected by the arrangement of the ports.

To study large-scale turbulence satisfactorily, a new test rig is required with a separately-controlled stable pilot flame. The cascade tests on axial-compressor blading have continued; a vortex tunnel for tests at low Reynolds numbers will be constructed during the coming year, and a 3,400-h.p. high-speed tunnel, also under construction, is expected to be working during the year. Continuing the investigation on pulverised brown coal as a gas-turbine fuel, a satisfactory combustion chamber has been developed, and work is now on hand, with a modified turbo-supercharger as a test engine, to determine whether ash separators are required; a combustion chamber with a fuel-handling and

metering system is also being developed. The work on pneumatic pulverisers, which have been found to require considerably more power than mechanical pulverisers, has been abandoned. Tests on an "ash erosion" rig, for determining the effects of hot ash impinging on turbine-blade materials, have shown that ash is more likely to build up than to erode the blades. The work on piston engines has been concluded, and studies on ram jets have now commenced.

As noted in the previous report, the Instrumentation and Electronics Division are mainly concerned with providing equipment for the various research projects, including control instruments for model aircraft, and laboratory equipment for testing such instruments, among which may be mentioned a very-low-frequency signal generator, at present being developed, having a sinusoidal voltage output in the range 0.005 cycle to 2 cycles per second.

MACHINERY FOR MANUFACTURING.*

IN each post-war year, about a fifth of the national output has gone into capital investment, which has been at least as high in real terms as in the best pre-war year and very considerably higher than the average for the 1930's; and industry has probably been getting a larger share. Yet, had more resources been available, the programme could have been much higher with advantage to the national economy; in the United States, something like twice as much per head has been invested since the war, and in manufacturing industry probably more than that. Manufacturing industry has been taking about 20 per cent. of United Kingdom total investment, compared with 15 per cent. for transport and 10 per cent. for fuel and power; and of plant and machinery alone, about a third. Since the war, about the same value of machinery has gone each year into manufacturing industry as into exports. A sample inquiry early last year suggested expenditure by manufacturers as shown in Table I.

TABLE I.

	(£ Millions.)		
	1948.	1949.	1950.
Total capital expenditure ..	283	423	496
of which—			
Plant and machinery ..	256	284	337
Compared with—			
Exports of machinery ..	233	280	319

Either physical or financial factors were limiting the total size of the investment programme in these years, and preference was being given to investment which would remove shortages of basic materials such as coal and steel, would help the expansion of exports, and would lead to a saving of imports. In manufacturing industry, the oil-refinery programme was growing rapidly in 1949-50, and here and in chemicals and metal manufacture there was heavy investment per head of the employed labour, as shown in Table II. The increases in 1950 given in the second column are, of course, value figures; the average increase in the prices of engineering goods between 1948 and 1950 was about 7 per cent., so there was obviously a real increase in supplies in 1950 for all the industries listed except the engineering and ceramics groups.

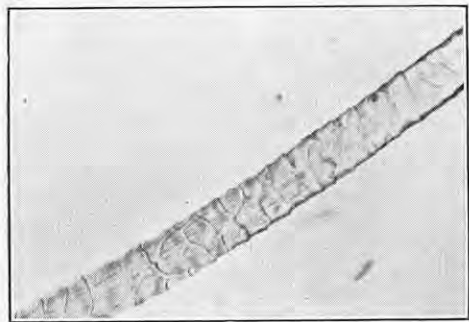
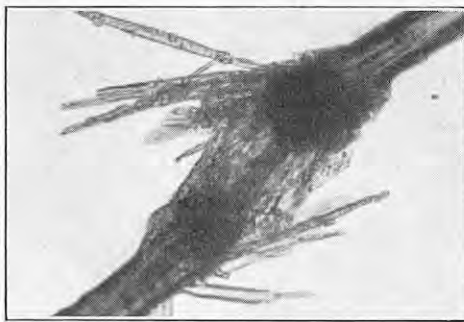
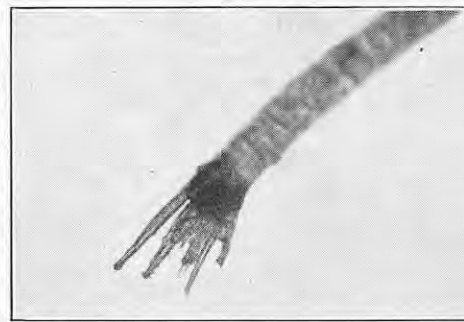
TABLE II.

Investment in Plant and Machinery.	£ Millions, 1950.	Per cent. Increase, 1950 Over 1948-49.	£ per Head of Labour 1948-50, Average.
All manufacturing ..	337	—	—
of which—			
Oil ..	21	133	990
Chemicals ..	45	47	80
Metal manufactures ..	42	31	67
Food ..	40	31	49
Ceramics and cement ..	12	0	42
Paper and printing ..	23	18	42
Textiles ..	38	13	36
Vehicles ..	27	39	24
Engineering, ships and electrical ..	42	3	23

The rate of supply to British industry was undoubtedly much better in 1950 than in previous years. In real terms, about 8 per cent. more machinery went into the factories in 1949 than in 1948 and about 15 per cent. more in 1950 than in 1949. But the

* From the *Bulletin for Industry*, March, 1952; issued by H.M. Treasury. Abridged.

MORPHOLOGICAL ASPECTS OF ABRASION AND WEAR.

FIG. 1. UNDAMAGED WOOL FIBRE. $\times 230$.FIG. 2. FIBRILLISATION OF WOOL FIBRE FROM WORN CLOTH (REF. 1.) $\times 230$.FIG. 3. BROKEN WOOL FIBRE (REF. 1.) $\times 230$.FIG. 4. WOOL FIBRE, ABRADED WITH EMERY PAPER (REF. 1.) $\times 230$.FIG. 5. WOOL FIBRE, FIBRILLISED IN LABORATORY TEST (REF. 4.) $\times 125$.

MORPHOLOGICAL ASPECTS OF ABRASION AND WEAR.*

By DR. G. SALOMON.

shadow of Korea lay already across the world, and it was clear that some cut-back would come if the arms programme was to be met. In June, 1951, the House of Commons was told: "... there will in 1951 be no increase in the supplies of plant and machinery available for home industry, while in 1952 and 1953 there must be a substantial reduction." It was added that, since a larger share must go to firms on defence production, "civilian" industry would get less, "even in 1951." In practice, however, it seems there was a further increase in 1951.

Making a rough allowance for price changes, the real increases in home market supplies of general machinery in 1951 (excluding imports) may have ranged from perhaps 4 per cent. for mechanical-handling equipment to an increase twice as large for rotating electrical machines, and four times as large for machine tools. Machine tools were a special problem thrown up by re-armament, and measures were taken very early to increase output and imports, limit exports, and restrict supplies to "civilian" firms. In 1951, output of metal-working machine tools increased (in real terms) by about 14 per cent., the increase in exports was only 8 per cent., imports went up by nearly 40 per cent.

Among the more specialised types of machinery, the chemical industry secured perhaps a 20 per cent. increase last year in supplies of home-produced equipment, and textiles perhaps a 10 per cent. increase—in both cases, considerably more of an increase than was secured in the output of machinery of these types. Imports of machinery in 1950 represented no more than about 5 per cent. of total British investment in plant and equipment; in 1951, leaving aside machine tools, the tonnage was reduced by nearly two-fifths.

This year, there will be a substantial increase in investment for defence purposes, and supplies to the fuel and power and steel industries must continue to rise. At the same time, exports need to be increased as much and as rapidly as possible. Turning to the supply side, on present prospects for steel and non-ferrous metals, any increase in output of machinery is bound to be modest; and imports—in present balance of payments difficulties—must be strictly limited. In 1952, therefore, it is proposed to reverse the trend of recent years, whereby a bigger supply of machinery has gone each year into manufacturing industry; and various measures, fiscal and physical, are in hand.

Over the whole field of plant, machinery and vehicles for civil use, the objective is to reduce home deliveries by 150% to 200% million (at current market prices) below the 1950 level. This "severe and unwelcome step" means an average cut of one-sixth below 1950 supplies. A large part of it will consist of cuts in vehicle supplies. So far as machinery alone is concerned, the level of home supplies will be largely determined by the speed at which the machinery makers can switch from home to export orders in industries where the production cycle is necessarily a long one.

THREE aspects are common to all wear problems, namely, the economic importance, the complexity of the process, and an approach which is essentially phenomenological. Wear phenomena of some organic materials of construction will be considered against the well-known background of metal science. Observations on changes in grain structure, the formation and growth of cracks and the appearance of fractured surfaces have led to a number of well-defined conceptions of wear in metal technology. Although damage to fibres is readily made visible by staining, comparatively scanty experimental evidence on the wear of textiles is available. Until the advent of nylon, little incentive existed to focus the attention of textile manufacturers on resistance to wear. Recent work in this field, together with some relevant observations on polymer films, will be surveyed.

A wool fibre is covered by overlapping scales† (see Fig. 1, herewith). Under conditions of wear, a gradual breakdown of the fibre surface could be expected. Actually, quite a different process takes place (see Fig. 2). The fibre disintegrates into a series of longitudinal elements which are probably the remainder of the original, but dead, cortical cells. Fig. 2 gives the impression that the wool fibre is a laminated material in which the adhesive layer is the weakest link. Obviously, the fibre has failed mechanically, long before complete rupture takes place (Fig. 3), with the formation of a "brush."

Damage due to abrasion gives a different picture. The cuticle layer can be bruised or the scales may be rubbed off, then forming a hard abrasive powder. Such phenomena can be caused by the polishing action of buttons‡ or by glass rods in the laboratory.§ Fibrillation, however, outweighs all other single causes of wear in service. Emery paper or other hard abrasives used in laboratory tests produce a cutting action¶ (see Fig. 4), which does not occur in practice. Tests on an abrasion machine therefore represent, even under the most favourable conditions, not more than an ill-defined general quality index. The reproduction of fibrillation in the laboratory has been recently achieved by Germans and van der Vegt (see Fig. 5). For this purpose, fibres were kept under tension and subjected to repeated blows by a little hammer.¶

Orientated chain-like macromolecules, e.g., natural rubber, fibrillise when fractured at low temperatures.

* Paper presented at the Conference on Abrasion and Wear, held at Delft, Holland, on November 14 and 15, 1951.

† See list of references on page 312.

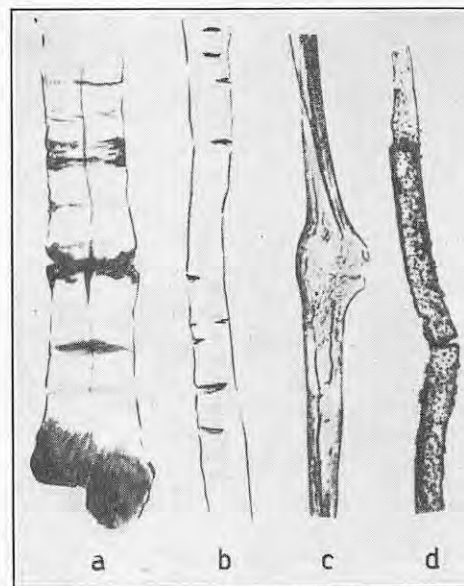


FIG. 6. DAMAGE TO CELLULOSE FIBRE (REFS. 5 TO 8.)

- a. Crack Formation in Cotton in Service Test.
- b. Flax after Heat Tendering.
- c. Cotton after Flex-Fatigue Testing.
- d. Staple Rayon from Worn Suit.

The question therefore arises whether fibrillation is really due to the presence of a morphological structure in the microscopic region. Disintegration into secondary fibrils has been reported for certain types of natural silk.⁵ Lack of tendency to undergo fibrillation is probably one of the reasons for the superior resistance to wear of nylon.

A quite different effect dominates the wear properties of flax, cotton, and rayon. It is the growth of cracks across the fibre which leads ultimately to a brittle fracture.⁵⁻⁸ Such cracks can be made visible by staining. They may originate from physical or chemical damage. Fig. 6, herewith, gives a series of typical cases taken from literature; similar cases have also been found at the Fibre Research Institute, T.N.O., at Delft (Vezelinstuut T.N.O.). Cracks appear sometimes as spirals and in other cases, after repeated bending, in the centre of the flattened bend.⁷ Typical fatigue fractures of rayon staple fibres are smooth, while a torn fibre can have a rugged cross-section.⁶ Fibrillation is perhaps not completely absent, but certainly it occurs only to a minor degree.

The actual cause of wear is a succession of brittle fractures initiated by local cracks. This vital point has been proved for cotton, by experiments in the Shirley Institute, by Miss G. G. Clegg.⁸ A fibrogram was made from threads of a new and a worn shirt, of identical quality. The results are illustrated by Fig. 7, opposite. It is apparent that the longest fibres have disappeared during wear and that the number of short fibres has increased considerably. The important consequence of the work just quoted, and of other similar investigations is the new concept of wear as a phenomenon of dynamic fatigue.

Another example of the correlation between brittle fracture and dynamic fatigue is to be found in the resin treatment of rayon (the Tootal process). Correctly applied, the resin polymerises in the core of the fibre which becomes more resilient and crease-resistant. Sometimes faulty finishing operations yield fabrics with fibres glued together by resin. Such faulty crease-resistant materials wear badly because the flexibility of individual fibres is impeded; therefore,

ASPECTS OF ABRASION AND WEAR.

Fig. 7.

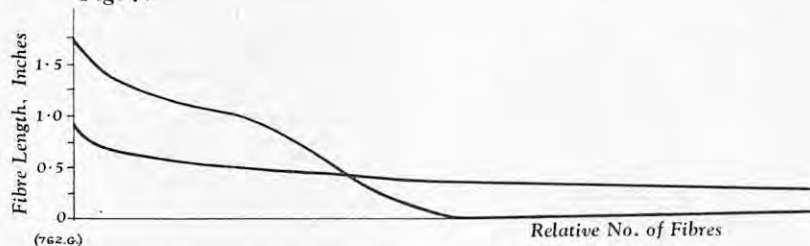
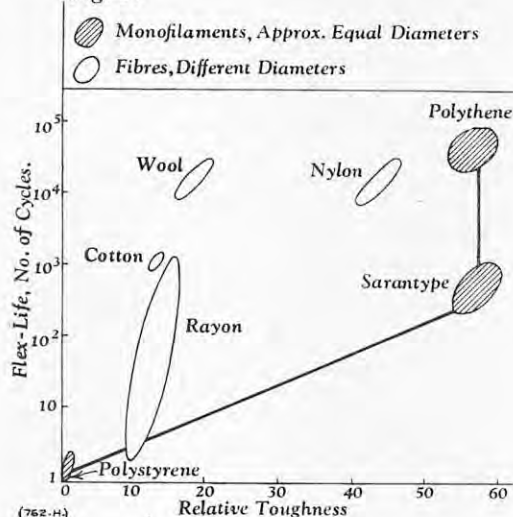


Fig. 8.



the probability of bending fracture increases. It was found by workers at the Fibre Research Institute that the quality of resin-treated fabrics can be estimated by flexing them on a fatigue tester generally used for paper, while tests on abrasion machines gave no significant correlation with wearability.⁹ Results obtained by fatigue testing were also confirmed by direct microscopic observations on the location of the resin in the fibre.¹⁰

Brittle fracture due to dynamic fatigue cannot be reproduced by the cutting action of emery paper on the conventional abrasion machines. There are, however, special cases in which abrasion can become the preponderant cause of wear. Cellulose-based fibres, for example, are frequently damaged when held in a rigid position during laundering or when stiffened by starching.⁸

Fibrillation of wool is obviously linked up with the morphological structure of the fibre. A possible influence of the molecular structure on the fatigue resistance of other fibres will now be considered.

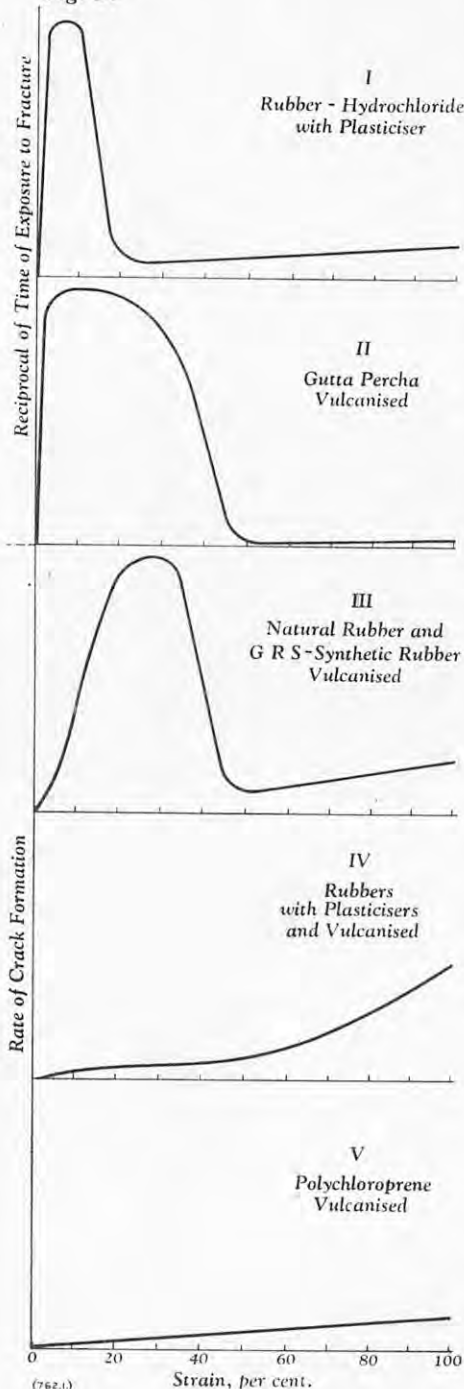
Seen as engineering materials, fibres are small beams of varying resilience, toughness and stiffness.¹¹ A relative measure of toughness (energy at rupture) can be derived from the stress-strain diagram. The stiffness of a beam is measured by the bending modulus, which increases with the fourth power of the diameter.¹² The useful thickness of a fibre will therefore depend on the brittleness of the bulk material. In fact, the flex-life of some monofilaments changes in the expected direction¹² (see Fig. 8, herewith).

Polyethylene is a tough plastic which becomes brittle only below -70 deg. C. Thick monofilaments of this polymer can survive at least 10^5 flexing cycles on a paper tester. Polystyrene is a brittle plastic and monofilaments with a similar diameter break instantaneously. The brittle point of the Saran-type polymer takes an intermediate position between these two extremes. The flex life of these saran-type monofilaments, which are plasticised by the addition of some low-molecular materials, takes an intermediate place in Fig. 8. With increasing fineness of the fibre, moisture absorption and orientation of the fibre become more prominent factors for the flex life than the intrinsic properties of the polymer. For this and other reasons, the data¹³⁻¹⁸ on the flex-life of various fibres, compiled in Fig. 8, are not strictly comparable.

Wool and nylon do not differ essentially in flex-life, when measured on the same apparatus.⁷ This result casts some doubt on the value of such bending tests. Furthermore, the data obtained for rayon depend very much on the degree of orientation of the fibre and on apparently small changes in experimental conditions. The latter crucial point is further elaborated below.

Quite recently, the significance of cracks which appear on the surface of fibres on bending or stretching

Fig. 9.



The cause of crack initiation, like the nucleation of crystals or the start of a chain reaction, is frequently obscure. However, cracks can be initiated by a controlled chemical reaction of ozone with certain polymers. This rare phenomenon will be used to illustrate the problem.

Ozone reacts with the double bonds of unsaturated polymers. Surface cracking of stressed films of these polymers is induced by the first minute traces of ozone. This effect is well known for vulcanised rubbers,²¹ and its existence has been established recently for two plastics, namely, the hydrochloride of natural rubber with some of the original double bonds still present,²² and raw and vulcanised gutta percha,²³ the isomer of natural rubber. Both polymers are partly crystalline. As in polyethylene, this crystalline phase is the cause of a high modulus of elasticity. Under certain experimental conditions, which will be discussed now, these strong films break after a little while when exposed to ozone. This growth of cracks has also been observed directly,²² but not so conveniently as in rubbers.²¹

The relevant point in the present discussion is the surprisingly large influence of prestretching on the rate of ozone-initiated crack growth (see Fig. 9). The shape of the five curves in Fig. 9 can be explained as follows. High stresses are set up in the two plastics (I and II) by very small strains. These stresses relax only slowly and, therefore, contribute to the growth of cracks. At higher strains, the tensile strength of the two plastics is so much improved by orientation that crack growth is retarded or even inhibited. The low-modulus rubbers (III) differ from the plastics (I and II) by having a higher rate of stress relaxation at small strains; ozone-sensitivity therefore reaches a maximum at higher strains.

The conventional technological recipe for the improvement of ozone resistance is the addition of certain plasticisers. Such rubbers (IV) have a high rate of stress relaxation and, therefore, develop cracks only at considerably higher strains than the preponderantly elastic rubbers (III). Finally, Neoprene (V) shows the smallest rate of crack growth. It is mechanically similar to the rubbers (III), but contains double bonds, which are about 10,000 times less reactive. The rate of chemical attack is so much reduced here that again stress relaxation, which eventually takes place in all elastomers, retards the growth of cracks.

The surface crazing of amorphous plastics²⁴ is a case of physically initiated cracking, closely related to ozone-cracking. By introducing certain rigidly-built molecular units in such polymers, the resulting brittle film acquires even the strain-sensitivity of metals (stress-coating).²⁵ Strongly cross-linked polymers cannot relax at all, even over long periods of time. Such resins (e.g., Columbia Resin CR 39) are suitable indicators of static fatigue in metals,²⁵ which is due to the gradual building up of stresses.

All these considerations refer to cracks produced by stretching or bending. The application of complex stresses leads to different and quite unexpected phenomena, which have been observed with polyethylene. While this plastic is very flexible on bending (Fig. 8), it behaves like a brittle solid under the influence of complex stresses or when bent in the presence of surface-wetting liquids.²⁶ The remedy applied by technologists is the one used already against ozone-cracking of rubbers, namely, the addition of plasticisers, which improve the rate of stress relaxation.²⁷

In the analysis of the wear of textiles, fatigue, followed by localised fractures of the individual fibres, was recognised as the preponderant cause of wear. Some generalisations can be made by discussing these three phenomena, wear, fatigue and fracture, in reverse order.

Fracture is the common denominator for all types of abrasion and wear. It is a rate process and can be properly understood only by a kinetic approach. In the ideal case, that of the fracture of brittle solids,²⁸ the probability of fracture depends on the number of "weakest links" in the material, but it is independent of the actual structure of the matter. This theory has been worked out recently in great detail.²⁹ However, the study of fractured surfaces³¹ and of service fractures³² has revealed that, during the progress of a brittle fracture, the mechanism of the process can change.³⁴ A brittle fracture initiated by a blow may be terminated by a "ductile" or a "plastic" fracture. In these other types of fracture, which are not yet well defined, the rate and direction of crack growth depend on the morphological and molecular structure of the material; such fractures are therefore "structure-sensitive."

This change from a brittle fracture to a "structure-sensitive" fracture is determined by the competition between at least two rate processes, namely, the rate of brittle fracture under the influence of external forces, and the rate of changes in structure during the progress of brittle fracture, under the influence of internal stresses. Examples of such changes are plastic flow orientation or recrystallisation.

has been recognised. Such cracks have been made visible on the surface of rayon and some synthetic fibres.¹⁹ Systematic work on the stress-cracking of fibres is lacking, however, and the following observations on films may serve as an introduction to what is still a virgin field.

Crack growth depends on stress concentration at the edges of the crack, and on the strength of the material at the lines of maximum stresses. Both factors are interlinked with the time dependence of stress-strain properties. A high rate of stress relaxation will counterbalance the first factor and retard or even inhibit crack growth. The second factor, the tensile strength of the material, can be improved by stretching. For this reason, an influence of prestretching on crack growth can be expected.

Fatigue means only that changes in structure have taken place, either under the influence of stress cycles (dynamic) or under the influence of a permanent load (static). Fatigue phenomena depend not only on the magnitude and the frequency of deformation, but also on the direction of the principle stresses. The properties of polyethylene, mentioned above, are a striking illustration of the difference between the effect of complex stresses and that of simple bending forces. The cause of brittle cracking is the same in plastics and in metals; it is the distribution of stresses, only the mechanism of relaxation is different for both materials. For this reason, an evident analogy exists^{26b 26c 27} between the stress cracking of polyethylene and the stress cracking and the stress corrosion of metals.²⁸

The rate of wear will depend frequently on cycles of such complex stresses. In general, their effect on a material can not be deduced from other dynamic measurements. The prediction of wear resistance of a material must be based, therefore, on the reproduction of the same stresses in the laboratory. In addition to this, the similarity between damage produced in actual wear and that in laboratory tests must be ascertained continuously. Direct microscopic observations are, in fact, still a powerful, but sometimes neglected, tool of abrasion research.

This work is part of a co-operative project on abrasion and wear recently instigated by the Nijverheidsorganisatie T.N.O. (National Council for Industrial Research T.N.O.).

REFERENCES.

- ¹ F. H. Germans. (a) *Communication No. 91*, Vezelinstituut T.N.O., 1949 (Dutch). (b) *J. Text. Inst.*, vol. 42, T185 (1951).
- ² Ch. Gorter. *Communication No. 87* Vezelinstituut T.N.O., 1948 (Dutch).
- ³ H. F. Schiefer and J. F. Krosney. *Text. Res. J.*, vol. 19, page 802 (1949).
- ⁴ Internal Report of the Vezelinstituut T.N.O. (1950).
- ⁵ A. Herzog and P. A. Koch. *Melliand Textilber.*, vol. 17, page 101 (1936).
- ⁶ J. Ecker. *Melliand Textilber.*, vol. 22, pages 194 and 314 (1941).
- ⁷ R. H. K. Thomsen and D. Traill. *J. Text. Inst.*, vol. 38, T43 (1947).
- ⁸ G. G. Clegg. *J. Text. Inst.*, vol. 40, T449 (1949).
- ⁹ Communicated by the Service Dept. of the Vezelinstituut T.N.O.
- ¹⁰ (a) R. Bernegger. *Textil Rundschau*, vol. 3, page 226 (1948). (b) C. van Bochove. Internal Report, Vezelinstituut T.N.O. (1950).
- ¹¹ H. DeWitt Smith. *Proc. A.S.T.M.*, vol. 44, page 543 (1944).
- ¹² Private communication by the Rubber-Stichting, Delft.
- ¹³ E. Franz and H. J. Henning. *Melliand Textilber.*, vol. 17, page 121 (1936).
- ¹⁴ P. W. Carlene. *J. Text. Inst.*, vol. 38, T38 (1947).
- ¹⁵ D. Finlayson. *J. Text. Inst.*, vol. 38, T50 (1947).
- ¹⁶ J. P. A. Lockner. *J. Text. Inst.*, vol. 40, T220 (1949).
- ¹⁷ W. E. Roseveare and R. C. Waller. *Text. Res. J.*, vol. 19, page 633 (1949).
- ¹⁸ J. H. Dillon. "Fatigue Phenomena in High Polymers," *Adv. Colloid. Sci. III, Interscience*, New York (1950).
- ¹⁹ S. Simmens and F. Howlett. *J. Text. Inst.*, vol. 40 T590 (1949).
- ²⁰ D. Entwistle. *Rev. Textile Progress*, vol. I, page 57, (1949).
- ²¹ (a) A. van Rossem and H. W. Talen. *Kautschuk*, vol. 7, page 79, 115 (1931). (b) J. Crabtree and A. R. Kemp. *Ind. Eng. Chem., Analyt. Ed.*, vol. 18 page 769 (1946). (c) R. G. Newton. *J. Rubber Res.*, vol. 14, page 27 (1945); R. Elliott and R. G. Newton. *J. Rubber Res.*, vol. 17, page 17 (1948). (d) J. T. Blake, "Symposium on Aging of Rubbers," *A.S.T.M. Spec. Techn. Publ.*, No. 89 (1949).
- ²² F. J. Hermann, H. W. Talen and G. J. Scheffer, Paint Institute T.N.O., *Circ. No. 68*, 1950 (Dutch).
- ²³ G. Salomon and A. Ch. v. d. Schee. Rubber-Stichting: Unpublished Results.
- ²⁴ (a) E. W. Russell. *Nature*, vol. 165, page 91 (1950). (b) C. C. Hsiao and J. A. Sauer. *J. Appl. Phys.*, vol. 21, page 1071 (1950).
- ²⁵ M. Hetényi. "Brittle Models and Brittle Coatings," *Handbook of Exp. Stress Analysis*, edited by M. Hetényi; Wiley and Sons, New York (1950).
- ²⁶ (a) R. B. Richards. *Trans. Faraday Soc.*, vol. 42, page 10 (1946). (b) I. L. Hopkins, W. O. Baker and J. B. Howard. *J. Appl. Phys.*, vol. 21, page 206 (1950). (c) R. H. Carey. *A.S.T.M. Bulletin No. 167*, page 56 (1950).
- ²⁷ J. B. DeCoste, F. S. Malm and V. T. Wallder. *Ind. Eng. Chem.*, vol. 43, page 117 (1951).
- ²⁸ H. L. Fox. "Fracture under Fatigue Conditions" in: *The Fracture of Metals* (1949). Publ. by the Institution of Metallurgists, London (1950).
- ²⁹ A. Nadai. *Theory of Flow and Fracture of Solids*, vol. I, chap. 15, 2nd ed.; McGraw-Hill Book Co., New York (1950).
- ³⁰ Work of Weibull (1939) and others, surveyed by B. Epstein, *J. Appl. Phys.*, vol. 19, page 141 (1948).
- ³¹ "Fractography," by C. A. Zapffe and M. Clogg. *Trans. Am. Soc. Metals*, vol. 34, page 71 (1945).
- ³² "Resinography," by T. G. Rochow and F. G. Rowe. *Analyt. Chem.*, vol. 21, page 465 (1949).
- ³³ R. E. Peterson. "Interpretation of Service Fractures"; *Handbook of Exp. Stress Analysis*, edited by M. Hetényi. Wiley and Sons, New York (1950).
- ³⁴ P. E. Shearin, A. E. Ruark and R. M. Trimble. *Rep. Conf. on Strength of Solids* (Bristol, 1947), publ. by the Physical Soc., London (1948).

LABOUR NOTES.

HUMAN relationships in the coal-mining industry, and the urgent need for the utmost improvement in them, were referred to at length by Sir Hubert Houldsworth, K.C., the chairman of the National Coal Board, in the course of an address delivered at a meeting of the Institute of Public Administration, held in London on Monday last. Sir Hubert said that the Board had realised, from the time of its establishment, that the solution of many of the problems confronting it was to be found in improving the relations between the men and the managements. If, by waving a wand, these relations could be brought to the same high standard of perfection in all parts of British coalfields as had been reached in some, there would be a very substantial increase in coal production straight away. He recognised that there had been failures to obtain this co-operation during the five and a half years of the Board's existence and there would probably be other failures to record in the future.

At the present time, the most urgent need in the industry was for the production of much larger quantities of coal for export, and, in Sir Hubert's opinion, the great danger confronting the country was that this job would not be done quickly enough. One of the most important duties of the Board and its officials was to convince everyone in the industry of the pressing need to push on with the job. Much progress had, in fact, been achieved in the industry and he believed that, in normal times, it would have been regarded as satisfactory. To-day, however, the country's needs were such that it was woefully inadequate. There was room, also, for further technical improvements and scientific methods but efficiency, even in these matters, depended upon the human element. A machine could be very cleverly constructed for use in the pits and could be very efficient when properly handled, but it would fail to give successful results unless it was used with determination and in a spirit of co-operation between miners and managements.

Recommendations that the working of voluntary shifts in the pits on Saturdays shall be discontinued will be put forward by the Scottish area of the National Union of Mineworkers at a national delegate conference of miners' leaders, which is to take place in London on March 14. The extended hours agreement in the industry, which comes to an end on April 30, was discussed at some length at a meeting of the union's Scottish area executive council in Edinburgh on Monday last, and it was decided to urge the national conference not to renew the agreement. The President of the union's Scottish area, Mr. Abe Moffat, stated, after the meeting, that the executive council's decision was arrived at for a number of reasons and that the recommendations which would be put forward would be quite permissible and constitutional under the terms of the agreement, which, in any case, had only been adopted on a temporary basis.

In spite of the temporary nature of the agreement, however, voluntary shifts had now been in operation, Mr. Moffat mentioned, for nearly five years, and to continue them for a longer period would render the industry's five-day week agreement null and void. Scottish miners resented the low average piece rates paid to them, which amounted to 2l. 4s. 5d. a shift, compared with an average of 2l. 9s. 3d. for the rest of Britain. The men felt that the Government's proposed economy cuts would adversely affect the living conditions of miners, as they would those of other industrial employees. It was not to be expected that miners would increase production for a Government which imposed such cuts when profits were "higher than they had ever been." The miners also considered, Mr. Moffat stated, that the increased production of coal was required, not to build up the country's national economy or to give householders more fuel, but to enable a huge rearmament programme to be put into effect.

Miners in some lodges in South Wales have stopped voluntary work on Saturdays for the past few weeks as a protest against the economy cuts, and a demonstration of miners against these cuts was held at Tonypany

last Sunday. The position regarding Saturday work was discussed at a meeting in Cardiff of the executive council for the South Wales area of the N.U.M., on Saturday last. The council decided to request the miners to honour the extended hours agreement and to continue the working of shifts on Saturdays, at any rate until April 26, the Saturday before the agreement expires. Area conferences will be held in Scotland and South Wales on March 17 to consider reports from representatives attending the national delegate conference in London on March 14. The National Coal Board reported last Saturday, March 1, that about 707 collieries throughout Britain were open for work on that day, compared with 626 at work on the preceding Saturday. The improvement on March 1 was largely due to more pits being open in Scotland, where it has been the custom for some time to work a Saturday shift once a fortnight only. About half the 159 collieries in South Wales were closed last Saturday and it was estimated by the Board that 50 of the idle collieries were concerned in a boycott of the Saturday shifts. The other pits closed were idle for technical reasons. On Wednesday, the union's executive council for Yorkshire decided by a large majority not to join in the boycott of Saturday working.

Demands for the increased subsidising of miners' travelling expenses were made on Tuesday last, when officials of the N.U.M., headed by the union's President, Sir William Lawther, met Mr. Ebby Edwards, the labour relations member of the National Coal Board. In effect, the trade union leaders asked that the Board should subsidise the men's fares so that none of Britain's miners, numbering over 700,000, would have to pay more than 5s. a week to travel to and from his work. It was claimed to be unfair that miners should be called upon to meet the increases in their fares. The district most affected is the South Wales area, where some forty thousand miners are threatening to go on strike on account of the abolition of workmen's fares and an increase of 25 per cent. in the rate for season tickets.

Some time ago, the Board agreed to subsidise fares exceeding 5s. a week of miners who had been transferred from one colliery to another, owing to redundancy or other reasons, and who had been unable to move their homes. This concession at present costs the Board about 500,000l. a year, and the Board has resisted, hitherto, all efforts to extend the privilege, maintaining that miners, in common with other classes of work-people, should pay their travelling costs out of their own wages. It is estimated that, if the latest demands of the union are conceded, the cost to the Board will be increased by about one million pounds annually. A further meeting between Mr. Edwards and the union's leaders will take place next week, after the matter has been discussed at a meeting of the full Board.

A sitting of the Industrial Court was held in London on Tuesday last at which evidence was presented by both sides in connection with the demands of engineering employees in railway workshops for increases in their pay. The claims of these railwaymen had been before the Railway Executive for some time and it may be recalled that, some weeks ago, when increases in wages were granted to other classes of railway employees, the Executive made an offer of an increase of 8 per cent. The National Union of Railwaymen was willing to accept the offer on behalf of the shopmen belonging to that union. The Confederation of Shipbuilding and Engineering Unions, however, to which a large proportion of the 125,000 shopmen employed by the Executive belong, declined to do so. This union requested that the increase granted to engineers in the railway service should be in the same proportion to that granted to engineers generally. Subsequently, the Confederation asked the Minister of Labour to intervene in the dispute in order that the issue might be sent to arbitration. It is expected that the decision of the Tribunal will be made known shortly.

Wage increases of 30s. a week, at least, for employees in the engineering and shipbuilding industries were demanded at a conference of shop stewards, held in Sheffield on Sunday last. The conference was arranged by the "Sheffield action committee" in co-operation with the Engineering and Allied Trades Shop Stewards' National Council. Some 250 delegates from 97 shipyards and engineering establishments are reported to have been present. They claimed to represent over a quarter of a million employees in the two industries. Other resolutions, carried unanimously at the meeting, asked for a consolidated basic rate for all operatives paid by results, with a minimum increase of 33½ per cent. thereon; 20s. a week more for employees under 21 years of age; and holiday pay based on average earnings over a stated period. A forty-hour week and bans on overtime in areas affected by short-time working were also demanded.

CONVEYING PLANT FOR STRAW BALES.

GEORGE W. KING, LIMITED, HITCHIN.

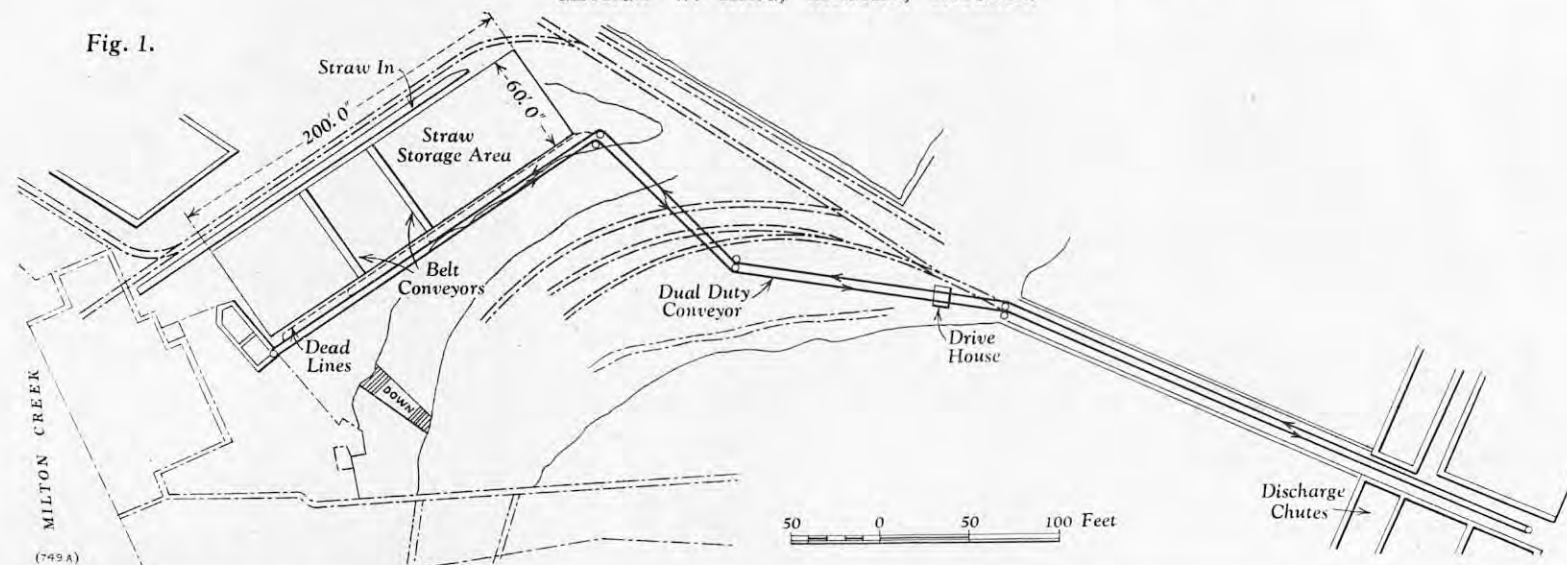


FIG. 2. LOADING BALES ON TO CONVEYOR.

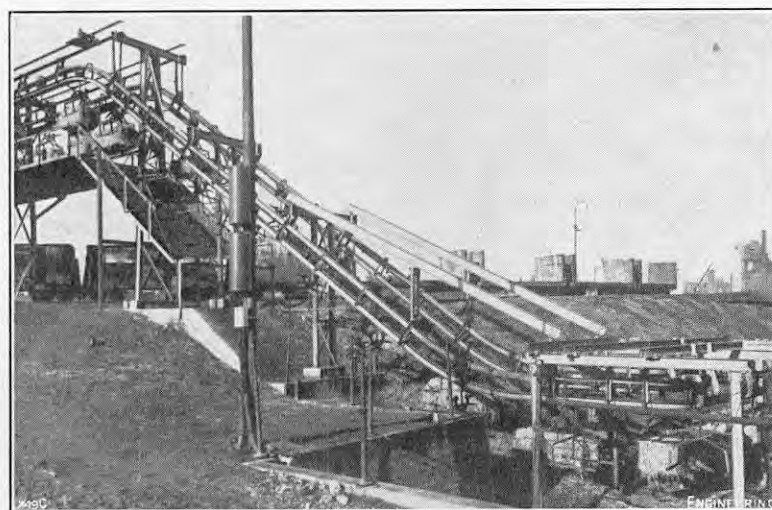


FIG. 3. BALES LEAVING STORAGE AREA.

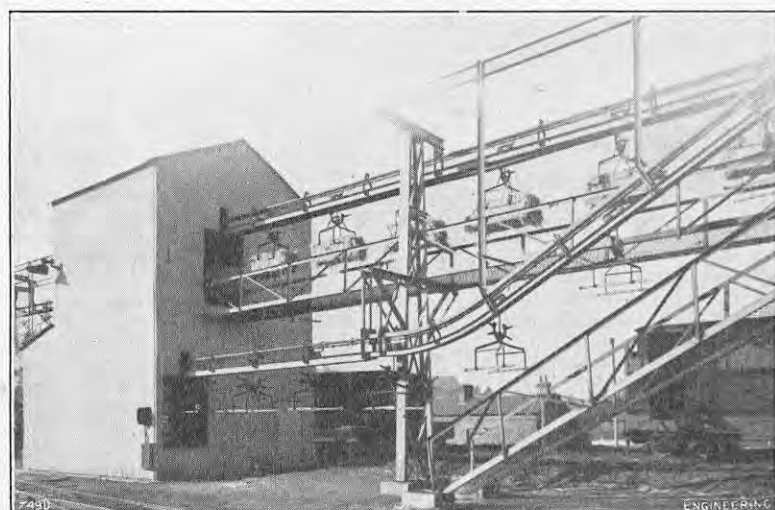


FIG. 4. CONVEYOR DRIVE HOUSE.

STRAW-CONVEYING PLANT.

AN interesting plant for conveying straw, used in the manufacture of straw paper for corrugated cardboard packing, and for producing bleached straw pulp for high-quality printing papers, has been designed by Messrs. George W. King, Limited, Hitchin, Hertfordshire, for Messrs. Bowaters Lloyd Pulp and Paper Mills, Limited, and has been in operation at their works at Sittingbourne, Kent, for the past year. The plant can handle bales of straw measuring up to 4 ft. long by 2 ft. wide by 1 ft. 6 in. deep, and weighing from 90 lb. to 150 lb. The layout of the plant is shown in Fig. 1, above, and various portions of the main conveyor are illustrated in Figs. 2, 3 and 4. Bales of straw arriving by

road or water are deposited in a store served by two mobile belt conveyors. From the store, the bales of straw are carried by the belt conveyors to the main Dual-Duty conveyor which transports them, crossing the railway and road, to three discharge chutes feeding the straw-cutting machines. The main conveyor motor and the discharge-chute selectors are remotely controlled by the cutting-machine operators. The arrangement of one of the store-house belt conveyors is shown in Fig. 5, on page 314. Each belt is 4 ft. wide. Power is provided by a 3-h.p. electric motor through a chain drive to a Croft's variable-speed gear (which gives a range of belt speeds from 10 ft. to 40 ft. per minute), thence through a gearbox and a chain drive to the head drum of the conveyor. The drive is protected against over-load by shear pins. The mounting of the tail drum is arranged on screwed rods which allow for adjusting the tension of the belt as wear takes place. For loading the bales on to the belt, there is an adjustable chute which can be swung to the horizontal position to allow bales to pass underneath on the belt. A removable plough is provided for off-loading bales at any point along the conveyor. Each conveyor can be traversed on three tracks along the length of the store by a hand-operated chain drive enclosed in a case at the tension end of the conveyor. At the drive end of each belt conveyor is a table to receive the

bales. The "dead line" of the main conveyor, on to which the load trolleys may be switched from the continuous-line track, is vertically above the tables, and the latter can be lifted by a pedal to allow the bales on them to be engaged by the grabs on the load trolleys, as may be seen in Fig. 2, after which the tables are lowered to receive the next bales. The loaded trolleys are then pushed into the live line of the main conveyor.

The arrangement of the main Dual-Duty conveyor is shown in Figs. 6 and 7, on page 314, from which it will be seen that the live line comprises twin tracks. The upper track carries the chain trolleys, spaced at 6 ft. 8 in. pitch, which are linked by a continuous Flat Flex driving chain of 70-ton steel, the links of which are connected by case-hardened drop-forged pins in hardened-steel bushes. The chain trolleys are provided with self-oiling bushes. The load trolleys, from which the grabs are suspended, are carried on the lower track; they run on roller bearings. It will be seen that the load trolleys are not connected in a continuous track, but are driven along the level or up slopes by pusher-dogs extending from certain of the chain trolleys. The dog in front of the load trolley engages with the latter only on a downward slope, to prevent runaway.

Where the track is bent in a vertical plane, the chain-track angles are reinforced to resist the thrust of the trolley. At sharp horizontal bends in the track, wheels mounted on heavy bearings in special dual-track corner units take the chain loads; at slight bends, hardened rollers carried on roller bearings are built integrally with the dual track. The use of non-continuous load trolleys has made it possible to divert individual trolleys at suitable points as already mentioned, by hand-operated track switches on to the dead-line track for loading operations to be carried out. The length of the live-line track is 1,585 ft. and that of the dead-line track 240 ft. There are 238 load trolleys and grabs.

The drive house, illustrated in Figs. 4 and 8, contains the 8-h.p. electric motor and reduction gearing driving the continuous chain of the Dual-Duty conveyor. A Dynamatic controlled-slip coupling, made by Messrs.

CONVEYING PLANT FOR STRAW BALES.

GEORGE W. KING, LIMITED, HITCHIN.

Fig. 5. ARRANGEMENT OF BELT CONVEYOR.

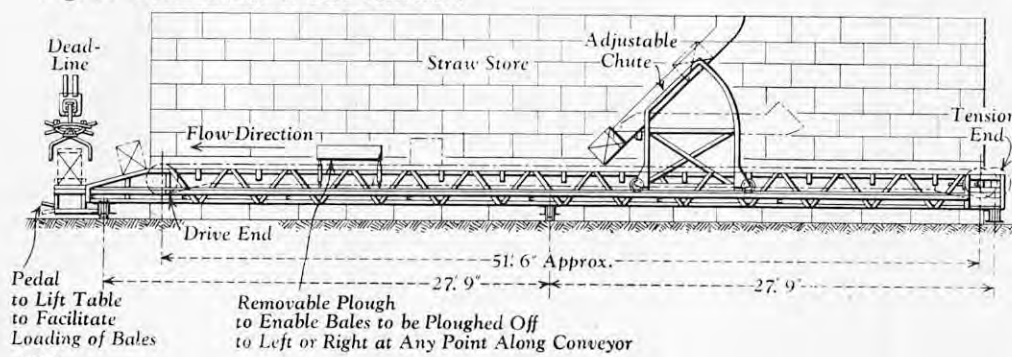


Fig. 6.

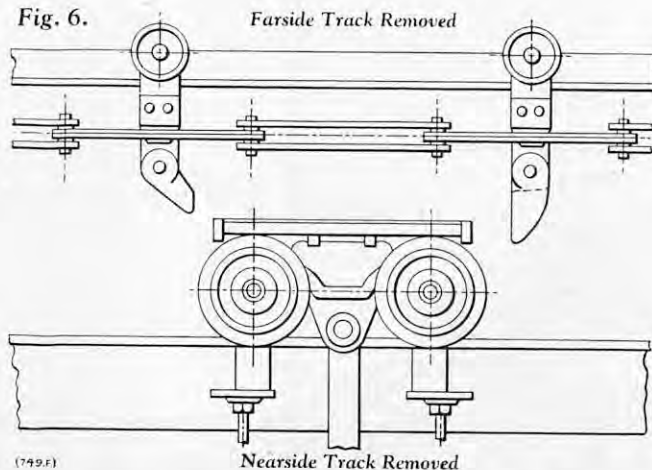


Fig. 7.

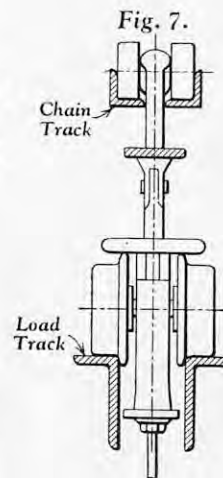
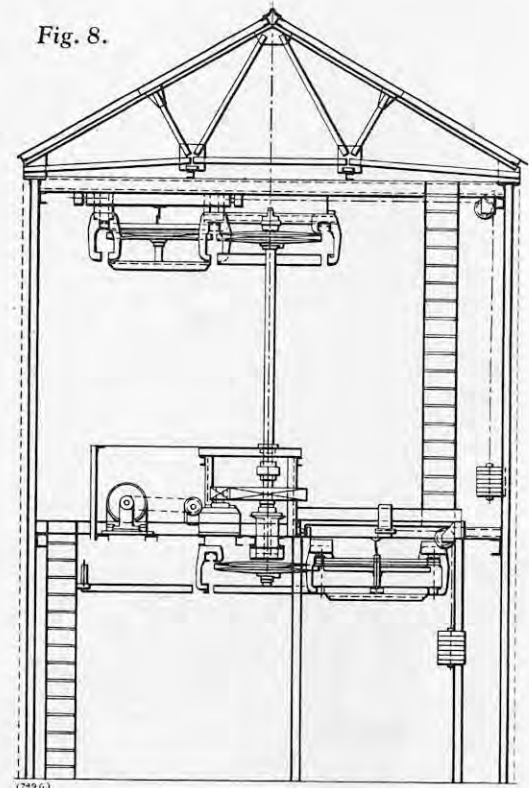


Fig. 8.



Heenan and Froude, Limited, Worcester, is incorporated in the drive to provide a conveyor-speed range of from 0 to 40 ft. per minute. The coupling, which is electromagnetic, also acts as a clutch and is said to provide a remarkably smooth load pick-up. The excitation unit for the coupling incorporates an automatic torque-control circuit which ensures that the coupling will not transmit torque if the current demanded by the driving motor exceeds a predetermined value, thus protecting the motor from overload and safeguarding the conveyor chain in the event of a jam. Should a fault develop in the control circuit, a further safeguard is provided by shear pins in the main driving-wheel bosses. The coupling is controlled remotely by an electronic unit in the straw-cutter house; the start-stop switch for the conveyor-motor circuit is also under the control of the cutting-machine operator. It is important, in the Dual-Duty conveyor, to maintain the correct tension in the chain, since otherwise the dogs would not engage correctly with the load trolleys. For this reason, weight-loaded automatic-tensioning units are provided in the drive house; limit switches are fitted at the extreme positions of the tensioning units to safeguard the conveyor against chain stoppages or excessive chain stretch.

As indicated in Fig. 1, there are three chutes discharging to the straw-cutter house. Two of these chutes feed the machines directly and the third delivers the straw to a storage area. The bales are released automatically at any one of the chutes pre-selected by the operator; in the case of the two chutes feeding the cutting machines, the bales can, if desired, be fed to each alternately. The grab release is actuated by a pair of ramps, pivoted on the track, which are lowered by pneumatic rams to engage grab-release rollers. The air supply to the rams is controlled by solenoid-operated air valves. The solenoid circuits are actuated automatically by switches on the rail track which are closed by pins on the grab link suspended from the load trolley (Fig. 7). The pre-selector switch, which has four chute positions and an "off" position, the isolating switch and the various relays and fuses for the automatic-release system, are grouped on a panel near the cutting machines. With the isolating switch closed and one of the chute positions selected, a blue light above the control box is illuminated. When, however, a trolley enters the discharge ramp, the blue light is replaced by a red light which warns the operator that the selector switch should not be shifted; if it were, the grab might close and jam at the next discharge point. After release of the straw, the empty load trolley continues on its journey over the conveyor line and returns to the loading point.



FIG. 9. GRAB RELEASE MECHANISM.

MOND NICKEL FELLOWSHIPS.

APPLICATIONS for the award of Mond Nickel Fellowships for 1952 are now being invited by the fellowships committee and awards will be made to selected applicants of British nationality, educated to university degree or similar standard, though not necessarily qualified in metallurgy, who wish to undergo a training in industrial establishments. The awards will normally take the form of travelling fellowships but awards for training at universities may be made in special circumstances. There is no specific age limit, though awards will seldom be made to persons over 35 years of age. Each fellowship will occupy one full working year and the Committee hope to award up to five fellowships every year, each having an average value of 750l. The objects of the fellowships are, in the first place, to allow selected persons to pursue such training as will make them better capable of applying the results of research to the problems and processes of the British metallurgical and metal-using industries, and, in the second place, to increase the number of persons who, if they are subsequently employed in executive and administrative positions in the metallurgical and metal-using industries in this country, will be competent to appreciate the technical significance of research and its results.

A third object of the fellowship awards is to assist persons having qualifications in metallurgy to obtain additional training which will be helpful in enabling them ultimately to assume executive and administrative positions in the British metal industries. A fourth object is to provide facilities whereby persons qualified in sciences other than metallurgy may be attracted

into the metallurgical field and may help to alleviate the shortage of qualified metallurgists available to industry. Applicants for a fellowship will be required to state the programme of training in respect of which they are applying for an award, as well as particulars of their education, qualifications and previous career. Further particulars and forms of application can be obtained from the secretary, Mond Nickel Fellowships Committee, 4, Grosvenor-gardens, London, S.W.1. Completed application forms must reach the secretary not later than June 1.

INQUIRY INTO LOSS OF S.S. "SOLIDARITY."—The formal investigation into the loss, on March 4, 1951, of the Steamship Solidarity, which was to be heard at the Convocation Hall, Church House, Westminster, London, on March 3, 1952, has been postponed until Monday, March 10, 1952, starting at 10.30 a.m.

THE INSTITUTION OF MECHANICAL ENGINEERS, EAST MIDLANDS BRANCH.—The annual dinner of the East Midlands Branch of the Institution of Mechanical Engineers was held in the Victoria Station Hotel, Nottingham, on Tuesday, February 26. Mr. W. N. Bray, chairman of the Branch, presided, and, in proposing the toast of "The Institution," remarked how seldom, in his experience, those who sought admission to it were aware of its aims or could give a really satisfactory reason for wishing to join it. He hoped that the Institution would always be well supported by engineers of high attainments in their profession. Mr. A. C. Hartley, C.B.E., President of the Institution, in replying, reviewed the work of the Institution during the past year, and reiterated the Council's determination to limit membership to those of high qualifications so that the designation M.I.Mech.E. might continue to be accounted a mark of distinction. He did not think there was any danger that the Institution might languish through lack of support because, in spite of the restrictions on entry, the membership continued to grow and had reached 37,000. About half this number were young men in the graduate category. In proposing the toast of "The Engineering Industry," Dr. H. L. Haslegrave, principal of the College of Technology, Leicester, made a plea for closer co-operation between industry and the educational establishments and suggested that young men of ability should be given more responsibility early in their careers. Mr. J. H. R. Nixon, of the Brush Electrical Engineering Company, Limited, having responded, the toast of "The Guests" was proposed by Dr. E. R. Walter, principal of the Technical College, Lincoln, and acknowledged by Mr. G. H. Stainforth, headmaster of Oundle School, who placed high among the essential attributes of a good engineer a command of his own language, without which, he said, no man could hope satisfactorily to communicate his ideas to others.

NATURAL-DRAUGHT WATER-COOLING TOWERS.

Fig. 1. GENERAL CORRELATION OF TEST RESULTS ON TOWERS A AND B.

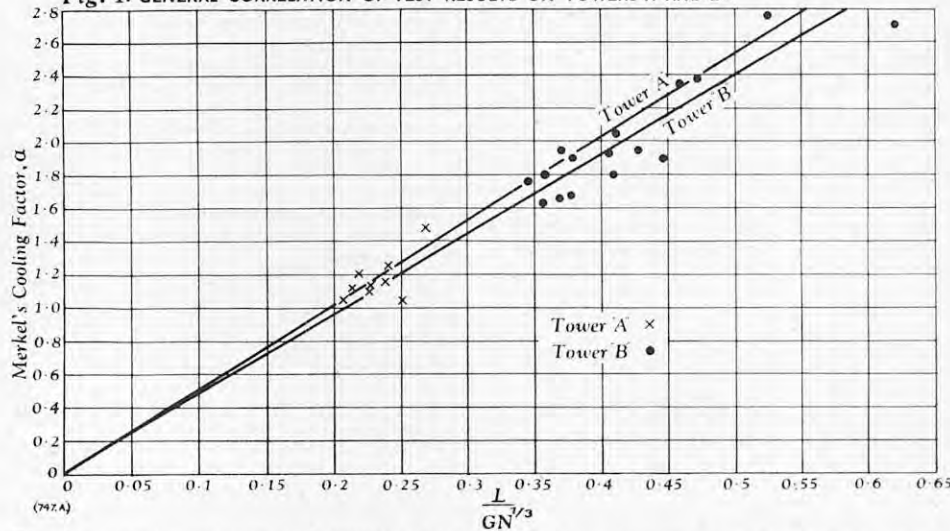


Fig. 2. RELATION BETWEEN PERFORMANCE COEFFICIENT, C, AND APPROACH TO WET-BULB TEMPERATURE.

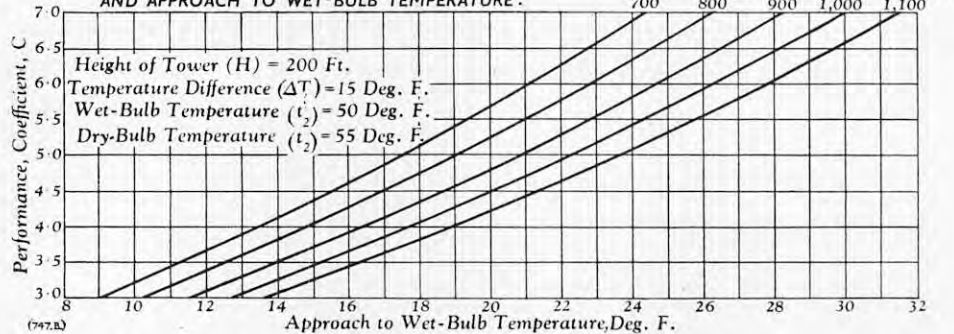


TABLE I.—DESIGN AND PERFORMANCE DATA ON TOWERS TESTED.

Tower.	Design Data.			Range of Variables.				Number of Tests.	Mean Performance Coefficient.	Type of Packing.
	Height.	Internal Base Diameter.	Depth of Packing.	Wet-Bulb Temperature.	Dry-Bulb Temperature.	Water Loading.	Cooling Range.			
A	290	194.75	22.5	40.72 to 52.96	42.5 to 59.4	782 to 840	12.75 to 16.28	9	5.05	Upper packing
B	140	92	23	32.53 to 58.5	37.1 to 74.1	1,160 to 1,780	8.0 to 22.5	16	4.79	Lower packing
C	125	95	20	36.0 to 70.5	38.7 to 77.0	56.4 to 1,156	8.3 to 20.0	117	5.49	
D	175	119	18	32.53 to 66.34	37.1 to 84.6	740 to 1,088	8.8 to 20.2	26	5.41	Square packing
E	175	119	18	32.53 to 56.43	37.1 to 64.2	742 to 1,090	7.5 to 20.0	19	5.46	Triangular packing
F	125	95	3.5	42.2 to 65.9	46.2 to 73.7	960 to 1,030	9.3 to 14.2	62	5.69	Corrugated asbestos sheets

TABLE II.—RESULTS OF HEAT-BALANCE TESTS ON TOWER "A."

Observation.	Units.	Test Number.								
		A1.	A2.	A3.	A4.	A5.	A6.	A7.	A8.	A9.
*Water loading to tower	lb. per hr. $\times 10^6$	23.22	23.27	24.71	24.21	23.56	25.01	24.73	24.91	24.09
*Water-inlet temperature	deg. F.	73.29	74.55	77.47	76.17	76.73	81.52	81.70	77.13	76.57
*Recooled-water temperature	deg. F.	59.29	60.83	62.17	60.75	63.14	68.77	66.61	63.17	60.29
Cooling range	deg. F.	14.00	13.72	15.30	15.42	13.59	12.75	15.09	13.96	16.28
Total water evaporated	lb. per hr. $\times 10^6$	0.2278	0.1844	0.2283	0.2192	0.2012	0.2400	0.2303	0.2243	0.2247
Heat lost by water	B.Th.U. per hr. $\times 10^6$	331.3	324.6	385.0	379.6	326.5	327.7	381.2	354.7	398.7
*Atmospheric dry-bulb temperature	deg. F.	46.62	47.52	43.25	42.98	51.58	57.38	59.40	49.23	42.5
*Atmospheric wet-bulb temperature	deg. F.	40.8	42.82	41.02	40.72	46.41	49.23	52.96	43.70	41.42
*Mean temperature of air leaving packing	deg. F.	67.57	67.05	69.94	67.46	69.34	75.02	75.79	70.23	68.0
*Measured mass flow of dry air	lb. per hr. $\times 10^6$	21.48	19.14	20.70	22.53	19.97	18.03	18.56	19.81	23.47
Heat gained by air	B.Th.U. per hr. $\times 10^6$	356.6	291.0	383.4	372.8	305.1	340.9	324.4	345.1	390.8
Ratio Heat lost by water		1.076	0.898	0.996	0.982	0.934	1.040	0.851	0.793	0.980
Resistance of tower to air flow	Velocity heads	120	140	160	124	118	147	128	140	119
Performance coefficient		4.9	5.0	5.52	5.25	4.88	5.49	4.17	5.19	5.05
Estimated recooled-water temperature	deg. F.	59.7	60.0	61.0	60.0	63.7	67.2	70.0	62.8	60.3
Discrepancy between estimated and measured recooled-water temperatures	deg. F.	+0.40	-0.8	-1.2	-0.8	+0.6	-1.6	+3.4	-0.4	0

* Measured quantities.

Fig. 3. DIFFERENCES BETWEEN MEASURED RECOOLED-WATER TEMPERATURES AND THOSE ESTIMATED FROM THE MAKER'S CHART.

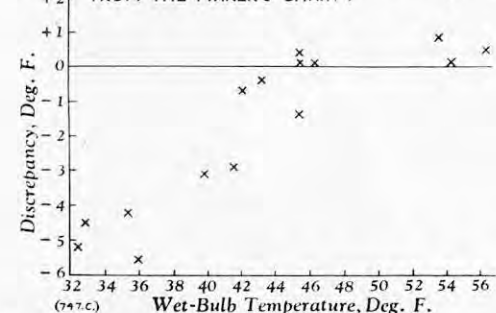
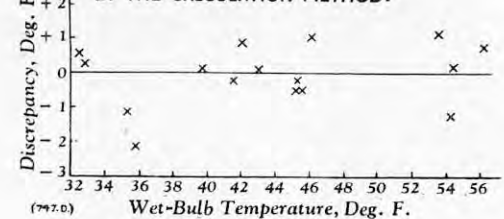


Fig. 4. DIFFERENCES BETWEEN MEASURED RECOOLED-WATER TEMPERATURES AND THOSE ESTIMATED BY THE CALCULATION METHOD.



NATURAL-DRAUGHT WATER-COOLING TOWERS.*

By H. CHILTON.

In a cooling tower, warm water is brought into intimate contact with atmospheric air and heat is transferred from the water to the air both by convection and evaporation. The dual nature of this transfer process makes a rigorous treatment of the theory difficult, but an approximate method has recently been developed, which is simple and direct to apply and requires only information that is readily available from conventional performance tests. It has also been found that there is a fortuitous relationship which simplifies these calculations and reduces the empirical factors to a single member termed the "performance constant," which is mainly a fraction of the depth and type of packing. By re-introducing the tower height and base cross-sectional area, a further factor is derived, termed the "duty coefficient," which defines the overall capabilities of a tower under all conditions.

Details of the six different towers from which a total of 249 test results has been collected are given in Table I and a set of test results is given in Table II.

Merkel's cooling factor, α , and the value of $\frac{L}{GN^{0.5}}$, where L is the mean water loading per square foot of reference plane in lb. per hour per square foot, and G the mean mass flow of dry air per square foot of reference plane per square foot of reference plane in lb. per hour per square foot, and N the resistance of the tower to air flow through it in velocity heads referred to the area of the reference plane. It appears from Fig. 1 that the correlation between these two quantities is

* Paper read at a joint meeting of the Steam Group of the Institution of Mechanical Engineers and the Supply Section of the Institution of Electrical Engineers, in the lecture theatre of the latter Institution, on Wednesday, February 27, 1952. Abridged.

reasonably good. This condition would not, however, be expected on theoretical grounds, neither can it be reconciled with the results of work on experimental towers. Nevertheless, the test results seem sufficiently numerous and the operating conditions and packing designs sufficiently diverse to justify it on an empirical basis.

It follows that the performance of a tower under all operating conditions can be expressed as the slope of the line through the orifice which best represents the test results expressed in terms of α and $\frac{L}{G N^{\frac{1}{2}}}$. This

slope is termed the performance coefficient and is denoted by the symbol C where

$$C = \frac{\alpha G N^{\frac{1}{2}}}{L}$$

The practical significance of this coefficient is indicated in Fig. 2, on page 315, which shows the relationship between it and approach to wet-bulb temperature at various water loadings for a tower 200 ft. high when the atmospheric dry- and wet-bulb temperatures are 55 deg. and 50 deg. F., respectively, and the cooling range is 15 deg. F. This performance coefficient is fairly sensitive to changes in performance and responds by roughly 0.25 to a change of approach of 1 deg. F. under the above conditions.

The divergence of individual results from the line which best represents them in Fig. 1 can be conveniently expressed as the discrepancy between the performance coefficients calculated from each test and their mean value for each tower. This discrepancy may be due to the test data not being sufficiently accurate; to the method of analysis not precisely representing the effect of the main variables; or to the tower performance being affected by factors other than those considered. Evidence shows, however, that all proper precautions were taken to ensure accurate measurements and that the method of analysis correctly represents the relationship between the main variables. The divergence of performance coefficient for different tests on the same tower is therefore attributable to extraneous factors.

Although the most satisfactory technique for determining the performance coefficient is the analysis of test results on the tower, it is not directly applicable to design problems, for the performance coefficient is mainly a function of the depth of type of packing and is affected by tower size only in so far as the latter may influence the entry and exit pressure losses, which depend on the ratio between the area available for air flow at inlet or exit and the area of the reference plane. It is not usually practicable to increase the height of the air inlet in proportion to the diameter of a tower. The inlet losses therefore tend to be greater on larger towers, thus increasing the constant, which defines the contribution of the shell to the overall resistance of the tower to air flow and hence raising the performance coefficient, unless the mean depth of the packing is correspondingly increased. For most design purposes, it is sufficiently accurate to estimate the performance coefficient from those measured on towers with similar packing. Table I suggests that a performance coefficient as low as 5.0 could be obtained using any of the packings shown without unduly great depth. Slightly greater performance coefficients up to about 5.5 may be preferred to give a "safe" design, especially for larger towers.

In recent years a number of cooling towers have been made larger than was necessary for the required duty with the object of reducing the nuisance caused by entrained circulating water being precipitated in the vicinity. This implies increasing the performance coefficient by reducing the depth of the packing. Now that more satisfactory methods have been devised for controlling precipitation, economic and aesthetic factors make lower performance coefficients desirable to meet the required duty with the smallest possible tower. In practice, the performance coefficient can be reduced by increasing the packed depth, but the costs of pumping head and of the packing set an economic limit to this increase. There is also a theoretical optimum depth of packing and increasing the depth above this limit reduces the performance of the tower.

The usual method of specifying a cooling tower is to lay down the recooled-water temperature under defined operating conditions. As soon as practicable after completion, the tower is tested and, as it is seldom possible to do this under specified operating conditions, some knowledge of the performance characteristics is essential to interpret the results. The designer provides performance curves which are commonly used for this purpose. Alternatively, the specified duty with the major dimensions of the tower may be used to calculate the required performance coefficient; hence the required recooled-water temperature under the conditions of test can be estimated and compared with the measured recooled-water temperature. Such calculations are, however, only justifiable when they give more reliable results. Using the results of the

tests on Tower E (Table I), the differences between the measured recooled-water temperatures and those estimated from both the makers' chart and the calculation methods are plotted against wet-bulb temperatures in Figs. 3 and 4, respectively. The discrepancies of the makers' curves are from -5.6 deg. F. to +2.3 deg. F., and of the calculation from -2.1 deg. F. to +1.2 deg. F. It is apparent that the makers' curves have a systematic error—over-estimating the recooled-water temperature under cold conditions and under-estimating it under hot conditions. The discrepancy approximates to zero when the wet-bulb temperature is 50 deg. F., which was the specified condition, indicating that the tower was able to meet specified requirements. This is confirmed by the mean discrepancy of the calculated recooled-water temperatures, which is 0.02 deg. F. The mean discrepancy of the recooled-water temperatures estimated from the designer's curves is -1.4 deg. F., suggesting that the tower was capable of cooling the water 1.4 deg. F. more than required by the specification, which is not true. Arbitrary performance curves can be avoided with advantage to both designer and user by specifying the capacity of a tower in a way which defines its performance under all operating conditions.

To sum up, the performance of a natural-draught water-cooling tower under all operating conditions can be correlated in terms of two derived factors: Merkel's cooling factor, α , and a modified form of the water: air ratio $\frac{L}{G N^{\frac{1}{2}}}$. Experimental results show

that the factors are simply proportional, so the constant of proportionality, termed the performance coefficient, is a unique expression of the tower performance. This conception provides a valid basis for the comparison of different tests on the same tower and of tests on different towers.

Nearly all cooling-tower problems which arise in the design and operation of electricity-generating stations and in economic studies, can be solved by the method suggested, from which data are either already available or can be collected without difficulty. Inconsistencies in test results are probably due, at least in part, to the effect of variables which cannot readily be taken into account either in design or in the interpretation of test results. A single test, no matter how carefully it is conducted, may be misleading as to the capabilities of the tower. Performance curves provided by tower designers do not invariably represent correctly the relationship between recooled-water temperature and operating variables. Errors may be serious at conditions far removed from those specified. A form of specification is therefore proposed which, by stipulating the performance under all conditions, makes performance curves unnecessary.

TRADE PUBLICATIONS.

Mechanical Handling Equipment.—We have received from Mechanical Equipments Ltd., 67-69, St. Paul's-street, Leeds, 1, an illustrated brochure giving technical data on, and descriptions of, a wide range of conveyors, bucket-elevators, skip hoists, chains, bunkers and hoppers, etc., manufactured by them.

Electrical Dictating Machines.—Details of the Emidiata dictation machines and of the accessories, such as the telephone coupling unit, stethophone and foot switch, with which it can be provided, are given in leaflets published by E.M.I. Sales and Service Ltd. (Emidiata Division), 363, Oxford-street, London, W.1.

Document Reproduction.—The Copyrapid process for reproducing office documents, whether opaque, double-sided, or in book form, in conjunction with the Copyfix developing machine, is described in a leaflet issued by Lawes Rabjohns, Ltd., Abbey House, Victoria-street, London, S.W.1. No darkroom, processing trays or drying apparatus is required, and the complete process can be carried out in 60 seconds.

Aluminium-Alloy Castings and Forgings.—We have received from the Northern Aluminium Co., Ltd., Banbury, Oxfordshire, a copy of a brochure describing the production of aluminium-alloy castings and forgings at the firm's foundry and forge at Handsworth, Birmingham. A note on the design and properties of castings and forgings, with some examples of the components produced at the Handsworth Works, is included.

Air Filters.—We have received two illustrated brochures from the Visco Engineering Co. Ltd., Stafford-road, Croydon, one of which describes their static filters, in which ring-type filter elements are coated with a highly-viscous mineral oil, and illustrates some of their applications. The other booklet describes their rotating self-cleaning air filters, also of the viscous type, which comprise a series of filter-cells arranged on an endless chain which in the standard model, can be rotated to bring the lowest cell into a cleansing oil tank; in a later development, the filter is not immersed but is lowered to a position where it can be subjected to a high-pressure oil spray.

WIND-VELOCITY VECTOR INTEGRATOR.

For the laying out of an aerodrome, the investigation of a site for a wind-power installation and for other meteorological purposes, a knowledge of the speed and direction of the wind in any particular locality averaged over a given period of time in different seasons of the year is generally useful and in some cases essential. It is possible to obtain the information from a recording anemometer, provided that the direction of the wind is recorded simultaneously, but the combination of the readings into a polar diagram, or "wind rose" as it is called, which is the most convenient form for use, is a tedious and by no means reliable operation.

The instrument illustrated on the opposite page, however, combines the readings of a cup-type anemometer with the movements of a wind vane and integrates the results so that the values of the wind components in the directions of the four cardinal compass points over a convenient time interval can be read off directly. The instrument, due to Mr. A. Whitaker and developed and constructed by Messrs. Nash and Thompson, Limited, Oakcroft-road, Tolworth, Surrey, has been in use for two or three years, and includes an interesting and ingenious mechanical device which may not be familiar to some engineers. From the photograph reproduced in Fig. 1, it will be seen that the anemometer is mounted at the upper end of a vertical tube with the wind vane below it and the vertical tube is attached to a cylindrical base containing the integrating mechanism. The latter is connected electrically to a meter containing four Veeder-type counters, which are provided with disc wheels to enable them to be set to zero. The meter is shown on the left of the base in Fig. 1, but can, of course, be placed in any convenient position. The counters can be read through slots in a sloping face of the meter casing, the slots being marked to correspond with the compass points.

Fig. 2 shows a section of the cylindrical base, the vertical tube supporting the anemometer and wind vane at the top being broken away to enable the mechanism to be shown on a larger scale. Inside the supporting tube, and coaxial with it, is a shaft a connected at its upper end to the anemometer and carrying at its lower end a pinion which drives, through a spur-gear train and a bevel pinion and wheel, a friction wheel b . The friction wheel rotates in a vertical plane and its vertical diameter is a continuation of the axis of the driving shaft a . The complete gearing assembly and the friction wheel are mounted on a pair of plates and are supported by a ball bearing c , so that the whole can be rotated about the axis of the driving shaft. Coaxial with the latter, and also enclosed in the supporting tube, is a tubular shaft d , the lower end of which is connected to the gearing assembly, while the upper end is connected to the wind vane. Thus the plane of rotation of the friction wheel b is turned about the axis of the driving shaft, so that it follows any change in wind direction. The speed of rotation of the friction wheel is, of course, always proportional to the speed of the wind.

Below the friction wheel, and making contact with its periphery, is a composition billiards ball e , which floats in a hemispherical cup formed in a mild-steel block, square in plan and containing mercury; the diameter of the hemisphere is only slightly larger than that of the billiards ball, so that a comparatively small quantity of mercury suffices for flotation. As the ball floats in mercury, it can rotate in any plane with negligible friction, and as the specific gravity of the ball is much lower than that of the mercury, the displacement of the latter results in a considerable upward force pressing the ball into contact with the friction wheel. The contact pressure can, however, be adjusted by means of a set-screw fitted into a tapped hole in the steel block communicating with the mercury reservoir, so that the level of the mercury can be raised or lowered.

Mounted on each of the four sides of the steel block in which the billiards ball floats is a small friction wheel f , with its axis horizontal and its periphery pressed into contact with the ball on its horizontal circumference. Each of these friction wheels, the planes of rotation of which are accurately at right angles, thus takes off a component of the velocity of the ball, and a light contact operated by the wheel transmits an electrical impulse to the appropriate counter at every revolution. The impulses, it should be mentioned, are transmitted through relays, so that the currents through the contacts are very small. Another point that should be made clear is that a very light ratchet mechanism is incorporated in the friction wheels so that they record in one direction of rotation only. The need for this will be clear if we consider the case of a wind blowing exactly from the north, so that there is no component in the east or west directions. The two friction wheels in the north-south plane will then rotate in opposite directions, but only that con-

WIND-VELOCITY VECTOR INTEGRATOR.

NASH AND THOMPSON, LIMITED, TOLWORTH, SURREY.



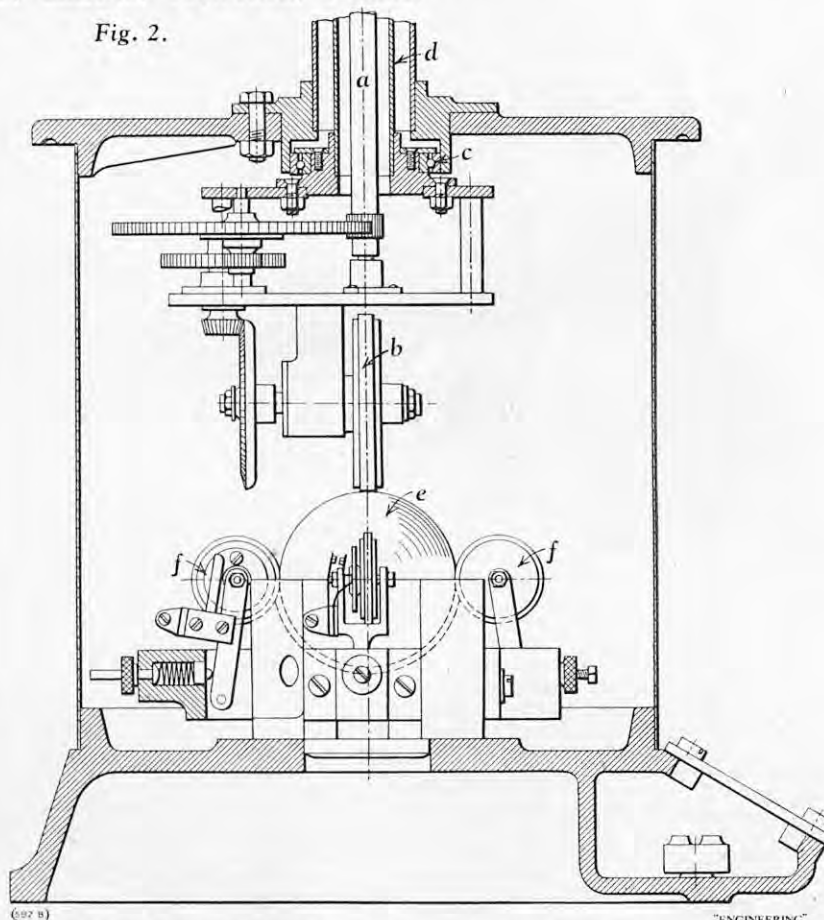
Fig. 1.

nected to the north counter will record; the two wheels in the east-west plane will, of course, remain stationary. Similarly, if the wind direction changes through exactly 180 deg., the direction of rotation of the billiards ball will be reversed, so that only the friction wheel connected to the south counter will record, the other wheel of the pair rotating freely in the opposite direction, but not affecting the north counter. As, with the cup-type anemometer, the arms always rotate in the same direction, independently of the direction of the wind, it may be worth while to point out that the reversal of the direction of rotation of the billiards ball is due to the friction driving wheel at the top having been turned through an angle of 180 deg. about its vertical diameter by the movement of the wind vane through the same angle.

The impulse circuits from the friction wheels are taken through a weatherproof terminal box to the relays and counters, which may be located at any convenient distance from the anemometer. The readings of the counters at the end of any period, or the difference between their readings before and after the period, give the radius vectors of the four cardinal points on the wind rose and for most purposes the latter is thus defined with sufficient accuracy; if necessary, however, eight, or even 12, take-off friction wheels could be incorporated. It would be a relatively simple matter also to arrange for the counters to be photographed automatically at stated intervals so that the variation of the wind rose with time could be investigated. Moreover, the impulses could be applied to a four-pen recorder, so that the components of wind velocity at any time could be obtained.

AERONAUTICAL SCHOLARSHIPS AND GRANTS.—The February *Journal* of the Royal Aeronautical Society draws attention to the following educational awards: the Royal Aeronautical Society Charter Scholarship, to the value of 300*l.* for one year, and the Geoffrey de Havilland Memorial Scholarship, to the value of 120*l.* for one year, which are awarded to suitably qualified students wishing to undertake advanced work in aeronautics, normally leading to a higher degree or diploma. Applications for these scholarships should be made to the secretary before June 1. For boys between the ages of 16½ and 18, who are unable, for financial reasons, to take up a course of education in aircraft engineering, grants are awarded annually by the Society of British Aircraft Constructors, to supplement the holder's means up to an amount sufficient for maintenance during the period of training. Application forms for these grants may be obtained from the secretary, Royal Aeronautical Society, 4, Hamilton-place, London, W.1.

Fig. 2.



ECONOMICS OF PRESTRESSED CONCRETE AND OTHER FORMS OF CONSTRUCTION.

THE Institution of Civil Engineers, on February 28, discussed the "Relative Economics of Prestressed Concrete compared with other Forms of Construction—Aluminium, Reinforced Concrete, Steel, and Timber." The discussion was introduced by Mr. John Ratter, C.B.E., B.Sc., M.I.C.E., who gave a general review, and by a speaker for each form of construction. The main points of their introductory remarks are given below.

The factors which must be studied in present-day construction, Mr. Ratter said, were: first cost; cost of maintenance; long life of the structure, with maximum resistance to corrosion or other forms of decay; ease and speed of erection; availability of material; security against fire risk or other emergency such as war damage; and aesthetic features. In straightforward work the first cost of a structure was usually less in prestressed concrete than in reinforced concrete or steel; but in complicated structures the reverse was often found. Though less material was required with prestressed concrete, manufacturing and labour costs were often high, partly due to lack of experience in design and erection. The situation might change, however, with experience. There were little reliable data on which to assess the cost of maintenance and the structure life, but there appeared to be no solid reason for fear on this score. For ease of erection, steel still had the advantage, particularly in bridges, though both reinforced and prestressed concrete could be used for such work in the form of pre-cast deck units and slab units. In larger structures concrete was at a disadvantage owing to the need for staging and shuttering. Regarding the availability of material, steel and aluminium had to be saved; timber was only slightly less scarce, but concrete was in good supply. Reinforced concrete and steel were extraordinarily resistant to bomb damage; prestressed concrete was not so secure. Little was known of the fire risk. From the aesthetic point of view, prestressed concrete could be made in attractive forms. Concluding his note, Mr. Ratter said that the most potent influence in the design of structures to-day was "not our arts, or our sciences, but international economics—the key-words of the era."

Mr. D. V. Pike, A.M.I.C.E., spoke on "Aluminium Construction." He said that there had been a remarkable decrease in the cost of aluminium alloys with the expansion of production during the past 50 years. Whereas the cost of alloy sections to-day was only slightly greater than in 1939, that of all other structural materials had at least doubled. If the applied loading on a girder was high compared with its self-weight,

the forces in the members were only slightly less in aluminium alloy than in mild steel, but if it was small the weight saving was much greater. While these weight comparisons required an adjustment, unfavourable to aluminium alloys, to allow for their higher elasticity, the adjustment might be minimised by employing special aluminium sections designed to use the material to greater advantage. Extrusion made this economical. The low weight of aluminium was beneficial where movement of the structure—for transport, erection, etc.—was significant. The high corrosion resistance of aluminium alloys was also important; in general, maintenance was low.

Mr. F. S. Snow spoke on "Reinforced Concrete Construction." He said that no other form of building was a serious competitor. The Dome of Discovery could have been constructed more economically in reinforced concrete, had not other considerations prevailed. Reinforced concrete was cheaper than structural steelwork in places where the latter had to be encased. First cost and maintenance were favourable with reinforced concrete, and the speed of construction need be no greater than for steel. Reinforced concrete could be designed to meet aesthetic requirements; it was superior, in resisting fire and bomb damage, to any of the other materials. Reinforced-concrete structures used only about one-third to one-half of the steel required in comparable structural-steel frames. Nevertheless, prestressed pre-cast units, used judiciously with a reinforced-concrete frame, would gain in favour by saving steel and cement and would detract still further from the present advantages of timber, aluminium, and steel.

Mr. H. S. Smith, O.B.E., B.Sc. (Eng.), M.I.C.E., was an advocate of steel construction. He pointed out that structural steel conformed to guaranteed limits of strength, etc., which were not dependent on supervision on site. Steel could be erected far more quickly than prestressed concrete, and it could be fabricated in the shops while the foundations were being prepared. Steel bridges were adaptable to various methods of erection such as cantilevering, and could be built with less staging than that required for a concrete bridge built *in situ*. By flame cutting and welding, steel structures could be made pleasing in appearance and could readily be modified. It was probable that the life of steelwork could be prolonged indefinitely—at the small cost of re-painting every seven to ten years—by means of grit-blasting, metal-spraying, and painting. The commercial production of structural stainless steel might not be many years ahead. Tubular steel construction was expanding, particularly on the Continent. With regard to prestressed concrete, the behaviour of the stressed wires with age was not known. It was

MALLEABLE-IRON WEDGE BLOCK FOR SHIPBUILDING BERTHS.

HALE AND HALE (TIPTON), LIMITED, TIPTON, STAFFORDSHIRE.

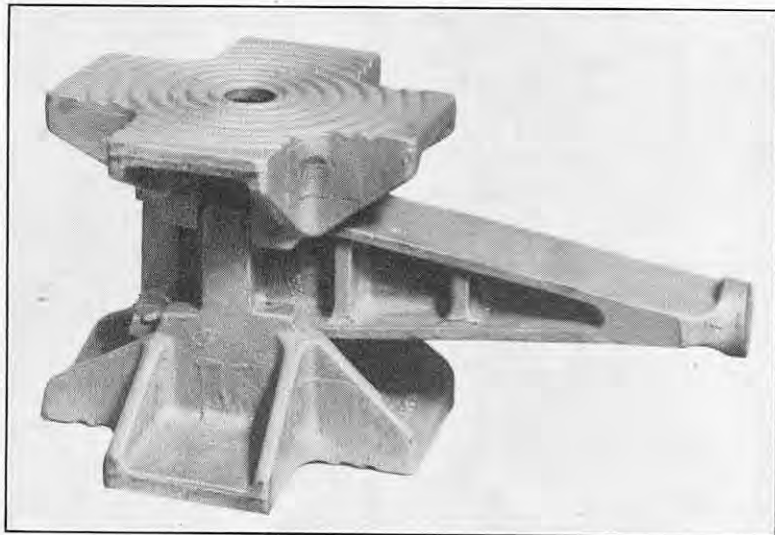


FIG. 1. BLOCK FULLY RAISED.

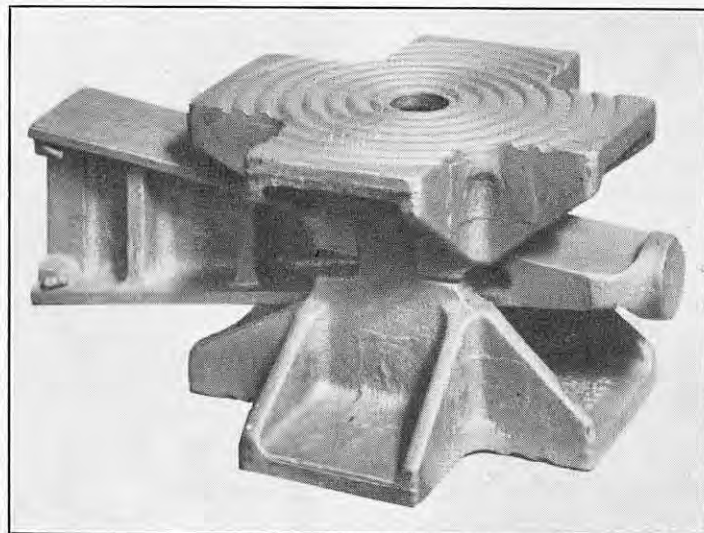


FIG. 2. BLOCK LOWERED.

not as economical as steel for building or as reinforced concrete for columns, and any saving it might give in beams was offset by the difficulty of achieving continuity. For bridges it was favourable only for small spans. Reinforced concrete generally was not maintenance-free, and prestressed concrete might be susceptible to frost and corrosion of the wires.

Mr. P. O. Reece, A.M.I.C.E., argued that, under certain conditions, timber, as compared with prestressed concrete, gave a better "specific strength"—a criterion defined as the load sustained by a unit weight of structural material under a particular condition of loading. On this basis, and assuming a constructional cost of 10d. per pound for Douglas fir and 2d. per pound for prestressed concrete, he deduced the results given in the following table:

Loading Condition.	More Efficient Material.	
	By Weight.	By Cost.
<i>Static loading:</i>		
Flexural rigidity ..	Douglas fir ..	Douglas fir.
Bending ..	Douglas fir ..	Douglas fir.
Tension ..	Douglas fir ..	Prestressed concrete.
Compression ..	Douglas fir ..	Prestressed concrete.
Shear ..	Douglas fir ..	Prestressed concrete.
<i>Energy absorption:</i>		
Bending ..	Douglas fir ..	Prestressed concrete.
Tension ..	Douglas fir ..	Douglas fir.
Compression ..	Douglas fir ..	Prestressed concrete.

The concluding introductory note, on "Prestressed Concrete Construction," was by Mr. John Cuerel, B.Sc., M.I.C.E. He said that the quality of the concrete and steel used had to be high, but the permissible working stresses were higher than in reinforced concrete. Taking merely drawing-office factors into account, it could be held that prestressed concrete was the most economic material for a wide range of structures or structural members. Given very high grade concrete, prestressed work was durable; it was strong, and so, properly applied, it was capable of producing graceful and pleasing forms. Maintenance should be small. Sooner or later, the difficulties retarding the spread of prestressed construction would be overcome—if, in the meantime, it had not wilted because of an overdose of frustrated enthusiasm.

DECK-LANDING TRIALS OF BRISTOL TYPE 171 HELICOPTER.—Preliminary take-off and landing trials have been carried out successfully, on board the aircraft carrier *Triumph*, by a Bristol Type 171 helicopter, constructed by the Bristol Aeroplane Company, Limited, Filton House, Bristol. The trials were undertaken on behalf of the Royal Australian Navy.

ANGLO-AMERICAN GAS-TURBINE CO-OPERATION.—An agreement has been signed between the de Havilland Engine Company, Limited, Edgware, Middlesex, and the General Electric Company, Aircraft Gas Turbine Division, 920, Western-avenue, West Lynn, Massachusetts, for a full interchange of their current and future knowledge and experience of gas turbines for aircraft, excepting nuclear propulsion for aircraft.

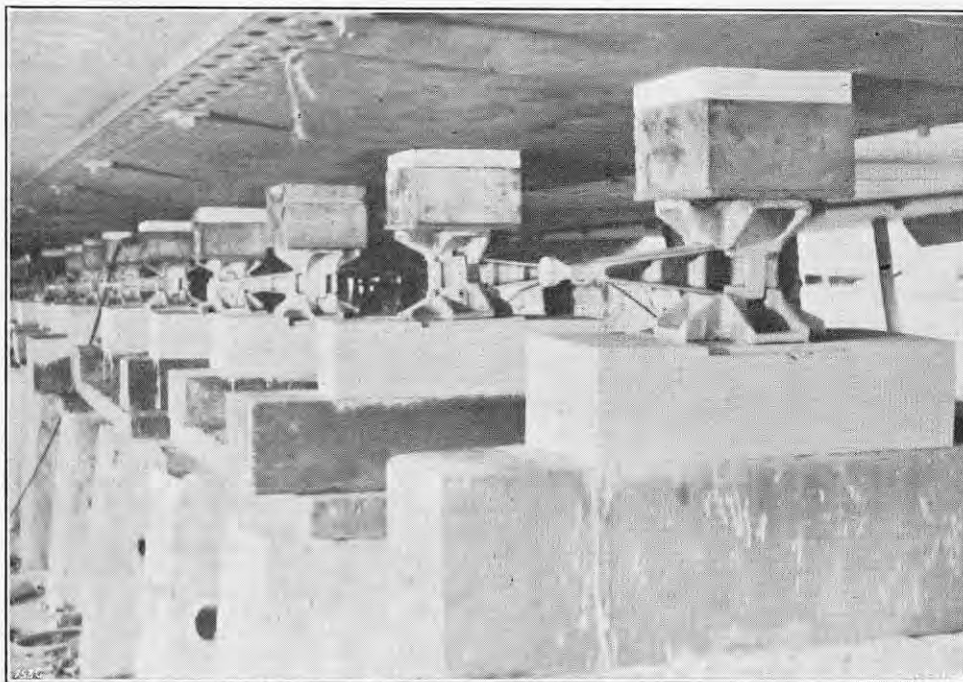


FIG. 3. BLOCKS IN POSITION UNDER SHIP'S HULL.

QUICK-RELEASE WEDGE BLOCKS FOR SHIPBUILDING BERTHS.

THE quick-release block shown in the accompanying illustrations, Figs. 1 to 3, has been developed by Hale and Hale (Tipton), Limited, from the wedge-type pit prop which they have made for a number of years. It was designed to simplify the operation of transferring the weight of a ship from the keel and bilge blocks to the launching ways at the time of the launch, but is equally applicable to any similar transfer of weight from one support to another. The device is an assembly of three components—two contact blocks and a central sliding wedge portion—and weighs approximately 60 lb. Longitudinal movement of the wedge causes separation of the contact blocks, and provides an infinitely variable height adjustment over a range of 1½ in. In the "up" position (Fig. 1), the wedge has an overall height of 8½ in., and in the "down" position (Fig. 2) 6½ in.

Both contact blocks are normally identical, being cruciform in shape and measuring 10 in. across each arm. The wedge can therefore be used either way up, there being no "top" or "bottom." It can, however, be made with the face of one of the blocks canted at an angle of ½ in. in 12 in. to the other if desired, in which case the canted face would normally be used at the top. Both faces are provided with a series of cast concentric indentations, to prevent slip on the timber cappings and supports. The faces can also be made

square instead of cruciform to provide a larger bearing surface for extra heavy duty.

The three components, which are of malleable cast iron to B.S.S. 310/1947, Grade 3, are assembled into a single unit and fitted with retaining pins so that they cannot come apart. The wedge is capable of carrying a load of 30 tons at any height within its range of adjustment, and will sustain this load indefinitely without movement. To release the wedge, the narrow end of the sliding portion is struck with a hammer; and to set it, the wedge is hammered in the reverse direction. Once the wedge has been set, unauthorised interference can be prevented by an Allen screw which locks against the flange of the sliding portion.

A set of these blocks has been tried under normal working conditions at the Scotstoun shipyard of Messrs. Charles Connell and Company, Limited. They were used during the building of the oil tanker *Castor*, which had a launching weight of 5,500 tons. Fig. 3 shows them in position under the bottom of the ship. Tank tests while the vessel was building increased the weight to a calculated figure of double that quoted. The wedges carried the load satisfactorily. They were easily released when necessary, and so became available for immediate re-use. In view of the high price of timber, and the fact that the soft-wood cap blocks hitherto used often must be split out, so that they are of no further use, the wedges obviously afford opportunity for a considerable saving in the cost of preparing a ship for launching.

THE WORLD'S SHIPBUILDING.

TABLE I.—SHOWING THE NUMBER AND TONNAGE OF MERCHANT VESSELS OF 100 TONS GROSS AND UPWARDS LAUNCHED IN THE VARIOUS COUNTRIES OF THE WORLD DURING THE YEARS 1918-1951.

Year.	Great Britain and N. Ireland.†		Other British Commonwealth Countries.				Belgium.		Denmark.		France.		Germany.		Holland.		Italy.		Japan.		Norway.		Spain.		Sweden.		United States of America.				*Other Countries.		Totals.		Year.
			Coasts.		Canadian Lake Ports.																						Coasts.		Great Lakes.						
	No.	Tons.	No.	Tons.	No.	Tons.	No.	Tons.	No.	Tons.	No.	Tons.	No.	Tons.	No.	Tons.	No.	Tons.	No.	Tons.	No.	Tons.	No.	Tons.	No.	Tons.	No.	Tons.	No.	Tons.	No.	Tons.	No.	Tons.	
1918	301	1,348,120	184	230,514	22	49,390	No	Returns	13	26,150	3	13,715	No	Returns	74	74,026	15	60,791	198	489,924	51	47,723	18	17,389	36	39,583	741	2,602,153	188	430,877	22	17,089	1,866	5,447,444	1918
1919	612	1,620,442	235	298,495	28	60,233	2	2,433	46	37,766	34	32,633	No	Returns	100	137,086	32	82,713	133	611,883	82	57,578	41	52,609	53	50,971	852	3,579,826	199	495,559	34	24,322	2,483	7,144,549	1919
1920	618	2,055,624	90	174,557	13	29,087	5	8,371	30	60,669	50	93,449	No	Returns	99	183,149	82	133,190	140	456,642	30	38,855	13	45,950	46	63,823	467	2,348,725	42	127,528	34	42,047	1,759	5,861,666	1920
1921	426	1,538,052	49	118,303	5	11,372	3	17,909	37	77,238	65	210,663	242	509,064	98	232,402	86	170,948	43	227,425	35	51,458	11	47,256	27	65,911	167	1,004,093	7	11,284	78	63,465	1,379	4,356,843	1921
1922	235	1,031,051	37	53,347	2	9,418	4	7,497	23	41,016	62	184,509	187	525,829	60	163,132	42	101,177	49	83,419	23	32,391	2	7,776	14	30,038	55	97,161	4	21,977	53	77,316	852	2,467,084	1922
1923	222	645,651	41	37,072	3	4,191	5	1,102	24	49,479	27	96,644	109	345,062	35	65,632	21	66,523	44	72,475	48	42,619	7	4,488	10	20,118	69	96,491	14	76,326	22	19,308	701	1,643,181	1923
1924	494	1,439,885	29	29,815	2	15,064	2	3,997	37	63,937	26	79,685	108	175,113	41	63,627	19	82,526	31	72,757	34	25,139	2	3,859	12	31,211	71	90,155	8	49,308	12	21,673	924	2,247,751	1924
1925	342	1,084,633	47	32,220	4	13,853	3	4,206	21	73,268	35	75,569	121	406,374	47	78,823	31	142,046	23	55,784	48	28,805	1	127	17	53,750	94	78,766	7	50,010	14	15,165	855	2,193,404	1925
1926	197	639,568	39	22,842	3	10,836	8	3,627	23	72,108	34	121,342	60	180,548	47	93,671	27	220,021	26	52,405	25	9,237	6	25,671	14	53,518	73	115,217	5	35,396	11	18,970	600	1,674,977	1926
1927	371	1,225,873	24	20,119	5	10,131	8	4,693	20	72,038	22	44,335	105	289,622	68	119,790	25	101,076	19	42,359	12	5,363	5	22,399	18	67,361	58	124,270	8	54,948	34	80,802	802	2,285,679	1927
1928	420	1,445,920	47	22,959	1	734	3	16,243	31	138,712	20	81,416	81	376,416	74	166,754	29	58,640	37	109,663	12	10,401	7	11,852	20	106,912	57	86,092	6	5,265	24	67,260	869	2,699,239	1928
1929	489	1,522,623	47	21,327	3	11,814	4	8,361	34	111,496	16	81,607	85	249,077	77	186,517	32	71,497	40	164,457	51	39,604	8	37,023	29	107,246	59	100,632	4	25,431	34	54,498	1,012	2,793,210	1929
1930	481	1,478,563	77	43,292	2	458	5	12,265	38	137,230	18	100,917	92	245,557	74	153,072	36	87,709	37	151,272	53	58,843	13	25,213	31	131,781	92	214,012	8	32,675	27	21,613	1,084	2,889,472	1930
1931	148	502,487	31	13,612	—	—	7	897	30	125,974	22	103,419	58	109,934	99	120,296	33	165,048	42	83,721	20	18,163	11	48,117	20	112,703	55	202,227	2	3,638	18	12,879	596	1,617,115	1931
1932	100	187,794	14	3,424	2	1,336	7	1,537	18	22,413	23	89,310	15	80,799	30	26,232	8	47,441	44	54,422	8	11,129	3	11,132	12	43,000	18	143,559	—	—	5	3,063	307	726,591	1932
1933	108	133,115	20	12,958	—	—	5	4,497	19	34,016	29	34,073	43	42,195	25	35,899	3	16,500	30	74,290	7	9,718	7	18,044	14	60,860	14	10,771	—	—	6	2,020	330	489,016	1933
1934	173	459,877	16	9,112	—	—	4	831	21	61,729	10	15,950	57	73,733	31	46,905	6	26,638	155	152,420	12	18,857	8	18,358	12	49,542	21	24,625	—	—	10	8,842	536	967,419	1934
1935	185	499,011	28	10,047	2	1,142	10	1,775	33	122,095	10	42,753	78	226,343	48	57,133	4	22,607	177	145,914	23	25,716	7	3,051	22	105,538	14	32,607	—	—	8	6,258	649	1,302,080	1935
1936	328	856,257	25	6,239	—	—	16	4,249	35	97,537	17	39,208	161	379,981	69	93,831	7	11,345	180	294,861	33	33,162	9	1,283	33	154,044	57	101,258	12	10,627	17	34,042	999	2,117,924	1936
1937	309	920,822	38	13,880	—	—	17	17,071	26	131,411	9	26,544	174	435,606	112	183,509	6	21,918	180	451,121	38	41,993	*	38	161,008	103	195,767	20	43,678	31	46,252	1,001	2,690,580	1937	
1938	267	1,030,375	59	28,151	2	1,949	21	30,197	35	158,430	7	47,290	193	480,797	142	239,845	13	93,503	146	441,720	42	54,654	*	40	166,464	62	163,114	43	38,137	47	58,967	1,119	3,033,593	1938	
1939	201	629,705	41	36,142	1	450	8	22,788	31	158,644	9	44,375	109	*300,106	130	189,833	28	119,757	121	*323,775	36	40,912	1	1,050	37	210,280	94	376,419	76	45,570	18	33,618	941	2,539,424	1939
1940	229	842,910	21	18,886	—	—	No	Returns	4	*12,350	4	*21,800	No	Returns	18	*36,567	10	*61,972	No	Returns	5	*10,070	—	—	31	153,727	93	528,697	74	50,713	6	10,506	495	1,754,198	1940
1941	245	1,185,894	34	90,595	—	—	No	Returns	No	Returns	No	Returns	No	Returns	No	Returns	No	Returns	No	Returns	No	Returns	4	12,150	31	163,554	177	1,031,974	10	3,265	9	3,741	510	2,491,173	1941
1942	273	1,270,714	115	720,672	—	—	No	Returns	No	Returns	No	Returns	No	Returns	No	Returns	No	Returns	No	Returns	No	Returns	7	5,880	36	141,568	803	5,479,766	58	191,054	8	5,715	1,300	7,815,369	1942
1943	243	1,136,804	151	1,002,850	1	3,600	No	Returns	No	Returns	No	Returns	No	Returns	No	Returns	No	Returns	No	Returns	No	Returns	12	15,343	45	146,114	1,584	11,448,360	41	131,162	1	343	2,078	13,884,776	1943
1944	279	919,357	135	692,405	2	4,800	6	*22,523	No	Returns	No	Returns	No	Returns	No	Returns	No	Returns	No	Returns	No	Returns	8	30,934	45	157,183	1,242	9,288,156	19	50,911	2	3,234	1,738	11,160,503	1944
1945	307	893,515	56	141,893	14	4,097	5	*10,447	7	*22,466	No	Returns	No	Returns	No	Returns	6	*9,588	No	Returns	4	*5,965	11	20,147	32	112,760	842	5,839,858	38	127,723	4	4,270	1,326	7,192,679	1945
1946	314	1,120,526	58	83,019	7	2,632	13	17,451	13	39,051	20	*32,205	No	Returns	23	33,290	57	61,742	No	Returns	20	34,428	17	41,289	50	146,875	95	500,909	1	385	2	9,900	690	2,114,702	1946
1947	343	1,192,759	59	124,432	4	4,900	17	26,132	15	60,695	36	91,911	No	Returns	65	87,801	45	82,247	No	Returns	45	36,854	16	10,692	52	222,598	65	162,095	5	2,753	20	16,752	787	2,102,621	1947
1948	342	1,176,346	65	110,130	16	13,479	34	52,456	20	99,426	46	138,260	No	Returns	97	142,485	47	111,555	No	Returns	49	46,974	31	21,521	56	245,896	42	123,503	7	2,915	20	24,797	872	2,309,743	1948
1949	320	1,267,467	38	77,588	3	24,169	16	45,402	26	86,134	59	154,859	No	Returns	100	169,295	46	99,150	84	147,974	47	59,213	27	15,428	71	323,099	60	619,357	6	13,949	23	28,731	926	3,131,805	1949
1950	275	1,324,570	29	50,101	3	24,412	11	66,317	27	125,490	52	180,846	173	*154,506	120	228,118	17	107,464	97	347,945	57	53,402	25	27,205	63	347,892	47	435,464	5	1,507	12	17,577	1,013	3,492,876	1950
1951	261	1,341,024	25	27,223	7	50,986	11	72,373	25	115,398	43	222,632	169	318,339	128	216,869	21	112,318	85	434,286	41	94,383	35	39,596	77	404,067	50	134,639	14	31,244	30	27,187	1,022	3,642,564	19

* Returns not complete.

cent. in Sweden. Motorships comprise 85 per cent. of all oil tankers launched last year, against 64 per cent. in 1950. Finally, a total of 457 ships, making together 2,225,676 tons, or 61.10 per cent. of the shipping launched in the world during 1951, are being built under the survey of the Society with a view to classification in *Lloyd's Register Book*. Of this total, 226 vessels, making together 1,205,218 tons, are being built in the United Kingdom and represent 89.87 per cent. of the tonnage launched in home shipyards.

NOTES ON NEW BOOKS.

Technical Data on Fuel.

Edited by H. M. SPIERS. Fifth edition, revised and enlarged. The British National Committee, World Power Conference, 201, Grand Buildings, Trafalgar-square, London, W.C.2. [Price 25s. net.; postage 6½d.]

WHEN the first edition of this hand-book appeared in 1928, it quickly made a name for itself as a most useful collection of information, tables and data of special interest to fuel technologists. Since then, its comprehensiveness has been so extended that it has grown from the original 200 pages to more than 500 in the fifth and latest edition, while an index of 36 pages instead of nine is now needed to cover the contents. These have never been very strictly limited to the somewhat narrow field that might be inferred from the title, which has been interpreted more and more liberally in the course of time. Some indication of the range of the book may be gathered from the variety of the sections that have been completely re-written for the present edition; they include the calculation of fluid flow in pipes, the measurement of fluid flow, heat transfer, metals and alloys, refractory materials, ignition of gases, detonation of liquid fuels, the rating of Diesel fuels, the melting of coal ash and the reactivity of coke. Among the new topics are the National Coal Board classification of British coals, the properties of coal-tar fuels, and the combustion of fuels with oxygen and oxygen-enriched air. New sections also include a description of the I-t diagram, which gives the combustion temperatures attained by gases of various calorific values when burned with different percentages of air, and an explanation of Seyler's charts for the classification of coals and other solid fuels. The book now contains 344 tables and 84 diagrams in addition to a mass of condensed information. Ten new tables, sponsored by the United States National Bureau of Standards, give thermodynamic properties of hydrocarbons, and additional tables of the properties of steam have been included. The Committee and the editor are to be congratulated on this new and up-to-date edition of a volume which is unique in character, and which may almost be called indispensable to engineers who have to make calculations concerning fuels, combustion, heat and refrigeration.

A Guide to the Principal Safety Requirements of the Factories Acts, 1937 and 1948.

Second edition (revised). The Royal Society for the Prevention of Accidents, Terminal House, 52, Grosvenor-gardens, London, S.W.1. [Price 15s. net.]

THE first edition of this manual was produced in 1949 for the use of supervisors on the staff of Imperial Chemical Industries, Limited, and its success in that limited circulation led to requests that it should be made available to a wider public. It is divided in 15 sections, dealing separately with such subjects as safe access, lifting tackle, cranes and other lifting machines, machinery, boilers, air receivers, fire and explosion, eye protection, etc. In each chapter the contents are further divided into definitions, direct requirements, exceptions and exemptions. A feature of the arrangement is the very complete system of indexing and cross-indexing, which justifies the claim that the book provides probably the only full index to some of the complexities of the Acts to which it relates, and the numerous statutory instruments arising from them. It is not put forward as a legal guide, no attempt being made to interpret the requirements or to advise on the methods of fulfilling them; but it is likely to prove a valuable clarifying medium and a great time-saver to all who are charged with the responsibility of applying the legal requirements in particular cases.

THE HEAT TREATMENT OF METALS.—A lecture on "The Application of High-Frequency Currents to the Heat Treatment of Metals" will be delivered by Mr. R. J. Brown, M.I.Mech.E., at the Northampton Polytechnic, St. John-street, Clerkenwell, London, E.C.1, on Monday, March 11, commencing at 7 p.m. The lecture will take place under the joint auspices of the Institution of Metallurgists and the department of applied chemistry of the Polytechnic. There will be no charge for admission.

ELECTRIC TROLLEY 'BUS.



SINGLE-DECK ELECTRIC TROLLEY-BUSES FOR ADELAIDE.

THE road transport system of Adelaide, the capital of South Australia, has, for many years, consisted of trams, motor 'buses and double-deck trolley 'buses, one of which is shown in the accompanying illustration. To open up new routes, however, 30 single-deck vehicles were ordered in 1950 from the Sunbeam Trolleybus Company, the chassis, complete with electrical equipment supplied by the British Thomson-Houston Company, Limited, Rugby, being shipped from this country and the single-deck bodies being built in Adelaide. The appearance of the new vehicles will also be clear from the illustration.

The electrical equipment includes a motor with a one-hour rating of 115 h.p. at 550 volts. This motor is designed to maintain a schedule speed of 16 m.p.h., assuming an initial acceleration of 3 m.p.h. per second with five stops per mile, when driving a 44-seater 'bus weighing, with a normal load, 11½ tons. The motor is of the compound-wound non-regenerative type and stabilised rheostatic braking is provided. This is applied when the brake pedal is first depressed, and it ensures effective braking down to a speed of about 4 m.p.h. Below this speed the mechanical brake is used to stop the 'bus. It is usual on trolley 'buses with a front entrance to mount the control panels on the chassis or at the rear. On these 'buses, however, it has been possible to mount the panels in the cab, thus giving improved accessibility and simplifying maintenance.

BOOKS RECEIVED.

Department of Scientific and Industrial Research. *Report of the Fuel Research Board, with the Report of the Director of Fuel Research for the Period 1st April, 1949, to 31st December, 1950.* H.M. Stationery Office, Kingsway, London, W.C.2. [Price 2s. 6d. net.]

Recommended Domestic Solid Fuel Appliances. List No. 4, prepared in consultation with the Ministry of Fuel and Power. The Coal Utilisation Council, 3, Upper Belgrave-street, London, S.W.1. [Price 6d.]

United Nations Economic and Social Council. The European Tractor Industry in the Setting of the World Market. Study prepared by the Industry and Materials Division. United Nations Economic Commission for Europe, Geneva, Switzerland.

The Cornish Engine. A Chapter in the History of Steam Power. By DR. H. W. DICKINSON. Revised edition. Art and Technics Limited, 58, Frith-street, London, W.1. [Price 7s. 6d.]

Three-Phase Motors. Theory and Operation. By DR. T. F. WALL. George Newnes, Limited, Tower House, Southampton-street, Strand, London, W.C.2. [Price 30s. net.]

Boiler Explosions Acts, 1882 and 1890. Report of Preliminary Inquiry (No. 3364). Explosion from a Cast Iron Stop Valve Chest at the Bristol United Breweries Limited, Bristol, 1. H.M. Stationery Office, Kingsway, London, W.C.2. [Price 6d. net.]

A Bibliographical Survey of Flow through Orifices and Parallel-Throated Nozzles. By T. H. REDDING. Chapman and Hall, Limited, 37, Essex-street, Strand, London, W.C.2. [Price 32s. 6d. net.]

BRITISH STANDARD SPECIFICATIONS.

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

Staff Location Systems.—The Council for Codes of Practice for Buildings, Construction and Engineering Services, Lambeth Bridge House, London, S.E.1, have issued, in final form, Code C.P. No. 327.402, covering staff location systems. The Code forms part of the series concerning telecommunication services in and about buildings, and deals with the installation of systems which provide audible or visual signals for attracting the attention of an individual who may be anywhere in a building or on a site. Advice is given on the necessary consultation at the planning stage and on the choice of materials, appliances and components. Recommendations are given on the design of various types of systems, on methods of wiring and on power supply. Sections on inspection testing and maintenance are included. [Price 3s., postage included.]

Shell Boilers of Riveted Construction.—A series of five revised specifications relating to shell boilers of riveted construction has now been issued. The five specifications concerned are the following: B.S. No. 537, covering Lancashire and Cornish boilers; B.S. No. 609, relating to horizontal multi-tubular boilers; B.S. No. 665, dealing with vertical cross-tube boilers; B.S. No. 761, covering vertical multi-tubular boilers; and B.S. No. 931, concerned with loco-type multi-tubular boilers. These are all first revisions, the original editions having been published during the years 1934-1937. In all cases the specifications have now been extensively revised. The terms "maximum permissible working pressure" and "safety-valve blow-off pressure" in the Factories Acts, 1937 and 1948, have been deleted and replaced by the term "design pressure." Other new provisions to bring the specifications into line with present-day practice have been included in the new editions. A notable example is that relating to standpipes which are fabricated and secured to the boiler shell by fusion welding. Other clauses are concerned with materials, construction, workmanship, scantlings, and the inspection and testing of the boilers. The formulae in the sections dealing with scantlings give the minimum scantlings in all cases and apply to boilers constructed throughout under competent supervision. [Price of each of the five specifications, 6s., postage included.]

Parallel Steel Dowel Pins.—A new specification relates to dowel pins manufactured from steel and a distinction is made between dowel pins, parallel pins and straight pins. Four grades of pin have been included, the grades following the degree of accuracy of the diameter. The two most accurate grades are designated precision-ground dowel pins. The range of diameters and lengths for the precision-ground dowel pins, it is considered, will cover all the normal requirements of the jig and tool industry. Materials and limits of tolerance are specified and particulars of dimensions and other matters furnished. The specification is B.S. 1804. [Price 2s., postage included.]