HOLLOW STEEL PROPELLER BLADES FOR AIRCRAFT.

The trend towards higher horse-powers in aircraft engines has now reached the stage where propeller diameters of 16 ft. or more, with wide blades, are required to absorb the power output from the larger engines. It is difficult, without incurring serious weight penalties, to provide solid aluminium-alloy blades of this size with the stiffness necessary to avoid setting up severe vibrational stresses in the blades during flight, which may be excited by engine-propeller resonances, interference effects, or cyclically-varying aerodynamic loads on the blades. To obtain the necessary rigidity, it is desirable to use a material with a higher elastic modulus; de Havilland Propellers, Limited, Hatfield, Hertfordshire, have therefore developed a method of manufacturing hollow steel propeller blades, under licence from the Hamilton Standard Division of the United Aircraft Corporation, East Hartford, Connecticut, U.S.A. The de Havilland process is not, however, identical with that of the American company.

Three methods of making hollow steel blades have been used in the United States: by flattening an elliptically-turned or extruded "eared" tube and swaging down the root end; by welding together the leading and trailing edges of two stiffened forgings, forming the face and camber aerofoil surfaces; and by brazing a forged-steel load-carrying core tube to a sheet-metal shell. The third method, which is that used by the Hamilton Division, has been chosen for development by de Havilland as being particularly suited to the technical requirements of the British aircraft industry and to the engineering resources of the country.

Figs. 1 and 2 show the plan and elevation of the core-tube and shell assembly of a de Havilland 16-ft. diameter hollow steel blade, and Fig. 3, typical end-on views. Fig. 4 shows the first complete de Havilland hollow steel propeller. The blade has a rectangular planform, with good root stiffness, and makes the utmost use of the outboard end of the blade, which contributes the major portion of the thrust, particularly under take-off conditions when the forward speed is low and most of the inboard section of the blade is stalled. The square tip can be adopted in this hollow construction without shifting the weight distribution along the blade towards the tip—which would lead to an undesirably low natural frequency—because the core tube is tapered in thickness, giving the outboard section a comparatively low section mass. It may be observed in Fig. 2 that the blade has a forward rake, which has been selected so that under cruising conditions the backward centrifugal bending moment on the blade is balanced by the forward bending moment due to thrust. Adjusting the vertical balance of the bades, however, is complicated by the forward rake; for this reason, the weight distributions of the core and shell are closely controlled during manufacture.

Fig. 1. DEVELOPED AND PROJECTED PLANFORM AND SIDE ELEVATION

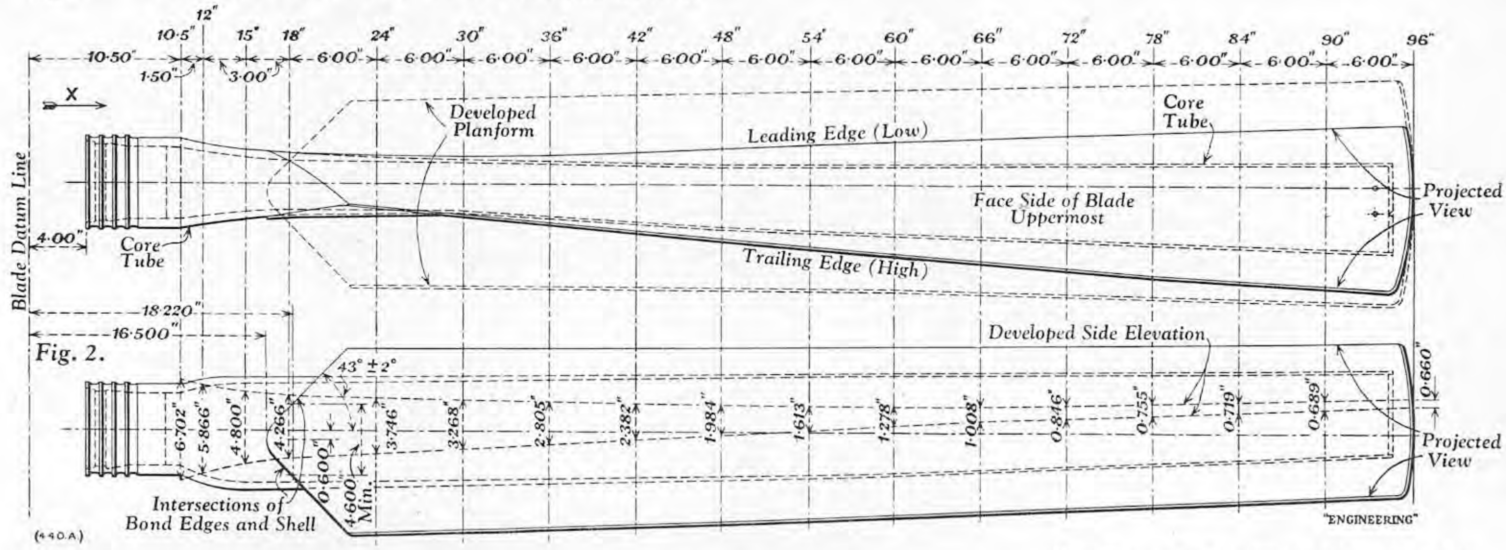

Fig. 2.

Fig. 3. VIEW IN DIRECTION OF ARROW "X"

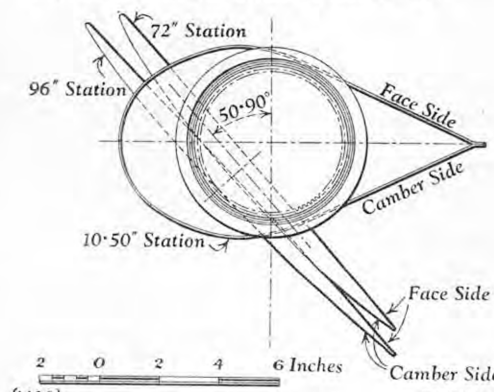

Fig. 4. First British Propeller with Hollow Steel Blades.

The manufacturing process, which is complex and requires several special techniques new to this country, is dictated by three main factors: the development of the maximum strength properties of the core, the shell, and the joint; the maintenance of a smooth aerofoil profile; and the control of weight distribution. The blade consists of a tapered alloy-steel core tube formed to an oval cross-section, an alloy-steel sheet-metal covering brazed along its length to the top and bottom surfaces of the core tube over a width of 7 in., and a light-weight nylon-reinforced filling compound of rubber and synthetic resin in the cavities between the core and the shell, and in the tip end of the bore of the core tube, which serves to restrain the skin from local "panting" under air loads, and also aids in damping general vibrations. The hollow construction makes it possible to incorporate the electro-thermal de-icing elements internally along the leading edge, thereby increasing the aerodynamic efficiency of the blade in comparison with that of a solid blade in which the de-icer must be mounted externally on the surface. The root end of the shell is finished by a moulded synthetic-rubber closure, formed simultaneously with the interior filling. The core tube extends beyond the root closure, and is formed with integral ball-race grooves for carrying the blade in the barrel, which is similarly grooved. It is estimated that the use of integral ball races in place of separate races stacked on the root of the core tube gives a weight-saving of 20 lb. to 25 lb. on each four-blade propeller.

The core tube is a 0·5 per cent. carbon nickel-chromium-molybdenum steel to a non-standard specification, selected for its high resistance to fatigue, in conjunction with its ultimate tensile strength, 60 to 65 tons per square inch. The alloy-steel sheet is similar, but with a lower percentage—0·35—of carbon. The material, as received, is in the spheroidised condition in order that it may be readily workable. To develop the optimum properties, it has to be heated above its critical point to a temperature of 900 deg. C., quenched, and tempered at a temperature of between 600 and 700 deg. C. for 15 minutes. As far as possible, these treatments are ingeniously combined with the forming and brazing operations, and special precautions are taken during the main heating to control the carbon potential of the furnace atmosphere so that no carburising or decarburising can take place; test pieces from the core and the shell are examined after each metallurgical operation.

The core-tube forgings, as received from the suppliers, the Chesterfield Tool Company, have stepped diameters and a smaller bore over a length of about 12 in. at the root end. Each tube weighs 400 lb. In its final condition, before hot-forming, the tube has a constant bore and a tapered outside profile, the thickness ranging from $\frac{5}{8}$ in. at the root end to 0·036 in. at about 2 ft. from the tip, after which it remains constant. Before being hot-formed, it passes through a series of machining operations, which may be summarised as follows. After turning the outside surface concentric to the rough bore and machining the root end of the tube to receive a chuck, the bore is machined on a gun-boring lathe. The outside diameter is turned roughly to size, a thread is cut in the root end of the bore to take a screw plug, and the bore is finished by honing to within a tolerance of 0·001 in. The outside diameter of the tube is then tapered by mounting the tube on a hydraulic mandrel and turning the profile on a cam-controlled contouring machine. This operation is illustrated in Fig. 5. Finally, the tube is polished on a linishing machine consisting of a motor-driven emery belt which is traversed along the rotating tube (Fig. 6) Measurements of tube thickness, and weight and balance checks are taken between each machining operation in order to control the weight distribution for balancing purposes. It may be mentioned here that de Havilland have found that the only practicable way of measuring the thickness of the closed sections of the propeller shell and core tube is by an ultrasonic thickness meter; for this purpose they use a Reflectogage manufactured by Sperry Products Incorporated, Banbury, U.S.A.

The tip end of the core tube is sealed by heating it locally in a small furnace, and crimping, followed by seam-weldng across the crimp, as shown in Fig. 7 opposite At the root end the screw plug is inserted, to which is attached a long handling pipe. A smaller pipe, which can be connected to a gas bottle, passes through the handling pipe. The core tube is prepared for heat-treatment by passing nitrogen through the inner pipe for several hours to eliminate any oxygen or moisture inside the tube. It is then soaked in an electric muffle furnace, supplied by the General Electric Company Limited, for $1\frac{1}{2}$ hours at 900 deg. C. Throughout the soaking period, nitrogen flows through the core tube to maintain an inert atmosphere.

Then follows a spectacular combined forming and quenching operation, in the cold dies of a 2,000-ton hydraulic press The press dies, which were cut by de Havillands on a Keller die-sinking machine, are shown in Fig. 8, opposite, with a core tube in position. The tube is removed from the furnace by three men and transferred immediately to the open dies; Fig. 11, on Plate XV, shows a blade shell being transferred, but the technique is identical for the core tube. A fourth man at the other side of the press locates the tip end of the core tube and gives the signal to the press operator. As the press dies are closed, nitrogen at a pressure of 400 lb. per square inch is released from the nitrogen bottles to "blow" the tube to the required shape, against the resistance of the press. Since the steel cools rapidly, it is essential to the success of the operation that the tube should be transferred from the furnace to the press in the shortest possible time. For this reason, a horizontal muffle type of furnace was selected, as shown on the right of Fig. 11, with a vertically-

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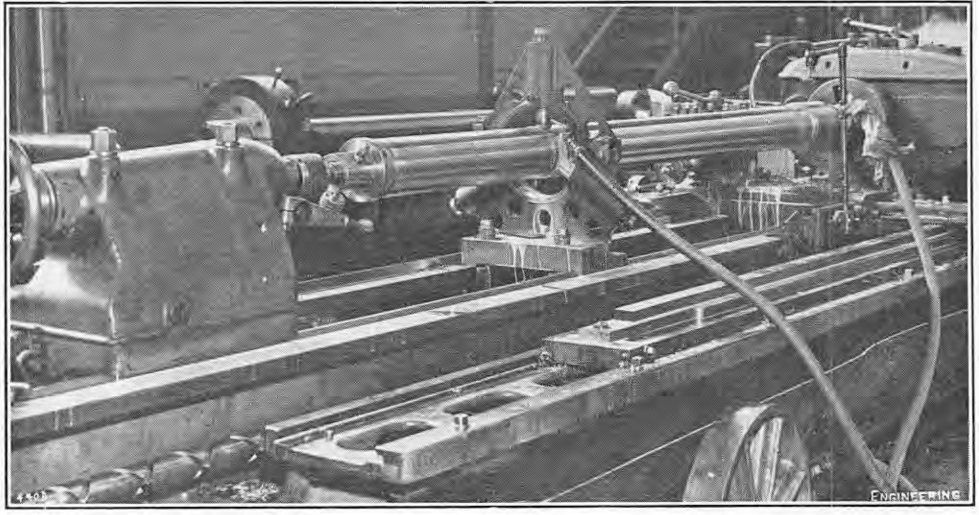

FIG. 5. CORE TUBE BEING TURNED IN CONTOURING MACHINE.

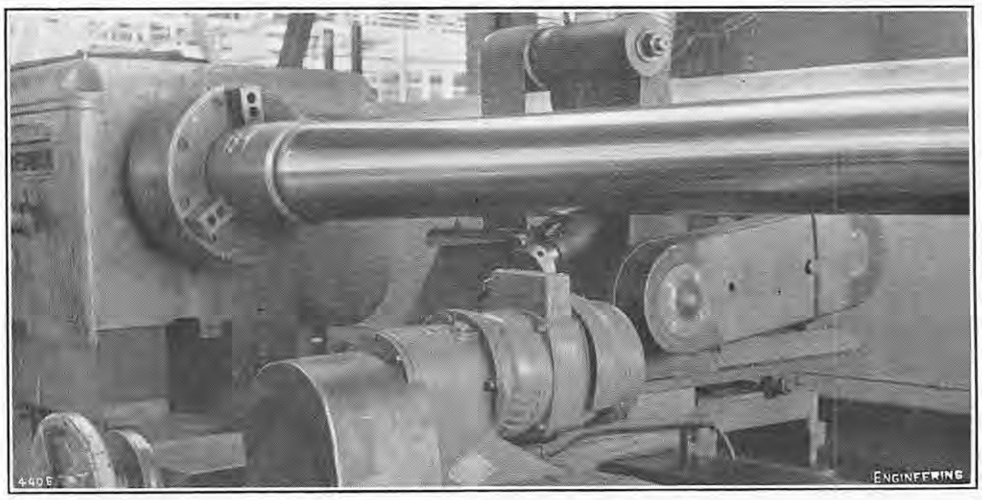

FIG. 6. POLISHING THE CORE TUBE.

sliding door at the front. The furnace muffle is fabricated from Inconel sheet, $\frac{3}{16}$ in. thick, and measures 3 ft. wide by 3 ft. high by 14 ft. 6 in. long. The muffle requires 180 kW for heating. It is supported on rollers to allow free expansion during heating, and it extends to the front face of the furnace, the door of which fits flush over the mouth of the muffle and is slotted so that the door can be closed with the handling tube projecting from the mouth of the muffle. A controlled atmosphere is fed into the muffle at the back and escapes at the furnace door. From opening the furnace doors to the closing of the press dies and the application of pressure, the manœuvre is carried out by six men in less than 12 seconds. Steel screens protect the operators from the effects of a blade bursting under pressure, which could happen as a result of a leaking gas valve. The root end of the tube lies outside the dies, and therefore provision is made for quenching it by an external air blast. The formed core tube, shown in Fig. 9, is now in a hard and brittle condition, and, therefore, an intermediate tempering treatment is given at a temperature of 500 deg. C., for one hour, to reduce the hardness to a safe value for subsequent operations.

The controlled atmosphere to the muffle furnace, which eliminates any scaling or changing of the carbon content at the surface of the blade, is supplied by a gas reactor specially designed by the General Electric Company, Limited, to work in conjunction with the furnace. This may be seen in the background of Fig. 11, between the press and the muffle furnace. It supplies a gas capable of maintaining a specified carbon content at the surface of the blade. It is necessary to purge the muffle at a high rate after the core tube or the shell has been inserted, since the burning of the controlled atmosphere in the muffle would produce gases which would decarburise the steel as the temperature was being raised. The reactor has therefore a maximum output of 1,500 cub. ft. per hour. The equipment consists of a gas generator, a gas cooler, and de-sulphurising towers. The generator comprises a series of heat-resisting vertical retorts containing a catalyst, heated by a 60-kW electric furnace; the temperature of the retorts can be controlled automatically at any temperature up to 1,100 deg. C. Metered quantities of town gas and air are fed into the base of each retort, where they react over the catalyst to produce the required atmosphere. After being cooled and de-sulphurised, the atmosphere passes into the back of the muffle. A separate gas connection is provided to enable the same controlled atmosphere to be used, when required, for other scale-free heating operations, as, for example, tip crimping.

An atmosphere suitable for providing a constant carbon potential at the surface of the hot steel blade consists mainly of carbon monoxide, hydrogen, and nitrogen, with small percentages of carbon dioxide, water vapour and methane. The operator can control the composition of the atmosphere by regulating the output, the ratio of town gas to air, and the retort temperature. If the amount of air mixed with town gas before passing through the retorts is greater than that required to convert the hydrocarbons in the town gas to carbon monoxide and hydrogen, excess carbon dioxide and water vapour will be formed. On the other hand, too small a proportion of air would result in cracking of the hydrocarbons and soot-formation in the catalyst, which would lose its efficiency. The desired balance occurs at a ratio of air to town gas of about 0·7 to 1; in practice, to maintain a high carbon potential,

(To face page 162.)

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(*For Description, see Page* 161.)

Fig. 9. Formed Core Tube.

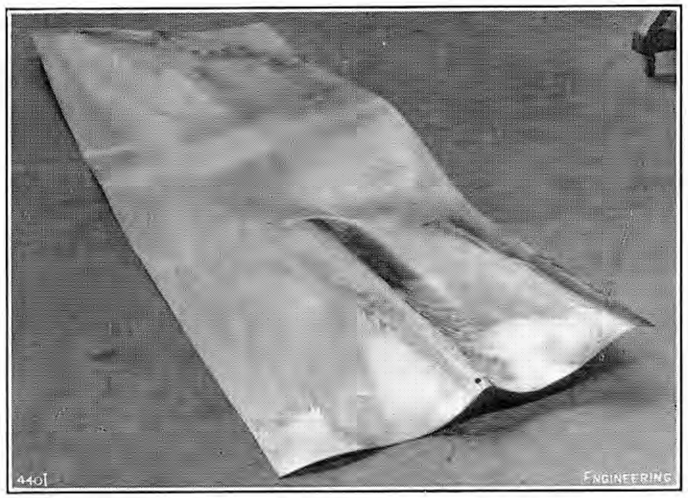

Fig. 10. Pre-formed Sheet for Blade Shell.

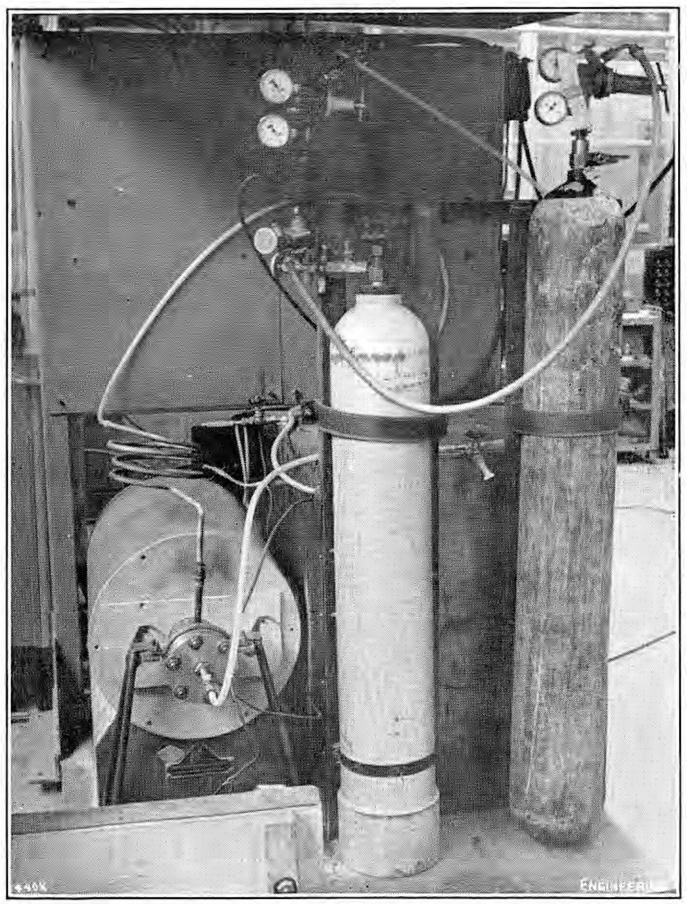

Fig. 12. Purification Plant for Fluxing Gas.

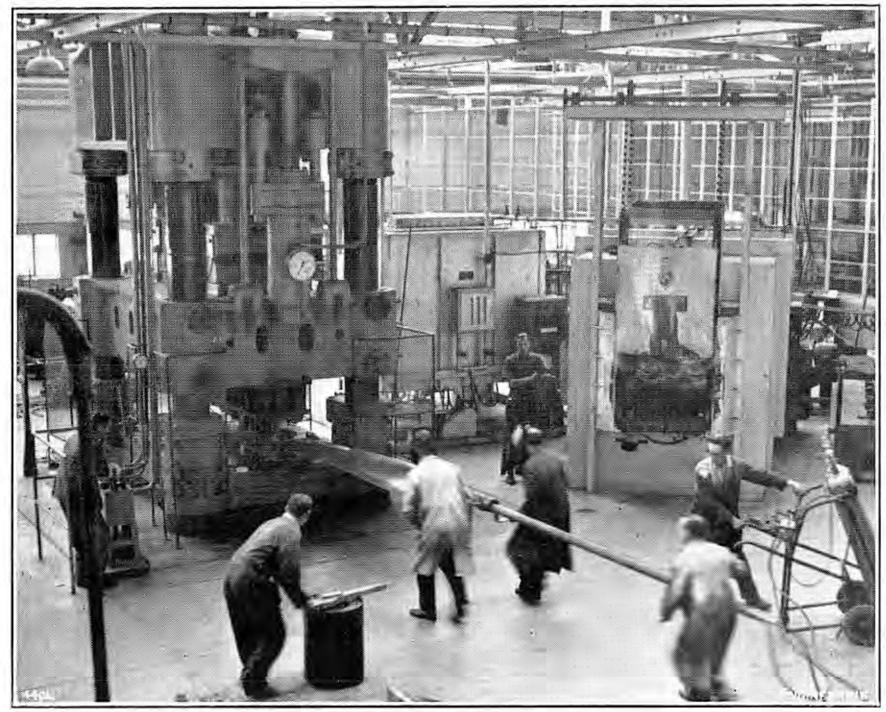

Fig. 11. Transferring Blade Shell from Furnace to Press.

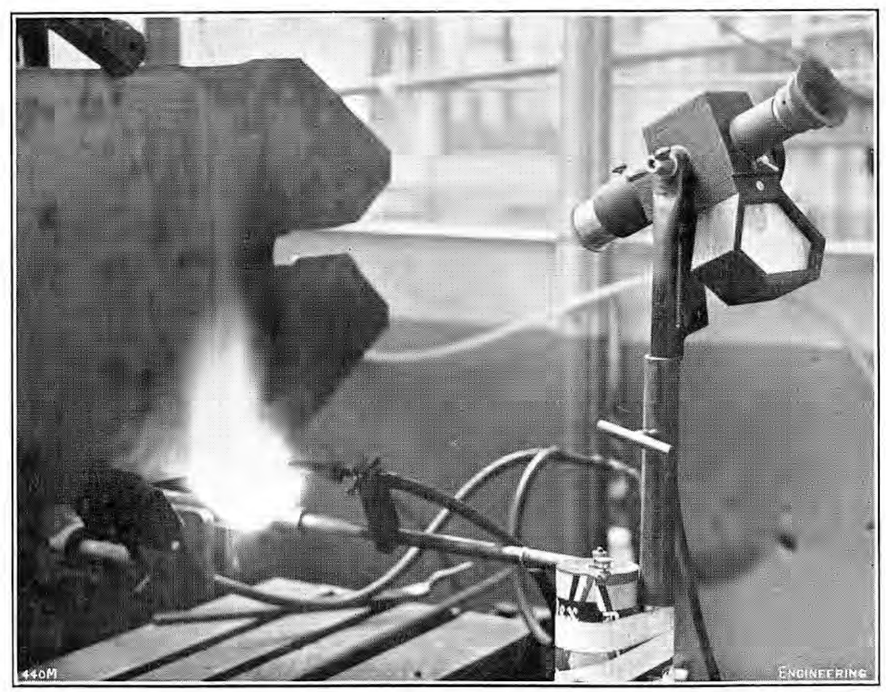

Fig. 13. Brazing Stiffening Fillet to Leading Edge of Shell.

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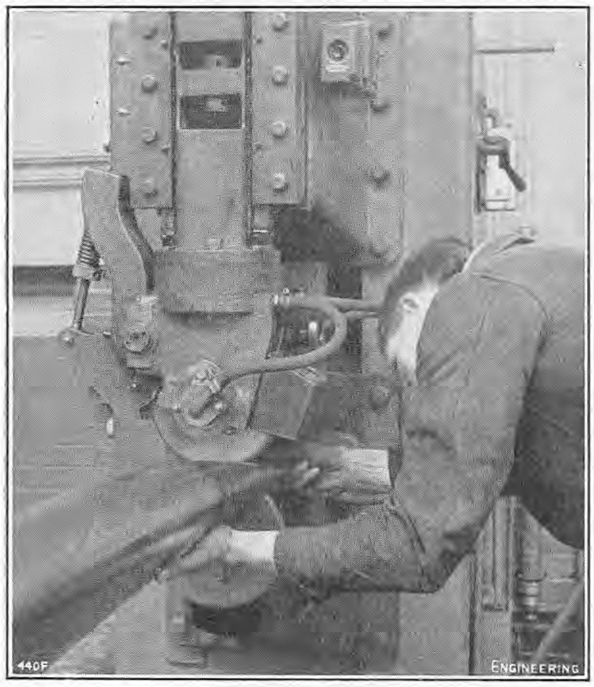


FIG. 7. SEAM-WELDING TIP OF CORE TUBE.

FIG. 8. CORE TUBE LOCATED IN DIES OF HOT-FORMING PRESS.

a slightly "sooty" mixture is used, soot accumulation being prevented by periodically running the generator on a mixture containing a larger proportion of air, every few weeks. Raising the temperature of the retorts causes a reduction in water vapour and carbon dioxide content; and decreasing the rate of flow through the retorts also produces a more carburising atmosphere, since the gas reactions over the catalyst are more complete. In the case of the core tube, the combined percentage of water vapour and carbon dioxide in the gas is held to 2 per cent., whereas in forming the shell, which is of lower carbon-content steel, a less carburising atmosphere is required and the ratio of air to town gas is increased to give a combined water vapour and carbon-dioxide percentage of 3 per cent.

A rough indication of the quality of the atmosphere is obtained by Orsat analyses; and, as an accurate indication of carbon potential, a carbon gauge is used, consisting of a cylindrical jacket inside which is suspended a fine soft-iron wire, 12 in. long. The gas to be tested is passed through the cylinder, and the wire is heated to a temperature of, say, 900 deg. C. by passing an electric current through it. The heating current is then switched off, and the wire, on absorbing carbon from the surrounding gas, undergoes a change of resistivity which can be measured and interpreted to determine the carbon potential of the furnace atmosphere.

The first stage in the manufacture of the shell is to pre-form the 40-in. wide 20-s.w.g. alloy-steel sheet on a stretcher press, prior to folding it. The thickness of the sheet is first carefully checked for this operation, and since there is always some variation along the length of the sheet, the thicker end is arranged to form the root end of the shell. After stretch-forming, the shell sheeting has the form shown in Fig. 10, on Plate XV. It is thoroughly sanded by a rotary sanding machine, with frequent thickness checks by the ultrasonic thickness gauge. The formed sheet is then folded down the centre-line to form the leading edge. This cold-forming operation is carried out on the 2,000-ton hydraulic press which is also used for the hot-forming operations. After folding, the shell sheet is placed in the same hot-forming dies that were used for forming the core tube, but in order to allow for the thickness of the shell, suitable packing pieces are placed between pads on the edges of the dies. A shaped aluminium bladder is inserted in the folded shell; the dies are closed, and the bladder is inflated with air at a pressure of 150 lb. per square inch to "distribute the shell sheeting. The two edges of the sheet, which protrude from the side of the die, are lightly tack-welded together. The roughly-shaped shell is then withdrawn from the dies, and seam-welded round the tip and down the trailing edge, leaving the root end open. A steel bulkhead with a handling pipe is then welded to the open end.

The blade shell is now given its first heat treatment, after purging with nitrogen, at a temperature of 900 deg. C. in the muffle furnace, but for half an hour only since the mass of material to be heated is much less than that of the core tube. The hot-forming and quenching operation is then carried out in exactly the same way as that for the core tube, except that the entire shell is enclosed by the dies. As already mentioned, Fig. 11 illustrates the transfer of the shell from the furnace to the press. The correct blade shape has now been impressed upon the shell, and the next stage is to seam-weld along the final seam-line where the pinch of the die has made its impression. The surplus metal is trimmed off by motor-driven hand shears, and to restore the ductility of the metal after the welding operation, the shell is given a ½-hour light tempering treatment. Weight and balance checks and Magnaflux inspections for detecting incipient cracks are carried out after almost every stage of the shell-forming process.

At the outboard end, the leading edge is provided with an internal stiffening fillet, 18 in. long with a 6-in. run out. The blade is placed upon a rig with the leading edge down, and is purged with nitrogen to remove all traces of moisture and oxygen in preparation for brazing the fillet. Pellets, $\frac{1}{32}$-in. in diameter, of 15 per cent. manganese-copper wire, are prepared in a chopping machine; they are fed into the V-groove of a long ladle which is inserted in the shell and then inverted so that the pellets are deposited in the leading edge.

The technique of the brazing processes used in the manufacture of hollow steel propeller blades is believed to be unique in this country. All internal brazing operations are carried out using a gaseous fluxing agent, since it has been found that the residue from solid fluxes cannot be entirely eliminated. Solid flux inclusions in a joint tend to act as stress-raisers, and, in the presence of even a small amount of moisture, can give rise to corrosion. For these reasons, boron trifluoride was selected; it is a gas at normal temperatures, and it is equally suitable for the main-joint braze between the core tube and shell, which is carried out at 640 deg. C., and for the leading-edge fillet which requires a temperature of 1,100 deg. C. for fusion of the pellets Boron trifluoride presents considerable problems in handling, since it attacks many organic and synthetic substances. Two of the few materials which are satisfactory for flexible tubing, regulator diaphragms, flowmeters, floats, etc., are unplasticised polythene and polytetrafluoroethylene (P.T.F.E., Teflon, or Fluon); unfortunately, the latter, which is completely inert, is scarce.

The fluxing gas must be absolutely pure; before being fed into the blade, therefore, it undergoes a cleaning process. It is passed into a heat-resisting cylinder, which can be seen on the left of Fig. 12 on Plate XV: the cylinder is filled with steel-wool and is maintained at a temperature of 850 deg. C. The impurities—sulphur compounds, oxygen, or water vapour—react with the steel wool and form powdery solids, some of which pass out with the gas steam, through a cooling coil, into an electrostatic precipitator. The latter comprises a steel chamber in which is suspended an insulated steel rod held at a negative potential of 15,000 volts; the particles agglomerate in this chamber and fall to the bottom, the residue being cleaned out periodically. From the precipitator, the purified fluxing gas is passed through the handling tube into the shell at a rate of about 6 litres a minute. To prevent atmospheric contamination, the exhaust gas is fed into a pure-aluminium tank containing glacial acetic acid, in which it dissolves.

To braze the manganese-copper fillet to the leading edge of the shell, the edge of the blade is traversed automatically through a pair of oxy-propane burners. A temperature of 1,100 deg. C. on the outside of the shell is necessary; it is checked by an optical pyrometer. The arrangement of the burners and pyrometer is illustrated in Fig. 13, on Plate XV. Propane gas is used in the burners to give a diffused heat zone, and to provide an optically-clear flame for use with the pyrometer. Following the fillet-brazing operation, the shell is subjected to a prolonged nitrogen purge to remove all traces of boron trifluoride; the nitrogen is purified in the same way as the fluxing gas. The shell is then re-heated in the muffle furnace and re-formed in the press, in the same manner as before, to eliminate the distortions caused by the fillet-forming operation.

(To be continued.)

LITERATURE.

The Friction and Lubrication of Solids.

By F. P. BOWDEN and D. TABOR. Oxford University Press (Geoffrey Cumberlege), Amen House, Warwick-square, London, E.C.4. [Price 35s. net.]

ALTHOUGH friction between solids is one of the most important of natural phenomena, its study has been curiously neglected by scientific men throughout the ages. For most persons with any knowledge at all of the subject, the science of friction consists of two laws, generally attributed to the French engineer, Amontons, who enunciated them in 1699, but probably known considerably earlier—there is evidence, for instance, which suggests that Leonardo da Vinci was aware of them almost 200 years earlier. That Amontons' laws were received with surprise and scepticism is not surprising, for they are remarkable both for their form and for their simplicity. After they had been verified by Coulomb in 1781, however, who gave a plausible and relatively simple explanation of them, the temporary excitement occasioned by their discovery appears finally to have died down. The subsequent general neglect of the subject can be attributed to the success with which the unwanted effects of friction were overcome by lubrication.

In more recent times, however, higher loads, speeds and operating temperatures in machinery have brought new problems in lubrication and, in an effort to solve these, attention has been turned to the basic causes of friction. The need for a thoroughly scientific attack on the fundamentals of the subject may be said to have been recognised more clearly in Britain than elsewhere and inspired the work of the late Sir William Hardy, whose researches on the lubricating properties of thin layers of hydrocarbon compounds shed so much new light on the subject. The extension of Hardy's work, including solid friction as well as thin film, or boundary, lubrication is the main subject of the book.

The first thing to be said of the book is that it is extremely well written and produced. It is, indeed, obvious that an immense amount of care has been lavished upon it. The result is an account which is a positive pleasure to read. As the authors state in their preface, however, the book is not to be regarded as a general text-book on lubrication, since it does not cover that part of the subject which, following Osborne Reynolds, is generally known as hydrodynamic lubrication. On the contrary, it deals almost exclusively with researches undertaken by the authors and their collaborators in Cambridge and elsewhere into the physical and, to a lesser extent, the chemical processes which occur when solids—particularly metals—slide on each other in the dry condition or when lubricated by extremely thin films of lubricant. The mechanism of friction and boundary lubrication are also discussed in detail.

The first chapter is concerned with the nature, and in particular the area, of contact between solids. Even when surfaces are highly finished, the departures from regularity on them are large compared with their molecular dimensions. It follows that, in all cases when two solids bear on one another, the actual points of contact are relatively few and the intensity of loading at each of them is correspondingly high, even when the total normal force between the solids is small. As a result, the surfaces undergo elastic and plastic deformation at the points of contact until equilibrium is attained. The normal stress at the regions immediately surrounding each area of contact will then equal the yield strength of the softer material, and the true area of contact will be determined by the ratio of the loading to the yield stress. Obviously, therefore, this area will be constant if the loading remains constant and independent of the nominal area of contact.

In the case of metals, it appears that cold welding can occur at the points of contact and that friction represents the force required to shear the welds. Since this force must be proportional to the area of the welds, Amontons' laws have a simple explanation. When the surfaces slide over each other, work is done at a rate proportional to the velocity of relative motion. Since the true area of contact is small, the resulting heat is localised and produces a rapid rise in temperature which may bring the surfaces to incandescence. Flashes of light originating in these hot spots have been observed in experiments conducted by the authors. These matters form the subject of the second chapter.

The subsequent chapters on dry friction are concerned with the effects of the motion on the surfaces. The heat generated during sliding results in surface flow and wear also occurs. The effects can be mitigated by thin films of soft metals deposited on the surfaces and are almost always reduced by the presence of films of oxide or contaminant. The final chapter of this part of the book contains a brief account of the frictional characteristics of certain non-metals. In the chapters on boundary lubrication which follow, the mechanism of lubrication by films of long-chain molecules is discussed. The subject is a complex one, and the result in any particular case depends not only on the lubricant but also on the material of the surfaces and the nature of the adhesion between them and the lubricant. Since the range of possible materials and lubricants is very large, and the number of experimental arrangements and techniques extensive, the study of boundary lubrication affords an almost unlimited field for experiment. It is natural, therefore, that the authors should regard their conclusions in this part of the book as far from complete.

The chapter on the nature of the contact between colliding solids deals with a subject of direct importance to engineers since the authors' conclusions are applicable to ball races and gears. It is shown that the forces transmitted through the oil film may easily cause plastic deformation and wear of the metals, though there is no direct metallic contact. A discussion of the nature of metallic wear is followed by a chapter on the adhesion between solid surfaces and the effect of liquid films on this adhesion. The final chapter deals with the chemical reactions frequently produced by impact and friction.

As the authors state, the book is far from being an exhaustive treatise on the subjects of friction and lubrication. There are now several schools of thought and research in this field and those working in them are far from being unanimous in their opinions. There may be some who will question a few of the deductions made in the book, but no one will deny that the authors have marshalled a formidable array of evidence in support of their conclusions and presented it with admirable lucidity. If, at times, it is difficult to see any practical applications for some of the work described, it should be borne in mind that, during recent years, important developments have taken place in extreme-pressure lubrication, and it may be that elsewhere also in the lubrication field similar important advances, made possible by basic research, are only round the corner. As an account of the work of an important research school, the book should be read by all interested in keeping abreast of developments in the subject.

Lehrbuch der Bergwerksmaschinen. (Kraft und Arbeitsmaschinen.)

By the late DR. H. HOFFMANN. Fourth edition, revised and enlarged by DIPL.-ING. C. HOFFMANN. Springer-Verlag, Reichpietschufer 20, Berlin, W.35, Germany. [Price 36 D.M.]

THIS finely-produced book, with its wealth of excellent drawings and diagrams, first appeared in 1926 as a text-book for students at the well-known German school of mining at Bochum. The field which it covers is a wide one and, though this inevitably compelled the author to adopt a certain brevity of treatment throughout, in order to confine the whole within a reasonable compass, the descriptive matter is generally adequate and often quite detailed. British readers, it is true, will notice certain omissions as well as a few seemingly unnecessary inclusions, which are wholly attributable to differences between British and German mining practice. The bulk of the matter, however, is excellent material for mining students everywhere and, though all, or most, of it can be found in English engineering text-books, we recall no single work in English which combines the essentials of the various branches of the subject in the same way.

The book opens with a chapter on thermodynamics in which particular attention is paid to the function of entropy tables and charts. The flow of fluids in pipes is then discussed and followed by a chapter on fuels. Steam boilers are dealt with very fully in the three succeeding chapters, the construction of boilers and mechanical stokers of various types being clearly illustrated. Chapters follow on steam engines and turbines, in which fundamental principles, design, governing, etc., are discussed in detail. Various uses of exhaust steam, the storage of heat and the interconnection of steam power units are then dealt with. What may be called the first part of the book closes with a chapter on internal-combustion engines, the development of which is described, and followed by a detailed consideration of the various types.

The three chapters immediately following deal with winding. The first of them is concerned with cages and skips, and with the various methods of winding. The Koepe system, so much employed in the Ruhr but, apart from a notable exception at Murton, hardly known in Britain, is, of course, included, and there is some account, as well as a drawing, of the four-rope Koepe winder installed in 1948 at the Hannover mine, Bochum, where the first Koepe system was introduced in 1878. The design of drums and winding pulleys and the selection and arrangement of ropes are considered in detail, as are the problems of their operation. The number of types of rope illustrated, however, is surprisingly small, and there is no mention of the locked-coil variety, much used in Britain. Methods of attaching the rope to the cage might have been given more space. Steam and electrical winding form the subjects of the next two chapters.

Four chapters are devoted to piston and turbo pumps and compressors, and the supply and distribution of compressed air are considered in detail. Chapters follow on compressed-air motors and tools, the operation of borers and cutters being well illustrated by drawings. Succeeding chapters deal with conveyors, underground locomotives, refrigeration and ventilation, and the book concludes with an account of the standard methods of measuring the flow, etc., of fluids, vapours and gases in pipes, taking indicator diagrams, making brake horse-power tests, and analysing flue and exhaust gases. In this new edition—the previous one appeared in 1941—the material has been revised in the light of recent developments and expanded where necessary. More than a hundred new drawings and diagrams have been added and the format has been changed so that the page is enlarged. The large page is a pleasing feature of the book which, though it remains primarily a text-book for students, should be a useful reference book for qualified mining engineers.

CONGRESS ON INDUSTRIAL DESIGN.—The Council of Industrial Design, with the co-operation of the Federation of British Industries, the Trades Union Congress, the Royal Society of Arts, the Society of Industrial Artists, and the Design and Industries Association, are organising a congress on "Design Policy in Industry as a Responsibility of High-Level Management," to be held at the Royal College of Art, London, on September 19 and 20. It will be attended by about 250 invited guests, mainly chairmen, directors and managers from leading firms in Britain, Europe and the United States. The papers, which have not yet been given titles, will be discussed in three groups, one of which will evidently deal with transport equipment, including railway rolling stock, ships, motor vehicles and aircraft. The Council's address is Tilbury House, Petty France, London, S.W.1.

OPACITY OF PAPER.—The measurement of the opacity of printing papers has been facilitated by some work carried out by the Printing, Packaging and Allied Trades Research Association, Patra House, Randalls-road, Leatherhead, Surrey. Printing opacity is the brightness of a sheet of paper when backed with black ink, expressed as a percentage of its brightness when backed with a number of similar sheets. Patra have prepared a set of papers, coated and uncoated, so that "some idea of the significance of a printing opacity figure may be gained and the effects of surface texture and colour appreciated," also to illustrate the relation between printing opacity figures and "show-through." In their laboratories, they have produced an instrument for the accurate comparison of brightness and measurement of show-through, and a control instrument for routine checking of opacity.

THE INTERNATIONAL CONFERENCE OF NAVAL ARCHITECTS AND MARINE ENGINEERS.

(*Continued from page* 137.)

DR. S. F. DOREY, F.R.S., President of the Institute of Marine Engineers, occupied the chair during the second part of the technical session on Thursday, June 28. The paper presented dealt with "Ship Motions," and was contributed by Mr. John C. Niedermair, of the Bureau of Ships, United States Navy Department.

SHIP MOTIONS.

The paper was based on a comparison of some "meagre experiments" with models and recently published theoretical results; in general, the author said, they were in agreement, though the indications were that the model wave heights used were excessive. At sea, too, regular series of waves were unusual. It was desirable, in rough-water model testing, that there should always be at least one common sea condition; a wavelength of 600 ft. and a wave height of 27 ft. were suggested as a reasonable standard. The validity of arbitrary wavelengths and heights should be checked by statistical studies of the waves encountered on well-travelled ocean routes; some work of that kind had been done in the Pacific Ocean, but similar studies for other ocean routes were needed. Measurement of full-scale ship motions at sea, plus the simultaneous recording of all the essential information needed to relate those motions, was a problem of great difficulty; but it ought to be done, to verify the validity of the assumed wave conditions in which models were tested, and the similarity of ship and model motions, given geometrically similar wave conditions. Information of value on the first of these subjects was on record, and more might be obtained by the statistical analysis of the logs of scheduled ships, travelling the same ocean route over a long period. The average speeds for any time of the year could then be compared with average wave conditions for the route. Rolling and pitching data also would be valuable. To cover the second subject was even more difficult, as it would involve instrumenting a ship fully, both to record the motions of the ship and to record simultaneously the surface of the sea. Instrumentation for the latter purpose had still to be developed, and would require the services of trained specialists; yet such a ship and team could only fulfil their purpose on the rare occasions when regular seas were encountered. The exciting forces of cross seas and irregular seas should be studied in model size, in addition to the ahead seas normally studied; but to simulate such seas would require new and extensive facilities, permitting complete six-degree freedom for the model.

The discussion was opened by Mr. R. W. L. Gawn, O.B.E., who considered that there was much to be said for investigating ship oscillations by small models. The author's models were nearly 5 ft. long; some experiments of the same character were carried out at Haslar, and described in a paper by R. E. Froude in 1905. They were about the same length as those of Mr. Niedermair, but the later models were about 7 ft. long, experience having shown that larger models could safely be used; nowadays, still longer models were generally used. Ship oscillations frequently built up and died down in a cycle of phases, and, to represent the true motion, a definite number of cycles must be completed during an experiment. The length of the tank mentioned in the paper was only eleven times the length of the model, and the number of waves which the model could meet was limited accordingly. This applied particularly to the longer waves, which were of the greater interest because of their greater motion. An interesting point was that the experiments were made with a constant towing pull applied to the model. At Haslar, it was usual to arrange for the model to move ahead on to the waves at a series of constant speeds of advance. The two methods were appropriate to the equipment in the respective tanks, but there might be something to be said for a constant pull as representing, perhaps, a closer approach to ship conditions. One consequence of a constant towing pull, however, was that the speed of advance varied during the test, and this departure from steady conditions was a disadvantag from the strictly scientific point of view of comparing with theory. With that in view, he had tried to see how far the results of the two methods—constant pull and uniform speed—approached, and he found that there was some measure of agreement.

One interesting confirmation was the author's conclusion, which Mr. Gawn thought was important, that, in spite of some rather wide hull differences between individual models, all the models behaved substantially alike. It did seem to be a fact, from experience of testing models of different types, that quite large changes in hull form were insignificant as compared with changes in the distribution of loading, which, of course, affected the radius of gyration and, therefore, the period. The author included in the definition of natural pitching period, the virtual mass, and said that the matter was controversial. That was an under-statement; for one thing, he assumed that the inertia coefficients could be calculated from the data for deeply submerged bodies. That was most probable; but the inertia coefficient of a floating body was vastly different from that of a submerged body, and no consideration had been given to the influence of damping or speed on the period. Would the author state whether any results were available for the still-water pitching period of the models, to determine the influence of the various factors? The pitching period of the ship, as distinct from the period of forced oscillation, was also subject to variation with the size of wave which the ship met, and again by the size of the waves created by the speed of the ship. He suggested, therefore, that the basic period should not be complicated by including only one factor, namely, virtual mass, and neglecting all other factors. The natural period should be that which had always been recognised in the Admiralty, calculated from the fore and aft radius of gyration and the longitudinal metacentric height.

Professor A. M. Robb thought that the presentation of the results had been affected considerably by the choice of an unpopular parameter; the graph dealing with the maximum pitching amplitude/maximum wave slope for individual models in seas of varying length, he suggested, was the vital figure in the paper. In fact, there was no such direct relation between maximum amplitude and maximum wave-slope. In the case of rolling, the maximum wave-slope was taken as a parameter; but with it was the assumption that the breadth of the ship was small in relation to the length of the wave. The author, however, postulated a length of ship which ranged from a major fraction of the wavelength to a multiple of the wavelength; in that condition, maximum wave-slope ceased to have any direct significance. The point was that, in the case of rolling, the maximum wave-slope was also the maximum statical angle of equilibrium, and that was the basic quantity. In the case of pitching, the maximum angle of statical equilibrium would also be taken. In that case, instead of the angle decreasing with increase of length of wave, as shown in one of the tables, an angle was obtained which increased with length of wave. Using that more rational parameter, Professor Robb suggested, there would be a totally different result in the graph, and a more rational plotting.

Dr. F. H. Todd observed that the problem of ship motions was intimately bound up with the seaworthiness of ships. The progress of knowledge on that subject had languished because there had never been an adequate theory of the basic elements with which to interpret the results obtained, either from models or ships, and to serve as a guide in planning experimental research. Seaworthiness had been given high priority in the work of the David Taylor Model Basin at Washington, and a recent paper* by G. Weinblum and M. St. Denis, of the staff of the Basin, would, he thought, become a classic guide to the subject. Nr. Niedermair's results of model experiments in waves showed general agreement with the theoretical work of Weinblum and St. Denis. One of the points he brought out was the effect of freeboard at the fore end of a ship. Some model experiments which Dr. Todd had made with large trawler forms showed clearly the immense value of freeboard forward in ensuring good sea performance, and that, with the relatively high speed/length ratio of those trawlers, quite fine angles of entrance could be adopted, thus ensuring dryness of decks. There was opposition in the first instance by captains and owners, who were quite certain that such fining of the fore end would make a bad seaboat, which would not rise to the waves; but they were proved to be wrong.

Model experiments on rough-water performance had been in progress for many years, notably under Mr. J. L. Kent, at Teddington; but they had been very restricted, the only tests possible being those in head-on and following seas, conditions seldom met in practice. Dr. Todd strongly endorsed the author's proposal for new facilities in which models can be run under all conditions of waves. The models used by the author were quite small but, with suitable care and precautions, the use of small models should give reliable comparative results. The application of the results to predict actual ship performance, however, was another question. Some fundamental work was needed on ship model correlation, to which end two parties from the Model Basin had been sent across the Atlantic in winter, and another was to spend a month at sea on a coastguard ship. The ships were not completely instrumented, but they had obtained powers and speeds, pitching and heeling records and accelerations. Seaworthiness was a very live subject in the United States, and the American Tank Conference had an active committee working on it; that committee had agreed to do systematic experiments on a number of merchant-ship forms of block coefficients varying from 0·60 to 0·80. The Hydromechanics Sub-Committee of the Society of Naval Architects and Marine Engineers had endorsed the suggestion, and a co-operative scheme was being arranged whereby the different model basins would each take one of the parent forms and make changes in such factors as freeboard, flare above water-line, types of sections forward, etc. At the same time, similar experiments were being undertaken at the Taylor Model Basin with some simplified mathematical forms, to determine the various inertia and damping coefficients so as to assist Mr. Weinblum and Mr. St. Denis in the further development of their theoretical work.

Mr. A. J. Williams said that, in the Department of the Director of Naval Construction, at the Admiralty, a considerable interest had been taken in ship motions in connection with the problem of armament control, and they had carried out a number of sea trials. The problem of weapon control was concerned primarily with angular motions, and, in particular, with the velocities and accelerations of angular motions. Curves had been derived, showing the variation of a measure of the amplitude of pitching motion with wavelength, and that the period of motion was equal to the period of encounter. From that information, other curves had been plotted, showing the variation of angular velocity and acceleration with wavelength. It would be unwise to attempt to draw too precise conclusions from those curves, but some general inferences might be made.

Professor A. J. Sims, O.B.E., R.C.N.C., said that the subject of ship motions had become one of greatly increased importance. As Mr. Niedermair had said, the study of rolling had progressed farther than has the study of other ship oscillatory motions; the time had come, however, when it was necessary to predict more accurately the characteristics of pitching, heaving and loss of speed in a head sea. There should be some standardisation of nomenclature for periods of pitching. There appeared to be three distinct periods. First, there was the basic period, to which Mr. Gawn had referred; it might be defined in the same way as the author has defined it, but ignoring the coefficient of inertia and also the damping coefficient, so as to leave only the plain straightforward period which could be calculated in any design office, given the longitudinal

* "On the Motions of Ships at Sea," *Trans. S.N.A.M.E.* (1950).

weight distribution and the hydrostatic features of the design. That, however, was a period of very limited use. The second and third periods he would call practical periods. One could be defined as the "still water at rest" period—meaning "at rest" as regards ahead motion. That was a clearly defined period. The third period was the "under way" period, in which changes took place in three components of the formula. One was the radius of gyration; the second was the coefficient of inertia; and the third was the damping factor.

Dr. J. Lockwood Taylor, in reference to surging, recalled some sea tests that he had carried out some years previously. It might be assumed, from the paper, that surging was a little-understood subject; but he would have said that it was the simplest motion and the one that was best understood, having in mind those particular sea tests. He had used the rather ingenious instrument of Professor T. B. Abell, namely, the recording short-period pendulum mounted on the long-period pendulum. The short-period pendulum had a stable platform and could record fore and aft accelerations. Using this on a cargo liner, he found that the observed surging accelerations could be correlated quite well with the calculated accelerations based on the orbital motion of the waves. There was a lot of scope for further work at sea on the subject of ship motions; even, for instance, on the basic question of the height of waves likely to be encountered.

Rear-Admiral C. D. Wheelock, United States Navy, referring to tests he had witnessed at the David Taylor Model Basin, recalled that, when the small models were towed, they were given a constant towing force and the wavelengths were varied. The wave heights were considerable, probably too high to be of real value in any analysis; Mr. Niedermair had recommended a series of tests with waves of half the height. It was probable that the whole range of conditions would have to be examined until it was possible to simulate in the model approximately what happened to the ship at sea; so far as he was aware, no instance had occurred where the conditions resulting in the model corresponded with the natural period in a series of waves. It seemed that the wave amplitudes were so great that they forced the model out of its own period into the wave period in all the tests; and he thought it would be necessary to reduce the wave heights to something very small indeed, to try to duplicate the experience at sea, where a ship would build up in pitching to a certain point, then steady and build up again.

Might it not be, also, that most of the confusion in the mind of the observer at sea was due to the smaller waves, having all the appearance of roughness, covering up and hiding the waves that were really affecting the ship? During his recent crossing of the Atlantic in the America, there was no time at which anyone could detect the waves which were influencing the ship in pitch, because the periods were too long. Only in the Pacific were there long waves to be seen; he had seen them on several occasions, waves of greater length than the ship, 600 or 700 ft., the surface being otherwise so smooth that they could be picked out easily. Sea-keeping was tremendously important, and the work described in the paper arose from the need of naval ships to maintain speed in rougher and rougher seaways. One of the reasons why this particular kind of test was made, wherein the towing pull was constant, was to determine whether, with a given horse-power, or a given thrust, it was possible to maintain higher speed in rougher and rougher waves.

Professor E. V. Telfer thought it rather significant that the two best forms tested were not those forms which had been reported on in practice as being the most seakindly ships. The curves graded the models in respect of low speed loss. On the other hand, it was quite usual for a captain to say that his ship was a good one, or seakindly, by reference to the amount of water taken on board. The tests on the two best model forms showed that the ships represented could quite easily keep up to the weather so far as holding speed was concerned; but they would probably be wrongly diagnosed by a captain because water was taken on board, and it would seem that the responsible naval architects might easily adjust the design to allow higher speed to be obtained.

With regard to absolute speed loss, the author stated that, whether starting from 20 or 30 knots, roughly the same amount of speed was lost. That was true, but it was an entirely wrong lesson to learn from the tests. To lose the same actual amount of speed meant that there was a greater relative loss when starting from the lower speed. His own opinion on that subject was that study of the motions, as such, would lead nowhere, but study of the effects on absolute power or thrust in facing given rollers was the most important line of attack. Finally, he thought that the pull necessary to move a particular form at a speed of 30 knots was a very insecure basis. It could easily be imagined that a vessel which needed a certain power for a speed of 25 knots in smooth water and required a terrific increase of power at 30 knots would show a much better relative performance in holding speeds at lower power; so much extra power had to be provided to achieve 30 knots that it could be used much more economically at 20 knots.

Mr. Neidermair said that he would prefer to make a written reply to the discussion. With regard to Mr. Gawn's comments, he wondered whether, if the model were run for a greater length of time in a longer tank, it would make much difference to the results. The real reason why he had written the paper was the need to have more discussions on the problem and to encourage further tests, at sea, in the model basin, and the theoretical work of mathematicians capable of doing it.

(*To be continued.*)

TWIN-ARC METALLIC WELDING.—The Quasi-Arc Company, Limited, Bilston, Staffordshire, announce that arrangements are in hand whereby they will become sole concessionaires throughout the world for the General Electric Company's twin-arc metallic-arc welding process. This process will be demonstrated at the forthcoming Engineering, Marine and Welding Exhibition, using Quasi-Arc twinned electrodes.

WILBUR WRIGHT MEMORIAL LECTURE.—The 39th Wilbur Wright memorial lecture of the Royal Aeronautical Society will be given by Mr. A. E. Raymond, a member of the Douglas Aircraft Corporation, California, U.S.A. The subject is "The Well-Tempered Aircraft." The lecture will be given on Monday, September 10, at 6 p.m., at the Royal Institution, 21, Albemarle-street, London, W.1; tea will be served before the lecture at 5.30 p.m. Following the lecture, a reception will be held in the offices of the Society from 8 till 11 p.m. Further particulars may be obtained from the secretary of the Society, 4 Hamilton-place, London, W.1.

THE EXHIBITION OF INDUSTRIAL POWER.

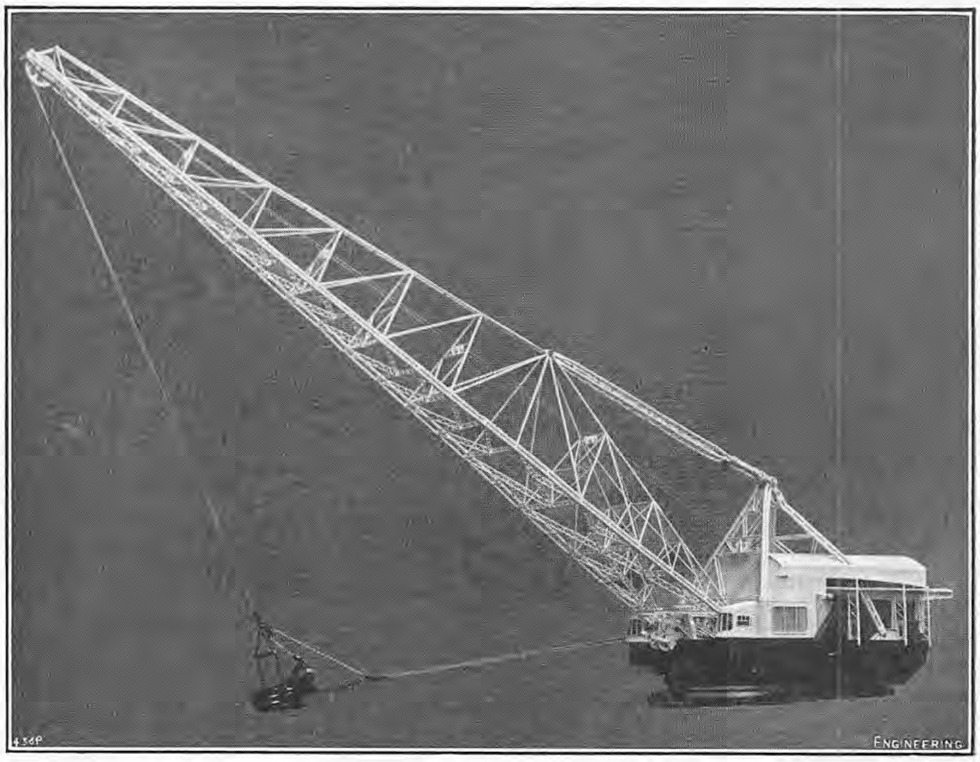


FIG. 143. MODEL OF WALKING DRAGLINE; RANSOMES AND RAPIER, LIMITED.

ENGINEERING IN THE FESTIVAL OF BRITAIN.*

IX.—EXHIBITION OF INDUSTRIAL POWER, GLASGOW.

(*Concluded from page* 136.)

AFTER leaving the Hall of Hydro-Electricity at the Glasgow Exhibition, visitors are enjoined to make their way to the Hall of Civil Engineering, a view of which is given in Fig. 147, on page 176. The exhibits in this hall are arranged to cover the subjects of public health, bridging and irrigation, as well as to show how the scope of the civil engineer has expanded from the days of Ancient Egypt to modern times. The centre of the hall is devoted to a pictorial display of steel-frame buildings and lock gates, and in the galleries there are examples of bridges and of the equipment, which goes to make up a modern water-supply system. At the far end, the contribution which the civil engineer can make to the increase of human welfare is demonstrated by illustrations of the Nile irrigation works. As in the other parts of the exhibition, full use is made of models, including one of the Sonninghill timber viaduct and another of the Keadby lift bridge.

Among the individual exhibits mention may be made of the model of the walking drag-line, which is being shown by Ransomes and Rapier, Limited, Ipswich, and is illustrated in Fig. 143, herewith. The actual machine is now under construction for Messrs. Stewarts and Lloyds, Limited, and will be used for stripping ironstone beds in Northamptonshire. It weighs 1,500 tons and consists of an all-tubular steel boom to which a 20-cub. yard bucket is attached. The height from the ground level to the boomhead is 175 ft. and the diameter of the base is 48 ft. It is supplied with power from two 1,500-h.p. generating sets.

Another exhibit in the same category is the "Super Ten" excavator shown by Messrs. Thos. Smith and Sons (Rodley), Limited. This is an all-steel electrically-welded machine, having a revolving frame extending from the jib feet lugs to

* Articles in this series on the Dome of Discovery, the Royal Festival Hall, the temporary bridges, the "Skylon," civil engineering works, and exhibits at the South Bank Exhibition appeared in the previous volume of ENGINEERING (vol. 171) in the issues of April 13 and 20, May 4, 11 and 18 and June 1, 8, 15, 22 and 29, 1951.

THE EXHIBITION OF INDUSTRIAL POWER, GLASGOW.

FIG. 144. RADAR DISPLAY UNIT; KELVIN AND HUGHES (MARINE), LIMITED.

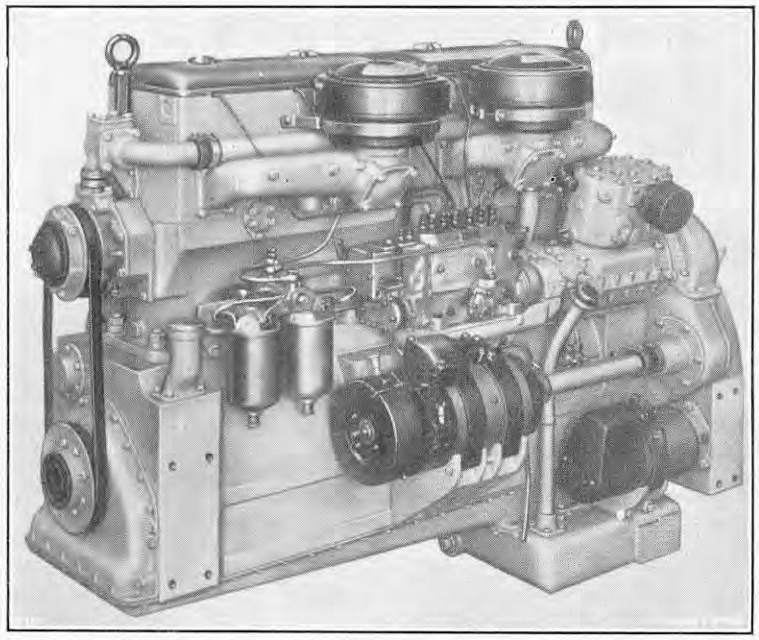


FIG. 145. 270-H.P. TURBO-CHARGED ENGINE; H. MEADOWS, LIMITED.

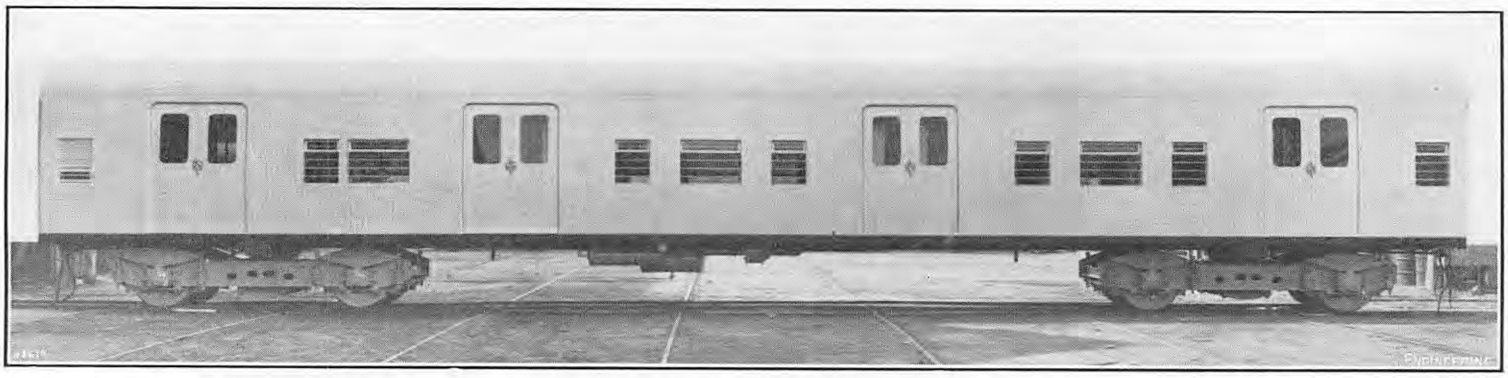


FIG. 146. COACH FOR INDIAN RAILWAYS; BIRMINGHAM CARRIAGE AND WAGON COMPANY, LIMITED.

the extreme tail and carrying the power unit and other machinery. The standard method of driving is a three-cylinder Diesel engine, developing 33 brake horse-power at 1,000 r.p.m. Electric driving can, however, be fitted as an alternative, in which case a 25-h.p. squirrel-cage or enclosed ventilated compound-wound direct-current motor can be used. Power is transmitted through two-speed gearing and a duplex roller chain. There are two main horizontal shafts, one of which carries the reversing clutches and the other the rope barrels. All the controls are "finger-light" and are conveniently grouped for the driver, who is seated on an adjustable seat in front of the house in which the superstructure, engine and machinery are enclosed.

The superstructure rotates on a large-diameter "live" ring of 14 rollers, which are mounted on self-lubricated bushes. The roller path is supported on a circular turret which, in turn, is mounted on the all-steel one-piece welded carriage frame. The crawler pad tracks are of the interlocking type and are linked together by alloy-steel pins in multiple shear. The transmission drive to the tracks consists of manganese-steel bevels and forged-steel chains, the travelling speed being up to $2\frac{1}{2}$ m.p.h. in either direction. The bucket front is made of alloy steel with reversible inset teeth and its door is provided with cast-steel hinges and latch gear, which are easily renewable. The capacity of the standard bucket is $\frac{3}{8}$ cub. yard.

Models of cranes are being shown by Messrs. Butters Brothers and Company, Limited, Glasgow, and of road rollers by Messrs. Aveling-Barford, Limited, Grantham.

A recent development in prestressed concrete is the Lee-McCall system, which is exhibited by McCall's Macalloy, Limited, Templeborough, Sheffield. In this system high-tensile steel bars, varying in diameter from $\frac{1}{2}$ to $1\frac{1}{8}$ in., are used instead of the more usual steel wires. These bars are stressed to about 42 tons per square inch by an hydraulic jack, the legs of which bear on a steel anchor plate embedded in concrete. An adaptor is screwed to the end of the bar and secured to the jack by a cotter. When the full pre-stress has been applied the bar is fixed by tightening the anchor nut. The jack and pump are both mounted on the same trolley, which also carries a small winch for raising the jack to the level of the bar to be stressed. Stressed Concrete Design, Limited, 54, South Side, Clapham Common, London, S.W.4, are showing examples of their Magnel-Blaton tensioning jack and cable, as well as a model and section of a pre-stressed beam; and the Freyssinet system of post-tensioned pre-stressed concrete is demonstrated by P.S.C. Equipment, Limited, 123, Victoria-street, London, S.W.1, who are exhibiting typical jacks, anchorage cones and cables. Examples of the Bison type of pre-stressed floor and a model of pre-stressed cantilever floor form part of the display arranged by Concrete, Limited, 16, Northumberland-avenue, London, W.C.2.

The last main hall of the exhibition is that in which the coal and water sequences converge and is jointly devoted to shipbuilding and railways. It consists of a ship-like structure with galleries, on which the vast contribution that Great Britain has made to shipbuilding is initially told by calling attention to the work of such pioneers in the art as King Henry V and King Henry VIII, Hawkins, Drake, Matthew Baker, Pett, Watt, Parsons and Froude. Next, running the length of the hall, comes the life story of a ship from the initial stage of an idea, roughly sketched out on the drawing board, to the time when the vessel sails on her maiden voyage. Navigation is dealt with by illustrating the work of Norward and Harrison and by showing how the compass was evolved from the first primitive lodestone to the latest electronic equipment. Near the centre of the gallery is a three-deck structure, which shows the arrangement of the navigation instruments, a modern stateroom, and an engine-room in which both the main and auxiliary plant are installed.

Working displays illustrating how echo-sounding and direction-finding equipments are used to assist in navigation are being exhibited by the Marconi International Marine Communication Company, Limited, Chelmsford. The echo-sounding display, which is shown on a panel 7 ft. long by $5\frac{1}{2}$ ft. high, is based on the Marconi Marine "Seavisa" and "Seagraph" echometers, instruments which emit pulses of energy, measure the time taken for each pulse to reach the sea bed and return, and thus present the depth of water beneath the ship in an easily readable form, without any calculation being necessary. A ship is shown moving across the panel, and at certain points in its travel a pulse, indicated by a light, is emitted, to be reflected as an echo from the seabed, and returned to the ship. At each pulse, the depth measured is shown by a light flash at the appropriate point on the graduated scale of the "Seavisa." The "Seagraph" traces on paper a contour graph of the variations in the sea bed, and a typical record obtained in this way is shown.

The direction-finding display, which is exhibited on a record panel, shows how a Marconi marine "Lodestone" direction-finder is used to determine a ship's position by radio when poor visibility conditions preclude celestial observation. In practice, radio beacon stations ashore transmit at regular intervals, and by using the "Lodestone" to ascertain the direction from which these signals are coming, the navigator can discover the bearing of the station from his ship. The point of intersection of two or more of these bearings is the position of the ship. The display shows three stations, each of which, in turn, transmits a characteristic signal in flashing light and in sound. Off the coast is a ship, bearing a replica of the "Lodestone" dial marked in degrees. When a radio beacon "transmits," the arrow on the dial moves to the direction of the station, so that the bearing can be read. Cross-bearings on the position are then taken on the transmissions of the other two stations, and a "fix" obtained showing the vessel's position. By pressing a button on each display, visitors can set them in operation.

Messrs. Kelvin and Hughes (Marine), Limited, New North-road, Barkingside, Essex, are giving a demonstration of their marine radar system, using simulated signals from a model. The equipment employed consists of scanner, transmitter and display units, with the wave guides and cables necessary for their interconnection, as well as a motor-generator and starter unit and a monitor signal unit. The scanner comprises a weatherproof housing, which carries the revolving aerial. The latter is a truncated paraboloid with apertures of 5 ft. in the horizontal and 4 in. in the vertical directions, so that the beam width, measured as a full angle between the half-power points, is 1·6 deg. and 27 deg., respectively. The scan is in the clockwise direction at a speed of 30 r.p.m. The scanner is connected to the transmitter unit, which is provided with a spark-gap discharge into a pulse transformer, giving a peak power of 7 kW with a pulse width of 0·2 microsecond and a pulse recurrence of 2,000 per second. The receiver is of the superheterodyne type with a reflex klystron local oscillator and crystal mixer. The preliminary intermediate frequency-amplifier in the radio frequency head is coupled to the main intermediate frequency-amplifier in the display unit by a coaxial cable. The ground wave is suppressed by the injection of a lock pulse from the pulse transformer. The intermediate frequency is 60 megacycles and the intermediate frequency band width 10 megacycles. The first stages of the receiver are housed in the transmitter unit, which is arranged for bulkhead mounting and can generally be accommodated without difficulty in the smallest wheel-house or chart-room.

The display unit, an illustration of which is given in Fig. 144, is designed for table mounting, but can also be fixed to brackets on the bulkhead. It is connected to the junction box by a flexible multicore armoured cable, and the controls for operating the installation are fixed to panels in a recess below the display panels and are made accessible by lowering the "roll-top" cover. The unit contains the cathode-ray tube of the plan position indicator, as well as those parts of the receiver which are not housed in the transmitter unit, and various other circuits associated with the production of the display. The main assemblies are fixed on hinged mountings and the control panel chassis can be withdrawn to facilitate inspection. The cathode-ray tube is 12 in. in diameter and operates at 9 kV. The motor-generator which supplies power to the equipment consists of a 110-volt or 220-volt direct-current motor, driving a single-phase inverter with an output of 0·45 kW at 180 volts and a frequency of 2,000 cycles; and a three-phase alternator with an output of 0·15 kW and a frequency of 50 cycles.

Messrs. S. G. Brown, Limited, Shakespeare-street, Watford, are showing one of their A.1 gyro compasses, complete with two bearing repeaters and a type E automatic helmsman. This equipment is arranged on a representation of a ship's navigating bridge.

A view in the Hall of Railways is given in Fig. 148, on page 176, in which, as a tribute to British pioneering efforts in this branch of engineering, stress is laid on the early history of the subject. As before, the tale is told pictorially, beginning with the work of Trevithick and Stephenson. An example of the modern locomotive, shown in the illustration, is the 4-6-4 R-class built for the Victoria Government Railways by the North British Locomotive Company, Limited, Glasgow. In the centre of the hall, the development of railway rolling stock from the days of primitive engines and open trucks to the streamlined expresses of to-day is demonstrated.

A reproduction of the upper class portion of an electric trailer car, which forms part of a contract for the Indian Government Railways, is being exhibited by the Birmingham Railway Carriage and Wagon Company, Limited, Smethwick, Staffordshire. An actual car is illustrated in Fig. 146, on page 167. Two of these trailers form the centre of a four-car train, the pair consisting of an open lower class saloon car and an upper and lower class segregation car with a portion reserved for women. The first of these cars can accommodate 122 seated and 109 standing passengers, and the second 98 seated and 95 standing passengers. The length over the body is 68 ft. $0\frac{3}{16}$ in., the width over the side panels 11 ft. $11\frac{3}{16}$ in., and the height from the rail 12 ft. $6\frac{1}{8}$ in. The gauge is 5 ft. 6 in. Aluminium paint is used for the finish of both cars.

Other reproductions include a lightweight non-driving motor car, embodying the latest developments of aluminium-alloy construction, and a multiple-unit electric motor car for use on the Indian Railways, both of which are being shown by Metropolitan-Cammell Carriage and Wagon Company, Limited, Birmingham. There is also a 10-mm. scale model of a 1,600-h.p. Diesel electric locomotive for the Egyptian State Railways, being shown by the Vulcan Foundry, Limited, Newton-le-Willows, and the English Electric Company, Limited; a 2,800-h.p. gas-turbine electric locomotive for the British Railways (Western Region), which is being exhibited by Metropolitan-Vickers Electrical Company, Limited, Manchester, and of a "River" class steam goods locomotive for the Nigerian Railways, as well as a number of smaller units.

Mention may also be made of the 270-h.p. turbo-charged compression-ignition engine, exhibited by Henry Meadows, Limited, Wolverhampton, and illustrated in Fig. 145, on page 167. This is of the four-stroke direct-injection cold-starting type and is fitted with an exhaust-gas turbo-charger so that its full power can be maintained at altitudes up to 3,000 ft. above sea level. This turbo-charger is water-cooled from the engine system and the air intake can be either through a filter-silencer or from a remote source of supply. The starting equipment includes two 24-volt motors and a dynamo.

The Hall of the Future, which forms the last stage on the suggested itinerary through the Exhibition of Industrial Power, is on three levels. In a series of pits the great pioneers of the past are seen at work. Present-day work on atomic research is displayed at floor level, while the future is depicted as an illuminated cone the top of which pulsates and throws off flashes to a "sky" which is arranged above it. The pioneers celebrated are Watt, Trevithick, Faraday, Parsons and Rutherford. The process of releasing atomic energy is explained on a series of panels. The individual models include one of a beam engine and another of an early turbo-dynamo, while a Tesla insulation tester with a normal operating voltage of 750 kV and a frequency of 130,000 cycles, which is usually installed in the Research Laboratories of the Metropolitan-Vickers Electrical Company at Trafford Park, is exhibited by that firm.

Radar in Merchant Ships.—Notice No. M.352, which has been issued by the Ministry of Transport and replaces Notice No. M.317 of May, 1948, lays down the precautions which must be taken by owners, masters and officers of merchant ships before radar sets are installed. Care must be taken to avoid interference with compasses and the aerial unit must be sited so that "shadows" are not produced. The alternatives of placing a single display unit in the chart room or wheel house are considered and some useful information is given regarding the lengths of wave-guides and cableruns, accident prevention and interference with radio reception. Copies of the notice are obtainable free of charge from the Ministry of Transport Marine (Navigational Aids) Division, Berkeley Square House, London, W.1, or from the Ministry of Transport Survey Offices at the ports.

THE JOINT ENGINEERING CONFERENCE, LONDON.

(Continued from page 152.)

The report given below of the paper and discussion on "Radio Masts and Towers" is followed by a report on the morning meeting of Wednesday, June 13, which was devoted wholly to the education of engineers.

Radio Masts and Towers.

The meeting held at the Institution of Electrical Engineers on Tuesday, June 12, was presided over by Sir Stanley Angwin, and a paper on "Radio Masts and Towers" was read by Mr. C. O. Boyse. The author pointed out that, when low frequencies were used, the higher the radiating wire could be raised above the ground the stronger became the received signal. This led to the use of wooden and, later, steel structures to support the aerial wires as high as possible, and it was also realised that the "centre of gravity" of current in the aerial could be raised by increasing the aerial height to approach half the wavelength. The height of aerial which was most effective in reducing fading was also half a wavelength. For broadcasting, the trend was therefore towards the use of such half-wavelength aerials employing slender masts supported by stay ropes. As the effect upon radiation of a large number of stay ropes was uncertain, masts supported by only one set of stays were built and, to economise steel, were tapered from points at the top and bottom to a maximum width at the stay attachment point. It was found, however, that the advantages of only one set of stays were not all-important and that variations in the cross section of the structure over its height were undesirable. Later masts were therefore parallel-sided and usually stayed at several points, each stay being divided electrically into sections by insulators.

To reduce high-angle radiation and its consequent fading effect, the radiator was divided electrically into two parts by insulation and by grading each part in a particular manner. With the increasing use of high-frequency waves directed into narrow beams, a suitable aerial for broadcasting was found to comprise a number of horizontal dipoles stacked in the form of a curtain of wires about two wavelengths wide and two wavelengths high. These always required groups of masts of medium height. At still higher frequencies, such as those used for television and certain communication systems, the aerials required were quite small, but their height above the ground was of paramount importance. For ultra and super-high frequencies, the aerials were usually in the form of radiators and reflectors, and the principal requirement of the supporting structures was that they should be extremely rigid with the allowable deflections in azimuth and elevation limited to not more than 1 deg. Self-supporting towers were generally used, their height depending upon the desired range of the repeater stations and the profile of the route of the link.

These points were illustrated by descriptions of typical British-built masts and towers. There was nothing to suggest that radio structures were likely to undergo any major change in form in the immediate future. Specific points, such as wind and ice loads on the aerial wires, would, however, need to be studied. Light alloys would come into use only if they led to cheaper structures. Welding might tend more and more to replace other types of connection. Above all, the aim would be to produce high-strength structural members having low wind resistance.

Discussion.

The discussion was opened by Mr. M. T. Tudsbery, who said that he still favoured the conditions for wind pressures on masts laid down by Elwell in 1923 and the old factor of safety of four for the whole installation; or, alternatively, the British Broadcasting Corporation's specification. Experience over 15 years showed that these conditions could not be improved upon. He would therefore like to ask the author what advantage he would expect from the new basis of design advocated in the paper. It would seem that the saving would be small.

Mr. C. D. Brown pointed out that the British Broadcasting Corporation's specifications laid down that there was to be an aerial pull of six tons in any direction. This raised a difficult problem for the structural engineer. It would pay to limit the amount of the deflection in the masthead and so keep the strength of the structure and the stays under control. An increase in the stay tension of 50 per cent., which was unthinkable, would only mean an increase in the maximum working load in the stay from 25 to 26½ tons, so that the problem of what happened to the bending moment when the stays were incorrectly tensioned was not so serious as suggested by the author.

Mr. A. Stewart said that the erection of masts called for close co-operation between the designer and erector. This would lead to panels of a more economic length being employed. A fitting might also be put on the structures to take the pennants and guides on the floating derrick. Built-in electric strain gauges would do much to solve tension problems.

Mr. E. Hall called attention to the difficulty of determining wind load, which was not steady but more in the nature of a turbulent stream. The only safe course was to assume the worst possible wind load and design the structure on that basis. As masts could not be easily replaced, a good factor of safety was justifiable. The wind velocities recommended by the author seemed rather high. He would like to have heard more about the justification for staying in three rather than four directions. Mr. F. D. Bolt thought it was necessary that a mast should support a load in any direction, particularly in short-wave arrays where the direction of the wave would be changed. This caused difficulties with the structural engineer.

Mr. H. W. Grimmitt said that the first requirement was that the tower should support itself without any load on it at all and with a certain amount of rigidity. He was not alarmed at a six-ton pull at the top of a 1,000-ft. tower, although he could not imagine how such a load occurred on these aerial arrays.

The chairman pointed out that, when the first heavy insulated masts were erected in this country, one of the biggest problems was with the insulators. The difficulty was not mechanical but with the dielectric losses, which caused internal fusing. Porcelain, however, could now be produced which stood up well to both dielectric and mechanical stresses. This was another example of the necessity for the closest co-ordination between electrical and mechanical requirements.

Mr. C. O. Boyse, in reply, said he had not advocated a reduction in safety or an appreciable reduction in cost. The factor of safety was a delusion and it was evident that there was no agreement as to what wind pressures should be allowed. A number of the items in mast design were unknown and were a matter of guesswork. That was one reason for advocating a change in approach; another was that it might be necessary to erect higher masts in future. The whole business of wind loading must be reduced to an empirical problem. He had not advocated ignoring ice on structures, but it was simpler to take a very heavy wind load without ice than to juggle with innumerable combinations of different amounts of wind and ice. When it came to wires, the problem was still more difficult and a serious attempt should be made to evolve some general working rules. He would like to see a formula, which would give some idea of cost, but there were too many variables involved.

University and Technical College Education.

Dr. D. S. Anderson, B.Sc., M.I.Mech.E., took the chair at the meeting on June 13, at the Institution of Civil Engineers, when Professor J. F. Baker, O.B.E., M.A., M.I.C.E., presented a paper on "The Development and Trend of University Education in Engineering," and Dr. H. L. Haslegrave, M.A., Wh.Sc., M.I.Mech.E., M.I.E.E., gave one on "The Contribution of the British Technical Colleges to Engineering Education." The papers were discussed jointly.

Professor Baker's review of the history of engineering education in the Nineteenth Century was epitomised by his quotation, dated 1870, that "it is not the custom in England to consider theoretical knowledge as absolutely essential." Progress was slow, and even by 1851, by which time some of the nation's greatest engineering achievements had taken place, there were only five schools of engineering in the United Kingdom. The early schools were at Durham University; University College and King's College, London; Glasgow University; Dublin; and Belfast. For 50 years, King's College was the largest engineering school in the country. Owen's College, Manchester, was founded in 1851; a chair of engineering was established there in 1868, also in the same year at Edinburgh, and the Cambridge chair was established in 1876. About this time, the development of teaching laboratories in engineering began, the pioneering work being largely due to Professor A. B. W. Kennedy of University College. Meanwhile, chairs of engineering were founded in colleges throughout the country, but staffs and buildings were generally inadequate for the needs, though 24,000*l*. were spent on the laboratories at Liverpool.

By 1931, Professor Baker continued, the problem of engineering education appeared in another form: industry accepted the graduate but did not know how to use him. The 1914-18 war had made industry realise the advantages to be gained from the application of science to production and design problems, though the universities generally were slow to respond. The 1939-45 war led to a definite modification of the university attitude, and to a doubling of the number of students in applied science. Some universities were now questioning the value of formal experiments in the laboratory and were introducing small investigations and projects in the final year as a means of encouraging initiative and a methodical approach to new problems. In his conclusions, Professor Baker mentioned particularly the thorny question of the place of technology in the universities, and stressed that engineers should be taught by engineers, who must themselves maintain contact with industry either by engaging in applied research or by acting as consultants. Reference was also made to the value and potentialities of post-graduate courses.

Dr. Haslegrave's paper on "The Contribution of the British Technical Colleges to Engineering Education" consisted of a historical review and suggestions for future educational methods and financing. The principal early developments were the founding of the Society of Arts in 1754, which was to have a considerable effect on the growth of technical education; the establishment of night schools, starting with one at Third Lanark Mills in 1784; and the founding of literary and philosophical societies and mechanics' institutes, which were local and voluntary efforts. The lessons to be learned from the history of this period, Dr. Haslegrave pointed out, were: voluntary effort was most important and valuable; technical education could only be built on a foundation of good general education; methods of teaching must be adapted to suit the characteristics of the students; and no student should be prevented by lack of financial resources from obtaining educational facilities up to the limit of his ability to profit from them.

From 1851 to 1870, Government financial assistance to night schools was inaugurated and developed; it had the disadvantage that the examinations reflected the experience of the officials who set them, in Government departments, dockyards and the armed services, rather than the needs of productive industry. An Act of 1890 authorised county councils to give funds for commercial and technical education, and 12 years later the power of the councils in this respect became complete. Meanwhile, several notable advances had taken place; the foundation in 1868 of the Whitworth Scholarships; the formation of the Trade Guild of Learning in 1873, fostered by prominent trade unionists and others; the contributions of the City Livery Companies towards the founding of technical colleges; the incorporation in 1880 of the City and Guilds of London Institute; the formation in 1847 of the Union of Lancashire and Cheshire Institutes; and the creation of numerous technical colleges, sometimes from the existing mechanics' institutes. Evening classes, which imposed a strain on the youths and adults who had long working days in the factories, were the general rule, though part-time day release had been granted in one works as early as 1884.

The four channels of development during the period 1905 to 1939, Dr. Haslegrave continued, were as follows: the formation of new colleges and extension of existing ones; the provision of related subjects and the development of the course system; the extension of part-time day releases; and the provision of courses in the engineering, and other, crafts. The 1914-18 war strengthened the ties between technical colleges and the engineering industry, an indirect result being the formation of the National Certificate Scheme. Unfortunately, National Certificate courses were often followed by students who should have taken craft courses, just as external degrees were often taken in cases where National Certificates would have been more appropriate.

After the 1939-45 war, which threw a tremendous load on the technical colleges, the developments in technical education which had been eagerly anticipated were prevented to some extent by the national economic conditions, though two of the recommendations of the Percy Committee were adopted, namely, the formation of national colleges and the setting up of regional advisory councils for further education. A scheme for the creation of a Royal College of Technologists was prepared with the object of attaining a higher standard of technical education. Concluding his historical review, Dr. Haslegrave mentioned two major problems of technical colleges—finance, and the fact that craft courses, and the technical sides of elementary, senior, and advanced grades are often carried out in the one institution, with some teachers taking classes in all the grades.

Looking to the future, Dr. Haslegrave outlined his suggestions for improving the educational facilities in technical colleges for the three groups of engineering personnel—professional engineers, technicians, and craftsmen. The courses for professional engineers would lead to the award of the Associateship of the proposed Royal College of Technologists. The courses would differ from the normal degree course, since it seemed, the author stated, that it is necessary for the young engineer to play an important part in actual production at an earlier age than is possible with students who take a full-time degree course followed by two years' practical training. The proposed courses for technicians and craftsmen were designed to meet the great diversity of needs.

Dr. Haslegrave's concluding suggestion related to a better method of financing at least part of the work of technical colleges. "The present method," he stated, "of the financial load being shared by the local authority and the national exchequer has many disadvantages; direct grants from the national exchequer also have disadvantages. Can a method be devised of direct industrial contribution similar to that obtainable in France? If industry paid part of its tax into a technical education fund, instead of first into the general national pool, and from this fund grants were made to technical colleges on the governing bodies of which sit representatives of the contributing industry, some of the benefits of local patriotism would be preserved; industry would see immediately the results from some of the taxes it had paid; and increased expenditure on a technical college would not depend upon the willingness of a local authority to increase its rate."

Discussion.

Colonel B. H. Leeson opened the discussion. He said that there were two main roads along which a man might travel to become a professional engineer; he might approach it from the university end or from the other end. With the first, the undergraduate had very little, if any, real contact with industry. He was approaching his subject as a fundamental science, which later on he would apply. The man who took the other road had very little idea of the sciences at all; he started from the practical end, and was familiar with a side of which the university student might never have had any real appreciation. His whole approach, therefore, was different; and, whether he went to evening classes or took part in "sandwich" courses, he could never have quite the same kind of training, although the training he received might in itself be even more effective in after life than the university training, depending largely on the man himself. Was it necessarily logical to say that where the two approaches overlapped, in the technologist, the award should necessarily be the same without regard to the approach? Here, Colonel Leeson would put his case merely by a plea to retain unaltered, and not to extend, the university degrees which had been established in this country, and which had a nation-wide and world-wide reputation. He would prefer to see some other award created, which would be similar but which would be built up by its own merit, because then it would be something which was permanent and stable. He would suggest that the emphasis in the report which proposed a Royal College of Technologists was in the wrong place. The first thing which should be done was to set up an administrative body which would have money to spend—so many million pounds a year—in the same way that money was spent on anything else to get services for industry. This body should be empowered to set up regional technical colleges—not a great number; they would have to grow, like everything else, but at all events a few regional technical colleges—with the most up-to-date equipment and also with the most up-to-date teachers, paid adequate salaries, and generally on the level which they would like to see if the provision made were to take its place alongside the level set by the universities. The colleges would be independent of local education authorities and under an administration under which they could develop and flourish.

Dr. S. Livingston Smith remarked that it had been said that in America the output of university graduates was rising exponentially, and thus keeping pace with the country's increasing productivity, whereas in Great Britain the rate of output was not keeping pace with the increased productivity of our industries. Professor Baker had said in his paper that the most striking change brought about by the 1939-45 war had been the doubling of the number of students in university departments of applied science. It was comforting to know, however, that the rate of output from the National Certificate scheme in mechanical engineering was rising exponentially. He was convinced that it would be far better for the university courses up to first degree standard to be very general indeed, and to teach the fundamentals of engineering science, on which could be built afterwards the specialised knowledge which the students might require after they had gone into industry. There was the controversial question of whether the universities laid too much emphasis on training a particular type of mind. The university curriculum in engineering science, and a large amount of the last few years at school in such subjects, was almost entirely based on the assumption that the individual taking the course had a mathematical and analytical type of mind. He had always been struck by the number of students who came to the university who he knew instinctively would make good engineers of a certain type—not designers, not scientific men to work in research, but men who would get things done. There was a place, he felt, for the training of people with that type of mind, which was able to deal with methods of manufacture, with production, with getting things done.

Mr. P. E. Sleight said there was an increasing demand in technical colleges for courses designed specifically to meet the needs of the civil engineer. With regard to the proposed Royal College, he would prefer a college diploma in civil engineering which would be of a sufficiently high standard academically to be worthy of recognition by the Institution of Civil Engineers for examination or exemption purposes, not on a subject-for-subject basis, but as offering complete exemption on its own merits and on the reputation of the college and the college teachers.

Major E. Thomas, delegate of the Société Royale Belge des Ingénieurs et des Industriels, in a contribution to the discussion read by the chairman, gave a brief account of what was being done by the Society to provide engineers with a means of improving and widening the knowledge which they had acquired in the universities. Special committees had been set up. The first was the research committee, which strove to have highly technical subjects, most of which were in the vanguard of progress, expounded by Belgian and foreign experts. It arranged for their discussion, and arrived at conclusions which were finally passed on, in the form of resolutions, to the competent authorities. Secondly, there was the lectures committee, which organised lectures in the form of general expositions of technical and industrial problems. Thirdly, there was the section for the study of industrial economics, which investigated the main problems in the field of economics. Fourthly, there was the committee for the study of technical problems in the Congo and engineering opportunities abroad. There was also a committee on publications, a library committee and a junior committee.

Professor R. L. Lickley referred to one of the national colleges, the College of Aeronautics. That college had not been formed as Dr. Haslegrave suggested, as a result of the Percy Report, but as a result of a committee set up by Sir Stafford Cripps under the Chairmanship of Sir Roy Fedden, to discuss the provision of specialised training in aeronautics. At the College of Aeronautics they took students from the universities and the technical colleges, so that they got an idea of how both systems of education were running and of the type of man which they turned out. The man from the technical college was much more self-reliant; by virtue of his part-time course, he had had to build up, probably, a greater strength of character, and his connection with the shops had made him appreciate the necessity of relying on himself. From the teaching point of view, however, he suffered from a weakness in fundamentals. The university man, on the other hand, knew the fundamentals and knew a good deal of mathematics, but often had extreme difficulty in expressing himself on paper, either drawing paper or report paper.

Dr. J. E. Richardson said he had gathered that there was a strong "caste-feeling" abroad, with pure science in the superior caste position and technology occupying a somewhat lower place. The fact of the extreme usefulness of technology in industry would appear to be the cause of its condemnation. He could not understand that attitude. The first thing that he would ask for all colleges was a greater degree of academic freedom. Some of the technical colleges had so conducted their affairs that they had gained the right to a much greater degree of academic freedom than they in fact enjoyed. In one London polytechnic, for example, there were 1,062 internal engineering students of the University of London; but what academic freedom did the polytechnic enjoy? Far less than was found in many a provincial university, handling one-quarter of the volume of university work.

Mr. R. H. Coates observed that technical education was for the most part given by men who had been trained as engineers and who had, by and large, received no training at all in how to impart their knowledge to others. Taking engineering knowledge as the basic phenomenon, teaching was the first differential. What he (Mr. Coates) was talking about was the second differential, the rate of improvement in the art of teaching. He suggested that that would give greater returns to-day than anything else. The greatest problem was not the teaching of the young at all; it was the teaching of the men between 35 and 65 years of age. The medical profession had a method of teaching in their great teaching hospitals whereby the men who were practising were also teaching. It would be interesting to know whether both the authors considered that the best solution was to leave education where it was at the moment, as far as it went, but also to take education into industry, and whether the large organisations in particular should not endeavour to develop some form of teaching within their organisation.

Mr. F. C. Mead expressed his conviction that the undergraduate stage was rather too early for specific training in management, and he thought that the immediate post-graduate stage was also too early. The first step in acquiring management skills was the realisation that social science, which was concerned with human beings, was very different from physical science, which was concerned with materials and mechanical systems. The behaviour of human beings depended far more on teleological factors than on the causal factors with which engineers were more familiar. That was the sort of thing that the undergraduate engineer could profitably study at the university, and Mr. Mead suggested that an elementary study of scientific methodology, or even philosophy, would best supply the need at that stage. The poor quality of technical reports and papers was probably not due to ignorance of language at all, but to lack of precision in thought, and the study of methodology or philosophy would do much to correct this fault. Training in an applied field of social science, namely management, must, like other training in applied science, go hand in hand with practical experience. Unless the mind of the engineer had been matured by some experience in handling people, he would not appreciate the special nature of the problems in this field and be in the right frame of mind to benefit by specific instruction in the techniques of management. For that reason, it would be better not to attempt any instruction in management at the undergraduate stage or the immediate post-graduate stage, either in the universities or at similar stages in the technical colleges. Such instruction would be most valuable after some experience of engineering work in the field.

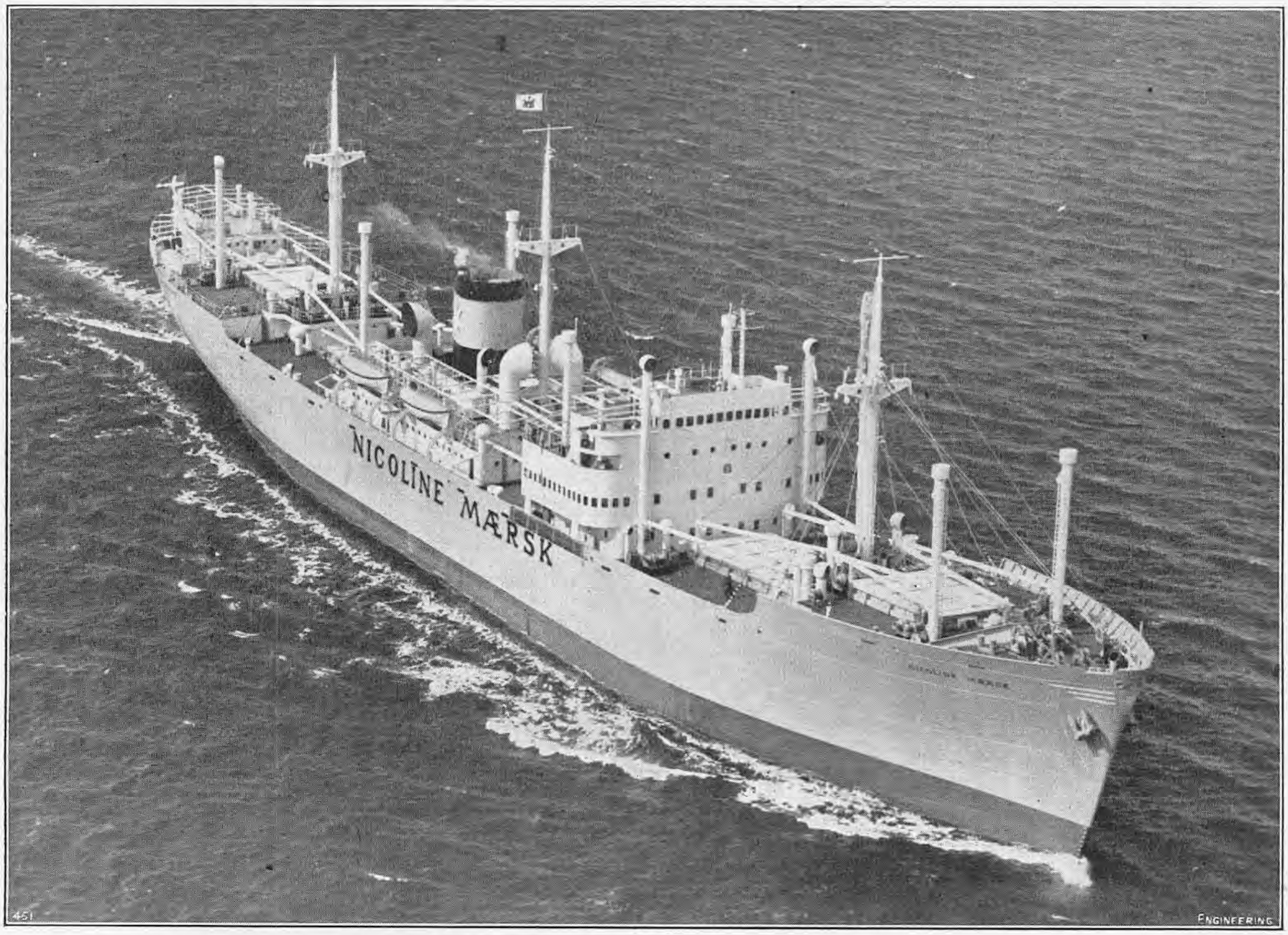
Mr. I. L. Holmes, who mentioned that he came from New Zealand, felt that instead of directing their attention to Government departments and committees, they could perhaps direct it to the public itself. They wanted a great deal more publicity for engineering education. It was to be hoped that the technical Press would give the Conference in this instance a little more than the half-inch of space which it seemed to be getting in the national Press. The national Press, it appeared, was concerned only with sensation, and even the senior daily papers had given more attention to an armed man-hunt and to social misfits than they had to the Conference. It might, therefore, be desirable to provide the Press with the sensation which they seemed to want. If it was desired to impress on the public the consequences of an inadequate expenditure on engineering education, something might be done, perhaps, to provide a sensation, and he suggested that "Engineering Faculty Closes Doors—Dean Refuses to Allow Overcrowding" might make a good headline. Public money was the first necessity, and its lack had been the principal cause of the slow developments in the past.

Professor Baker, in reply, said that Colonel Leeson and Dr. Livingston Smith seemed to approve of what was done at Cambridge and of his view of the function of the university, at least in its first degree course, namely, to keep the course as general as possible and not to have undue specialisation. He felt that since the war there had been some tendency in the universities to depart from that. It had to be resisted, however, and it could be resisted without the feeling that anybody was being hurt if the general scheme which he had outlined in the conclusion of his paper were borne in mind. Personally, he was not in sympathy with the idea of doing any specialised work after the three-year undergraduate course. Three years in an academic atmosphere was long enough for an impresssionable young man. What such a young man should do after that was to go out into the world and find out something about engineering and become enthused by it in a way which could not be done in the universities, and then he could be brought back. He said quite seriously that if industry was not prepared to take these opportunities of higher education then, as far as the universities were concerned, the best plan would be not to go on striving to do anything for engineering but to take the line of least resistance and return to academic mathematics and so on.

Dr. Haslegrave, in reply, said he thought that Dr. Richardson was too pessimistic. The technical colleges could make their own status. It must be remembered that of nearly 300 technical colleges in the country there were very few that could claim to be doing work equivalent to that of a university.

(*To be continued.*)

M.V. "NICOLINE MÆRSK."



THE DANISH M.V. "NICOLINE MÆRSK."

ON page 128, *ante*, we recorded that the shelter-deck motorship Nicoline Mærsk had been delivered to her owner, Mr. A. P. Møller, of Copenhagen, by the builders, Messrs. Burmeister and Wain, also of Copenhagen. By courtesy of the builders, who were also the contractors for the main propelling plant, we are enabled to illustrate the vessel herewith, and to append the following details of the ship and her machinery.

The Nicoline Mærsk is a single-screw cargo vessel of 9,210 tons deadweight carrying capacity, with machinery amidships, and has the following dimensions: length between perpendiculars, 445 ft.; beam 63 ft. 6 in.; depth at side, to upper deck, 41 ft. 6 in., and to second deck, 31 ft. 6 in.; summer draught, loaded, 27 ft. 8 in. She has a total cargo capacity of 630,000 cub. ft., of which 9,000 cub. ft. is refrigerated, for the carriage of meat or fruit, the temperature being adjustable between 12 deg. and —12 deg. C. Of the five holds, Nos. 1, 3 and 4 are provided with extra 'tweendecks, and the lower parts of Nos. 3 and 4 form four deep tanks for the transport of vegetable oil. The vessel has two continuous decks. She has been built under the survey of Lloyd's Register of Shipping. Welding has been used to a considerable extent in the hull. The vessel has three masts and ten derrick posts. The equipment for working cargo comprises one 50-ton and one 15-ton derrick, twelve 5-ton derricks, and eight of 3 tons lifting capacity, served by sixteen 3-ton winches and four of 7 tons capacity. All the winches, and the anchor windlass, are electrically operated and were supplied by De Forenede Maskinfabrikker, of Nakskov, Denmark. The steering gear, also electric, was supplied by Thomas B. Thrige, of Odense.

The propelling machinery consists of a Burmeister and Wain direct-reversing single-acting two-stroke Diesel engine of the airless-injection crosshead type, having ten cylinders with a bore of 740 mm., a stroke of 1,100 mm., and an output of 9,200 brake horse-power at 115 r.p.m., giving a loaded speed of $17\frac{1}{4}$ knots. The auxiliary machinery is all electric, power being provided by three six-cylinder four-stroke Diesel engines of the airless-injection trunk type, each driving a dynamo of 200-kW capacity at 200 volts at 425 r.p.m. The cylinders of these engines have a bore of 245 mm. and 400 mm. stroke, and each engine is of 300 brake horse-power. The larger pumps are of the vertical type, directly coupled to their respective motors. They include two screw pumps, each with a capacity of 340 cub. m. per hour, for circulating the lubricating and piston-cooling oil to the main engines; two centrifugal pumps with a capacity of 370 cub. m. each, to circulate salt water for cylinder cooling; and one of similar capacity for fresh cooling water. Two pumps, each with a capacity of 30 cub. m. per hour, are fitted to supply cooling water to the auxiliary engines; one of these pumps salt water and the other fresh water. The ammonia refrigeration plant was supplied by Thomas Sabroe.

The lubricating oil is drawn from a double-bottom tank under the main engine and is delivered through filters and oil coolers. The fresh-water pump, mentioned in the preceding paragraph, is used to maintain a closed circuit from the main engine to the fresh-water coolers and back to the main engine; an expansion tank for this circuit is fitted in the engine-room casing. The salt-water pumps draw from the sea and discharge through the oil coolers and the fresh-water coolers, and thence overboard. All the coolers are of generally similar design, with steel bodies, cast-iron covers, and yellow-brass tubes and tubeplates. In addition to the pumps mentioned above, there is a vertical-spindle self-priming centrifugal ballast pump, with a capacity of 150 cub. m. per hour; a two-cylinder reciprocating bilge and sanitary pump with an output of 40 cub. m. per hour; and a fuel-oil pump of 50 cub. m. per hour capacity. Starting air for the Diesel engines is provided by two electrically-driven two-stage compressors, each capable of compressing 5 cub. m. of free air per minute to a pressure of 25 atmospheres. There are two starting-air receivers, each of 15 cub. m. capacity. In the engine room there is also an auxiliary boiler for space-heating, steam heating being used throughout the accommodation for both crew and passengers; this boiler has a heating surface of 70 sq. m. and works at 7 atmospheres pressure. It is oil-fired.

Accommodation is provided on the bridge deck for 12 passengers in four single-berth and four two-berth cabins, with separate bathrooms and lavatories; and the deck officers also have their quarters on this deck. The engineers and the stewards have single-berth cabins round the engine-room casing; and the deck and engine-room ratings occupy single-berth cabins on the poop. The general equipment includes four 25-ft. lifeboats, carried in Welin-McLachlan gravity davits; and a full outfit of radar, wireless, and direction-finding instruments, a gyro-compass, and an echo-sounding machine. The hatchways measure 31 ft. 6 in. long by 18 ft. wide; 44 ft. $7\frac{1}{2}$ in., 34 ft. $1\frac{1}{2}$ in., 39 ft. $4\frac{1}{2}$ in., and 31 ft. 6 in. long by 20 ft. wide. Of the five holds, Nos. 1, 3 and 4 have extra 'tweendecks, the lower parts of Nos. 3 and 4 forming four deep tanks for the carriage of vegetable oils. A combination of natural and mechanical ventilation is provided in all holds, and there is mechanical ventilation in all the living spaces.

COURSES ON ROAD MATERIALS AND CONSTRUCTION.—Lecture courses dealing with the fundamental properties of road materials and their application in modern practice will be held at the Road Research Laboratory, Harmondsworth, West Drayton, Middlesex. Courses on concrete will be held from October 23 to November 1, and January 1 to 10, 1952; on tar and bituminous materials from November 6 to 22 and from January 15 to 31, 1912; and on soil mechanics from December 4 to 14 and from February 5 to 15, 1952. A special course, on road traffic and safety, of about one week's duration, will be held in the week commencing February 18. It will take place in the Traffic and Safety Division of the Laboratory at Langley Hall, near Slough. If sufficient entries are received, a special intensive course will be held for senior officers, from November 26 to 30. This course will include a survey of the most recent developments in road construction and usage. A fee of 7*l*. 7*s*. is charged for each course and will cover tuition and registration fees; the Laboratory does not provide living accommodation. Further particulars and forms of application may be obtained from the Director of the Laboratory at Harmondsworth.

DIESEL-ELECTRIC LOCOMOTIVE FOR CEYLON.

NORTH BRITISH LOCOMOTIVE COMPANY, LIMITED, GLASGOW.

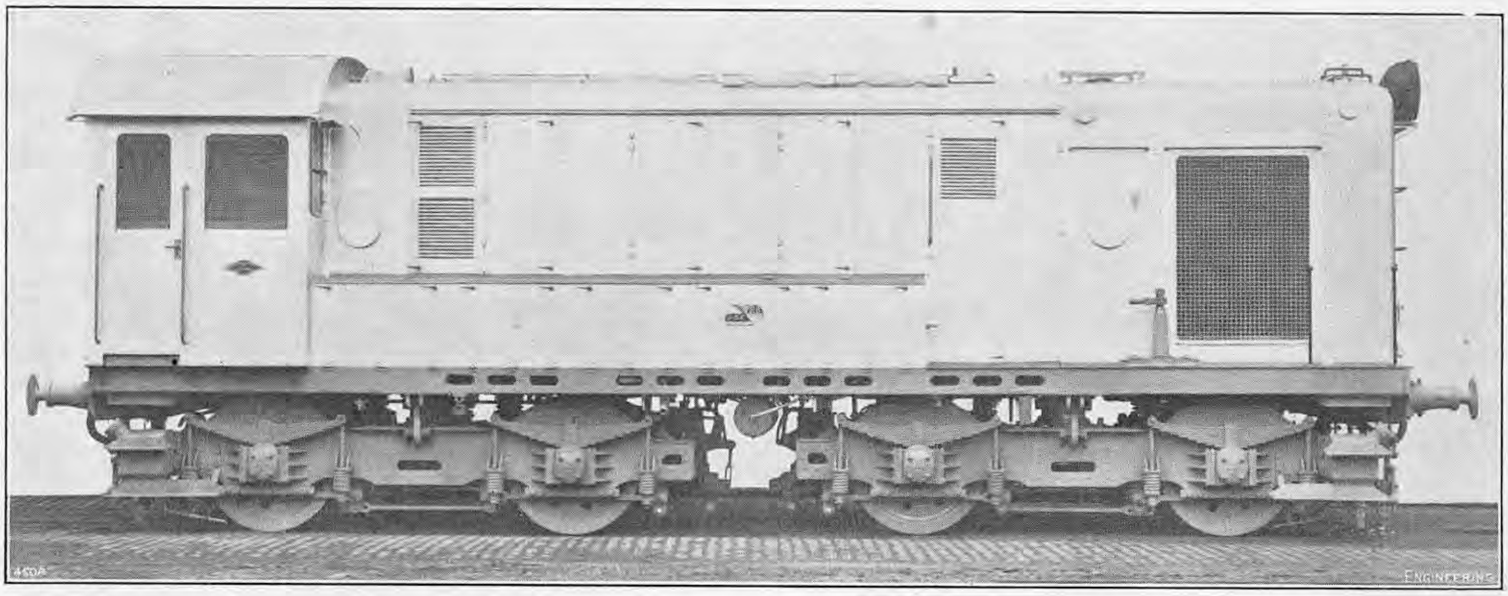


FIG. 1. GENERAL VIEW OF LOCOMOTIVE.

DIESEL-ELECTRIC LOCOMOTIVES FOR CEYLON.

EIGHT Diesel-electric locomotives for shunting and freight working on the Ceylon Government Railways, of which the track gauge is 5 ft. 6 in., have been built by the North British Locomotive Company, Limited, 110, Flemington-street, Springburn, Glasgow, N. One is illustrated in Fig. 1, herewith. The locomotives have been designed by the builders to the requirements of Mr. K. Rampala, chief mechanical engineer of the Ceylon Government Railways, and of the Crown Agents for the Colonies. The electrical equipment, main and auxiliary generators, traction motors and control gear, were designed and built by the General Electric Company, Limited, and the 12-cylinder V-type Diesel engines, type 12 RPHX, developing 625 brake horse-power at 1,250 r.p.m., were made by Messrs. Davey, Paxman and Company, Limited, Colchester.

The locomotive is carried on two four-wheel bogies, one of which is shown in Fig. 3, opposite. The total weight in working order is 54 tons; the axle load was restricted to 13 tons 10 cwt. The tractive effort is 35,000 lb., and the maximum speed is 20 m.p.h. Other dimensions are as follows: length over buffers, 37 ft. 9 in.; bogie wheelbase, 8 ft.; total wheelbase, 25 ft.; wheel diameter, 3 ft. 7 in.; and reduction-gear ratio, 17·14 to 1.

The main frames and bogie frames are welded structures of steel sections and plates, as light as possible consistent with strength. Side bearers with rubbing faces of manganese steel, each backed by a damping pad of rubber, are mounted on the bogie frames to carry the weight of the body. The spherical seat of each bearer sleeve is supported on a helical spring. The bogie centre pins carry the traction forces only, and have spherical collar mountings in the bogie cross-stretchers to allow for variations in track aspect. Each double-reduction drive from the four traction motors is housed in a single gearcase, the intermediate shaft running in bearings in the gearcase itself. The bogie suspension springs are slung above the axleboxes on adjustable links supported by shock-absorbing helical springs. S.K.F. double roller-bearing axleboxes with grease lubrication are mounted outside the wheels, and manganese-steel liners are fitted to the axleboxes and their guides.

The radiators are located on each side of the superstructure at the forward end, the fan motor drawing air through the radiators and expelling it through the roof. By suitable screening, the air passages of the radiator system are completely separated from the rest of the locomotive. The fan motor is connected across the auxiliary generator so that it runs up with the engine when the power unit is started. It is arranged to run at reduced speed on the first six controller steps and at full speed, by means of a field tap, on the last six steps. These speeds are selected entirely automatically by means of contacts on the master controller.

One main fuel tank is placed at the front end of the engine compartment and a second at the rear end of the generator compartment, the two being connected by a balancing pipe. A fuel service tank, mounted over the front tank, is supplied while the engine is running by a fuel transfer pump, driven by a $\frac{1}{4}$-h.p. electric motor connected across the auxiliary generator. The motor can be operated from the battery if there is insufficient fuel in the service tank for starting the engine. The filling connection is at platform level, with a low-pressure compressed-air service line for transferring fuel oil to the locomotive tanks. Special attention has been paid to filtration of air and oil services: fuel oil passes through a gauze and two fabric filters, while the engine lubricating oil passes through a magnetic filter as well as a large-capacity fabric filter. The locomotive superstructure embodies hinged side doors, easily removable for access to the engine and generator compartments, and removable roof sections over the engine and generator. A bulkhead separates the generator from the Diesel engine. Cooling air for the generator enters the generator compartment through panel filters on the sides. A portion of this air is used for the traction motors on the rear bogie, while cooling air for the front bogie motor is drawn in from a panel filter unit mounted behind the front door of the superstructure.

The Diesel engine and main generator, with an overhung auxiliary generator, as shown in Fig. 2, opposite, are mounted on a light-weight welded underbed, supported on the main frame at four points. Adequate distribution of load is provided by a four-point mounting system, which incorporates Neo-K-Tex shock-absorbing pads in conjunction with the holding-down bolts to give insulation from shocks and frame flexure. The engine, which drives the generators through a Wellman-Bibby flexible coupling, has a bore of 7 in. and a stroke of $7\frac{3}{4}$ in. It develops 625 brake horse-power at 1,250 r.p.m., with a brake mean effective pressure of 110 lb. per square inch. The combustion system is the Ricardo Comet Mark III. Twin Brown-Boveri gas superchargers are fitted, producing a normal increase in rating of 25 per cent. Exhaust piping connects with the two turbine inlet ports of each supercharger, the outlets being through ducts up through the roof of the locomotive. The air intakes are fed through circular Vokes five-ply filters integral with the superchargers.

The lubricating system is primed by a Roloid oil pump driven by a $1\frac{1}{2}$-h.p. motor. In this locomotive, the fuel-pump control is operated by the lubricating-oil pressure, and an increased fuel supply is provided when the priming pump for the lubricating oil is in operation before the engine governor has taken charge; this provides excess fuel at starting. The priming-pump motor is stopped automatically and the normal engine lubricating pump takes over well before idling speed. An oil-operated relay prevents the engine being started until the lubricating-oil pressure has reached a suitable value, and will stop the engine should the pressure fail. Engine speed is governed by a centrifugal hydraulic servo-governor, driven by bevel gearing from the end of the camshaft. In addition to controlling the fuel supply, the governor is linked to a valve which can admit oil to the servo-motor of the automatic load-control rheostat if the engine speed varies from that selected by the speeder bar. The engine speed is set by pneumatic pistons, operated by electro-pneumatic valves energised through the master controller, which act on the speeder bar. Eight speeds are obtained with only three pistons by means of a linkage between the piston rods and the speeder bar.

The main and auxiliary generators are built as a compact unit, attention being paid to providing maximum accessibility in a design suitable for installation in a confined space. Excitation for the main series winding of the main generator is provided by the auxiliary generator, no separate exciter being employed. In addition, the main generator has a self-excited winding which assists the separately-excited field; a series winding arranged to give a drooping characteristic to the generator output and to limit the maximum current; and a starting winding to enable the generator to be motored for starting the Diesel engine.

The locomotives are being delivered with a removable stop fitted on the ninth controller notch, the three remaining notches, giving engine speeds up to 1,250 r.p.m., being unnecessary for the class of service on which the locomotives are to be employed at present. Alternatively, steps are being provided so that the controller may be limited to any of the top three steps to suit any service conditions which the locomotives may have to undertake at a later date. Constant engine loading is obtained through adjustment of the main-generator field by means of an oil-operated rheostat under the control of the engine governor. This feature does not operate on the lower notches, where full engine output is not absorbed. When it is operative, it also safeguards the engine from being stalled and permits the locomotive to be worked safely for short periods even if an engine fault has reduced the engine output far below normal. The action of the automatic control is quite simple. Should the Diesel engine be overloaded by a change in gradient, it will slow down, causing a change in the governor setting, which operates the rheostat in such a way that the voltage on the main generator is reduced. This, in turn, reduces the supply voltage to the traction motors and the speed of the locomotive. When the gradient eases and the tractive effort falls off, the locomotive speed will be increased, absorbing constant output.

The auxiliary generator is a 25-kW machine giving an output of 110 volts for all auxiliaries, battery charging and control circuits. Voltage is maintained within $\pm$ 3 per cent. by a carbon-pile regulator. Normally, the auxiliary generator is excited from the battery, but in the event of the battery being completely discharged and a road start being necessary, contacts on the battery isolator provide for self-excitation of the generator. In addition to the fan motor and oil-priming pump, the auxiliary machines comprise a Westinghouse DH 25 compressor for the control equipment and locomotive braking, and two Westinghouse 3V73 Westex exhausters for the train brakes. Both machines are supplied from the battery. Normally one or both exhausters, according to the type of train, are run at low speed in order to maintain a vacuum. When the driver's brake handle is placed in the release position and a trigger switch in the handle is depressed, the exhausters run up to full speed for rapid release of the brakes. Application of the train brakes by

DIESEL-ELECTRIC LOCOMOTIVE FOR CEYLON.

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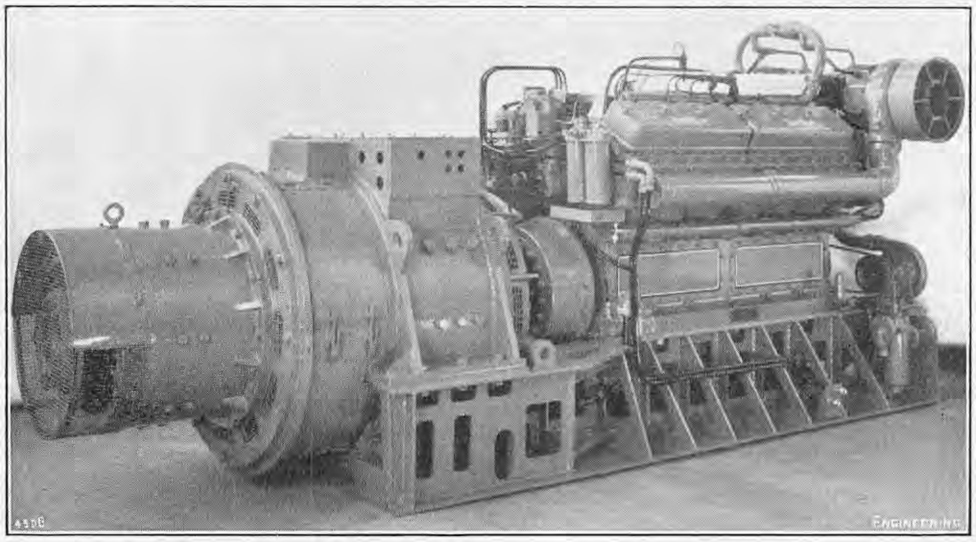

FIG. 2. DIESEL ENGINE AND GENERATOR.

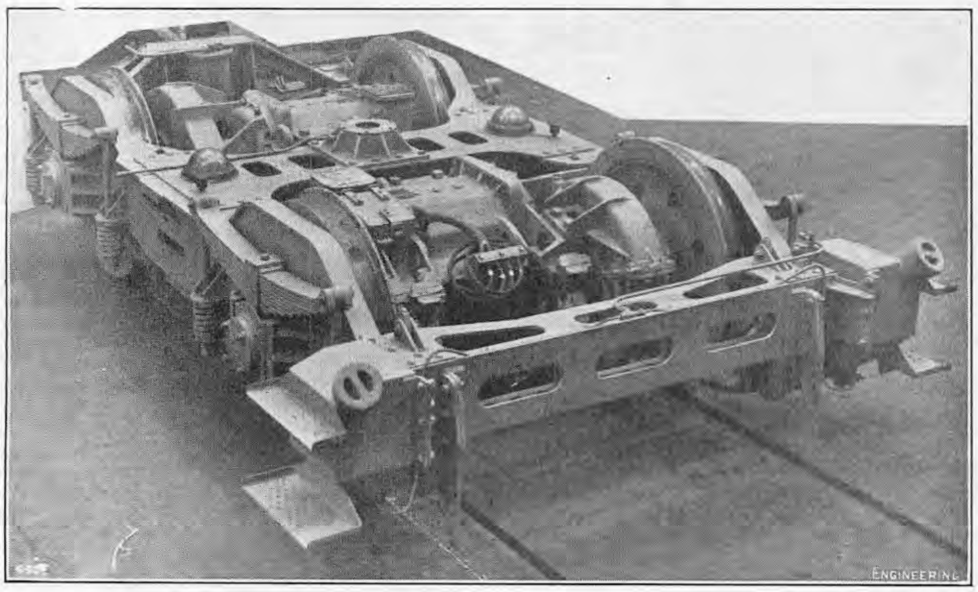

FIG. 3. BOGIE.

means of the vacuum-brake handle causes automatic application of the locomotive brakes to a corresponding degree by the action of a vacuum-air proportional valve. All the lighting and control circuits are connected across the battery, and are run normally at 110 volts.

The master controller and the two brake valves are mounted in the driver's desk. They are provided with duplicate operating handles for convenient operation from either side of the cab. The master controller is locked in the "off" position, and the locomotive immobilised, by means of a reverse key lock operated by a key removable only in the "off" position. The reverse key lock also has an "engine-test" position which, while keeping the reverse drum in the "off" position, permits the accelerating drum to be operated to test the Diesel engine through its full operating range of speed without moving the locomotive. Also mounted on the desk is a control key switch, the key of which is removable only in the "off" position, when all the control current is cut off. Two dead-man's pedals are provided, one on each side of the desk in a recess near the floor; there is a time delay on the operation of this control, so that the driver can move from one driving position to the other without stopping the locomotive. All switches and controls which are not in frequent use are housed inside the control desk. A comprehensive range of instruments is mounted on a sloping panel at the back of the desk. This panel also carries the push-buttons for starting and stopping the engine, the exhauster switches and most of the lighting switches. A voltmeter and ammeter are provided for the main generator and the battery. The ammeter for the battery has a centre-zero scale to show charge or discharge. An Elliott electric speedometer, operated from a generator on the rear axle of the rear bogie, is fitted in the centre of the panel. Other instruments include two exhaust temperature indicators, an engine revolution indicator, air-pressure gauges, and the usual gauges for the vacuum and Westinghouse braking systems. In addition, the locomotive is equipped with a mileage counter, with compensation for reduction in wheel diameter, and with a recording instrument showing the time during which the locomotive is running or stopped, or standing with the engine idling.

"NEW POWER STATIONS FOR THE B.E.A.: XV.—BLACKWALL POINT": ERRATUM.—Our attention has been drawn to an error, which we regret, in the article on Blackwall Point power station, on page 692, in our issue of June 8. It was stated that one of the coal conveyors is being supplied by Messrs. Robert Dempster & Sons, Ltd., which is correct; but their address should have been given as Elland, Yorkshire, not Manchester.

BRITISH MINESWEEPER FOR BELGIAN NAVY.—H.M.S. Fancy, a minesweeper of the Algerine class, has been transferred to the Belgian Navy. The ship was formally handed over at Portsmouth on August 9 by Rear-Admiral J. P. L. Reid, C.B., Chief of Staff to the Commander-in-Chief, Portsmouth, and accepted on behalf of the Belgian Ministry of National Defence by Lieut.-Col. E. Delelienne, the Belgian Military Attaché in London. The Fancy is the fourth ship of this class which the Belgian Navy has acquired. H.M.S. Liberty was handed over at Portsmouth in November, 1949, H.M.S. Cadmus at Chatham in January, 1950, and H.M.S. Ready about a month ago at Portsmouth.

FRENCH TURBO-JET ENGINE ATAR-101.

WE have received recently a brochure issued by La Société Nationale d'Étude et de Construction de Moteurs d'Aviation (S.N.E.C.M.A.), 150, Boul. Haussmann, Paris (8e), France, in which, in addition to numerous photographic reproductions illustrating their facilities for development work and manufacture, there is a description of the first large axial-flow turbo-jet engine, the ATAR-101B, of French design and construction, which has undergone successfully the official type-approval test. During the test, which was carried out in February at the Centre d'Essais de Moteurs et Hélices, the static-thrust rating at sea level was 5,300 lb. (2,400 kg.). The engine has since been developed, and a similar unit tested at the Société's own test beds at Melun-Villaroche achieved a static thrust of 5,750 lb. (2,600 kg.) during a 15-hour run. Thrusts of 6,600 lb. (3,000 kg.) have also been recorded on several occasions. The lowest specific consumption attained up to the present was 0·96 lb. per pound-thrust per hour. The engine, installed in a Glen Martin Marauder aircraft, has also carried out about 100 hours of flight testing up to a maximum height of 24,500 ft. (8,000 m.).

The ATAR-101 engine, which has some unusual features, has a seven-stage axial-flow compressor with a compression ratio of about 4·5 to 1 at the maximum static r.p.m. The rotor, which is carried in a front deep-groove bearing and a rear roller bearing, is coupled to the single-stage axial flow turbine by a hollow shaft. The turbine guide vanes are of hollow steel and are air-cooled; the turbine blades, of a nickel chromium alloy, are solid. The walls of the combustion chamber, which is of the annular type, are double. Primary air is fed directly past 20 burners with duplex injectors; secondary air flows through the annular space between the combustion-chamber walls and enters the flame chamber through a series of orifices. The combustion chamber is equipped also with ten special starting burners and two sparking plugs. In order to prevent ice formation, hot air from the final compressor stage is led back to the air inlet.

An interesting feature of the ATAR-101 is the variable-area exhaust nozzle, which is automatically controlled by a regulator unit to maintain a constant gas temperature at the entry to the turbine, in accordance with the engine-r.p.m. setting selected by the pilot on his single-lever control. The temperature is measured indirectly from the rate of fuel flow and the pressure drop across the compressor. The regulator unit also includes a centrifugal engine-speed governor which varies the rate of fuel flow to maintain the engine revolutions at the value selected by the pilot. The fuel supply comprises a constant pilot flow and a variable main flow which is controlled by the fuel-metering mechanism in the regulator. Fuel is fed to the burners by a composite fuel pump consisting of a centrifugal feed pump discharging through a filter into a high-pressure gear pump, all enclosed in the same housing. An electrically-driven booster pump supplies fuel to the starting burners when starting the engine. Dry-sump lubrication is provided by an oil-pressure pump and three scavenge pumps, housed in a single unit; the pressure pump feeds to a distributor and thence to spray nozzles on the main bearings, the intermediate gears, and the regulator unit.

Power for the aircraft auxiliary systems is furnished either by two lateral or two vertical take-off shafts in front of the compressor. The total power available for driving the accessories is 250 h.p. From the take-off shaft, a universally-jointed intermediate shaft carries the drive to a remote auxiliary gearbox carrying a starter motor, a generator, a hydraulic pump, an air compressor, and a vacuum pump. An engine change can, therefore, be carried out without interfering with the auxiliaries.

The ATAR-101 engine has been designed as a compact and comparatively light weight unit, so that it can be completely buried in a wing installation. The maximum diameter over the turbine casing flange is 34·9 in. (886 mm.), an additional local allowance of 1½ in. being required to accommodate certain accessories. The overall length is 112 in. (2,845 mm.); the net dry weight of the version which will go into production, the ATAR-101C, without the starter and the remote auxiliary gearbox, is about 1,975 lb. (895 kg.). This mark of engine has a static thrust of 6,170 lb. (2,800 kg.), a maximum continuous thrust of 5,070 lb. (2,300 kg.), and a specific consumption of 1 lb. per pound-thrust per hour under maximum continuous thrust conditions. It is intended to develop the engine for higher thrusts, firstly by injecting water into the hollow guide vanes of the turbine, and subsequently by using after-burning in conjunction with water injection. It is estimated that maximum static thrusts of 7,300 lb. and 8,800 lb., respectively, may thus be attained. Engines with the first modification will be designated ATAR-101E and those with the second will be ATAR-101F.

NOTES FROM THE INDUSTRIAL CENTRES.

SCOTLAND.

SCOTTISH DIVISION, NATIONAL COAL BOARD.—The number of areas in the Scottish Division of the National Coal Board is to be raised to eight as from January 1, 1952, by the splitting of the Fife and the Ayr and Dumfries Areas into East and West Fife and East and West Ayr respectively. Mr. F. M. T. Bunney, at present area production manager in No. 4 Area, East Midlands division, is to take charge of the East Fife area, and Mr. Campbell Parker, area production manager, Central East area, Scottish Division, will take over East Ayr.

SHOT-FIRING IN COAL MINES.—Mr. H. R. Houston, Divisional Inspector of Mines for Scotland, said at Cowdenbeath on August 2 that more explosives were being used to extract a ton of coal to-day than ten years ago, and he thought too many shots were being fired in relation to the coal produced.

SCOTTISH MINERALS.—A display of some Scottish minerals and rocks which have been the subject of technical or commercial development, or study, in recent years, is being presented during the next few weeks in the Engineering Centre, Glasgow, by the Mineral Resources Panel of the Scottish Council (Development and Industry). The examples include, *inter alia*, serpentine, talc, garnet, dolomite, barytes, diatomite, silica, and quartzite.

EARLY MINING FINDS.—Parts of a simple pump, a large wooden shovel, and some iron wedges were among items of primitive mining equipment recovered from re-opened workings in an area of the Ell Coal seam, previously worked from the Quarter Colliery, near Hamilton. This pit was originally opened by the Duke of Hamilton early last century. Other relics included a length of guide rail believed to be for a sledge track, and old footwear, both men's and women's.

LEAD-ZINC ORES IN SCOTLAND.—An option on the mineral rights for the lead-zinc ore deposits at Leadhills and Wanlockhead, which have been unworked for from 15 to 20 years, has been negotiated by the Siamese Tin Syndicate, Ltd. The mines are expected to be re-opened if the results of a geological survey now being undertaken by the company prove favourable.

BRICKS FROM BELGIUM.—A shipment of 250,000 Belgian bricks has been landed at Leith to ease a shortage of Scottish bricks which is threatening to delay building work. Of common-clay quality, they will be used in one of Edinburgh Corporation's schemes. At a landed price of about 220*s*. per 1,000, they stand at about the same level as English bricks.

WOMAN LABOUR FROM ITALY.—As an alternative to a scheme to recruit 200 girls from the Greenock area to work in the Ferguslie Mills, Paisley, a proposal has been made to bring about 150 girls from the neighbourhood of Lucca, Italy, where there is a thread mill associated with the J. and P. Coats organisation.

PRIORY COLLIERY, BLANTYRE.—The question whether the Priory Colliery, Blantyre, which has been idle since April because of an overflow of water into the workings, should be re-opened, as suggested by the National Union of Mineworkers, or become a pumping station, as the National Coal Board consider it should from the point of view of safety, has been submitted to the Divisional Inspector of Mines for decision. Normal production at the pit amounted to about 600 tons a day.

FACTORIES FOR HERRING PRODUCTS.—Sir Frederick Bell, chairman of the Herring Industry Board, has announced in Edinburgh that a quick-freezing factory will be brought into commission at Port Glasgow in a few weeks' time. Reduction factories at Ayr and Peel (Isle of Man) are other projects of the Board to deal with the herring surplus.

CLEVELAND AND THE NORTHERN COUNTIES.

SUPPLY AND DEMAND OF NORTHERN PRODUCTS.—Conditions in the North-East Coast iron and steel producing areas continue to be disturbing, but movements that encourage the hope of a considerable increase in the supplies of commodities wanted in very large quantities are not absent. A check to industrial expansion is primarily attributable to the shortage of raw materials and scrap, and an appreciable increase in the deliveries of these commodities is expected. Already, in fact, the increase of foreign-ore imports is fairly large and the improvement promises to be more than maintained. Stocks, however, are at low levels. The enormous demand for iron and steel scrap is much greater than sellers can cope with, but deliveries are well maintained at the recent higher levels. Energetic efforts to secure larger quantities of scrap from home sources of supply are meeting with considerable success and a promise of the resumption of substantial imports from Germany is a very welcome announcement. Steel producers still experience great difficulty in dealing satisfactorily with their extensive commitments as they become due for delivery, but the feeling is growing that the fear of consumers regarding unavoidable huge restrictions in supplies may be exaggerated.

BARROW IRON AND STEEL WORKS.—The Iron and Steel Corporation of Great Britain, Chester-street, London, S.W.1, have agreed to take over the Barrow Iron and Steel Works from the Ministry of Supply, and have arranged for the works to remain under the management of the United Steel Companies, Ltd., Sheffield. The hoop rolling mills at the works, which are believed to have good prospects, are being modernised and an experimental pilot plant is being installed to try out a new process for the continuous casting of steel billets for the mills. Owing to the shortage of raw materials, steel production is expected to be limited to the mills' requirements, with the result that two out of seven open-hearth furnaces may be shut down and a number of employees permanently displaced during the next few months. The timing and application of this change is being discussed with the trade unions concerned. There are, however, several vacancies in the Barrow area and the Corporation hope that new jobs will be found for all the men involved.

LANCASHIRE AND SOUTH YORKSHIRE.

STEEL RESEARCH STATION.—The first two buildings of the steel research station, at Sheffield, sponsored by the British Iron and Steel Research Association, are in the skeleton-steelwork stage, and it is expected they will be ready for use by the end of the year. They include the mechanical-working division's building, where heavy plant, including a high-speed 14-in. cold strip-rolling mill and wire-drawing plant will be housed, and a melting shop where steel melting will be carried out in a 10-cwt. electric arc furnace. The buildings are estimated to cost 250,000*l*.

RE-INTRODUCTION OF STAGGERED HOURS.—Last winter, in Sheffield and district, the working of staggered hours was abandoned in favour of load-spreading, to give a 10 per cent. power reduction. It is probable that, this winter, staggered hours may have to be re-introduced in view of the vital necessity to avoid power shortage. Regional boards of industry are to submit plans to the Joint Advisory Council's meeting in October.

SHEFFIELD WATER ENGINEERING.—During the local holiday week, the Sheffield Corporation Water Department pursued the novel course of opening, for public inspection, their filter stations at Redmires, Rivelin, Ewden, Bradfield and Langsett. Advantage was freely taken of the invitation, visitors coming from as far as Cambridge and Buxton. A lighted filter, which was open, gave viewers an opportunity of seeing the process at work.

RECRUITMENT OF CRAFTSMEN FOR REGULAR ARMY.—There are some 4,000 notified vacancies in various branches of Sheffield industry, but recruiting for the Regular Army is being well maintained in the city. The number enlisting would have been much higher had it not been that as many as 40 per cent. of the applicants failed to meet the high educational standards now required. It is pointed out that the Army now has 99 recognised trades, and civilian employers are willing to accept ex-Service tradesmen as fully competent craftsmen.

THE MIDLANDS.

STEEL CONSUMERS' COUNCIL.—The Iron and Steel Consumers' Council, set up under the Iron and Steel Act, 1949, includes several Midland industrialists among its members. They are Mr. Ralph Bennett, chairman and managing director of Smethwick Drop Forgings, Ltd.; Mr. W. D. Wilson, chairman and managing director of George Wilson Gas Meters, Ltd., Coventry; Mr. M. C. Wade, of Charles Wade & Co., Ltd., Birmingham; and Mr. Basil Darby, senior partner of Darby & Co., of Birmingham. Mr. W. H. Stokes, who was for a long period chairman of the Midland Regional Board for Industry, and who recently resigned from that post when he was appointed a member of the Iron and Steel Corporation, is also a member of the new Council.

WEST MIDLAND MINING.—Following the decision of the National Union of Mineworkers to lift the ban on Saturday morning working, which was to have remained until September 1, 54 pits in the National Coal Board's West Midland Division were at work on July 28. The number of men who reported for the morning shift was 11,300, and the estimated output of coal was 18,000 tons.

THE MIDLAND REGIONAL BOARD FOR INDUSTRY.—The chairman of the Midland Regional Board for Industry is Major C. R. Dibben, who succeeds Mr. W. H. Stokes with effect from August 1. Major Dibben is well known in Midland industry as a director of J. Brockhouse & Co., Ltd., of West Bromwich, chairman of several Midland manufacturers' associations, and a member of the Grand Council of the Federation of British Industries. Major Dibben was a member of the Regional Board throughout the war, and has continued to serve on it since it was reconstituted as an advisory body.

BLAST FURNACE DISMANTLED.—No. 3 blast furnace at Round Oak Steelworks, Brierley Hill, is being dismantled. At present, about half the work has been done, and the site will be cleared in the course of the next few months. No. 3 is a large hand-charged furnace, built in 1941, and two earlier and disused furnaces were removed to accommodate it. The furnace was built with Government assistance as an emergency stand-by in case of damage by enemy action to other plants. It was dried out and was ready for use, but it was not needed, and so was never blown in. The auxiliary plant, including hot-blast stoves, is being dismantled at the same time, and a considerable quantity of valuable iron and steel scrap will be recovered. Thomas W. Ward, Ltd., Albion Works, Sheffield, are the contractors for the demolition.

COLE VALLEY DRAINAGE.—Birmingham Corporation have applied to the Minister of Local Government and Planning for authority to borrow 627,000*l*. for reconstruction work in the Cole Valley. The money is required for the construction of a new sewer between Hay Mills and Yardley sewage works. There are two existing sewers, but they were built in 1875 and 1877, and are too small for present-day needs. An inquiry has been conducted by Mr. I. H. Hainsworth, an inspector appointed by the Ministry. Mr. H. J. Manzoni, engineer and surveyor to the City of Birmingham, said at the inquiry that the overflow of untreated sewage into the River Cole was almost continuous, and many complaints had been received.

SOUTH-WEST ENGLAND AND SOUTH WALES.

REFUSE TIP AT NANTGARW COLLIERY.—Manufacturers on the Treforest Trading Estate, near Cardiff, are taking steps to oppose the National Coal Board's intention to place a tip for waste on the east side of the Estate, and in close proximity to their factories, to dispose of the refuse from the new Nantgarw Colliery. They point out that many of the factories depend upon a dust-free atmosphere. In a statement, Mr. John Partick, secretary of the Treforest Estate Manufacturers' Association, said that the Board, having spent 4,000,000*l*. on modernising the Nantgarw Colliery, were now proposing to revert to outworn methods in the disposal of waste. The 67 firms on the Estate employ more than 10,500 hands and, in the event of the establishment of the tip, many would be compelled to transfer elsewhere.

SATURDAY SHIFTS AT THE MINES.—South Wales miners have been urged by their leaders to abide loyally by the national decision and to work the Saturday shifts in August; the district, with Scotland, had voted against a resumption. It is not expected, however, that the response to the appeal will be on a large scale unti towards the end of the month, when the staggered holidays in the coalfield end. On the first Saturday, when the voluntary shift was re-introduced, only four collieries worked, all in the Aberdare area, and they produced less than 1,000 tons of coal between them.

BARRY DOCKS OIL STORAGE.—Oil-storage capacity at Barry Docks, at present being constructed by Cory Brothers, Ltd., is being greatly extended. Making reference to this at a luncheon last week, Mr. Tom Carpenter, the docks manager, said that the company would bring the total storage capacity in the area up to 120,000 tons of oil.

HILL FARMING SCHEME.—A recent report by the Welsh Department, Ministry of Agriculture, states that, up till June 30, approval had been given to 803 schemes, costing 1,094,598*l*., submitted by farmers in Wales for improvement of their land under the Hill Farming Act, 1946. "Live" schemes totalled 2,459, representing an estimated cost of 2,970,558*l*.

MINISTRY OF LOCAL GOVERNMENT AND PLANNING.—The Minister of Local Government and Planning (Mr. Hugh Dalton), has decided to set up in Cardiff a Welsh Office of his Department to administer the planning functions in Wales, and also the housing and local government functions hitherto carried out by the Welsh Board of Health. Mr. William Thomas, formerly a member of the Welsh Board of Health, will take charge of the Welsh office, which will be in the Welsh Board of Health building at Cathays Park, Cardiff.

NOTICE OF MEETING.

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.

ASSOCIATION OF SUPERVISING ELECTRICAL ENGINEERS. —*South-West London Branch:* Tuesday, August 14, 8.15 p.m., St. George's Hall, St. George's-road, Wimbledon. "Carbon Brushes for Electrical Machines," by Mr. C. T. Lawrence. *Manchester Branch:* Wednesday, August 15, 7.30 p.m., The Engineers' Club, Albert-square, Manchester. "The Swann Diploma," by Mr. W. Langley.

CONTRACTS.

CRAVENS RAILWAY CARRIAGE AND WAGON CO., LTD., Darnall, Sheffield, 9, have been awarded a contract by the Railway Executive for the supply of 1,000 four-ton steel containers of a new type for carrying ground limestone, dolomite, fluor spar, cement and similar products.

THE NORTH BRITISH LOCOMOTIVE CO., LTD., Springburn, Glasgow, N., have received an order from the South African Railways and Harbours Administration for 25 S1-class light locomotives and tenders.

THE BURNTISLAND SHIPBUILDING CO., LTD., Burntisland, Fife, have secured a contract to build a cargo motorship of 4,610 tons deadweight, for the Dundee, Perth and London Shipping Co., Ltd., Dundee. The vessel will have a length, between perpendiculars of 315 ft., a beam of 47 ft. 10 in., and a depth moulded of 26 ft. 3 in. The propelling machinery will consist of 1,900-b.h.p. Ailsa-Doxford Diesel engines constructed by AILSA SHIPBUILDING CO., LTD., Troon, Ayrshire.

During July the British Electricity Authority placed contracts for equipment for power stations, transforming stations and transmission lines amounting, in the aggregate, to 3,237,052*l*. The principal contracts include orders for one 30,000-kW turbo-generator set for Acton Lane "B" power station, Willesden, and one 52,500-kW turbo-generator set, feed-heating and condensing plant for Brighton "B" power station, with RICHARDSONS WESTGARTH AND CO., LTD.; jetty and river works at East Yelland power station, Barnstaple, with CHAS. BRAND AND SON, LTD.; structural steelwork for Tilbury power station, with ALEXANDER FINDLAY & CO., LTD.; boiler feed pumps for Meaford "B" power station, near Stone, Staffordshire, with MATHER AND PLATT, LIMITED; circulating-water intake and discharge works for Uskmouth power station, Newport, with HOLLOWAY BROS. (LONDON) LTD.; generator transformers for Ince power station, Cheshire, with the GENERAL ELECTRIC CO., LTD.; generator transformers for Roosecote power station, Barrow, with the METROPOLITAN-VICKERS ELECTRICAL CO., LTD.; high-pressure pipe work for Braehead power station, Renfrew, with BABCOCK AND WILCOX LTD.; a 75-MVA 132/33-kV transformer and earthing transformer for the Bedford National Aeronautical Establishment, with the ENGLISH ELECTRIC CO., LTD.; 132-kV 2,500 MVA switchgear and extensions for Kirkby substation, Lancashire, with FERGUSON PAILIN LTD.; 20-MVA 132/11-kV transformers and earthing transformers for Fawley substation, Hampshire, with the GENERAL ELECTRIC CO., LTD.; and 75-MVA 132/66-kV transformers and auxiliary transformer for the Dunston substation, Newcastle-upon-Tyne, with FERRANTI LTD.

ELECTRICAL INSTRUMENT TRAINING COURSES.—For many years Messrs. Elliott Brothers (London), Limited, Century Works, Lewisham, London, S.E.13, have provided training facilities for the staffs of the users of their electrical measuring and other instruments. These facilities have now been extended by establishing regular training courses, which will last three weeks and will be available free to employees of instrument users. The courses are intended for engineers with a basic knowledge of instruments and will cover the theoretical and practical aspects of maintenance and repair. Particulars of the scheme can be obtained from the Service Training Department of the firm.

SHEET METAL WORKING MANUAL.—A little work, entitled "The 'Besco' Pocket Manual for those engaged in Sheet-Metal Working," has been published by F. J. Edwards, Limited, 359-361, Euston-road, London, N.W.1. It has been compiled by Mr. J. W. Langton, M.B.E., B.Sc., M.I.Mech.E., and contains data on the bending, drawing and shearing of metal; succinct descriptions of sheet- and plate-working and tin-plate machinery, mechanical presses, and hand tools; and tables of various quantities, dimensions, factors, and equivalents. Many line drawings and half-tone illustrations are included. Copies of the manual are obtainable from the firm, price 3*s*. each.

LAUNCHES AND TRIAL TRIPS.

M.S. "CORNWALL."—Single-screw refrigerated-cargo vessel, built and engined by Alexander Stephen & Sons, Ltd., Linthouse, Glasgow, for the New Zealand Shipping Co., Ltd., and associated companies, London, E.C.3. Main dimensions: 460 ft. by 62 ft. 6 in. by 40 ft. 3 in.; deadweight capacity, 9,800 tons on a draught of 26 ft. 6 in.; gross tonnage, 7,600. Two Stephen-Sulzer Diesel engines working in conjunction with British Thomson-Houston slip couplings. Sea speed, 16 knots. Launch, June 21.

S.S. "VAN EYCK."—Single-screw trawler, built by Cook, Welton and Gemmell, Ltd., Beverley, Yorkshire, for the Motorvisscherij, N.V., Ostend, Belgium. Second vessel of an order for three. Main dimensions: 170 ft. by 29 ft. by 15 ft. 3 in.; gross tonnage, 580; fishroom capacity, 12,600 cub. ft. Triple-expansion engines and one oil-burning boiler, developing 900 i.h.p. at 125 r.p.m., constructed and installed by Charles D. Holmes & Co., Ltd., Hull. Speed, 12 knots. Trial trip, July 18.

M.S. "SAINT-GERMAIN."—Twin-screw vessel, carrying 500 passengers, built and engined by the Elsinore Shipbuilding and Engineering Co., Elsinore, Denmark, to the order of the French National Railways, Paris, for the train-ferry service between Dunkirk and Dover. Main dimensions: 380 ft. by 62 ft. by 35 ft. 9 in.; deadweight capacity, about 1,300 tons on a draught of 13 ft. 5½ in. Two Elsinore-B. and W. nine-cylinder two-stroke single-acting trunk-piston Diesel engines together developing 9,600 i.h.p. at 180 r.p.m. Speed, 18 knots. Trial trip, July 20.

S.S. "CANADA."—Single-screw tug, built by Cochrane & Sons, Ltd., Selby, Yorkshire, for Alexandra Towing Co., Ltd., Liverpool. First vessel of an order for three. Main dimensions: 99 ft. between perpendiculars by 26 ft. 6 in. by 13 ft.; gross tonnage, 230. Triple-expansion engines, developing 1,000 i.h.p., constructed and installed by Chas. D. Holmes & Co., Ltd., Hull. Trial trip, July 20.

M.S. "BRITISH GUIDE."—Single-screw oil tanker, built by the Furness Shipbuilding Co., Ltd., Haverton Hill, County Durham, for the British Tanker Co., Ltd., London, E.C.2. Tenth tanker built for these owners. Main dimensions: 490 ft. 10 in. overall by 61 ft. 9 in. by 33 ft. 11 in.; deadweight capacity, 12,135 tons on a summer draught of 27 ft. 6¾ in. Hawthorn-Doxford four-cylinder opposed-piston reversible heavy-oil engine, developing 3,300 b.h.p. at 108 r.p.m., constructed by R. and W. Hawthorn, Leslie & Co., Ltd., Newcastle-upon-Tyne. Service speed, 11½ knots. Trial trip, July 23 and 24.

S.S. "GEORGIOS."—Single-screw cargo vessel, built and engined by William Gray & Co., Ltd., West Hartlepool, for Mr. N. G. Livanos, Piræus, Greece. First vessel of a series of four. Main dimensions: 457 ft. 6 in. overall by 57 ft. 8½ in. by 38 ft. 3 in. to shelter deck; deadweight capacity, 10,185 tons on a draught of 26 ft. 5¼ in. Triple expansion steam engines, developing 2,580 i.h.p. at 77 r.p.m., and three oil-fired forced-draught boilers. Service speed, 11¼ knots. Trial trip, July 26.

DUNLOP RUBBER COMPANY PLANS.—Two developments for increasing the output of tyre fabric have been introduced by the Dunlop Rubber Company, Limited, St. James's-street, London, S.W.1. In two years' time they hope to begin production of rayon tyre cord in the new building about to be constructed near Londonderry by the Government of Northern Ireland. Labour there will be exclusively male, and, although the plant will be mostly new, some machinery is to be transferred to Londonderry from the company's main mill at Rochdale. In Dunfermline, the Victoria mill, one of Dunlop's two factories there, is being extended for the increased production of rayon tyre fabric and of cotton fabric for colliery conveyor belting. An extra 120 employees are to be taken on, and the same number of men will be employed when the Londonderry mill is in full production.

PRESERVATIVE TREATMENTS FOR TIMBER IN BUILDINGS.—The Council for Codes of Practice for Buildings have now issued for comment Code 112-100, "Preservative Treatments for Timber in Buildings," prepared for the Council by a Committee convened by the Institution of Structural Engineers. It deals with the preservation of timber by means of wood preservatives against fungal and insect attack and sets out recommendations for the structural use of preserved timber in buildings. Guidance is given in assessing the factors affecting the choice of preservative, on the preparation of timber for treatment and the methods of treatment and conditioning after treatment. The Code is in draft form and is subject to amendment in the light of comments, which should be submitted by September 11, 1951. Copies may be obtained from the British Standards Institution, 24-28 Victoria-street, London, S.W.1, price 2*s*., post free, by quoting reference CP(B) 1020.

PERSONAL.

SIR HARRY RAILING, of the General Electric Co., Ltd., London, and MR. R. G. D. RYDER, of Thomas Ryder and Son, Ltd., Bolton, have been appointed members of the Iron and Steel Consumers' Council, by the Minister of Supply.

SIR JAMES SWINBURNE, F.R.S., who was chairman of Bakelite Ltd., 18, Grosvenor-gardens, London, S.W.1, from the inception of the firm until 1948, has resigned his directorship. He has been appointed honorary President of the company. MR. P. HUFFMAN, MR. N. H. DOCKER, and MESSRS. C. C. LAST and G. W. HODDS, joint general managers, have been elected to the board.

WING-COMDR. H. P. POWELL, D.F.C., A.R.Ae.S., joined the Lockheed Hydraulic Brake Co., Ltd., Leamington Spa, on August 1, to promote a closer liaison between the firm's aircraft division and the aircraft industry and Services.

The British Electricity Authority announce that MR. W. WILDE, B.Sc. (Eng.) (Lond.), A.M.I.E.E., A.M.I.Mech.E., Group II generation engineer (operation), London Division, has been appointed chief generation engineer (operation) of the London Division. MR. R. E. CORNISH, A.M.I.E.E., senior assistant engineer, system operation branch, chief engineer's department, has been appointed system operation engineer of the Midlands Division of the Authority. MR. J. WHITFIELD, A.M.I.Mech.E., A.M.I.E.E., A.M.C.T., station superintendent at Stuart-street, Manchester, has been made generation engineer (operation) in charge of No. 3 subdivision of the Authority's North-Western Division. He succeeds MR. O. S. WOODS, who has been appointed to the East Midlands Division as chief generation engineer (operation). MR. ERNEST LONG, deputy chief accountant (finance) has been appointed secretary of the Authority in succession to MR. H. F. CARPENTER, who, as stated on page 787 of our issue of June 29, is retiring in the autumn.

MR. R. H. CHILTON, for many years associated with I.C.I. (Alkali Division) Ltd., Northwich, has joined the firm of G. F. Ward and Partners, consulting engineers, Old Colony House, South King-street, Manchester, 2, as a partner.

MR. A. J. BOURNE, who has been works manager of Earle Bourne and Co., Ltd., for 27 years, has been elected a director of the company.

MR. W. R. HEROD, who is now a co-ordinator of the North Atlantic Defence Programme, has tendered his resignation as a director of Associated Electrical Industries, Ltd.

MR. G. F. SLY, formerly chief designer to United Ebonite and Lorival, Ltd., Little Lever, near Bolton, has been promoted to the position of assistant to the works manager of the firm, MR. F. E. LOWE. MR. J. KIRKPATRICK, formerly Mr. Sly's assistant, has been appointed chief designer in his stead.

MR. J. PEASE has been made technical sales manager of Guy Motors Ltd., Wolverhampton, and of its subsidiary concern, the Sunbeam Trolleybus Co., Ltd.

MR. A. CHENEY, B.Sc., Northern Counties engineer of Acheson Colloids Ltd., 18, Pall Mall, London, S.W.1, has moved to a new office at 7, Hunters-lane, Rochdale, Lancashire.

MR. DONALD MACKINNON, manager of David MacBrayne, Ltd., Glasgow, retired on July 31 after a long association with the company.

MR. H. M. MUSTILL, secretary, and MR. E. JONES, sales manager, have been appointed directors of Towler Brothers (Patents) Ltd., Rodley, Leeds, manufacturers of hydraulic pumps and valves.

MR. I. S. HORABIN has been appointed sales manager of Scottish Mechanical Light Industries, Ltd., ScotMec Works, 42-44, Waggon-road, Ayr. MR. J. A. CULLEY has been appointed liaison officer to ScotMec dealers.

JOY-SULLIVAN, LTD., manufacturers of mining machinery, have removed from Battery Park, Greenock, to their factory in the new industrial estate at Cappielow, Greenock. The premises vacated at Battery Park have been taken over as temporary headquarters by INTERNATIONAL BUSINESS MACHINES CORPORATION, of New York, U.S.A.

BRITISH INSULATED CALLENDER'S CABLES, LTD., announce that the telegraphic address of their Liverpool branch is now Bicalbest Liverpool 1. The telephone number of their branch at 48, Stoke-road, Shelton, Stoke-on-Trent, is now Stoke-on-Trent 44256-7. The telephone number of the BRITISH INSULATED CALLENDER'S CONSTRUCTION CO., LTD. office at Clarence Chambers, Kingsway, Stoke-on-Trent, is now Stoke-on-Trent 44368.

The headquarters of the BOARD OF TRADE are being transferred to Horse Guards Avenue, Whitehall, London, S.W.1. (Telephone: TRAfalgar 8855.)

LESLIE TURNER AND PARTNERS, consulting engineers, have removed their offices to 6, Grove-road, Sutton, Surrey. (Telephone: Vigilant 0042.)

THE EXHIBITION OF INDUSTRIAL POWER, GLASGOW.

(*For Description, see Page* 166.)

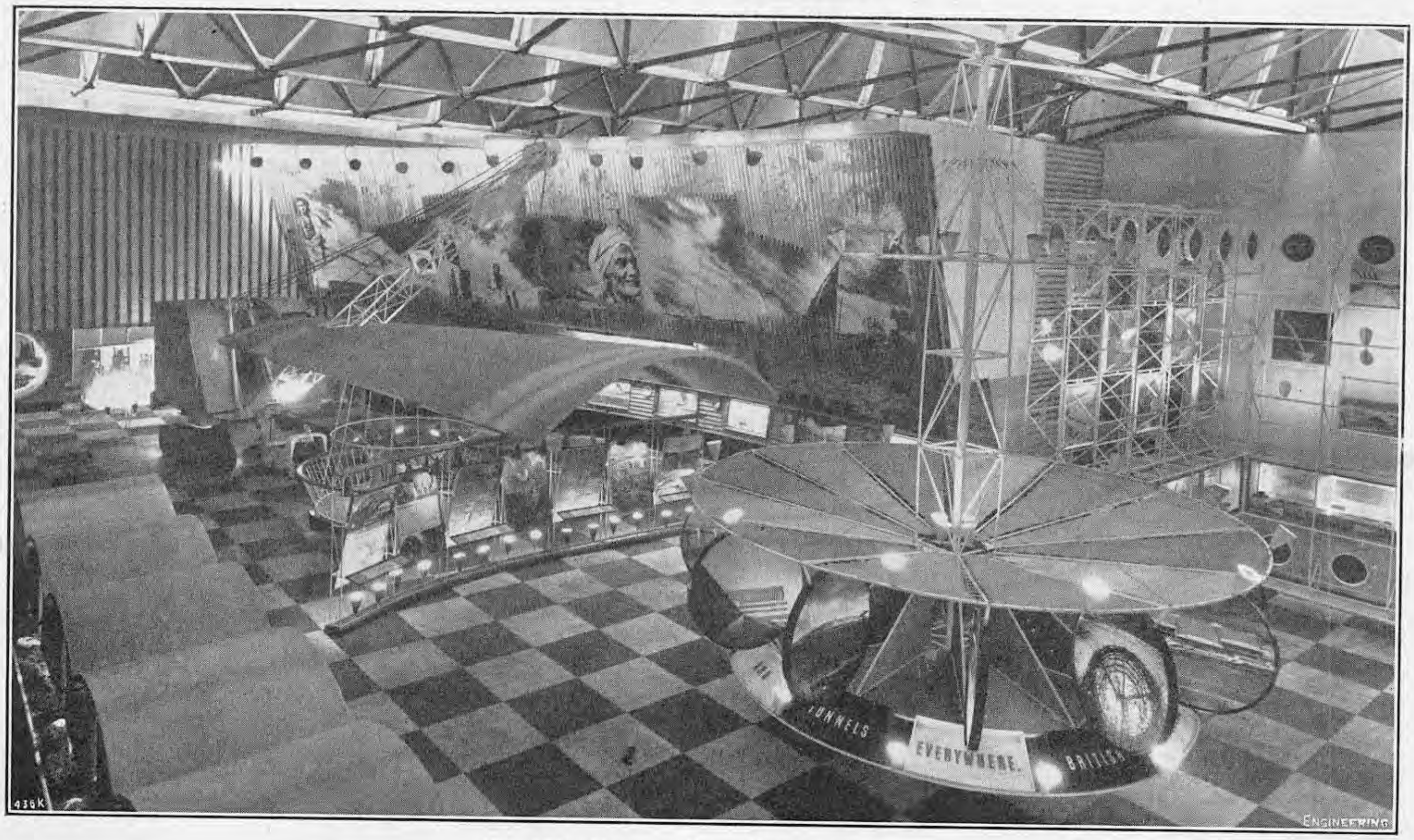

FIG. 147. HALL OF CIVIL ENGINEERING.

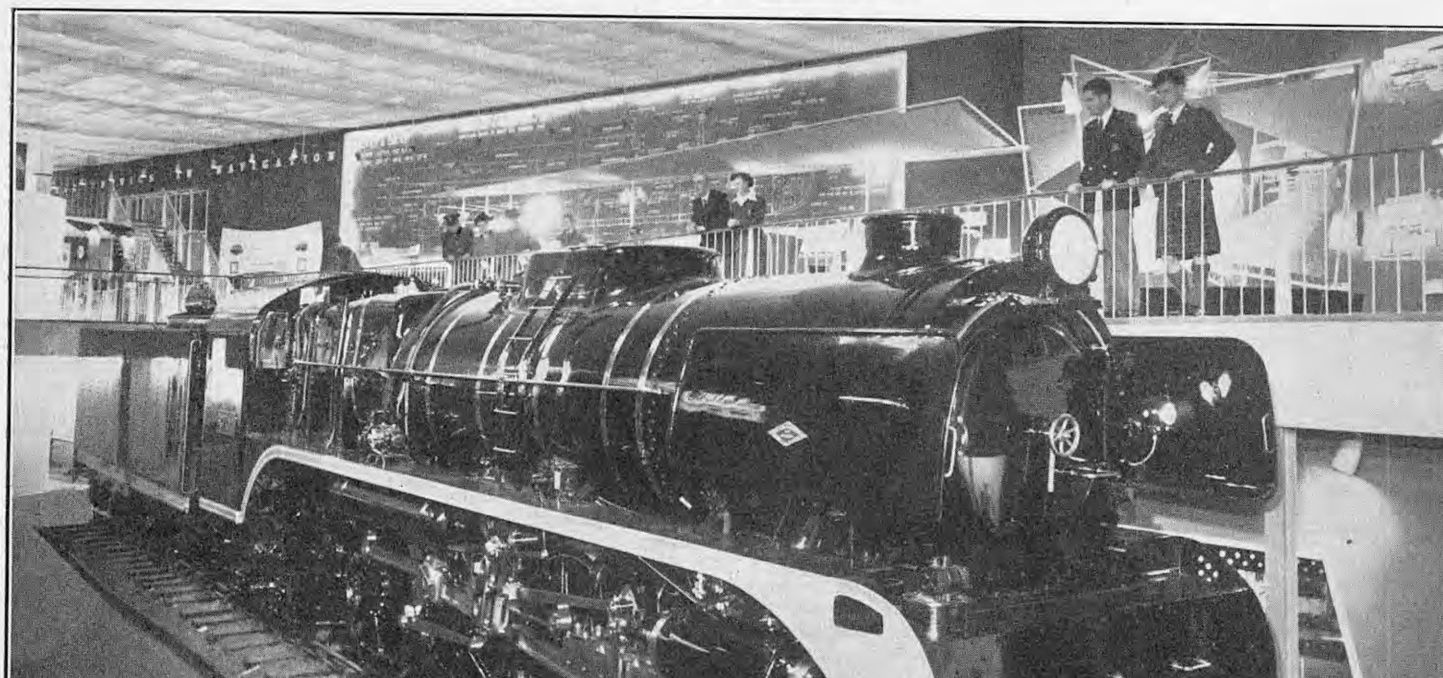

FIG. 148. HALL OF RAILWAYS AND SHIPBUILDING.

ENGINEERING,

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ENGINEERING

FRIDAY, AUGUST 10, 1951.

VOL. 172. No. 4463.

THE BRITISH ASSOCIATION MEETING AT EDINBURGH.

THE 113th annual meeting of the British Association for the Advancement of Science opened in Edinburgh on Wednesday, August 8. At a ceremony held in the University's M'Ewan Hall in the evening of that day, H.R.H. the Duke of Edinburgh, K.G., F.R.S., who is this year's President, received the honorary degree of Doctor of Laws from the University of Edinburgh. An inaugural general meeting followed, at which members of the Association were officially welcomed by the Lord Provost of the city, the Rt. Hon. James Miller, and the Principal of the University, Sir Edward Appleton, after which His Royal Highness delivered his presidential address on "The British Contribution to Science and Technology in the past Hundred Years." As the seating accommodation at the M'Ewan Hall was inadequate, an overflow meeting was held in the Usher Hall where another large audience was able to follow the proceedings in the M'Ewan Hall on a large television screen. The President's address was also broadcast by the British Broadcasting Corporation. Present indications are that, apart from the Association's centenary meeting in London in 1931, the attendance this year will prove to be a record one. The previous highest record for meetings was that established at Manchester in 1887, when the official attendance was 3,838.

In view of the spectacular advances in science during the past two decades, and the rapidly expanding interest in the subject among the general public, it may seem surprising that the attendances at the post-war meetings of the Association have not, before now, surpassed a record established more than 60 years ago, which itself testifies to the great scientific curiosity of the Victorians. In recent years, rapidly rising costs of travel and accommodation have undoubtedly acted as a deterrent to many who, otherwise, would have attended these meetings. The attendance, however, is always governed largely by local factors and, Edinburgh being a city with a long and distinguished association with science, as with literature and the arts, it is not surprising that about half of those attending the meetings are local inhabitants. To mark the year of the Festival of Britain, the Association has included in its programme a series of reviews of progress during the past century, without departing substantially, however, from its usual practice of discussing mainly items of current interest and importance. This year's president of the Engineering Section is Sir Claude Gibb, F.R.S., whose presidential address on "Two Thousand Years of Engineering" is due to be delivered to-day.

Before commencing his address, the Duke of Edinburgh read to the meeting a message from the King, in which His Majesty said: "I shall be glad if you will express to the members of the British Association for the Advancement of Science my appreciation of their having once more honoured a member of my family by inviting him to be their President. I trust that this year's meeting of the Association will further the development of Science for the benefit of mankind throughout the world, and prove an encouragement to all those men and women who are so devotedly working to that end." In acknowledgment, said the Duke, he proposed to reply that "The Members of the British Association for the Advancement of Science assembled at Edinburgh send Your Majesty their humble duty and their loyal thanks for Your Majesty's Patronage of the Association and your gracious message of encouragement. I am to assure Your Majesty that the development of Science for the well-being of Your Majesty's Realm and for the general welfare of mankind is the constant object of the Association. We will strive with all humility and with the grace of God to apply the blessings of scientific and technological improvement to the problems which face us all to-day." The proposal was received with acclamation.

The address which the President then proceeded to deliver, and which we reprint on page 182 of this issue, was a notably comprehensive, and yet concise, review of a field more varied and much more extensive than is customarily surveyed in a presidential discourse; and not less noteworthy was the clarity and forthrightness of its delivery. It is probably not too much to say that many of those who listened to the broadcast of it received, not merely a new insight into the contributions that Britain has made to scientific thought and achievement, but a new mental concept of the vigorous personality of the President himself; a concept of a kind not to be gained from the newspapers, especially of the more popular sort, through which alone that personality has been presented to a large part of the people of this country. His was not an easy task, by any standard, but it was carried through in a thoroughly seamanlike manner, as Sir Harold Hartley, chairman of Council of the British Association, observed in his speech of thanks. The reception of the address by the meeting left no doubt of their appreciation of the fact, though it may be that not many of the audience were historians enough to reflect, on the spur of the moment, that the Prince Consort, to whose address at the Aberdeen meeting in 1859 the Duke referred, had the advantages, at that time, of 20 years' experience of public life and public speaking, and of being by no means a stranger at British Association meetings, whereas the Duke had not attended them before.

The present meeting, as stated above, is the 113th since the British Association met, for the first time, at York in 1831; the missing meetings in the sequence were, of course, those of the war years, when both considerations of the members' safety and the urgent claims of war upon the activities of scientists in all fields, made the holding of meetings impracticable. That it should have been possible, over so long a period of years, to produce such comprehensive programmes, and for the successive Presidents, of the Sections as well as of the Association, to maintain so high a standard of freshness and vitality in their addresses, is a testimony at once to the sheer volume of scientific work constantly in progress and the high sense of responsibility with which the preparation of these addresses has been consistently approached. Their character is, necessarily, in some respects, different from that of an ordinary presidential address to a technical or scientific institution, just as the character and purpose of the Association itself differ from those of such specialised bodies. There is, in fact, no organisation in this country, on anything approaching a national scale, which corresponds even approximately to the "B.A."; the nearest equivalents are, perhaps, the relatively few "literary and philosophical" societies, such as that in Newcastle-on-Tyne, which aim primarily to cater for that section of the public which, while not being actively engaged in scientific and cognate pursuits, finds in the study of them a mental satisfaction akin to that of the art-lover who is not a practising artist.

It is significant that most of these societies had their origins in the Eighteenth and early Nineteenth Centuries, when applied science, as a result of industrial expansion, began to be a matter of general interest to the thinking public. In the course of years, the appeal of the British Association to that section of the public undoubtedly has been intensified, but this is a development which, apparently, was only one of the initial objects in the minds of its founders, and not then the most important. The resolution formally proposed by the Rev. William Vernon Harcourt, F.R.S., for its foundation submitted that it should be established "to give a stronger impulse and more systematic direction to scientific inquiry, to obtain a greater degree of national attention to the objects of science, and a removal of those disadvantages which impede its progress, and to promote the intercourse of the cultivators of science with one another, and with foreign philosophers."

For most of these purposes, other organisations and media now exist, though the majority of them operate in more or less specialised fields. The active interest of successive Governments in the practical applications of science, and in the promotion of scientific research, has resulted in a much closer co-ordination and direction, and has done much to remove the chief disadvantages which impeded progress, namely, the provision of adequate training, equipment and finance; though it should be remarked that private, and often personal and individual, generosity and foresight set the example in this respect. International organisations in great profusion now exist to promote co-operation with "foreign philosophers." There remains the purpose of obtaining "a greater degree of national attention to the objects of science," which has thus become the primary aim, the realisation of which depends so greatly upon the quality of the inaugural address of the President at each annual meeting. The innovation at this year's meeting, due to Sir Edward Appleton, of relaying the proceedings by television to a second audience in another hall is an advance of the highest significance in this regard, opening up possibilities for the future influence of the British Association, upon the public awareness of scientific achievement and potentialities, beyond anything that its founders can have hoped.

WELDING RESEARCH.

The employment of welding for joining the majority of the metals used in engineering, though not unknown from the earliest days, received considerable impetus in the course of the 1914-18 war. During the following 20 years, too, a great deal further was done to consolidate the position by carrying out detailed examinations of the scientific aspects of the subject and thus providing evidence to convince those who were doubtful of the soundness of this method. By 1935, in fact, sufficient progress had been made for it to be possible to hold an International Welding Convention in London. This gathering was attended by some 800 delegates from 20 different countries and, perhaps the most useful results of its deliberations were a recognition of the fact that research into the various aspects of welding must be organised on broad lines and that it was necessary to lay down the principles upon which this work should be carried out. From the international point of view, a setback was inevitably brought about by the 1939-45 war. Nevertheless, a meeting was held in Brussels in 1948 which was attended by representatives of 14 countries. As a result, the International Institute of Welding was formed and a number of commissions were appointed to deal with technical matters. This body met again in London and in Oxford in July. Its programme is sufficient indication of its usefulness and of the advances that are being made.

As far as the part played by this country in these developments is concerned, it may be recalled that as long ago as 1936 welding research was inaugurated in this country by a Welding Research Council under the ægis of the Institute of Welding; it continued to operate until early in 1945, with the assistance of a grant from the Department of Scientific and Industrial Research. This aid may be taken as some indication that the importance of the work was recognised in official circles, since the policy of the Department is to make grants only to autonomous associations. In the meantime, however, history had repeated itself and the 1939-45 war had given a stimulus to the use of welding, as is shown by the statement that, during the six years of hostilities, the number of welders was trebled, the number of welding machines trebled, and the output of welding material multiplied by four. It was therefore possible to form a British Welding Research Association to take over the functions and programme of the earlier Welding Research Council. Since that date, a great deal of useful work has been carried out by that body under the administration of a number of committees and good progress has been made in equipping laboratories and workshops at Abington, near Cambridge. Finance has not always been easy, for the amount contributed by industry—upon which, of course, the size of the Government grant depends—has neither been as large as is desirable nor has it been distributed over a wide enough membership. Moreover, the report for the year ended March 31, 1951, shows that only one-quarter of the members contribute more than the minimum subscription.

Nevertheless, it is clear from this document that much progress is being made. Not the least important of the researches now being conducted is the investigation, at Birmingham University, into the fundamental factors which cause cracking in the hardened zone adjacent to welded joints. For this purpose, measurements are being made of the internal stresses in martensite and of the effect of high-temperature heating on the transformation of austenite. The work has advanced sufficiently for the conclusions to be reached that the magnitude of the internal stresses depends mainly on the carbon content, and that the very high stresses associated with a 0·3 per cent. carbon steel may be due to a tetragonal structure in the martensite. The internal stresses which have been recorded are very high, and, in some cases, exceed the yield point. In general, the tests show a rough correlation between hardness and tensile properties.

A new test of weldability, which can be employed for specification purposes, has been approved. In this the severity is controlled by the rate of heat flow away from the weld. Members of the Association are being asked to give the new test a thorough trial so that its value can be assessed. In the course of developing weldable structural steels of higher strength, a further examination was made of the mechanical properties of certain 2-ton casts. As a result, it is satisfactory to be able to record that success has been attained in developing steels which have both good weldability and good mechanical properties in thickness up to ½ in. Work on the weldability of a low-alloy steel with a yield strength of 25 tons per square inch has also been continued.

An investigation on the pressure welding of light alloys, which has been carried out at the Royal School of Mines, has shown that it is easier to make joints between aluminium and some of the heavier metals, particularly copper, than between aluminium and aluminium. The reason for this is believed to be that the harder metal acts as an "ice breaker" of the aluminium-oxide film. According to theory, tin should react in a similar way to aluminium, but it welds to the heavier metals only at high deformations. Under the heading of fusion welding it has been found that, when welding aluminium alloys containing 5 per cent. of magnesium with a metal arc, it is possible to obtain a considerable increase in strength by employing a particular sodium-free flux of a type used in foundries. Rods coated with this flux are, however, difficult to handle, and a problem is thus presented for the consideration of the electrode manufacturers. Investigations into the argon-arc welding of aluminium alloys has continued in conjunction with the British Electrical and Allied Industries Research Association. In these a 600-ampere manual torch has been used for welding plate up to 1 in. thick. Work is also being carried out on the metal-arc process, using an inert-gas shield.

The increasing use of welding in all branches of engineering has naturally raised a number of problems. Among these mention may be made of the behaviour of rigid-frame structures, work on which is being carried out in the Engineering Laboratory at Cambridge. During the year, experimental and theoretical investigations on the bending of simply-supported rolled-steel joists have been completed. One of the objects of these researches was to provide information for the structural analysis of full-scale portal frames on which collapse loading tests had already been carried out, with particular reference to the calculation of deflections. The problems of the lateral instability of structural members, loaded beyond the yield point of the material, received further attention, and work was also continued on the behaviour of stanchions when loaded to collapse. In the first series of tests, frames were used in which it was possible to develop the full plastic moment in the stanchions by loading only the beams on the major axis. In a further series, the stiffness of the beams on the minor axis was reduced from frame to frame. In this way, failure was produced by the stanchions collapsing about the minor axis before the full plastic moment about the major axis was attained.

As regards the behaviour of welded structures under dynamic loading, further experimental work with registering strain gauges of the electrical inductance type was undertaken, "push-pull" fatigue tests on welded bridge members were also continued, and a series of *ad hoc* fatigue tests on welded mild steel and welded magnesium alloy specimens were made. The investigations of the committee charged with this branch of the work seem, however, to have been hampered by the lack of equipment, a disability which it is hoped to overcome without delay.

NOTES.

THE SCRAP PROBLEM IN EUROPE.

THE future of the steel industry throughout Europe is bound up with the problem of a sufficient supply of scrap, and one of the more practical activities of the United Nations Economic and Social Council (Unesco) has been the investigation of the international scrap situation in the light of post-war difficulties. In November, 1950, the Steel Committee of the Economic Commission for Europe decided that their Panel on Scrap should resume its inquiries into the scrap resources of the European countries and the use that was made of them. The Panel was also charged with the collection of relevant statistics, and the organisation of a systematic documentation of the use of scrap. Those were its original terms of reference, but the Steel Committee, in resolving that the Panel should resume this work, extended the survey to cover "countries not hitherto covered . . . but which would in the future express interest in them." A report by the Panel to the Steel Committee, recently issued, reviews the situation as it appeared down to the end of June. Until the end of the third quarter of 1950, the report states, scrap supplies had been adequate, though there were "indications of an unbalance" which subsequently became more acute. This had four main causes, namely, a sharply increased demand for steel, a considerable reduction in scrap exports from Western Germany, the resumption of scrap imports from Europe by the United States and other American countries, and delay by "certain countries, in view of changed circumstances," in developing to the maximum the collection of scrap and its distribution to the steelworks. The reduction in supplies from Germany, of course, was to be expected, and was the natural result of the diminishing availability of scrap that could be easily recovered, and the raising of the authorised level of German steel output. The principal factor, however, was adjudged to be the greater demand resulting from increased steel production, and the inability of pig-iron producers to increase their output correspondingly, either because of lack of blast-furnace capacity or shortages of rich iron ore and of coke. It will be necessary, the Panel state, to increase the consumption of iron ore considerably if a continuing scrap shortage is to be avoided. For some years, the consumption of iron ore per ton of steel produced has been falling; it was 1·52 tons in 1938, but 1·42 tons in 1948, and only 1·34 tons in 1949, as a world average, though the world production of steel, in millions of metric tons, was 110, 153 and 157, respectively. Steel production in the world was 185 million tons in 1950 and is planned to reach 224 millions in 1952, so that an increased rate of scrap collection is essential.

ANGLO-AMERICAN AERONAUTICAL CONFERENCE.

More than 500 delegates, of which 95 are from the United States, are to attend the Third Anglo-American Aeronautical Conference which is being organised by the Royal Aeronautical Society and is to take place in Brighton from Monday, September 3, to Friday, September 7. The Brighton Corporation have placed the Dome and the Corn Exchange at the disposal of the Society for the reception on Monday evening and for the lectures to be given on the four following days. The programme of lectures to be given is as follows: on Tuesday, September 4, "Infusion of Safety into Aeronautical Curricula," by Mr. Jerome Lederer; "Flight Development of a Thick Suction Wing," by Mr. T. S. Keeble; "Advances in Aircraft Structural Design," by Professor G. T. R. Hill; and "Structural Problems of Future Aircraft," by Professor Nicholas J. Hoff; on Wednesday, September 5, "Plastics and Plastic Structures," by Mr. J. E. Gordon; "Performance Characteristics of Jet Nozzles," by Mr. George S. Schairer; "Propellers for High Powers and Transonic Speeds," by Mr. George W. Brady; "Some Problems of Turbine Transport Operations in Europe," by Mr. K. G. Wilkinson; "The Reduction of Drag by Distributed Suction," by Professor Sir B. Melvill Jones, F.R.S., and Squadron-Leader M. R. Head; and "A Review of High-Speed Hydrodynamic Development," by Mr. Ernest G. Stout; on Thursday, September 6, "Heat Transfer Studies Relating to Rocket Power Plant Development," by Mr. Louis G. Dunn; "Some Aerodynamic Advances," by Mr. A. Fage; "Material Properties for High Altitude Operation," by Dr. T. P. Hughes and Mr. H. W. Hall; and "The Aerodynamics of Low Aspect Ratio Wings and Wing-Body Combinations," by Mr. A. H. Flax and Mr. H. R. Lawrence; on Friday, September 7, "Engineering Problems of Aircraft Operation," by Mr. B. S. Shenstone; "Some Experimental Deformations of Swept Wing Models," by Mr. A. H. Hall; "Dynamic Stability and Control Research," by Mr. William F. Milliken, jun.; "Some Research Relating to High-Speed Flutter," by Mr. I. E. Garrick; "The Influence of Size on the Performance of Jet Engines," by Mr. S. J. Moyes and Mr. W. A. Pennington; and "Experimental Methods for Transonic Research," by Mr. John Stack. The Mayor and Mayoress of Brighton are to give a supper and dance for delegates and their ladies on Wednesday, September 5. The Conference dinner will be held on Friday, September 7.

SIR ISAAC NEWTON EXHIBITION.

In connection with the Festival of Britain, the Royal Society have arranged a small exhibition in their apartments of items concerning Sir Isaac Newton. It will be open from Monday, August 13, to Friday, August 31, from 11 a.m. to 4 p.m. daily except Saturdays and Sundays, and admission will be free. Newton was the Society's greatest President. Born in 1642, he was elected a Fellow in 1672, and was President from 1703 to his death in 1727. The exhibits include the Society's Journal Book, open at the page recording his election as Fellow, and a reproduction of the Society's Charter Book, also open at the appropriate page, where Newton, in accordance with custom, signed the "obligation." Some other signatures of particular interest are those of Charles II, Robert Boyle, Samuel Pepys, Joseph Priestley, Sir Humphry Davy, Michael Faraday and Charles Darwin. A solar dial, cut in stone by Newton when a boy, is preserved and shown in a glass-fronted case; it was taken in 1884 from the wall of his birthplace, the manor house at Woolsthorpe, Lincolnshire. The *Principia* is represented by the manuscript from which the first edition was printed (it was written out by an amanuensis, but contains corrections in Newton's hand), and by copies of the three editions, the ordinary, the large-paper, and the extra large-paper copies of the third edition. The tercentenary of Newton's birth was celebrated in a modest way, owing to the war, in 1942, but formal celebrations were held in 1946; copies of the volumes recording these occasions are displayed, as well as the translations into Russian of the *Principia, Lectiones Opticae, Mathematical Works*, and *Opticks*, which were presented to the Royal Society by the Russian delegation to the 1946 celebrations. Other exhibits, the total number of which is 31, include Newton's watch, a lock of his hair, the reflecting telescope, made by himself, which he presented to the Royal Society in 1671, a rough sketch by Newton of the telescope, and various portraits, engravings, etc.

THE COAL UTILISATION JOINT COUNCIL.

The annual report for 1950 of the Coal Utilisation Joint Council, published recently from their office at 3, Upper Belgrave-street, London, S.W.1, devotes considerable attention to the finance needed to enable the Council to carry out their plans to promote, on a national scale, the better use of solid fuel for domestic purposes. The programme that they have in mind, which was prepared by a special planning committee in 1949, is stated to require an annual income of about 250,000*l.*, or four times the actual income at the beginning of 1950. It is now stated that the National Coal Board have offered to contribute three-fifths of this amount if the other members of the Council—the coal merchants, and the makers and distributors of appliances—would make up the balance, which they have agreed to do. Following the establishment of an information centre in Manchester, the Council propose to set up others in the various Regions. Offices have been opened in Cardiff, Bristol and Leeds, and suitable premises are being sought in Nottingham, Birmingham, Newcastle and Cambridge. An office and showroom to serve as a centre for Scotland have been acquired in Bath-street, Glasgow. A start was made during the year, through the regional committees of the Council, to promote local liaison between the distributors of coal and of coal-burning appliances.

CLAYTON FELLOWSHIPS AND GRANTS, 1951.

Under the Clayton Bequest the Institution of Mechanical Engineers has made eleven awards, comprising eight Fellowships and three grants, for post-graduate training or research in mechanical engineering. The awards amount, in all, to about 3,800*l.*, for the year 1951. The successful candidates for the eight Clayton Fellowships are all graduates of the Institution, and the Fellowships have been awarded to Mr. B. E. L. Deckker, B.Sc., of Birmingham, for research on the wave action occurring in the exhaust pipe of a two-cycle oil engine; Mr. F. Ellis, B.Sc., of London, W.9, for an experimental and theoretical examination of stress distribution in hot and cold rolling; Mr. J. Halling, B.Sc., of Mitcham, Surrey, for an experimental investigation of rolling friction in relation to surface finish and loading; Mr. J. Houghton, B.S. (Eng.), of Coventry, for an experimental and theoretical investigation of the effect of end constraint on thin-walled and solid cylinders of hyperbolic aerofoil shape with special application to turbine blades; Mr. D. Howe, of Lanchester Hall, College of Aeronautics, Bletchley, Buckinghamshire, for an investigation reviewing certain existing knowledge on loads and stresses in swept-back aeroplane wings; Mr. G. Moss, B.Sc. (Eng.), of London, E.5, for an experimental and theoretical investigation of a method of continuous filtration; Mr. H. Naylor, B.Sc., of Baildon, Yorkshire, for research on lubrication in wire drawing; and Mr. M. Ruddick, B.Sc. (Eng.), of Grays, Essex, for research on heat transmission in the cooling of gas-turbine blading. Clayton grants have been awarded to Mr. J. Huddart, A.M.I.Mech.E., of London, W.4, for an investigation of high-amplitude pulse transmission in pipe lines, with special reference to internal-combustion engine exhaust systems; Mr. D. R. S. Rabley, B.Sc. (Eng.), A.M.I.Mech.E., of Plymstock, Plymouth, for a post-graduate course in photo-elastic methods; and Mr. N. D. Thomson, B.Sc., G.I.Mech.E., of Sheffield, for a tour of observation of steelworks and rolling mills in this country and on the Continent.

LETTERS TO THE EDITOR.

"HIGH-SPEED SMALL CRAFT."

TO THE EDITOR OF ENGINEERING.

SIR,—In the review of my book, "High Speed Small Craft," which appeared in your issue of June 8, on page 680, and in the reference to Chapter III, detailed criticisms were put forward on specific and minor, though none the less, interesting technical points. I feel that some, at least, of these criticisms are not altogether justifiable beyond possibility of doubt, but are based upon theses generally applicable to craft running in the lower speed/length range. This type of criticism was expected, but it is hoped you will forgive my further explanation.

It is particularly pleasing, however, to note that your reviewer, in referring to "hard chine" craft, says that "a great deal of propaganda has been published about such boats, but very little information has been given that is of technical or scientific value. Commander Du Cane's book is, therefore, especially welcome and meets an undoubted need." The comment in the final paragraph is, therefore, surprising, in that your reviewer overlooks the fact that photographs of the products of some of the firms mentioned are incorporated; but, in fairness, it must be doubted if this book could really be considered an appropriate medium for the type of publicity or propaganda it is suggested should have been incorporated. Incidentally, in any list of names distinguished in the world of high-speed craft, it would be wrong to omit those of Mr. R. W. L. Gawn, the Superintendent of the Haslar Tank, or

Mr. W. J. Holt, of the Department of the Director of Naval Construction at the Admiralty. Also, I suppose, to be consistent, one should mention a number of foreign workers in this field.

I would like now to deal with the technical points raised by your reviewer. Referring to my discussion of the relative qualities as regards rolling inherent in the hard chine and the round form types of craft, my script is loosely worded and was the subject of a *corrigendum* which was too late for publication, though I submit your reviewer is similarly guilty in referring to "rolling proclivities." He interprets "undesirable rolling qualities" as referring to violence in roll, whereas I consider the unpleasant feature in certain types of round-form craft to arise from "tenderness," involving large amplitude of roll combined with relatively slow recovery. He infers, *inter alia*, that the hard chine form achieves greater transverse metacentric height by virtue of greater beam. I suggest that the form of section greatly influences matters here, apart from considerations of beam. It is true that, in the case of the larger and more conventional types of ship, a naval architect will endeavour to keep the metacentric height within strict limits, both as regards the maximum as well as the minimum figure. In the case, however, of smaller craft, of either the round-form or hard-chine type, it is difficult to incorporate features such that the metacentric height is excessive. The reason is that, in small craft, the practical seaman will prefer safety to theoretical comfort.

Turning now to another point: although it is known that the centre of pressure in the case of "normal" rudders moves away from the leading edge with increasing angles of helm, it is submitted that this refers to normal types of ship, speeds and rudder. It is suggested that, where relatively high speeds are concerned, more data could well be made available before authoritative statements as to the behaviour of the centre of pressure are justifiable. It is suggested that, where high speeds are concerned, some element of cavitation may well be present, which may result in unorthodox behaviour of the centre of pressure, similar to that experienced in the case of aircraft controls at, near, or beyond the speed of sound. Pressure patterns for front and back faces at varying speeds and angles would be valuable, but I venture to doubt whether your reviewer has available to him such data on which to base his assertions. My remarks as to a "reversal" taking place could, perhaps, have been prefaced by the word "effective," though it is agreed that if, for instance, a rudder possessing 20 per cent. balance could be increased in angle to 90 deg., it is not difficult then to agree a substantial move of the centre of pressure away from the leading edge. It has been found that the limiting factor, so far as this question of balance is concerned, is the amount of balance which can be used without running the risk of involving excessive forces to return from the "hard over" position. No hand gear, including the Mathway, good as it is, can offer really acceptable performance at the higher speeds in an M.T.B. type at appreciable angles of helm; at least, without involving an excessive number of turns from "hard over" to "hard over."

Thirdly, I agree that the depth of rudder is not the only factor influencing the matter of heeling inwards in a turn; I think your reviewer has read more than is justified into my script when he suggests that the inference is that the rudder position is the one and only factor influencing inward heel. Experience leads me to suppose this is a very important point, but of almost equal significance is the underwater shape, to the effect that a well-Veed transverse section, especially in the after body, will greatly assist that banking up of water on the outside of the turn, referred to by your reviewer. Incidentally, in referring to depth of rudder, the length from the highest point on the rudder to the lowest is also referred to.

Fourthly, the reason that the Vosper steering gear depicted does, in fact, relieve the coxswain to some extent at substantial angles of helm, is that, for a given angular movement of the steering wheel near the "hard over" position, the resulting angular movement of the rudder stock is reduced in comparison to what would occur at the midships position, thereby resulting, in effect, in an increased mechanical advantage.

Finally, your reviewer's remarks on the subject of "ponderous propeller calculations" would appear to overlook the brief statement, made earlier in the text, that "there are several useful tables available from which the propeller dimensions can be determined quite rapidly." Such data, at the best, however, can only give approximate dimensions; the accurate design of a propeller for a high-speed craft is of necessity a lengthy and involved process, and, in many cases, would be even more involved than the example given. The definition of quasi-propulsive coefficient is incorrect and requires correction as suggested.

I welcome such intelligent criticism of technical points arising in the world of high-speed craft, and must concede that your reviewer has, at least, taken the trouble to read the book with some care. It is all too seldom that the naval architect will condescend to turn his talents to these specialised problems, while, even now, many still appear to be left to the engineer to solve.

Yours truly,
PETER DU CANE.

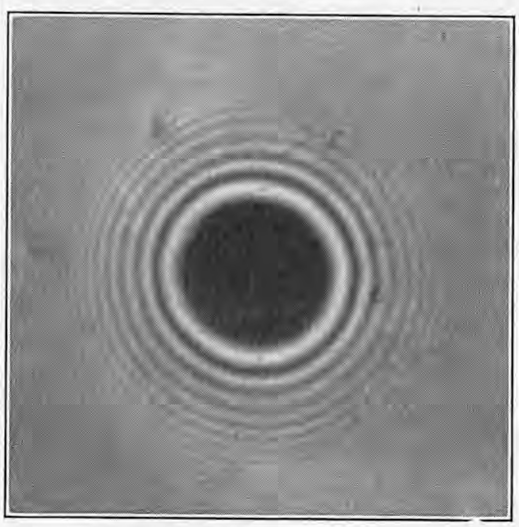
Vosper, Limited,
Portsmouth.
July 10, 1951.

PRECISION MEASUREMENT OF ROCKWELL HARDNESS DIAMOND PENETRATORS.

TO THE EDITOR OF ENGINEERING.

SIR,—Mr. F. R. Tolmon and Mrs. Jill G. Wood present, in their article on page 89, *ante*, a number of interferograms taken from Rockwell diamond penetrators, but, in their Figs. 6 to 9, all the points shown are defective. They fail to show a Rockwell point which approaches the regular shape of the steel ball given in their Fig. 10. Why do they not show a good Rockwell point for comparison?

In the writer's laboratory, attempts have been made to produce Rockwell cones of better shapes, by a special technique which consists in grinding



the cone on an impregnated diamond grinding wheel, and then polishing it on an Arkansas wheel to remove the finest inaccuracies. In another technique, the diamond cone is produced first from a 16-facet diamond pyramid by polishing on a cast-iron lap, using diamond powder. The facets are later on broken into 32 and then the cone is treated again on an Arkansas wheel to break the small facets. The interferogram reproduced herewith (magnification 720) shows one of the cones produced in this way. It is not claimed, of course, that the shape is perfect, and the polish is not free from blemishes, but the laboratory method seems to indicate the possibility of producing improved diamond penetrators.

Yours faithfully,
P. GRODZINSKI, A.M.I.Mech.E.

41, Tudor-close,
Belsize-avenue,
London, N.W.3.
July 31, 1951.

THE REMOVAL OF SULPHUR COMPOUNDS FROM INDUSTRIAL GASES.

By WILFRID FRANCIS, M.Sc., Ph.D., F.R.I.C.

THE question of the recovery of sulphur from indigenous sources had not received the attention it deserved, until the recent announcements of shortages of sulphur and sulphuric acid in the Press had brought home to all concerned with the welfare of the State the importance of this question. As has been pointed out by the author and his collaborators in several publications during the past few years,* more than 30 million tons of coal, containing nearly 400,000 tons of sulphur, are consumed yearly by electricity-generating stations in Great Britain, and this sulphur is recoverable by various flue-gas washing processes, although at the present time no power station in the country is equipped for this purpose. Considerable quantities of oxides of sulphur are also emitted from other large fuel-consuming sources, employing either industrial coal or oil, in addition to the multitude of small users whose aggregate consumption is still greater. If the larger users of fuel alone recovered the sulphur in the flue gases as sulphur, ammonium sulphate or sulphuric acid, we should be largely independent of external sources of sulphur. That such a recovery is possible, technically, is agreed by all authorities on the subject and, indeed, at two of the largest power stations in the London area, namely, Battersea and Fulham, plants have been in operation for the removal of oxides of sulphur from the flue gases by washing with suspensions of lime or chalk, the efficiency of removal being in excess of 92 per cent.

Details of flue-gas washing processes that may be applied to practically all industrial fuel-burning installations have been described in the publications mentioned above. More recent examination of these processes has shown that their cost can be greatly reduced by simplification in the design of the plant and by the use of modern processes for the conversion of the primary products of flue-gas washing into useful by-products that are both efficient and economic. Contrary to many expressions of opinion that have appeared in technical literature, the costs of these modified flue-gas washing processes are not unduly high, and it has been calculated that the cost of recovering products such as calcium sulphate, sodium sulphate or ammonium sulphate from flue gases will not exceed 30*s*. per ton, provided due allowance is made for the necessary cost of removing grit from such gases by the more usual appliances, such as electrostatic precipitators or banks of cyclones. When it is considered that these chemicals can be produced conveniently in industrial areas, where products in the form of sulphur, sulphur dioxide or sulphuric acid, or by-products such as cement, find ready markets, it will be seen that there is little justification for the present apathy towards such processes in spite of the grave difficulties in which the country finds itself due to the shortage of sulphur and sulphuric acid.

Up to date, notwithstanding the fact that these points have been raised from time to time, official blessing has not been given to any project for the recovery of sulphur from flue gases, except in the case of the ammonia process, which is only applicable in a limited number of cases. On the other hand, a number of schemes are contemplated for the recovery of sulphur from coke-oven and refinery gases, in addition to the existing normal gasworks practice of recovering sulphur from town gas by using iron-oxide boxes. Since the consumption of coal in coke-oven practice exceeds that in gasworks, it is evident that a large untapped source of sulphur is available in coke-oven and refinery gases. The actual production of coke in coke ovens during 1948 was in excess of 16 million tons, representing some 21 million tons of coal. Assuming that this coal contains an average of 1·2 per cent. of sulphur

* *Boiler House and Power Station Chemistry*, W. Francis; Edward Arnold and Company, 1948. "Flue Gas Washing Processes," W. Francis, *Power and Works Engineer*, January to March, 1946. "Recovery of Sulphur from Flue Gases," W. Francis and G. H. Lepper, ENGINEERING, page 36, *ante*.

and that 50 per cent. of the sulphur appears as volatile sulphur compounds in the gases, it is evident that some 120,000 tons of sulphur per annum is available from this source alone. Since the standard iron-oxide method of purification is unsuitable for coke-oven practice, it may be useful to review briefly a number of scrubbing processes that have been developed abroad in recent years for the recovery of sulphur from coke-oven and refinery gases. The better known of these processes are: (1) the I.G. active-charcoal process; (2) the Girdler Corporation, Girbotol process; (3) the Koppers Seaboard process; (4) the Standard Oil Ferrox process; (5) the Koppers Thylox process; and (6) the caustic wash process. These are briefly described below.

The I.G. active charcoal process is based upon the low-temperature oxidation of hydrogen sulphide in the presence of active charcoal, according to the equation:

$$H_2S + \tfrac{1}{2}O_2 = H_2O + S.$$

This equation requires one volume of oxygen to two volumes of hydrogen sulphide in the gas to be treated, which is mixed with a trace of ammonia and passed with air, in slight excess, over active charcoal. The optimum concentration of ammonia is five volumes of ammonia to 100 volumes of hydrogen sulphide. Cylindrical vessels, similar to normal active-charcoal absorbers, are suitable for this process, in which the gas enters in the centre of an annular space containing active charcoal and is removed at the top and bottom of the outer cylinder. The maximum satisfactory operating temperature is 140 deg. F., and at temperatures below this almost complete removal of hydrogen sulphide is accomplished with gas velocities of 0·2 ft. per second. A typical plant consists of a cylindrical vessel 4 m. in diameter by 4 m. high constructed of mild steel in which the active charcoal is supported on two grids or trays. The coarse particles of active charcoal are placed on the first few inches of each grid, with normal grain-sized active charcoal placed above, to a depth of 1·3 m. The absorbers have a volumetric throughput of 350 to 400 cub. ft. of gas per hour, per cubic foot of active charcoal. Each vessel will handle 6,000 cubic m. of gas per hour, with a pressure drop of 60 milli-atmospheres. The maximum permissible inlet sulphur content without causing excessive rise in temperature is 8 grammes per cubic metre. Absorbers run for between 2 and 3 weeks before becoming saturated with sulphur and absorb a total of 10 tons of sulphur from $3{\cdot}4 \times 10^6$ cub. m. of gas. When saturated, the carbon contains its own volume of sulphur and the rise in temperature is equivalent to 5 deg. C. per gramme of sulphur removed. A charge of active charcoal will normally last about two years, though occasionally a batch lasts more than three years.

The sulphur is recovered from the active charcoal by washing with a solution of ammonium sulphide. This is sprayed over the carbon in the saturator and is drawn off at the base. The carbon is never flooded with liquor, but is sprayed three or four times, each batch of spray taking about 1½ hours to pass through the carbon. Approximately 30 cub. m. of solution is used for each treatment, commencing with liquor nearly saturated with sulphur and finishing with fresh liquor. The fresh liquor contains approximately 170 grammes of ammonia per litre and 80 grammes of hydrogen sulphide and will take up approximately 250 grammes of sulphur per litre. The strong liquor taken from the absorbers is decomposed by steam in continuous stills at 1·5 atmospheres gauge pressure. The vapours leaving the top of the still, at 90 deg. to 95 deg. C., contain all the ammonia and the hydrogen sulphide from the liquor. The vapours are cooled in heat exchangers and are condensed to give liquor containing approximately 300 grammes of H_2S per litre. The water and sulphur are run from the bottom of the still into a pressure vessel lined with bricks. This is heated to 120 deg. C., when the sulphur melts and it is tapped off into a settling vessel every few hours. After settling and skimming off impurities, sulphur is poured into metallic trays to solidify. Following extraction of the sulphur from the carbon, the ammonium-sulphide solution remaining in the absorber is removed, first by washing with hot water and then by steaming. During the steaming process, the vapours are condensed and the surplus mixture of water and sulphur returns to the vessel containing the weakest solution of ammonium sulphide.

The active charcoal used in the I.G. process in Germany was prepared from low-temperature brown coal coke. This is ground and sieved and the fraction containing particles of 1 to 4 mm. in diameter is heated with combustion gases and steam at 800 deg. C. for two to three hours before use. This process of activation may also be used for the re-activation of carbon exhausted after long use in the absorption plant. The activated carbon is stored in airtight drums ready for use. The sulphur produced is of excellent quality, being almost entirely pure in favourable circumstances, so that it may be used medicinally. The process is applicable to many types of gas, and the only limitation appears to be that the maximum concentration of H_2S that may be permitted is equivalent to 8 grammes per cubic metre, or 4 grains per cubic foot.

The Girbotol process, developed by the Girdler Corporation in the United States, is another physical process in which a solution of triethanolamine is used as the scrubbing medium. The gas is washed by passing up a scrubber, down which passes a 50 per cent. solution of triethanolamine in water at a pressure of about three atmospheres. Stronger solutions are difficult to circulate owing to viscosity troubles, and weaker solutions tend to froth. The normal circulating rate required for the removal of more than 95 per cent. of the sulphur is 1 gallon of solution to 1,000 grains of hydrogen sulphide removed. These circulation rates cover a range of from 300 to 2,400 grains of hydrogen sulphide per 100 cub. ft. of entering gas. With the triethanolamine, the hydrogen sulphide forms an unstable compound which may be decomposed by the use of live steam. The solution from the scrubber passes through a system of heat interchangers to a second still at atmospheric pressure and a temperature of about 101 deg. C., which is the boiling point of the 50 per cent. solution of triethanolamine. The gases evolved are cooled to condense the steam and to recover the triethanolamine.

When treating pure hydrocarbon gases, or gases containing little carbon dioxide, the gas from the still contains more than 90 per cent. of hydrogen sulphide and is very suitable for treatment by any controlled oxidation process. At least two plants have been installed on an experimental basis in the United States, one at Baton Rouge and one at Bayway. The triethanolamine solution has a long life and no deterioration may be observed after several months' operation. The simplicity of the process is extremely attractive and it is of considerable advantage to obtain a gas containing such high proportions of hydrogen sulphide. This can be readily converted into sulphur, by controlled oxidation, or into sulphuric acid by complete oxidation followed by the normal catalytic sulphuric-acid process.

The Seaboard process was developed by the Koppers Company, in the United States, primarily with the object of removing the hydrogen sulphide from coke-oven gases, without recovery of the sulphur. It is applicable to coke-oven gases, water gas, natural gas and refinery gases, and is described here since the Ferrox and Thylox processes, in which recovery of sulphur is normally practised, are based upon the use of sodium carbonate, the alkali used in the Seaboard process. In this process, the gas is passed up a scrubbing tower, down which passes a dilute solution containing between 2 per cent. and 4 per cent. of sodium carbonate. The hydrogen sulphide is dissolved by the sodium carbonate to form sodium-hydrogen sulphide and sodium bicarbonate. Carbon dioxide is also absorbed to produce sodium bicarbonate, according to the following equations:—

$$H_2S + Na_2CO_3 = NaHS + NaHCO_3$$
$$CO_2 + H_2O + Na_2CO_3 = 2\,NaHCO_3$$

After stripping the gas, the above reactions are reversed by passing large volumes of air up the tower. The foul gas was formerly released to the atmosphere but may now be processed to recover the sulphur. Secondary reactions take place in the scrubbing medium which result in the build-up of undesirable constituents, such as sodium thiosulphate. This increases the gravity of the solution and represents a loss of soda, which must be replaced. The rate of ciculation of liquor depends upon the concentration of the hydrogen sulphide in the gas. The richer the gas, the greater the rate of circulation, which is limited by the rate of formation of fixed salts. Fixed-salt formation is increased by increasing the strength of the solution and by raising the temperature. When hydrogen cyanide is present, sodium thiocyanate is also formed. The optimum circulating temperature is about 70 deg. F. and 100 to 200 grains of hydrogen sulphide are dissolved per gallon of solution, with a scrubbing efficiency of between 85 and 95 per cent. The normal air rate corresponds to a stripping of 2 to 3 grains of hydrogen sulphide from fouled liquor per cubic foot of air. The amount of make-up soda is checked by determining the alkalinity of the solution, and the proportion of rejected liquor is determined by controlling the gravity of the solution. The principal difficulties of operation are due to the use of dirty gas and the corrosion of metal parts, including the spray nozzes. These difficulties are not serious with properly designed plant.

The Ferrox process, by the Standard Oil Company, is a development of the Seaboard process and is applicable to the same range of gases. In this process, the hydrogen sulphide is removed by scrubbing with a dilute solution of sodium carbonate containing a fine suspension of iron oxide. In addition to the reactions mentioned in the Seaboard process, the following reaction also takes place with the iron oxide:—

$$3H_2S + Fe_2O_3 = Fe_2S_3 + 3H_2O$$

As in the Seaboard process, aeration causes reversal of the first equations and a revivification of the iron oxide, according to the equation:—

$$2Fe_2S_3 + 3O_2 = 2Fe_2O_3 + 6S.$$

The liquor from the scrubbing chamber passes over a succession of cloth bags through which air is diffusing under slight pressure. The rising air carries the resultant sulphur slurry to the surface and the reactivated liquor returns to the absorber tower. The sulphur is recovered from the slurry by passing through filter presses. Side reactions again occur, which are not eliminated in the aeration process. The formation of these salts is more rapid than in the case of the Seaboard process, and it is therefore necessary to operate with a lower concentration of soda; for example, a 1 to 2 per cent. solution. The quantity of oxide in suspension varies from about 0·1 to 0·2 lb. per pound of circulating liquor, and from 20 to 50 grains of hydrogen sulphide are removed per gallon of circulating liquor.

In the aeration system, the depth of liquor through which air is bubbled has a direct bearing on both the soda consumption and the heating efficiency of the system. Too great a depth results in the excessive formation of fixed salts and in excessive soda consumption: too low a level results in insufficient aeration, so that the depth is usually kept between 4 ft. and 6 ft. The decanting conditions are important, since too low a concentration of sulphur in the slurry results in the filter presses being overloaded. Too high a sulphur concentration results in excessive amounts of sulphur remaining in the circulating system. The amount of air used is usually such as to accomplish recovery of 10 to 20 grains of hydrogen sulphide per cubic foot of air used. Iron oxides as well as soda are added from time to time to maintain the proper concentrations of these ingredients. The principal difficulties of this process reside in the aeration system, since the bags require regular cleaning and replacement when faulty. There is also the difficulty of handling the oxide suspensions in an efficient scrubbing system. The sulphur product is of poor quality, containing 80 to 85 per cent. of free sulphur contaminated with iron oxide. Its most likely application is for combustion to sulphur oxides for use in a contact sulphuric-acid plant.

The Thylox process, also developed by Koppers, is similar to the Ferrox process, except that arsenious oxide is used in solution in place of iron oxide in suspension. Consequently, many of the difficulties associated with the use of a suspension of iron oxide are eliminated by the use of the soluble arsenious oxide. The quality of the sulphur may be improved by heating in an autoclave, with steam, at moderate temperatures and pressures. An additional difficulty in operation is, however, the introduction of the poisonous arsenious oxide, since it is difficult to dispose of effluents which are poisonous in nature. The sulphur and waste liquors may be used for insecticidal purposes, and here this difficulty becomes an advantage.

In the caustic-soda wash process, caustic soda is used and this removes the hydrogen sulphide as sodium-hydrogen sulphide. The process may be used where high concentrations of hydrogen sulphide are present and generally, in the presence of organic gases, organic sulphur compounds are also formed during the absorption. These organic impurities, which are chiefly mercaptides, may be removed by passing excess of gas through the solution, which may then be sold as a concentrated solution of sodium-hydrogen sulphide or may be converted to sodium sulphide by neutralisation with a further quantity of caustic soda. Alternatively, carbon dioxide may be blown through the solution to release hydrogen sulphide. The caustic-soda solution used contains from 25 to 30 per cent. of caustic soda and absorption takes place in two vessels in series at 40 deg. C. One vessel only is used for purification, the remaining vessel being charged and filled with fresh solution. After one vessel has been filled, the order of absorption is reversed, so that the last drum always contains fresh caustic soda. The chief difficulty in this process is to remove the mercaptides completely from solution, which is necessary in order to sell the solution of hydrosulphide readily.

All the above processes have been tried out on a large scale in industrial practice, and some of them have been operated continuously over a period of many years in Germany and in the United States. They are all much more convenient in coke-oven practice than iron-oxide boxes and represent a ready means of recovering much of the sulphur now being wasted in coke-oven and refinery gases.

LIGHT-ALLOY CRANE JIBS.

High-strength aluminium alloys, with their low weight (one-third that of steel), and almost complete resistance to corrosion, are being used for heavy engineering structures to an increasing extent. In particular, they are used for crane jibs and dragline booms, a class of work where low weight and good resistance to corrosion are specially desirable. Dragline booms were, it is believed, the first heavy engineering job in the world to be constructed of light alloy, and although aluminium has since been applied to many types of structures, it is only in the last few years that it has found its way back to jibs. The dragline booms referred to are those which were used on the Mississippi's embankments in 1930. One at least of these is still in existence, having found its way to this country under lend-lease and been acquired by Messrs. George Wimpey and Sons, Limited, who are still using it. Recently it came into the works of Messrs. Head Wrightson Aluminium, Limited, Thornaby-on-Tees, for repairs; it was found to be in good condition and only needed repairing because it had been accidentally dropped. The buckled sections have now been replaced and it is back in service again.

Twelve high-duty 10-ton derricks recently supplied to Sir Robert McAlpine and Sons, Limited, 80, Park-lane London, W.1, all have light-alloy jibs, one being 150 ft. long and the other eleven 120 ft. The jibs were designed and fabricated by Messrs. Head Wrightson Aluminium, Limited, and the rest of each crane was made by Messrs. John M. Henderson and Company, Limited, King's Works, Aberdeen. The long jib is constructed of extruded angles of the alloy HE 10-WP (B.S. 1476-1949) connected with steel rivets. Its total weight is 3½ tons. In general design the only difference from normal steel practice is a slight increase in the overall depth of the centre section in order to provide for the low value of Young's Modulus, and the use of thinner members for some of the bracing members made possible by the fact that corrosion is not a factor. In 1930, when the Mississippi jibs were made, aluminium was much more expensive than steel. Since then, however, while the cost of steel per pound has risen considerably, that of aluminium alloy has stayed almost constant, and the present disparity in price is such that for long jibs the extra cost of using alloy is more than offset by the improved performance and life.

THE BRITISH CONTRIBUTION TO SCIENCE AND TECHNOLOGY.*

By H.R.H. The Duke of Edinburgh, K.G., F.R.S.

The Prince Consort had very much less reason to be modest about addressing you at Aberdeen in 1859 than I have, because this year we celebrate the anniversary of the Exhibition which was his greatest achievement, and an event which had an untold value to Science. Let us hope that this year's Festival will be judged a worthy successor and an inspiration for the future. I am proud to pay tribute to this man who saw so clearly the part Science was destined to play in the future of this country, and my address to you to-night is largely the story of the fulfilment of his hopes.

In a review of British science and technology, 1851 is a convenient starting point for two reasons. Firstly, the Exhibition of that year can be regarded as a gigantic stocktaking of the national resources and technical skill. Secondly, because it marked the end of the Industrial Revolution and the conversion of Victorian England to the policy of industrial expansion on which our future still depends. The period as a whole saw the climax of our industrial supremacy and its inevitable decline when countries with greater resources and population learned from us the lessons of the mechanisation of industry. It also covers the birth and growth of the new concepts of modern science.

Social conditions of a hundred years ago were, generally speaking, the outcome of the Industrial Revolution, but with all the traditions of the England of agriculture, cottage industry and small market towns. The population of 20 millions was growing fast, but still small compared to our 50 millions of to-day. Education was limited to a minority and was almost entirely classical, so the new profession of engineering had to draw its recruits from a different sphere, that of self-educated men. A new wealthy class was growing up in the commercial world to rival the old aristocracy. There was unbounded optimism about the future, and ample scope in commerce and industry to attract all intelligent and enterprising men. The number of poor was on the increase and their conditions were deteriorating because, as yet, no social conscience had grown up to replace the patriarchal responsibility of the landowners and master craftsmen.

In the domestic field, lighting was by candle and oil lamps, cooking and heating by coal or wood in ranges or open fires with the consequent enormous waste of energy. Food had to be fresh or crudely preserved, and thus needed to be produced locally. In health and hygiene the figures speak for themselves. In 1851 the infant death rate was 150 per 1,000 living births, compared with 25 per 1,000 to-day. Anæsthetics, antiseptic surgery, biochemistry, tropical medicine, were all virtually unknown or in their infancy. Psychology had not yet achieved independence from philosophy on the one hand and physiology on the other.

This was the age of the practical engineer and of processes arrived at by intuition born of experience and by trial and error. Technology was concerned with the application of steam power, with metallurgy and the working of metals for various purposes, and with the production of machine tools and precision machinery. Men were already turning their minds to other types of engines and the internal-combustion engine was in the process of development.

Scientists, while continuing their search for the secrets of Nature, were beginning to turn their attention to exploring the empirical developments of industry. Their numbers as yet were small, the endowments for research were negligible and much of their work was carried out in the watertight compartments of the different sciences. But the seed had been sown and it was not long before scientists and engineers were preparing the way for the great technological harvest of the Twentieth Century.

The changes brought about in the lives of men and women in the past hundred years have been greater and more rapid than during any other period in history, and these changes have been almost entirely due to the work of scientists and technologists all over the world. They have not only affected the way of living of all civilised peoples, but have also vastly increased our knowledge about ourselves, the earth we live on and the universe around us. I cannot emphasise too much that the sum total of scientific knowledge and technological progress is an international achievement to which every civilised country has made some contribution.

The great stimulus of the 1851 Exhibition created a growing interest in technical education and research, followed by a widening of the scientific horizon which was soon to find expression in borderline subjects. In most fields, there was a wide gap between science and industry. Electricity was an exception and the groundwork was already being laid for the electrical revolution of the Victorian age.

Between 1851 and 1870, practice, in many industries, was ahead of science, and in that period the large number of inventions of the industrial revolution were progressively improved and widely applied. These inventions were mainly the work of British genius. They were of great economic advantage to this country and were quickly exploited commercially. New factories and plants were built to include the latest ideas, and with the expansion of industry came the demand for more and more new ideas and greater efficiency. We are still struggling with the social results of this vast expansion.

From 1870 to 1890 the high-water mark of British industrial expansion, as compared with other countries, had been reached and the competition of the United States and Europe was just beginning to be felt. But the lack of serious competition hitherto had bred a feeling of over-confidence and satisfaction in the methods and processes employed. The result was a conservative attitude towards technical change and, particularly in the older industries, neglect of scientific research. Concurrently, a subtle change occurred in the type of British exports. So far, the products of our machinery had been shipped abroad for immediate use, but now machines themselves were exported. The result was to intensify foreign industrial competition between 1890 and 1914, but, with the increasing demands from the Colonies, the volume of British exports was not greatly affected.

Then came the critical years of the First World War. For the first time in history, a real attempt was made to enlist the services of science in the war effort, and the Department of Scientific and Industrial Research was founded to further the application of science in industry through Government laboratories and research associations. The effects appeared clearly in the inter-war years, when there was a marked swing of education from classics towards science. Scientific progress was no longer confined to the work of a few brilliant individuals, but came also from teams of research scientists, each working on different parts of the same problem.

The war had also shown a great weakness in our dependence on foreign production for many vital articles, such as dyestuffs, scientific instruments and optical glass, in the manufacture of which scientific research played an essential part. It is true that manufacturers in some of the older industries still clung to traditional methods, in spite of the pressure of competition from America and other countries. It is significant that the history of production engineering after 1890 is almost entirely confined to the United States.

It was, however, a period of rapid development in Britain. The invention of the internal-combustion engine and the pneumatic tyre had opened new branches of industrial engineering, and the demand for fuel for motor cars and aircraft gave birth to the new technology of oil. In the electrical, chemical and aircraft industries, science was fully enlisted in the fields of electronics, synthetic fibres, plastics, aerodynamics and light alloys. Consequently, the outbreak of war in 1939 found us in a much stronger position to meet the immense demands it made on all branches of technology for new gadgets, machines and weapons. It was only the intimate partnership of science and engineering with the staffs of the fighting Services that enabled us to meet the menace of total war.

The tremendous demands on our industries had some good after-effects. Once again these demands revealed weaknesses where our industrial capacity was out of date. The realisation of this has initiated comprehensive reconstruction on most modern lines. Our industry and productivity have shown a wonderful improvement, but there is still a lot more that can be done. Our physical resources have dwindled, but the intellectual capacity of our scientists and engineers is as great as ever and it is upon their ingenuity that our future prosperity largely depends.

I would now like to make a brief survey of the British contribution to natural knowledge and technology and pay a tribute to some of the great men of science of the past hundred years. In some branches almost the whole story can be told, since one problem after another has been solved by British scientists. There can be no doubt that during this period the contribution of the British Commonwealth has been of outstanding importance.

Chemistry has fascinated man from the earliest times, and vast progress has been made in the past hundred years, both in knowledge and theory. Much fresh ground was broken by Crookes by his work on spectra, his discovery of thallium and of "radiant matter," known later as cathode rays. Long after everyone was quite sure of the composition of the air, Rayleigh found another ingredient which he called

* Presidential address, entitled "The British Contribution to Science and Technology in the past Hundred Years," delivered to the British Association for the Advancement of Science at Edinburgh on Wednesday, August 8, 1951. Abridged.

argon and so started the hunt for other inert gases. In organic chemistry, Perkin and Robinson added enormously to our knowledge of the structure of carbon compounds, and to our power to copy natural products synthetically. The development of X-ray analysis by the two Braggs, father and son, has given us a means of finding the actual arrangement of the atoms in the molecule. This is a most striking example of the power of the theoretical and practical scientist to penetrate Nature's secrets. Thomson's discovery of the nature of the electron was the first attack upon the integrity of the atom. Next, thanks to Rutherford's brilliant research and keen intuition, came the nuclear theory, which revolutionised our ideas of matter. He was the first man to succeed in the transmutation of an element.

Parallel with this activity in the physical sciences, there occurred a technological revolution of even greater scope and variety. The Darbys of Coalbrookdale were the lineal ancestors of Bessemer, Thomas and Siemens, and the whole technology of metals. First, cheap cast iron, followed by cheap steel, then steel from phosphatic ores, completely changed the materials available to engineers, shipbuilders and architects. Scientific metallurgy can be said to have started when Sorby first applied a microscope to the surface of metals. The way was opened for the investigation of the metallic alloys which came in quick succession from developments in which Hadfield and Rosenhain made outstanding contributions. The great majority of the mechanical developments of the period were due to new alloys which could withstand higher stresses. But, before these materials could be fully used, Maudslay and Whitworth had to lay the foundations of production engineering, and Mushet had to do pioneer work in developing tungsten steel as the first high-speed cutting tool.

The reciprocating steam engine was the main source of power until Parsons invented the steam turbine, which revolutionised large-scale power production on land and sea. The internal-combustion engine, in which Dugald Clerk and Akroyd Stuart were among the early pioneers, has proved to be a formidable challenger in many fields. In marine engineering, Froude's work on hull forms and propellers enabled the full benefit of the new prime movers to be reaped at sea.

Restrictive legislation drove the development of the motor car abroad, until the repeal of the speed limit in 1903 gave scope to the genius of Royce, Lanchester and Ricardo. In place of the motor car, however, we have Lawson to thank for the invention of the safety bicycle; and all wheeled vehicles, except those running on rails, owe their rapid development to Dunlop's invention of the pneumatic tyre. The material required for this started the vast natural and synthetic rubber industry, and has made famous the name of Wickham for a brilliant feat of smuggling, when he brought the rubber seeds from Brazil to Kew, from which sprang the rubber plantation industry of the East.

In flying, more than in any other mechanical science, the development of aerodynamics has been shared by many nations, but Lanchester's vortex theory was one of the stepping stones to powered flight, and the achievement of Alcock and Brown in making the first Atlantic flight in 1919 speaks highly for the tremendous scientific and technological background of flying in this country. Of outstanding importance and consequence was the genius which Mitchell brought to aircraft design, and, more recently, Whittle's pioneer work has given us the lead in jet-engine production.

The most far-reaching development of the period has been that of electricity and electronics. Although the key discovery belongs to Faraday in an earlier period, the second founder of the science is undoubtedly Clerk Maxwell, with his classic treatise on electromagnetism. The use of electricity for domestic and industrial purposes was helped by Wilde's development of the dynamo and then by Swan's incandescent lamps. Wheatstone and Kelvin pioneered the use of electricity for communication by their work on line and cable telegraphy. Wireless telegraphy soon followed and the work on tuned circuits by Lodge, and Marconi's many brilliant developments, made in this country with the General Post Office and the Navy, soon made radio a practical proposition. Heaviside and Appleton made further contributions on the propagation of radio waves. The technique used by Appleton was later developed by Watson-Watt into radar, which is now almost indispensable to airmen and seamen all over the world. Randall's development of the magnetron for high-frequency radar was one of the major contributions to the Allies' equipment for war. Television has a wide parentage, but Baird's name will always be linked with the first successful pictures.

Another great innovation of this hundred years was the discovery and development of plastic and synthetic materials. The story starts with Parke's discovery of celluloid, and Cross and Bevan's manufacture of viscose, which gave birth to the rayon industry and the many later types of synthetic fibre. Perkin's mauve, first of the aniline dyes, and Kipping's new silicon compounds were, however, disregarded by industry in this country. We see to-day a change of heart in the development in our industrial laboratories of two new plastics, Perspex and polythene, with almost an unlimited range of applications in the air, on the ground, and at sea.

The effect all this has had upon the citizen varies, naturally, with where and how he lives, but basically it has given him reliable light and heat in his home, push-button communication with almost any part of the world, and home entertainment of a high quality. His transport on land, at sea, and in the air is quick, comfortable and clean. In addition, he has a vast range of materials with which to clothe himself and to furnish and embellish his home. Almost more important, these developments have brought about a complete change in his conditions of work.

If Lister was the father of modern surgery, then Manson was the father of tropical medicine, and in this field the British contribution has led the world. The discovery by Ross that malaria is carried by the *anopheles* mosquito and, much later, the work of Fairley in Australia on its prevention and cure, have been of the greatest benefit to mankind. Bruce will always be remembered for his discovery of the part played by the tsetse fly in the transmission of sleeping sickness, and his work on Malta fever. Finlay, Adrian Stokes and Hindle stand high among the names linked with the study and prevention of yellow fever.

These were all vital efforts towards the prevention of sickness, but there is another aspect of medical practice in which the Commonwealth has taken a leading part—the promotion of health. It was Sir John Simon, the first medical officer appointed to a central authority, who made a careful statistical study of the causes of sickness, with a view to taking effective measures for the health of the community at large. Through his leadership, health services have been provided in regular stages throughout the country.

There are two other fields in which the biological sciences play a major part. The first is in the preservation of food and in nutrition, which has had the most profound economic and social effects. The ability through freezing, drying and canning to import large quantities of food has enabled a rapidly increasing population to maintain and increase its standards of living, which would have been impossible had it been dependent on British agriculture alone. Mort had the first freezing works in the world at Sydney, and was a pioneer in refrigeration, but success in transporting meat to Britain had to wait for the development of more reliable refrigerating plant. Since 1918, the Food Investigation Laboratories of the Department of Scientific and Industrial Research, of which Sir William Hardy was the first director, have established the basic biological knowledge on which the storage, and transport of meat, fish and fruit are now largely based.

The second field is in agriculture. Lawes discovered how to make and use superphosphate, and started the great fertiliser industry. He founded Rothamsted, now the oldest agricultural research station in the world, and there he and Gilbert carried out the first scientifically controlled field experiments, which laid the foundation of agricultural science. Later, Biffen's pioneer work in plant breeding at Cambridge became one of the greatest contributions to the problem of feeding the world's growing population. The mechanisation which was to revolutionise farming in all parts of the world was also under way and Britain was playing a leading part. The reaping machine, for instance, was invented by Patrick Bell in 1826, although it was not manufactured until 1853.

There is one science which I have not yet mentioned. It is both the youngest science and the oldest problem. The study of man's mind was the province of the philosopher until the middle of the Nineteenth Century, when it separated from him and began its independent existence as the science of psychology. The foundations were not laid in this country, but important contributions were made. Probably the most outstanding figure in this country was Galton, who was the first to develop an interest in the mental differences between individuals—a field in which British psychology has made some of its greatest contributions.

The concrete measurement and indirect effect of all scientific effort is the general improvement in the condition in which people live and work; it is in the improvement in health, in the expectation of life and standards of living. Much has been due to the politicians and administrators, and behind them to religion, morals, education, art and the complex influences which we call culture; but even there science has stood beside the authors of progress to advise, to help and sometimes to guide.

Now, as science and technology are so vital to the future strength and prosperity of the British Commonwealth, the great problem is to discover the conditions under which they are most likely to flourish. The records show that both depend very much on co-operation, and upon the linking up of a long chain of discoveries, one with another; so that it is quite exceptional for the credit of a great advance to belong to one man or even to one country. For many reasons, but principally because of the increasing complexity of research and its cost, teamwork is becoming more and more the rule. We need not repine at this, but it would be a disaster if the individual inquirer, working in his own laboratory, were discouraged out of existence.

While the quality of scientific work is determined by the quality of the scientist, the quantity of scientific output is determined by the money available. The rapid progress of science in Britain has owed much to the growing support and sympathy of Government and individual benefactors, and to the endowment of research by industrial corporations; though the basic discoveries that mark the great advances depend on the accident of individual genius and are not at our command. The scope and intensity of the progress of applied science and technology, on the other hand, bear a close relationship to the circumstances of the time. Technology, as the combination of scientific knowledge with the practical ability of the inventor to apply that knowledge to the solution of particular problems, comes into play with any new discovery of scientific fact. It is a sad reflection that the urgent demands of modern war can produce advances that might otherwise take many years to develop, especially in the costly and uncertain experimental stages.

The rivalry between large commercial undertakings, using science to improve their products or processes as a direct means of competition, has produced a steady flow of improvements and developments. However, the fruits of this form of scientific work are sometimes open to considerable misuse. The discoveries of these commercial laboratories may be kept secret and, in some cases, a number of teams may be working on the same problem, which may have already been solved elsewhere. The buying up and suppression of patents and discoveries to protect equipment from becoming obsolete has also been known to happen.

It would seem that science has become so well established that nothing can stand in the way of its natural growth. This is far from the truth. Since the earliest times, the natural conservatism of laymen has acted as a powerful brake to the adoption of new ideas, which do not rigidly conform to his notion of the correct order of things. The resistance towards anything new or unexpected is balanced, on the other hand, by bursts of enthusiasm that some particular discovery or invention will see the end of all our troubles. The belief in the philosopher's stone seems to be just as great as ever.

As the front of pure science has advanced, so its lines of communication to practical exploitation have got longer and longer. A great army of scientists, technicians, inventors, designers and production engineers are required to keep the lines of communication open. How important some of the members of this follow-up team have become is not always appreciated. In his presidential address in 1948, Sir Henry Tizard emphasised this point when he said: "All depends on good design and production. Our weakness in the war was not to be found in what was best to do, nor in the scientific work of how to do it. It was when the stage of design and production was reached that we fell short of the best standards."

A more general and far-reaching matter for concern, and possibly the most vital factor affecting the industrial application of scientific research, is the lack of a co-ordinated system of scientific and technological education in this country. Excellent as they are, the existing institutions, which have grown up to meet particular circumstances, do not produce anything like enough trained technologists to meet the urgent needs of scientific development in industry and to provide leaders for the future. It is to be hoped that the new and rather uncertain science of education will develop sufficiently quickly to point the way to a speedy solution of this problem.

The shortage in Britain of "personnel trained and eager to apply scientific knowledge and scientific methods to practical ends"—as Sir Ewart Smith said last year—is only one of the many shortages which the world is now facing. Among them are food, non-ferrous metals, steel alloy metals and sulphur. These very shortages are due to the scientific complexity of present-day life and it is only by science that they can be overcome. Naturally, there are many ways of tackling this problem; but the most obvious are, firstly, by improved design to secure economy in production and the minimum use of scarce materials. Secondly, by the development of substitutes made from raw materials which are still abundant. Thirdly, by the reclamation of scrap and improved methods of using low-grade ores. Finally, the development of renewable raw materials, such as timber to satisfy the world demand for cellulose.

It is only by an accurate knowledge of the world's resources that we can foresee the scope and magnitude of the future problems that science and technology have to meet, and that only they can solve. It is, therefore, good news that the Economic and Social Council of the United Nations has resolved "to promote the systematic survey and inventory" of those resources which are not already covered by the Food and Agriculture Organisation.

The pursuit of truth in itself cannot produce anything evil. It is in the later stage, when the facts dug up enter the process of application, that the choice between the beneficent and destructive development has to be made. It is quite certain that it is an exception if any particular discovery cannot be used equally well for good and evil purposes. Happily, the beneficent exploitation of scientific knowledge has kept pace with its destructive application.

It is vital that the two sides of scientific development are fully and clearly understood, not only by the research scientist, inventor, designer and the whole scientific team, but also by all laymen. The instrument of scientific knowledge in our hands is growing more powerful every day; indeed, it has reached a point when we can either set the world free from drudgery, fear, hunger and pestilence, or obliterate life itself. Progress in almost every form of human activity depends upon the continued efforts of scientists. Superiority, or even our ability to survive in war, is a direct measure of the excellence and capacity of the scientific team.

This team of research workers and engineers has a dual responsibility, one for its work and the other as informed citizens, and it can only fulfil its proper functions if its members have a sound general education as well as a thorough training in science. It is no less important that the people who control the scientific machine, both laymen and scientists, should have a proper understanding and appreciation of what science has grown into and its place among the great forces of the world. It is clearly our duty as citizens to see that science is used for the benefit of mankind. Of what use is science if man does not survive?

CIVIL AVIATION.

REVIEWING the progress in British civil aviation during the past year at a meeting of the National Civil Aviation Committee on July 26, the Minister of Civil Aviation, Lord Ogmore, said that the planning of helicopter services was progressing. At London Airport, plans were in hand for the passenger-handling buildings, the control tower, and the freight building in the central area; large permanent hangars were being built for the national Airways Corporations, and work on the tunnel linking the central terminal area with the Bath-road had begun. At Prestwick, the main runway was expected to be complete this autumn; construction of the subsidiary runway could not be started before 1953. New black and white markers along the runways of the larger airports had helped to solve the problem of informing pilots how far ahead they could see when landing in bad weather. The national airways system, brought into operation last winter, was working smoothly and was being continuously improved. The Decca Navigator system had shown itself to be superior to all other medium-distance navigational aids; the International Civil Aviation Organisation had recommended that the system should be thoroughly evaluated in Europe, and it was therefore receiving strong official support from this country. British European Airways were testing it in Europe, and the British Overseas Airways Corporation were to test a long-range development of the Decca Navigator in the de Havilland Comet air liner. A memorial to Sir John Alcock and Sir Arthur Whitten-Brown, who made the first trans-Atlantic flight in a Vickers Vimy aircraft in 1919, was to be erected at London Airport.

REPORTS ON RAILWAY ACCIDENTS AT GREENFORD AND AT ALLOA.—The Ministry of Transport have now published, through H.M. Stationery Office, the reports of the Inspecting Officers of Railways on the accidents which occurred at Greenford, Middlesex, on December 20, 1950, and at Alloa Junction, Clackmannan, on January 10, 1951. At Greenford, an "auto-car" train, consisting of a single coach propelled by a 0-6-0 tank engine, left the bay platform at Greenford station against a starting signal that was at danger and ran into a spur line, demolishing the stop blocks. Brigadier C. A. Langley, who held the inquiry, found that the driver was to blame for passing the starting signal. In the Alloa accident, an express passenger train from Perth to Glasgow ran into a light engine, the position of which was obscured by smoke and steam from another engine. The inquiry was held by Colonel R. J. Walker, who found the driver of the express to blame, in that he was travelling at a speed which was excessive in the circumstances, and so was unable to pull up in time. The price of the reports is 6*d*. each.

LABOUR NOTES.

RESTRICTIONS on strikes and lock-outs, which were imposed during the war and have been in force ever since, are to be completely removed. Mr. Alfred Robens, the Minister of Labour, announced in the House of Commons on August 2 that the Conditions of Employment and National Arbitration Order, generally known as Order 1305, would be rescinded on August 14, and its place would be taken, as from that date, by a new Order, to be known as the Industrial Disputes Order, 1951, No. 1376 (H.M. Stationery Office, price 4*d*. net). In the course of his statement, Mr. Robens referred to the existing Order as a war-time measure, which had remained in operation after 1945 with the agreement of both sides of industry and on the understanding that it could be revoked at any time at the request of either side. In his opinion, the time had arrived for the Order to be reviewed. Experience had shown, for example, that the enforcement of penal sanctions against persons taking part in strikes and lock-outs gave rise to extreme difficulties. Mr. Robens paid a tribute to the public spirit and statesmanlike approach to the problem, which had been shown by the British Employers' Confederation, the General Council of the Trades Union Congress and the representatives of the nationalised industries, during discussions lasting for several months. He reported to the House that a large measure of agreement existed between the two sides of industry for the replacement of the existing Order.

Under the terms of the existing measure, strikes and lock-outs were illegal unless 21 days' notice of the intention to take such action had been given to the Minister of Labour and he had neither referred the dispute to arbitration nor taken other action to settle the difficulty. Compulsory arbitration, as previously understood, will not exist under the new Order, which has been designed to remove entirely the atmosphere of penal restraint. It is intended to encourage and, where necessary, assist free negotiations between employers and trade unions in the settling of industrial disputes. The existing National Arbitration Tribunal will be replaced by an Industrial Disputes Tribunal, consisting of five members. The chairman of the new tribunal and two other members will be appointed by the Minister of Labour, and the remaining two members will be chosen to represent employers and workpeople respectively. A panel of appointed members of the Tribunal will be constituted by the Minister, and panels of persons chosen to represent employers and workpeople will also be constituted by the Minister, after consultation with the British Employers' Confederation and the Trades Union Congress, respectively.

The new Order provides that all disputes must be referred to the industry's own collective bargaining machinery, where such exists, before they can be reported to the Minister, and reporting to the Minister before strike or lock-out action is taken will not be compulsory. When a dispute is reported to the Minister, he will refer it to the Industrial Disputes Tribunal within fourteen days, but the Minister may extend the period if he so desires. He is empowered to take no action if it appears to him that either party to the dispute is causing a stoppage of work by attempting to compel the acceptance of terms and conditions of employment. If a strike or lock-out commences after a dispute has been referred to the tribunal, all proceedings may be suspended. The award of the Tribunal will be final and binding, but no sanctions will be taken against those who, being dissatisfied with the award, cease work.

The new measure is likely to substantially discourage the formation of breakaway unions and such-like bodies. Mr. Robens informed the House of Commons that the provisions of the new Order were framed to develop and strengthen the voluntary systems of negotiation and to uphold the sanctity of agreements and awards. With this in view, access to the Industrial Disputes Tribunal would be limited to employers, organisations of employers and trade unions that habitually took part in the settlement of terms and conditions of employment through voluntary machinery established in the industry, where such machinery existed. If such machinery did not exist, access would be limited to the employer concerned and the union that represented a substantial proportion of the employees.

Mr. Robens stated that such matters as the employment or non-employment of a person and claims for reinstatement had been excluded from the Order, as experience had shown that such matters were not susceptible to settlement by compulsory arbitration. There would be no possibility of using the new measure as an appeal against an award under the Industrial Courts Act or settlements reached through the voluntary machinery. While there would be no longer a general obligation on all employers to observe recognised terms and conditions of employment, the Order provided the means for settling issues of this kind in respect of particular employers. The Order would be experimental and it would be reviewed immediately, Mr. Robens announced, if at any time either side of industry expressed a wish for the Order to be discontinued.

Many wage claims are now pending, a number of which will involve very substantial sums of money. In addition to the claims of the three principal railway unions, reported on page 152, *ante*, demands have been put forward on behalf of agricultural employees, miners, and workpeople in the building, transport, and electricity industries. Many grades of Civil Service personnel are concerned in other demands. In connection with these claims, much importance may be attached to the decisions of the annual conference of the Confederation of Shipbuilding and Engineering Unions, which will be held at Swansea from Tuesday to Friday next week. Almost half the motions on the Confederation's agenda, issued on August 2, are connected in some way with demands for more wages. Although the demands of the unions making claims vary considerably as to the amounts of the increases requested, and the methods of payment, many of the 37 unions affiliated to the Confederation have made it clear in their motions that they will press the Confederation very strongly to take prompt and active measures to obtain the increases for which they ask.

Wage claims to be presented to the Confederation on behalf of 2,500,000 manual employees in the engineering and shipbuilding industries would add at least 125 million pounds annually to the nation's wage bill, if they were conceded in full. In addition to the request for an increase of 20*s*. a week for these workpeople, the Amalgamated Engineering Union will propose that the extra 20*s*. shall be added to the existing basic rate, and that the new consolidated rate shall form the basis for the calculation of overtime and piecework rates. The A.E.U. will also urge that the prices for piecework shall be such as to enable employees to earn at least 33⅓ per cent. above the plain time rate, and that the existing differential rates between skilled and unskilled operatives, and between district and district, shall be fully maintained.

The Amalgamated Union of Foundry Workers has sponsored a motion demanding an increase of 20 per cent. on the consolidated time rate for all its members, and the payment of 33⅓ per cent. above the new consolidated rate to employees engaged on piecework. Motions put forward by the Electrical Trades Union and the United Society of Boilermakers ask for a "substantial" increase for all their members. The Iron and Steel Trade Society has requested an immediate advance for pieceworkers and the Transport and General Workers' Union wants a "substantial" increase for all male employees. The motion of the National Union of Vehicle Builders puts forward a claim for an increase of 22*s*. a week for workpeople in the vehicle-building industry. The opinion is held in some quarters that, with all these rather varying demands before it, the Confederation may well decide to advocate an all-round increase of 20 per cent.

Towards the end of last week, it was reported that some sections of the employees at Marylebone and Battersea power stations had decided to impose a ban on overtime, as a protest against the rejection by the British Electricity Authority of a demand for an increase of 10 per cent. on behalf of the 12,000 manual employees of the Authority. The demand was submitted in April. By Tuesday last, bans on overtime and working-to-rule methods were in operation at 12 of the 48 power stations in the London area and, in all, nearly 4,500 workpeople were involved, although, at some of the stations, the proportion of employees banning overtime was not large. The men's action is unofficial and has not received the support of the five unions catering for the electricity industry, which sponsored the claim for an increase of 10 per cent.

A counter offer by the B.E.A., which would have had the effect of increasing the pay of the Authority's employees by 5 per cent., was rejected by the trade-union side at a meeting of the National Joint Industrial Council for the Electricity Supply Industry (Manual Workers) in July. Shortly afterwards, the employers' side of the Council requested the trade unions to agree to joint terms of reference, in order that the claims might be submitted to an industrial court for decision. It is understood that no reply was received, possibly owing to intercommunication between the five unions concerned, and, at the beginning of this month, notice was given by the employers' side to the Minister of Labour, in accordance with the terms of the Conditions of Employment and National Arbitration Order, that a dispute existed.

WATER TURBINES FOR HYDRO-ELECTRIC PROJECTS.*

By R. W. WEEKES, M.I.C.E., and A. FEINER, A.M.I.E.E., Assoc.I.Mech.E.

THE fundamental basis of the transformation of hydraulic energy into electrical energy by driving an electric generator with a water turbine is well known, and the system appeals, at first sight, because of its inherent qualities for the production of electrical power at very low running costs. But the capital cost of harnessing nature's bounty in the form of "white coal" can be high and the opposition of landowners difficult to overcome. Also, despite the advantages accruing from hydro-electric power generation, a number of countries have found it more economical to produce electrical power by using the more complicated, less efficient, and more costly to operate heat engine as prime mover. There are, however, areas as in New Zealand, Norway, Canada and Switzerland, where the natural resources allow water power to be used more economically than, and almost to the complete exclusion of, other forms of electric power generation. In territories where there has previously been difficulty in justifying the utilisation of water power, the demand for hydro-electric power is growing due to industrialisation, with its attendant improved standard of living, high costs of labour, increasing world population, the opening up of hitherto uninhabitable parts of the world, made possible by medical science, and the increasing difficulties in gaining from the earth its rapidly exhausting mineral content for use as fuel.

One of the main difficulties in utilising the more economic sites is that, by the very nature of things, they are quite often far removed from centres of population capable of absorbing the power. Developments which have taken, and are taking, place in the transmission of electrical current over long distances at higher and higher voltages are meeting this disadvantage, as is also the setting up of new industrial centres in the vicinity of the power sites. Other fields of human endeavour have made hydro-electric generating stations economic propositions as subsidiaries of the main purpose as, for example, in schemes of flood control, irrigation, navigation and water supply, and general advances in all branches of engineering have contributed to the attractiveness of hitherto uneconomic sites.

While this paper is, of necessity, primarily restricted to the water-turbine aspects of hydro-electric projects, the application of a hydraulic turbine to a specific project must take account of all sections of engineering science connected with the scheme as a whole. Of a large number of different types of turbines employed during the last century, three remain in almost universal use, namely, (1) the Pelton wheel or tangential-flow impulse turbine; (2) the Francis or mixed-flow reaction turbine; and (3) the propeller or axial-flow reaction turbine. In the third case, the blades may be permanently fixed or capable of rotation, and hence such turbines are further sub-divided into fixed-blade and adjustable-blade (or Kaplan) machines.

In the impulse turbine the potential energy of the water in the pipeline is entirely transformed into kinetic energy in a nozzle from which a jet of water issues at a velocity of approximately $0 \cdot 98 \sqrt{2\,g\,H}$, where g is the gravitational acceleration, and H is the effective head of water, using the same system of units. Since, throughout this paper, the ft.-lb. system is used, g is expressed in feet per second per second and H is expressed in feet. The rotating element, or runner, consists of a central disc to which buckets are attached. The jet impinges on each bucket in turn (Fig. 1). The buckets may be cast integrally with the disc or bolted thereto either singly or in segments of greater number. Modern practice favours integral buckets since: (1) the bucket attachment is absolutely solid and there is no question of loosening of the buckets due to the frequent and high impact forces of the jet or other vibration; (2) the prime cost of the complete runner is a minimum; and (3) if excessive wear occurs its effects will apply to all the buckets and not merely one or two; it would then be more economical to replace the complete runner, if the occasion demanded it, rather than provide a set of separate buckets requiring considerable skill and care in fitting.

Fig. 1

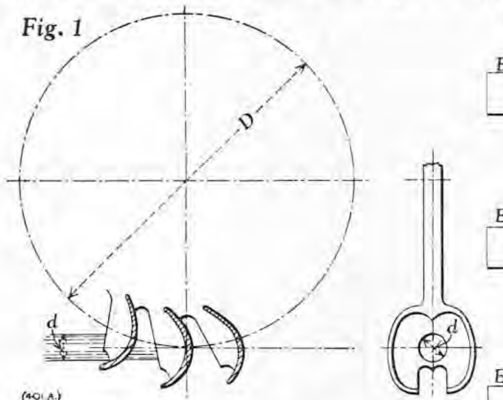


Fig. 2.

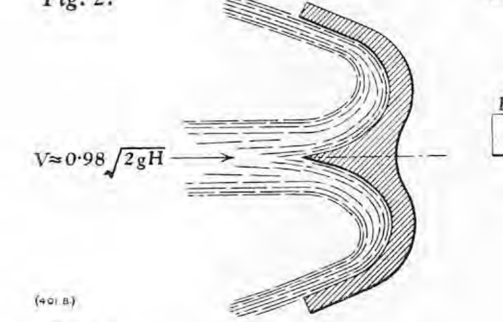


Fig. 4

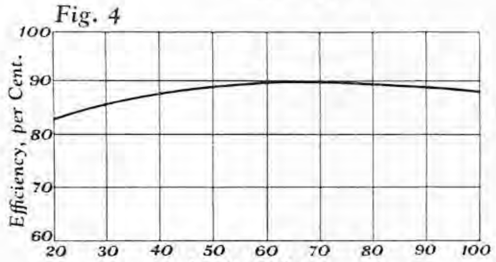
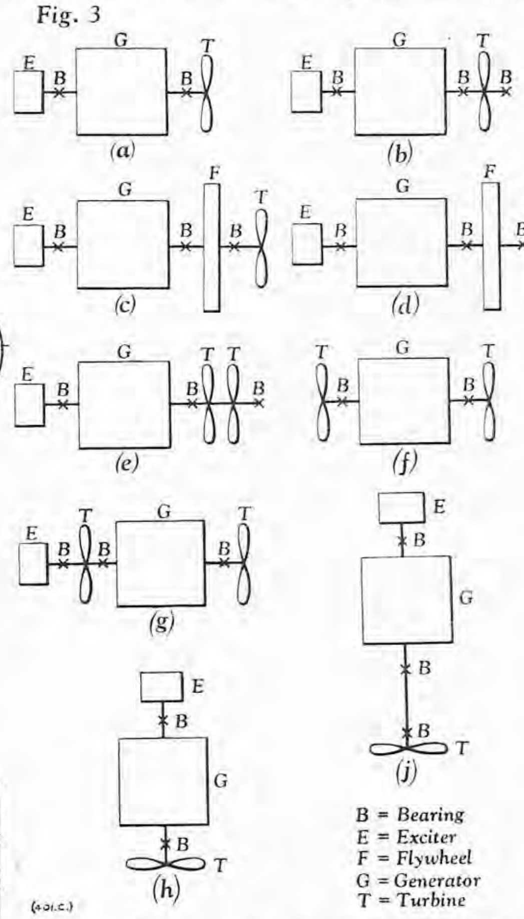


Fig. 3



Water enters and strikes each bucket with a minimum of disturbance because of the bucket outcut, is divided equally by a splitter, and is finally diverted through almost 180 deg. by the bucket (Fig. 2). In theory, the peripheral speed of the buckets, measured on the pitch circle of the wheel, should be half that of the jet; in practice it is limited to approximately 0·46 of the free spouting velocity $\sqrt{2g\,H}$. The ratio of the peripheral velocity of the wheel to the free spouting velocity is denoted by ϕ.

As the peripheral speed is given by $\pi \frac{D}{12} \frac{N}{60}$ ft. per second, where D is the pitch circle diameter of the wheel in inches, and N is the speed of rotation in r.p.m., $\pi \frac{D}{12} \frac{N}{60} = \phi \sqrt{2\,g\,H}$, where g is in feet per second per second and H is in feet. Hence, $D = \frac{1840\,\phi \sqrt{H}}{N}$.

Thus, it is seen that the diameter of the runner is fixed by the effective head and speed of rotation. As will be shown later, N may be raised by increasing the number of jets. With multi-jet machines it is imperative to ensure that the jets do not interfere with each other. Jets of up to 14 in. diameter have been used, but normally diameters are restricted to 10 in., and the number of jets increased if necessary.

The diameter of a jet is derived as follows:—

$$d = \sqrt{\frac{4\,Q\,144}{0 \cdot 98 \sqrt{2\,g\,H}\,\pi}} = \frac{4 \cdot 83 \sqrt{Q}}{H^{\frac{1}{4}}}.$$

Since

$$Q = \frac{550\,P}{62 \cdot 4\,\eta\,H}$$

$$d = \frac{14 \cdot 35}{H^{\frac{3}{4}}} \sqrt{\frac{P}{\eta}},$$

where d is the jet diameter in inches, Q is the water quantity in cusecs, H is the effective head in feet, P is the horse-power developed and η is the efficiency of the machine.

Impulse turbines may be arranged with either horizontal or vertical shafts, most machines installed, however, being of the former type. On horizontal machines more than two jets are seldom allowed to act on one wheel, and thus where higher speeds are desirable, the number of wheels is increased, but only in exceptional cases have more than two wheels been used; thus, in effect, the maximum number of jets is limited to four. If one wheel is used it is normally overhung on an extension of the generator shaft, as shown in Fig. 3(a), if all the flywheel effect required for speed regulation is in the generator rotor. This makes for a very simple unit having only two bearings. A twin-jet 8,500 brake horse-power 500 r.p.m. Harland-Morgan Smith turbine with this arrangement is to be installed in the Livishie power station of the North of Scotland Hydro-Electric Board.

Sometimes an outboard bearing is used for the runner, Fig. 3 (b). Where a separate flywheel is necessary, it is usually placed between the turbine and generator, a third bearing installed between the flywheel and turbine, the runner being attached to a shaft fixed to the flywheel and either overhung, Fig. 3 (c), or provided with an outboard bearing, Fig. 3 (d). Where two runners are used, both may be disposed at one end of the generator, usually with an outboard bearing, Fig. 3 (e), such as one by Boving at Dolgarrog, North Wales; or there may be one runner at each end of the generator, such as the 8,500 brake horse-power four-jet (two jets per wheel), 428 r.p.m. Harland-Morgan Smith machine for the North of Scotland Hydro-Electric Board's Allt-na-Lairige power station. Where a separate electric motor-driven exciter is permissible, the runners may be overhung, Fig. 3 (f); otherwise an outboard bearing is inevitable, Fig. 3 (g). The impingement of the jet on the bucket should produce no hydraulic end-thrust, but to cater for any which may occur in practice, a small thrust bearing suitable for taking load in either direction is combined with one of the journal bearings.

The ease with which water is expelled from the buckets without interfering with the jets enables more than two jets to be used on a vertical-shaft runner, and up to six jets have thus been employed, as, for example, in the Peltonwheel Company's 62,000-brake horse-power Bridge River machines in British Columbia, Canada. In this way only one runner is necessary, giving results equivalent to two or more runners. The turbine is located below the generator and, depending upon the importance attached to ease of access to the turbine and lower regions of the generator, the runner may be carried by the extended generator shaft, Fig. 3 (h), or by a turbine shaft solidly coupled to the generator shaft with the addition of a bearing, Fig. 3 (j). Any small axial hydraulic thrust is simply taken by the axial-thrust bearing which is, in any case, required for supporting the generator and turbine rotating parts. Despite a number of advantages accruing from the use of multi-jet vertical impulse machines, including simpler control and an overall saving in total cost, some operators prefer the horizontal arrangement, mainly for its slightly better accessibility.

The most important characteristic of the impulse turbine is its high efficiency over a wide range of load, as is evidenced by Fig. 4. It has been found that the best efficiency is usually obtained with a runner to jet diameter ratio of about 10. Only slight changes occur with higher values, but efficiencies drop rapidly below this value, and normally the minimum $\frac{D}{d}$ is fixed at 7 because a lower value makes it difficult to provide a sufficient number of buckets with proper clearance of water from the buckets. It is evident that there is an advantage in adopting a low $\frac{D}{d}$ since the speed of

* Paper read before Section G of the British Association at Edinburgh on Thursday, August 9, 1951.

the turbine varies inversely as the diameter of the runner.

In the case of reaction turbines, the pressure energy of the water is only partly transformed into kinetic energy before entering the runner, the flow through the runner taking place under a varying pressure, the passages remaining full. The forces on the rotating parts are due to changes in pressure and in the direction and velocity of water flow. The water enters the turbine either through a pressure casing of the volute or cylindrical type, or from an open flume, and is almost universally regulated in quantity before the runner by a set of movable wicket gates arranged in a circle. In the Francis turbine the runner inlet is set level with the gates so that water flows through the runner radially inwards and is then guided through 90 deg. to discharge axially. In propeller turbines the runner is set below the level of the gates and flow through it is axial. After passing through the runner the water is led through a sealed, slowly expanding draught tube which partly recovers the kinetic energy remaining in the water issuing from the runner, and, by creating a suction below the runner, can permit the turbine to be placed above tailwater level without loss of head. It may not always be possible to utilise this latter feature, since, to avoid cavitation of the turbine, the runner outlet pressure must be maintained above vapour pressure.

In Francis turbines, the runner inlet peripheral velocity coefficient ϕ varies between about 0·65 and 0·9, depending upon the optimum speed of the runner adopted. The minimum outlet diameter D_2 is restricted since the runner exit water velocity must be kept reasonably low to prevent serious vacuum conditions and consequent vaporisation at the outlet of the runner. If the ratio of runner discharge velocity to the free spouting velocity is ϕ_2, the runner outlet diameter is given by

$$D_2 = \frac{14 \cdot 19}{H^{\frac{3}{4}}} \sqrt{\frac{P}{\phi_2 \eta}}.$$

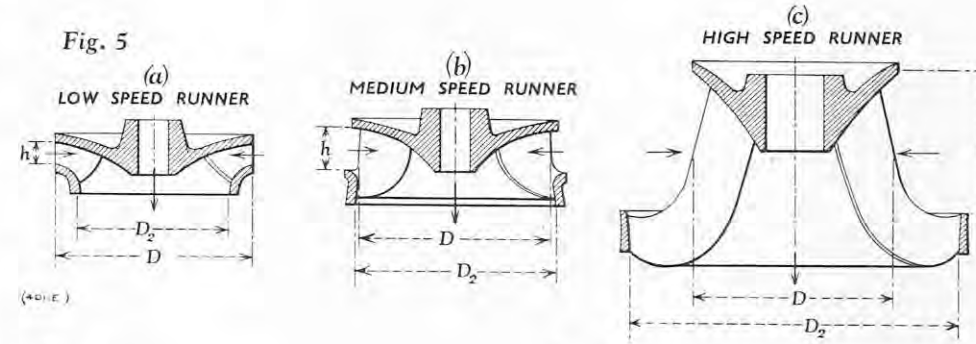
The coefficient ϕ_2 usually varies between about 0·20 and 0·35. Similarly, the vertical height at the runner entry is also determined by the velocity of the water through the wicket gates. Thus, for a given velocity the inlet height varies directly as the water quantity and inversely as the diameter. Fig. 5 compares diagrammatically three Francis runners of the same power output, (*a*) being a low-speed type for operating under a high head with a small quantity of water, while (*c*) is a high-speed type for use under a low head with a large quantity of water. The efficiency characteristics of such runners are shown in Fig. 6. It will be observed that the higher the speed of the runner the more peaked is the curve so that the corresponding part-load efficiencies are lower.

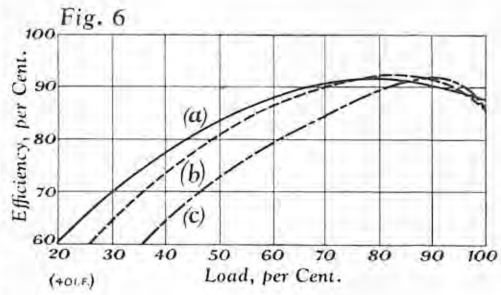
In propeller turbines, the inlet and exit diameters of the runners are identical. The peripheral coefficient ϕ varies between about 1·45 and 1·85, which means that the peripheral speed of the runner is greater than the free-discharge velocity of the water. This is understandable since the runner is in a contraction where the water velocity may be greater than the spouting velocity. This increase in velocity shows that for a given diameter the propeller runner can handle greater quantities of water than a Francis wheel. The runner outlet velocity coefficient ϕ_2 is usually not greater than 0·7.

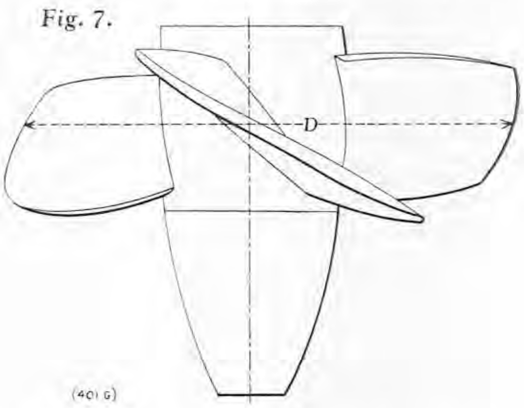
Fig. 7 indicates the form of a fixed-blade propeller turbine, and Fig. 8 shows a section through an adjustable-blade turbine. The blade-operating servomotor is usually located within the shaft between the turbine and generator coupling, but is sometimes housed in the runner itself, though this results in mechanical complication. The blades, under certain conditions, may be arranged for hand operation with the machine at standstill or running, or electrically by Selsyn motor. The advantage gained in varying the pitch of the runner blades will be understood by reference to Fig. 9. For each angular position of the blades, the runner is, in effect, a fixed-blade propeller with its own efficiency characteristic. The envelope of the peaks gives an exceedingly flat curve, so that the machine produces a greater output for the same water quantity at part loads. The position of the wicket gates is synchronised with the runner blade angle to give the best efficiency.

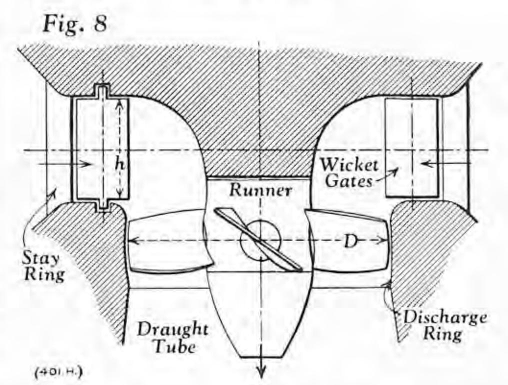
For mechanical and hydraulic reasons the propeller turbine is almost universally set vertically, even though it may be sited well above flood-water level in the tailrace. If the speed and output are low, it may be economical to drive a horizontal-shaft generator through a bevel-gear speed-increasing unit. More than one runner is never used in an attempt to increase the speed because of the great depth of excavations required and the difficulty of solving the mechanical problems satisfactorily. The general form of arrangement is as given in Fig. 3 (*j*), which was adopted in the case of the Bonneville power station units in the United States, where ten 74,000-brake horse-power Morgan Smith Kaplan turbines are in operation under heads from 45 ft. to 70 ft. and running at 75 r.p.m. The runners are 23 ft. 4 in. in diameter and when in running order each weighs about 200 tons.

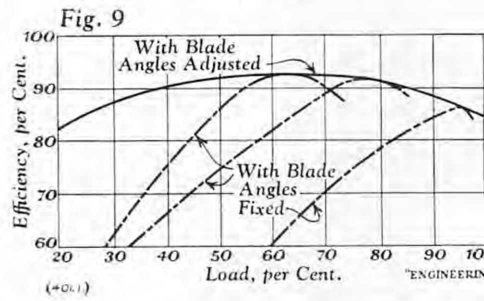
WATER TURBINES.











Francis machines may be arranged either horizontally or vertically, the latter being the most favourable hydraulically. When horizontal, the arrangements are usually as in Fig. 3 (*a*) and (*c*), because outboard bearings entail shafting through the draught tube restricting and disturbing the discharge flow at a critical point; furthermore, the small-diameter shafts which have to be used under these conditions do not materially assist the mechanical stability, despite the additional bearing, and rubbing of rotating and stationary parts sometimes results. In Scotland, Harland-Morgan Smith horizontal Francis turbines, each of 4,250 brake horse-power, are installed at the Loch Striven power station using the arrangement in Fig. 3 (*a*), whereas a typical horizontal-flywheel arrangement will be installed at the Storr Lochs power station in Skye, using 1,150-brake horse-power Gilbert Gilkes and Gordon turbines. For similar reasons, where more than one runner is used to increase the speed of the set, the arrangement of Fig. 3 (*f*), which involves separately-driven exciters, is much to be preferred over Fig. 3 (*e*) and (*g*). The multiple-runner vertical Francis turbine has been almost universally replaced by the arrangement shown in Fig. 3 (*j*), because of the latter's compactness of design and savings in the excavation, foundation, and building works. The most powerful Francis turbines in the world are those at Grand Coulee in the United States, where nine 150,000-brake horse-power Newport News 120-r.p.m. turbines are thus arranged. Six further machines, each of 165,000 brake horse-power, have yet to be installed. Nearer home, the largest output machines in Scotland are the four 45,500-b.h.p. English Electric turbines at the Loch Sloy power station, which, together with those by Boving at Clunie power station and those by the Harland Engineering Company, Limited, at Grudie Bridge power station, are forerunners of a number of large-capacity vertical Francis turbines planned by the North of Scotland Hydro-Electric Board using the arrangement of Fig. 3 (*j*).

The means adopted for feeding water to Francis and propeller turbines depend upon the head, general topography and other site conditions, and economic considerations. Sometimes the setting is fixed by the personal preference of the purchaser, based on his past experience. An open-flume casing, as in Fig. 10, opposite, may be constructed of concrete, stone or wood. It is limited for use with heads up to about 25 ft. where the relationship between size of turbine and head is such as to provide a sufficient depth of water over the turbine to avoid air being drawn into the runner. The water surface above the turbine is open to atmosphere, and the generator must be set high enough to prevent flooding at maximum headwater level. The casing is ideal from the hydraulic standpoint, since, if the dimensions are ample, the water flows from the forebay to the turbine with virtually no loss of head. The wicket-gate linkage mechanism is submerged in the water.

Cylindrical pressure casings for low heads, up to about 50 ft., are necessary when the turbine is fed by a pipeline or a free headwater level immediately above the turbine is impracticable. The gate linkage mechanism may be immersed or arranged in a dry pit as shown in Fig. 11, which, being more accessible, allows proper inspection to be undertaken without having to dewater the turbine. Furthermore, the linkages are kept clear of any abrasive matter in the water. The casing may be constructed of concrete or plate steel of riveted or welded construction.

The spiral casing is the type in most common use to-day. Below about 100 ft. head it may be formed of concrete, but above that figure cast iron, cast steel, or riveted or welded plate steel become necessary. The shape of the case when formed in the concrete sub-structure of the power house is usually rectangular with chamfered corners. Fig. 12 indicates a metal spiral-cased turbine, and it will be seen that concrete formwork is completely eliminated and that the compact design reduces the size of the power house. The straight conical draught tube as included in the sketch is used for small sizes of machines, but to minimise excavation a concrete elbow tube is essential for larger outputs (Fig. 13). Open-flume, cylindrical pressure cased, and spiral-cased turbines may be either vertical or horizontal. The semi-spiral casing used on heads below about 60 ft. where large volumes of water are involved is invariably formed in concrete. The upstream half is similar to a cylindrical pressure casing, but the remainder is spiral shaped.

For very low heads (from about 7 ft. to 18 ft.) where a sufficient depth of water cannot be provided above

WATER TURBINES.

Fig. 10.

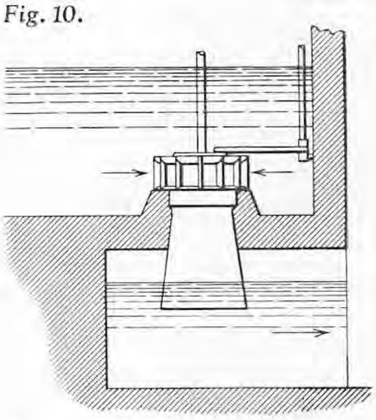


Fig. 11.

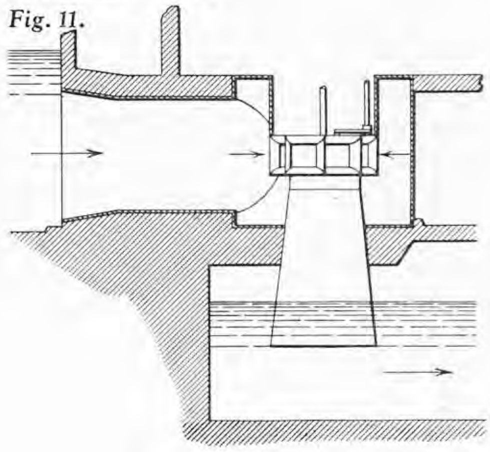


Fig. 12.

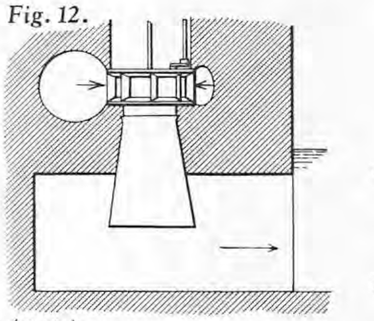
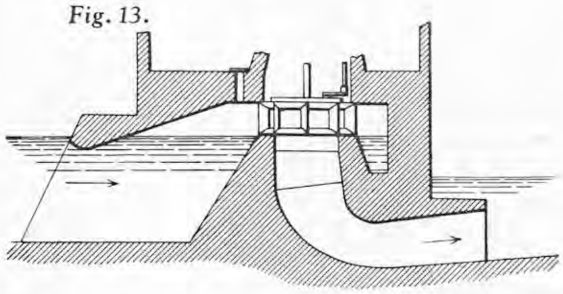


Fig. 13.



(401. K.&L.)

the gates to prevent ingress of air to the turbine, the vacuum flume setting is adopted (Fig. 13). At standstill, the level of water in the flume is the same as the headwater. Before starting, air is evacuated, and while the unit is running the highest point of the casing is connected to the draught tube to guard against breaking the syphonic effect. The casing may be rectangular in shape, but quite often a semi-spiral casing is used to reduce overall dimensions. The advantage gained from this setting is that the depth of excavation is curtailed, and one large machine may be used instead of a number of small units in an open flume to give the same output.

As has already been shown, the chief items affecting the design of a turbine are the head H, quantity Q, power P, and speed N. For turbines of the same design and diameter

$$Q \propto \sqrt{H}, \quad P \propto H^{\frac{3}{2}}, \quad \text{and} \quad N \propto \sqrt{H},$$

and designating these quantities in terms of unit head (one foot):

$$Q_1 \text{ (unit quantity)} = \frac{Q}{\sqrt{H}};$$

$$P_1 \text{ (unit power)} = \frac{P}{H^{\frac{3}{2}}};$$

and

$$N_1 \text{ (unit speed)} = \frac{N}{\sqrt{H}}.$$

All the effective areas of runners vary directly as the square of the diameter, hence with constant head

$$Q \propto D^2; \quad \text{and} \quad P \propto D^2,$$

and the speed is inversely proportional to the diameter, i.e. $N \propto \frac{1}{D}$.

In order to classify turbines and indicate the design of the runners, the specific speed n_s is used. This is defined as the speed at which a water wheel would run if it were so reduced in size as to develop unit power under unit head. From the previously given relationships of geometrically similar runners:—

$$\frac{P}{P_1} = \frac{D^2}{D_1^2}.$$

When P_1 is unity,

$$\frac{D}{D_1} = \sqrt{P}.$$

But

$$\frac{N_1}{N} = \frac{D}{D_1} = \sqrt{P}.$$

Reducing N and $\sqrt{P}$ to unit head

$$N_1 = n_s = \frac{N}{\sqrt{H}} \sqrt{\frac{P}{H^{\frac{3}{2}}}}.$$

Therefore,

$$n_s = \frac{N\sqrt{P}}{H^{\frac{5}{4}}},$$

where N is expressed in revolutions per minute, P in horse-power, and H in feet. Hence, knowing n_s, P, and H, the speed N of any given turbine may be determined.

It is evident that with a fixed n_s and H, the speed of any turbine may be increased by dividing the power between more than one jet in the case of an impulse turbine, and between more than one runner in the case of a reaction turbine. Since the specific speed thus becomes proportional to the square root of the power

$N \propto \sqrt{\text{number of jets}}$, for an impulse turbine, and

$N \propto \sqrt{\text{number of runners}}$, for a reaction turbine.

Thus, for a two-jet impulse wheel or twin-runner reaction turbine, there is a 41·4 per cent. increase of speed, as compared with a single-jet or runner machine. Three-jet, four-jet, five-jet, and six-jet turbines are 73·2 per cent., 100 per cent., 123·6 per cent., and 145 per cent. faster, respectively.

Specific speed may be expressed in terms of runner dimensions and velocity coefficients, thus:—

For any turbine:—

$$N = \frac{1840\,\phi\sqrt{H}}{D} \qquad . \quad . \quad . \quad (1)$$

$$P = \frac{Q\,\eta\,H}{8 \cdot 81} \qquad . \quad . \quad . \quad . \quad (2)$$

where Q is the water quantity in cusecs, and H is the effective head in feet.

For impulse turbines:—

$$Q = \frac{\pi\, d^2 \phi_j \sqrt{2\,g\,H}}{4 \times 144},$$

where ϕ_j is the velocity coefficient of the jet.

$$n_s = \frac{N\sqrt{P}}{H^{\frac{5}{4}}} = \frac{1840\,\phi\sqrt{H}}{D\,H^{\frac{5}{4}}} \sqrt{\frac{\pi\, d^2 \phi_j \sqrt{2\,g\,H}\,\eta\,H}{4 \times 144 \times 8 \cdot 81}}.$$

Therefore,

$$n_s = 130\,\phi\,\frac{d}{D}\sqrt{\phi_j\,\eta}. \qquad . \quad . \quad (3)$$

For Francis turbines:—

$$Q = \frac{\pi\, D_2^2\, \phi_0 \sqrt{2\,g\,H}}{4 \times 144}.$$

where D_2 is the outlet diameter of the runner in inches, and

ϕ_0 is the water velocity coefficient at the runner outlet.

$$n_s = \frac{N\sqrt{P}}{H^{\frac{5}{4}}} = \frac{1840\,\phi\sqrt{H}}{D\,H^{\frac{5}{4}}} \sqrt{\frac{\pi\, D_2^2\, \phi_0 \sqrt{2\,g\,H}\,\eta\,H}{4 \times 144 \times 8 \cdot 81}}.$$

Therefore

$$n_s = 130\,\phi\,\frac{D_2}{D}\sqrt{\phi_0\,\eta}. \qquad . \quad . \quad (4)$$

For Francis and propeller turbines:—

At the gates, at diameter D in.,

$$Q = \frac{\pi\,D\,h\,\phi_g \sqrt{2\,g\,H}}{12 \times 12},$$

where h is the gate height in inches, and ϕ_g is the water velocity coefficient through the wicket gates.

$$n_s = \frac{N\sqrt{P}}{H^{\frac{5}{4}}} = \frac{1840\,\phi\sqrt{H}}{D\,H^{\frac{5}{4}}} \sqrt{\frac{\pi\,D\,h\,\phi_g \sqrt{2\,g\,H}\,\eta\,H}{12 \times 12 \times 8 \cdot 81}}.$$

Therefore

$$n_s = 260\,\phi\sqrt{\frac{h}{D}}\,\phi_g\,\eta. \qquad . \quad . \quad (5)$$

It is evident by reference to Fig. 5(*a*) and formulæ (4) and (5) that there is a lower limit to the specific speed of a Francis turbine, since the inlet blade heights become very small, and the blades become long, making for poor hydraulic conditions and difficulties in casting and processing the runner. The lower limit is usually fixed at about 13, but in actual practice the normal economical limit is about 20. Expression (3) shows that, for a range of $\frac{D}{d}$ between 7 and 12, the corresponding specific speeds are 7·83 and 4·57 per jet.

In settling the design of a turbine, one of the first duties of the designer is to choose as high an operating speed as possible, for in so doing, the dimensions of the turbine, generator, and buildings (and hence the cost of these items) should become a minimum. However, this is not always the case, for, by increasing the speed:—

(1) If the flywheel effect required from the generator is high, generator diameters may have to be increased to the point of having to change from a bolted-on pole construction, which is simple and cheap, to a dovetailed-pole construction, which is complicated and expensive.

(2) By using multiple jets for impulse and multiple runners for all types of turbines, the turbine itself would not be cheapened. In the latter case the sizes of foundations and buildings increase, inlet pipes have to divide to feed each runner, and a separate valve is usually advisable for each runner.

(3) Onerous conditions in the draught tube may result, necessitating a very low setting of turbine runner relative to the tailwater level. The use of special turbine materials, such as stainless steel, may become imperative.

(4) The normal speed may exceed 1,000 r.p.m. for 50-cycle operation or 1,200 r.p.m. for 60-cycle generation. Due to the high runaway speed as compared with other prime movers this may entail uneconomic methods for generator rotor construction and cooling.

(5) There may be a general reduction in turbine efficiency due to the machine not working at its best speed. This results from the fact that most manufacturers have a series of standard runners covering the whole range of specific speeds for the type in question, and there is obviously one particular speed at which the runner produces the best results. If a higher speed is absolutely essential and the standard runner cannot be adapted, special designs and model tests become necessary, thereby increasing the cost of the turbine and lengthening the time of its manufacture.

(6) Uneconomic designs may be necessary for the turbine runner to ensure its having sufficient strength to withstand the stresses due to centrifugal force and water pressure.

Generally speaking, the impulse turbine is used over a head range of 700 ft. to about 6,000 ft., and the Francis turbine is used for heads above about 50 ft. up to about 1,000 ft. There are notable examples of Francis machines running at much higher heads, and at present three vertical shaft Kvaerner Brug Francis turbines are under construction in Norway, each developing 70,000 brake horse-power at 500 r.p.m., and designed for a maximum net head of 1,456 ft. (n_s = 14·72). Since 1949, two similar machines, each 60,000 brake horse-power at 500 r.p.m., and designed for a mean net head of 1,302 ft. (n_s= 15·67), have operated satisfactorily at the Hol Hydro-Electric Development in Norway. There is no reason why, for very large output machines, Francis-type turbines should not be used under even higher heads, provided that the correct materials for their construction are chosen, that a conservative speed is adopted, and that model tests are undertaken to ascertain cavitation performance. The impulse turbines operating under the highest head in the world are at Dixence, Switzerland, where five horizontal-shaft Charmilles units each of 50,000 brake horse-power capacity are designed for a maximum head of 5,707 ft. and a minimum head of 5,117 ft. Each unit comprises two runners disposed one on each side of the alternator, and each runner has one jet acting upon it. As the machines run at 500 r.p.m., the specific speeds per jet are 1·59 and 1·83 for maximum and minimum heads respectively.

Propeller turbines operate at all heads up to a normal maximum of 100 ft. However, a 7,600-brake horse-power Charmilles Kaplan turbine is in operation under a head of 184 ft. at Rocchetta power station, Italy, though the minimum head is 46 ft. There is no reason why Kaplan turbines for up to at least 200 ft. head should not be used for large output machines.

(*To be continued.*)

USE OF HIGH-ASH COALS IN THE ELECTRICITY-SUPPLY INDUSTRY.*

By A. ALAN TAYLOR, Ph.D., M.Sc., F.Inst.F.

THE present shortage of boiler and power plant in the electricity-supply industry emphasises, among other things, the importance of improved availability of plant and the necessity for that plant to be able to give its full output. Even in other circumstances, improved availability would be a national asset for it means better use of the capital expended and better use of the manpower employed in manufacturing, operating and maintaining the plant. The electricity grid has enabled big savings to be made in the costs of power generation by reducing the amount of spare plant needed for emergency and also by the economic loading of power stations. Both these factors make it all the more necessary that such plant as is installed should be able to operate to the full extent that is required and that, so far as is practicable, the power stations which produce electricity most cheaply should be able to operate continuously throughout the year at full load.

The problem of boiler availability had become of major importance even before the war, and as a direct result of attention being drawn to this by Sir Johnston Wright, who was then chief engineer of the Central Electricity Board, the Boiler Availability Committee was formed under the chairmanship of Mr. M. H. Adams. The Committee was representative of the boiler manufacturers and users, as well as of research organisations. The problem at that time was to improve the availability of boilers under the conditions then existing and the work was not directed particularly to the use of high ash content coals efficiently and with good availability. When war came, and as the war progressed, however, it became more necessary than ever for power stations to consume larger and larger quantities of poorer coal. Shortages of manpower, inadequate coal-cleaning plant, the intensification of mechanical mining and the working out of the better coal seams, all contributed towards the raising of ash content. Demands for electricity have doubled since 1939, and a measure of the contribution made by the electricity industry towards the use of high-ash coal may be indicated by the fact that nearly a quarter of its increased coal requirements since 1939 have been made up of coals with a dry-ash content higher than 22·5 per cent. The curtailment of new power-station construction during the war prevented the building of plant specially for using high-ash coal, and the immediate problem confronted the industry of using these poor coals on existing boilers which had been designed for coal of much higher quality. In solving this problem, much of the work which was done by the Boiler Availability Committee was of assistance, because the difficulties encountered, apart from the purely physical ones, such as disposal of large quantities of ash, spring from the same causes as did the earlier availability troubles.

When the problem of using high-ash coal began to be of real importance during the war, by far the greatest part of the boiler plant in power stations in Great Britain was fitted with travelling-grate stokers. Special types of coal were required for the few retort-fired boilers in operation and the pulverised-fuel fired boilers were relatively adaptable to the increasing ash content, so attention was directed mainly to the boilers fired with travelling-grate stokers. Three main difficulties were encountered: firstly, to burn coal satisfactorily and efficiently; secondly, to remove and dispose of the large quantities of ash produced; and thirdly, to keep the boiler heating surfaces clean. As far as the combustion process is concerned, the higher the ash content of the coal, the more difficult it becomes to maintain a good clean fire. Because the air supply cannot be so easily controlled through the different parts of the grate, the shape and length of the flame may be materially affected and the fire may become ragged. Generally, a long flame results in the rapid fouling of the boiler heating surfaces, and a ragged fire prevents the combustible matter in the coal from being properly burnt away, so that the ash removed from the boiler may contain a large amount of unburnt fuel and cause a serious drop in efficiency. Difficulties may also be experienced in maintaining ignition.

Alterations in the quantity and distribution of secondary air can be used to improve the contour and size of the flame, while various means have been developed for improving the control of the air supply through the grate. There are means, too, of controlling where the ignition of the fire will take place, but the application of this principle has not normally been necessary. Details of these methods of control have been given in the various publications of the Boiler Availability Committee. The removal and disposal of the large quantities of ash are largely physical problems, which on existing plant may offer insuperable difficulties. It has not been practicable, generally, to alter the ash-handling equipment and it was necessary therefore to avoid sending high-ash coal to those plants which had insufficient ash-handling capacity.

In keeping boilers clean and ready for service when required, probably the first factor is to ensure that good combustion conditions exist and that the flames are kept as far as possible within the furnace and not allowed to pass among the boiler and superheater tubes. Directly connected with this is the actual temperature of the heating surfaces, especially in the superheater. There has been a feeling, borne out by observation, that boilers with high superheated-steam temperature or with high metal temperatures in the superheater tended to have a lower availability than other plant. On the other hand, it is difficult to be certain that these higher surface temperatures do of themselves seriously affect boiler availability, because it is not completely possible to compare plants where the only important differences lie in the metal temperatures. It is, of course, essential that this question should be cleared up because, in order to attain higher overall efficiencies, the British Electricity Authority is building a considerable amount of plant with high superheated-steam temperatures. Whether or not it is a fact that these temperatures have a major bearing on the fouling of the boiler, economiser or air heater, it is certainly known that good combustion conditions which tend to keep the superheater metal temperatures at a minimum on a given boiler are the first factor in keeping boilers clean.

The availability of a given boiler can be influenced markedly by certain properties of the coal; in particular the amounts of sulphur, sodium or potassium, and phosphorus in the coal and the grading of the coal. Broadly, the sulphur may give rise to sulphuric acid which, by condensing in the air heater, may cause serious corrosion and by forming a sticky surface there may block the air heater. It may also enter into reaction with the sodium or potassium present and give rise to hard and ash-like deposits in the hotter parts of the boiler, while the phosphorus (which does not generally occur to any marked extent in the coals with high sodium or sulphur content) may give rise to very hard and compact deposits, sometimes in the superheater, but more seriously in the economiser. The troubles which result in this way are not easily overcome with existing plant, but it is known that certain boilers are less affected by these undesirable properties of the coals than others, and where it has been practicable and economic to do so, the troublesome coals have been segregated and burnt in those boilers. Pulverised-fuel fired plant generally is less affected by sulphur, sodium and phosphorus in the coal, and although the amount of pulverised-fuel fired boiler plant installed at the time when the use of high-ash coals became imperative was not very large, it has helped considerably in this problem.

After doing all that was possible to ensure that good combustion was achieved with the high-ash coals, and after avoiding, as far as was practicable, using the more troublesome coals on boilers which were susceptible to them, there still remained a good many cases which had to be dealt with by other methods. The principal means adopted have been improvements in the means of cleaning boilers while they are on load, improved means which are either quicker or more thorough of cleaning boilers when they are shut down, or modifications to the plant in order to improve operation. In "on-load" cleaning, the effectiveness of soot-blowers can often be improved if they are carefully maintained and operated, but in many cases water-lancing has had to be adopted for removing bonded deposits from superheaters on load. Water-lancing has proved to be very effective and with proper application causes practically no damage. "Off-load" cleaning of boilers presents an entirely different problem, for the loss of availability is affected by the speed with which the cleaning can be carried out, and the subsequent run on the boiler is influenced very much by the thoroughness or otherwise of the cleaning. Many parts of the heating surfaces are not easily accessible and thorough cleaning may be extremely difficult and prolonged to carry out by hand. Two main methods have been widely adopted for overcoming this, depending on the kind of deposit encountered: firstly, one in which the deposit is first softened by gentle soaking in a steamy atmosphere (some deposits do not soften by this method but the key which holds them on to the tubes can usually be broken). Subsequently the deposit is removed either with water jets or by allowing the deposit to dry in a current of air and cleaning any material which has lodged among the tubes by hand rodding. Alternatively, a fine water-spray may be substituted for the steam. A very quick method of removing deposits which are easily softened by water has been used occasionally, and this consists of heavy sluicing of the heating surfaces with water, taking great care to avoid damage which might otherwise be caused. (Complete details of methods of cleaning, covering all parts of boilers are included in the first Bulletin of the Boiler Availability Committee, MC/131; the improved cleaning of economisers and air heaters is also dealt with.)

The modifications that have been made to boilers with a view to improving their availability have been done principally either with the intention of affecting the combustion processes or the temperature of the gas leaving the furnace. On some plant fired by travelling-grate stokers, auxiliary pulverised-fuel burners have been installed. These have the combined effect of reducing the load on the stoker for a given output from the boiler and also of improving the availability. It is believed that the burning volatile matter over the fuel bed affects the formation of certain bonded deposits. Perhaps one of the most successful modifications to plant for improving availability was that carried out some three years ago on two large power-station boilers. After much effort on the part of the station staff, the average length of run on the boilers had been increased from about two or three weeks to seven or eight weeks. By means of a simple alteration, a proportion of the waste flue gas which was leaving the boiler on its way to the stack was diverted and mixed with the air entering the boiler for combustion. Some 10 per cent. of the flue gas was recirculated in this way. The effect of this is to dilute the air so that it contains less oxygen and, in consequence, there is a reduction in the intensity of combustion and in the temperature of the gas in certain parts of the boiler. The measurable effects on fuel-bed and gas temperature have been extremely small, but the boilers, instead of being able to operate for about seven or eight weeks, can now comfortably operate for at least six months continuously.

In some cases where air-heater corrosion or blockage has been serious, it has been necessary to take steps to overcome the difficulties. The most drastic of these has been to reverse the air flow and thus give a parallel-flow heat exchanger. Availability has invariably been improved and, although some loss in efficiency would be expected from this modification, in actual fact there has generally been an improvement in annual efficiency because of the greater cleanliness of the heating surfaces.

This brief review of measures which have been taken partly to enable high-ash coal to be used successfully and partly for other reasons of boiler availability, is by no means complete and is intended to cover only some of the major items. The electricity-supply industry is now burning about twenty times as much of the very high-ash coal as it did in 1939, and this is a considerable achievement. How far this trend should continue is an economic question, depending largely on mining methods, the costs of cleaning coal, and the relative costs of using the better and poorer qualities available. Each case presents its own problems, but there are likely to be many cases, especially where load centres are close to coal supplies, where it will be in the national interest to generate electricity from the high-ash coal rather than to clean the coal.

* Paper read before Section G of the British Association at Edinburgh on Thursday, August 9, 1951. Abridged.

GRADUATE COURSE IN ENGINEERING PRODUCTION AT BIRMINGHAM UNIVERSITY.—A one-year post-graduate course in the principles of engineering production and management will commence at the University of Birmingham on October 1. It will provide advanced training in engineering production, production planning, work study, and production management for engineering graduates and those possessing equivalent qualifications who have already had industrial experience. Preference will be given to men sponsored by their employers, but some scholarships will also be available for independent candidates. Further information may be obtained from the secretary, Department of Engineering Production, The University, Edgbaston, Birmingham. Applications should be submitted not later than August 31.

PRODUCTION AND EXPORTS OF THE BRITISH MOTOR INDUSTRY.—During the first six months of this year, it is stated by the Society of Motor Manufacturers and Traders, nearly 245,000 cars and 135,000 commercial vehicles were produced by British automobile manufacturers. Owing mainly to the shortage of steel sheet for bodies, about 18,000 less cars were produced in comparison with the first six months of 1950; commercial vehicle production has remained at about the same level. Other shortages, particularly of alloying elements in steel, have been overcome by the development of substitute materials. During the same period, 186,000 cars and over 70,000 commercial vehicles were exported; this is about 20,000 less in number than in the corresponding period in 1950, but is slightly higher in value, due partly to the export of a greater number of public-service vehicles, and partly to price increases necessitated by rising production costs. Nearly 55,000 agricultural tractors were exported, about 18,000 more than in the first six months of 1950.

THE DESIGN OF LARGE BOILER PLANT FOR USING HIGH-ASH COAL.*

By W. G. Marskell, B.Sc., F.Inst.F.

There has been a marked increase in the ash content of coal supplied during recent years as compared with pre-war years, mainly due to the very rapid mechanisation of mining compared with a slower increase in coal-cleaning facilities. From the steam generation point of view the situation may, therefore, be a temporary one and its resolution will depend on economic factors. On the other hand, a progressive rise in the ash content of coal as mined is to be expected as a result of the exhaustion of the better seams. A boiler designed to utilise coal of high ash content is larger and more expensive for a given output than a boiler designed for coal of low ash content. From a national point of view, therefore, the question to be settled is whether it is cheaper to build cleaning plant, or to build larger boiler plant and also to face the added transport cost inherent in the use of high-ash fuels. There is not likely to be a simple answer to the problem and each case must be considered on its merits. Thus it will probably be economic to transport only low-ash coal over long distances and to use high-ash coal near the point of production.

It must be borne in mind, however, that coal cleaning introduces its own problems. Present-day mining methods produce a lot of fines and dust, and in order to suppress dust underground, wetting with water sprays is extensively used. Wet-cleaning methods are, therefore, the only feasible means of reducing the ash content and result in an aqueous suspension of the fine material in the washery water which, in the concentrated form, is known as "slurry." Some 10 per cent. of the national production of coal is less than ⅛ in. in size and some 5 per cent. of the output from a washery will appear as slurry. In the older washeries, the washery water is run into settling ponds and the slurry allowed to settle out by gravity. In modern plant, it is customary to filter off the slurry by means of continuous drum filters and the material then appears in the form of filter cake. This has a moisture content of 25 to 33 per cent., with ash contents varying from about 15 to 30 per cent. If the conditions justify it, slurry may be further cleaned by froth flotation. The amount of slurry produced nationally is too great to be wasted and it must, therefore, be utilised. From the steam-raising point of view, the simplest method would be to mix it back into the clean coal. At first sight, this may seem to be a retrograde step. The amount of slurry, however, will be only about a tenth of the amount of coal below 1 in. in size, so that as long as the resulting mixture can be handled and transported by existing equipment, the resulting increase in fines and ash content need not seriously disturb the economy of boiler plant designed for the fuel. The mixing, however, would have to be done very thoroughly so as to get a fuel of regular and consistent grading.

If mixing back cannot be considered, the slurry or filter cake may be used by itself; a more difficult problem, as the combined ash and moisture contents may be as high as 60 per cent. It is uneconomic to transport such low-grade material, so it must be at the point of production. The problem is largely one of handling and drying the material. In modern plant on the Continent it is utilised on specially-designed boiler plant by feeding it into special types of pulverising mills through which high-temperature flue gas is passed. As the material is already very fine, the mills are not called upon to pulverise the material so much as to agitate and dry it. The milling and boiler plant, however, is of very special type and must be fairly large to justify the capital expenditure. The electrical power generated is far in excess of the associated pit and washery plant requirements and must be an integral part of the public-service supply. The conditions met on the Continent, however, are somewhat different from those in Britain.

The mineral matter in coal may be divided broadly into the inherent mineral matter and the extraneous mineral matter. The inherent mineral matter is that which is inextricably mixed with the coal substance. A good deal of it is associated with the mineral matter contained in the original vegetable material or in material laid down with it at the time of deposition. The inherent mineral matter is high in compounds containing sodium, potassium, calcium and iron. The resulting ash, therefore, tends to have a low fusion temperature. The extraneous mineral matter consists largely of shale and similar material. As this includes much aluminium silicate, the resulting ash is comparatively high in fusion temperature.

The increase in ash content consequent upon the change in mining methods and lack of cleaning facilities has largely resulted from the extraneous mineral matter. High ash content is, therefore, not necessarily associated with a more fusible ash; in fact, the reverse is generally the case. The increased ash content in present-day coal supplies has, therefore, been more of the nature of an inert diluent and has not, in general, involved any special problems in the formation of fused slags and deposits. It can be stated with confidence that boiler plant can be designed to utilise any material with sufficient heating value to support combustion. There must be a point, however, when the capital charges and other costs would far outweigh the value of the steam raised.

For economic and technical reasons, boiler plant in electrical-generating stations is now very large. Boilers capable of evaporating 200,000 lb. to 300,000 lb. of water per hour are common and there are boilers capable of evaporating as much as 800,000 lb. to 1,000,000 lb. of water per hour. A boiler with an evaporation of 500,000 lb. of water per hour will consume some 28 tons of coal per hour and will produce some 5½ tons of ash per hour when using a coal with an ash content of 20 per cent. The handling of such quantities of fuel and ash is, of course, entirely mechanised. The handling and disposal of large quantities of ash is, in many cases, a big problem and the form in which the ash is obtained is an important factor. The various methods of burning coal on large boilers produce ash of varying physical types and the form in which the ash is obtained may play a big part in deciding what type of firing is adopted.

The most usual method of firing coal on large boilers is either by mechanical stokers or as pulverised fuel. Mechanical stokers are, in general, used for boilers of less than 250,000 lb. per hour evaporation. For larger boilers, pulverised fuel is almost exclusively used. When firing coal by mechanical stokers, the bulk of the ash remains on the grate and is mechanically discharged to the ashpit, largely in the form of partly sintered clinker. In some areas, mechanical-stoker ash can be sold for making up land and roadways and for similar purposes. Even in cases where it is to be dumped, it can be relied upon to stay in place and not be blown away by high winds or washed away by heavy rain. In pulverised-fuel firing, however, all the coal is ground very fine and is air-borne in the furnace. The resulting ash is, therefore, largely air-borne and a good deal of thought has had to be given to the problem of separating the maximum amount of ash in a form which can be readily handled. The flue gases, even when the major part of the ash has been separated, are still very dusty and must be cleaned by elaborate and expensive precipitator plant if atmospheric pollution is to be avoided.

One of the difficulties of disposing of pulverised-fuel ash is its fineness. For this reason it is not a satisfactory "fill" and cannot, for example, be used for underground stowage in mining. When dumped it is liable to cause a dust nuisance. Very great efforts have been made in this country, and especially in America, to find a use for pulverised-fuel ash for making bricks, concrete and for similar purposes. Unless the pulverised-fuel fired plant is situated close to the point where the products are to be manufactured, the cost of handling and transport of the ash is likely to make it difficult for it to compete with other materials. With the increased amount of pulverised-fuel fired plant coming into use, there is little possibility of utilising more than a small proportion of the ash produced.

The most usual type of mechanical stoker used in this country is the travelling grate. As the coal travels into the furnace it is ignited by heat radiated from the furnace. Air for combustion is supplied through the upper strand of the grate from a windbox supplied by the forced-draught fan. The gases are drawn through the boiler setting by the induced-draught fan. "Overfire" or "secondary" air is supplied above the fuel bed to complete the combustion of gases rising from the fuel bed. The ash is discharged from the rear of the stoker into the ashpit.

The mechanism of combustion on travelling grates has been the subject of much detailed investigation. It has been established that the fuel bed on a travelling grate may be divided into three zones, namely, the ignition zone, where the ignition plane is travelling through the bed, leaving behind a bed of incandescent coke, above which the gases are smoky owing to the hydrocarbons being distilled from the fuel bed; the combustion zone, where the coke bed is burning from the bottom upwards and the fuel bed is very hot, the gases above this part of the fuel bed being free from hydrocarbons and, therefore, from smoke; and the burning-out zone, where the last part of the carbon is burned from the ash before discharge. The gases above this part of the bed are also smoke-free.

British coals contain appreciable amounts of sodium and potassium and may contain smaller, but significant, quantities of other volatile elements, such as boron, arsenic, etc. The fuel-bed temperatures attained in the ignition and combustion zones are amply high enough to volatilise the alkali metals, particularly when chlorides are present. The volatilised alkali and other metals carried by the gases may react with oxides of sulphur and phosphorus in the gases and condense on boiler and superheater tubes and other comparatively cool surfaces as sulphates and phosphates, cementing together fly-ash particles which would not otherwise adhere to these surfaces. Troublesome deposits, known as "bonded deposits," may thus be formed, which may necessitate shutting down the boiler for special cleaning. It has been found that, while the alkali metals are volatilised from the fuel bed in the ignition and combustion zones, the presence of hydrocarbon smoke in the ignition zone appears to inhibit their appearing as troublesome deposits. It has thus been concluded that it is, in general, the material in the gases from the combustion and burning-out zones of the fuel bed which are responsible for the formation of these bonded deposits. In 1943, the author and co-workers were able to establish that, if liquid fuel is burned over the rear of a stoker so as to introduce smoke into the gases which are normally free from smoke, the formation of deposits may be largely suppressed. Similarly, the introduction of turbulence in the gases above the fuel bed, so as thoroughly to mix up both the clear and the smoky gases, has a pronounced ameliorating effect on the formation of deposits.

With pulverised-fuel firing the formation of bonded deposits is not a major problem. This is probably because there is no segregation in the combustion process and carbon particles are present in all parts of the furnace. In addition, the time of exposure of an ash particle to high furnace temperature is, in general, less than that of a corresponding particle in stoker firing. There is, therefore, less time for the volatilisation of the volatile elements. The exact mechanism by which smoke particles suppress the formation of bonded deposits is not clear. The most likely explanation is that the alkali vapours condense on the carbon particles. The carbon particles subsequently burn, but at much lower temperatures than those encountered in the fuel bed. The alkalis are not re-volatilised, therefore, but are left in the gas as a very fine dust. In the laboratories of the author's firm an investigation of deposits has shown that the sintering temperature of a bonded deposit is always lower than the sintering temperature of dust in the same vicinity. The sintering temperature of the deposit and the sintering temperature of the dust are respectively lower and higher than the flue-gas temperature in the vicinity.

In addition to bonded deposits there are, of course, the ordinary accumulations of partly-fused slag. Slag deposits form when the gas temperature in the vicinity is higher than the softening temperature of the ash particles in the gas stream. Slag deposits and bonded deposits are most troublesome when they occur within banks of tubes, where they are very difficult to remove. An obvious way to avoid formation of slag deposits within banks of tubes is to cool the gases down sufficiently before they enter the tube banks, so that slag particles are not soft enough to stick. A very noticeable feature in modern boiler design as compared with older designs is that the furnaces are almost entirely water-cooled and are very tall. A very large proportion of the heat absorbed by the boiler is absorbed through the furnace walls, while the heat absorbed by convection in the tube banks is correspondingly reduced. One of the effects of this change of design is to cool the gases below a certain critical figure before the gases enter the tube banks. This has very largely eliminated slag deposits on the convection surfaces. Slag deposits on the furnace walls, if they adhere to any extent, usually build up to an equilibrium thickness, the outer layers becoming progressively hotter until they become molten, or slag layers break away before building up to a troublesome thickness. Where slag accumulates on walls to an inconvenient amount it is fairly easily removed by steam or water jets.

It has been realised for a considerable time that the avoidance of ordinary slag deposits is largely a question of proper disposition of heat-absorbing surfaces. Evidence is accumulating which indicates that it is also important, in avoiding bonded deposits in superheater and boiler tube banks, that the gases should be cooled below certain critical temperatures before entering the tube bank. It is as yet difficult to assess in each case what these critical temperatures are likely to be because of the segregation of the volatile ash constituents. The gases when they pass through the economiser and air-heater prior to discharge to the stack are at temperatures approaching the acid dew-point. It is important that they should not be cooled too much, otherwise troublesome deposits of acid, sulphates and phosphates can be formed. There is thus a critical temperature range for the gases in the boiler, superheater, economiser and air-heater passages if troublesome deposits are to be avoided.

Another development designed to avoid troublesome deposits is to arrange the convection heating surfaces

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* Paper read before Section G of the British Association at Edinburgh on Thursday, August 9, 1951. Abridged.

with comparatively wide gas passages, so that the deposits do not interfere so readily with the passage of gas. The wider passages also render cleaning by steam sootblowers and water lances comparatively easy. It must be appreciated, however, that the provision of wider gas passages may increase the size and cost of the boiler very materially. A considerable part of bonded deposits is water-soluble, so that the deposits can be generally disintegrated by washing the boiler surfaces with water or by soaking in a steam atmosphere during shut-down periods. Boiler designs now make provision for such washing processes if they are likely to be necessary.

Pulverised-fuel fired boilers in this country are not subject to the formation of bonded deposits and can, therefore, run for long periods without it being necessary to shut them down for hand cleaning. Pulverised-fuel fired furnaces may be divided into two classes, one class being known as "dry bottom" furnaces, the other "wet bottom," or more usually "slag tap." In the first type, the disposal of the cooling surfaces is such that the ash settling out in the furnace is in a solid form. In a slag-tap furnace, the ash is allowed to fuse and to collect as a pool of molten slag at the bottom of the furnace. The slag is tapped off and disintegrated into granular form by the action of water jets impinging on the slag stream. With the dry-bottom furnace only about 25 per cent. of the ash is caught in the furnace. With the slag-top furnace, about 50 per cent. of the total ash is collected in the slag pool. In both cases, the rest of the ash separates out as dust in the gas passages, where suitable collecting and disposal points must be provided. Finally, the gases which carry a very heavy fine dust burden must pass through mechanical dust separators or electrostatic precipitators of high efficiency before discharging to the stack.

It will be seen that, while slag-tap furnaces are a step in the right direction, they are only a partial solution of the problem. In addition, the ash must have a consistent and comparatively low fusion temperature, and the rate of firing of the furnace must be maintained to keep the slag pool fluid. Variation in the steaming rate and the frequent starting up and shutting down of such boilers is to be avoided. These conditions are difficult to satisfy in this country. Large boiler plants must obtain coal from a variety of sources, so that the fusion temperature of the ash is liable to vary within wide limits. The night and week-end electrical demand is also small compared with that required during working hours, so that boilers must be able to cope with wide variations of load.

In an effort to increase the percentage of ash retained in the furnace and to decrease the quantity passing through the gas passages of large boilers, a system of firing known as the cyclone furnace has been introduced in America and has met with considerable success. The cyclone furnace consists of a cylindrical water-cooled chamber, the axis of which is slightly inclined from the horizontal. Crushed coal, about ¼ in. in size, is blown tangentially into the cyclone by a high-velocity air stream. The centrifugal action throws the fuel against the wall of the chamber. The rate of combustion is very high, so the walls of the chamber are covered with a layer of fused ash. The coal particles stick to the ash layer, and the high velocity of the air stream past the coal particles results in a very high rate of combustion. The molten slag is tapped off at the lower end of the cyclone on to the bottom of a primary furnace, from which it drips and is disintegrated by water jets as in slag-tap furnace operation. There may be more than one cyclone furnace to each boiler, discharging into the primary furnace, which is a small chamber lined with water-cooled refractory. The primary furnace chamber, in turn, discharges into a large water-cooled chamber very similar in appearance and design to the furnace of a normal pulverised-fuel fired boiler, the port of connection between the primary chamber and the secondary chamber being arranged with a screen of studded tubes which act as slag scrubbers. If variation in the rate of firing required is greater than can be accommodated by varying the rate of firing of each cyclone, one or more cyclones may be shut off. Operating experience shows that cyclone firing retains approximately 90 per cent. of the ash in the furnace. This very greatly simplifies the problem of cleaning the flue gases, as the cleaning plant is only required to deal with a fraction of the amount of material present in the gases from a pulverised-fuel fired boiler.

Earlier in this paper, it was stated that travelling-grate stokers are most suitable for boilers of less than about 250,000 lb. per hour evaporation, while pulverised-fuel firing or cyclone-furnace firing is the only feasible method for firing boilers with evaporation greater than 250,000 lb. per hour. Boilers of less than 250,000 lb. per hour evaporation can be fired by pulverised fuel, but mechanical-stoker firing is generally cheaper. Both methods of firing have their own special advantages and limitations. In an effort to combine the advantages of both forms of firing, 20 boilers of about 200,000 lb. per hour evaporation are being put into commission in this country in which spreader-stoker firing has been adopted. Fourteen of these boilers are already operating. In spreader firing, the coal is thrown into the furnace by means of rotating paddles or by air jets. The finer particles burn in suspension, while the larger particles fall on to the grate and complete their combustion there. For large boilers, it is usual to combine the spreader method of firing with the use of a travelling grate which removes the ash continuously. The mode of combustion on a spreader is very different from that on a travelling-grate stoker. The fuel is spread evenly over the whole grate area and ignites and burns in a uniform manner. There is no segregation laterally into the ignition zone, combustion zone, etc., as there is on a travelling-grate stoker. The conditions over the whole of the grate are uniform and the gases above the fuel bed are uniformly smoky. The high-temperature zone of the fuel bed is at the surface and, in general, it is at a somewhat lower temperature than that experienced on ordinary travelling-grate stokers. The high-temperature zone is also quite thin, so that the ash material is not subjected to a high temperature for so long as it is in travelling-grate firing. There should, therefore, be far less volatilisation of alkalis and this, combined with the inhibiting effect of the smoky gases in the furnace, should greatly reduce the incidence of bonded deposits on the heating surfaces. The ash discharge from a spreader-fired furnace is much less sintered than the ash from a travelling-grate or retort-type stoker. A considerable amount of grit is carried away from the furnace by the hot gases, but this is readily caught by cyclone-type grit arresters and, so far, there is no indication that more elaborate cleaning methods, such as electrostatic precipitators, will be necessary.

It is hoped that this brief survey has given an appreciation of the general problem. Large boiler plant is costly and, in general, must be designed for an economic life of 20 years. It is, therefore, essential to know the conditions it is likely to meet during its life. While boiler plant can be designed to burn any commercial fuel with reasonable efficiency, a given plant cannot burn an unduly wide range of fuels with equal efficiency. It can be just as uneconomic to feed coal of low ash-content to boiler plant designed for a high ash-content coal as it is to fire high ash-content coal to a plant designed for one of low ash-content. With the nationalisation of mining and transport, it ought to be easier to get a more comprehensive picture of future coal supplies than was the case when a multiplicity of interests was involved. The problem of the boiler designer and boiler operator should, therefore, be correspondingly eased.

NEW SLEEPING COACHES FOR BRITISH RAILWAYS.—British Railways are constructing at their Derby and Doncaster workshops 21 sleeping coaches, of new design, for the use of third-class passengers. The vehicles will be of two types; one will have twelve compartments, and the other eleven compartments and an attendant's section. Two berths, one above the other, will be provided in each compartment, in place of the customary four; the upper berth being reached by a short step ladder. All berths will be fitted with individual lighting and well-sprung mattresses, and full bedding will be provided instead of rugs and pillows. A special feature will be the ample headroom and luggage accommodation. There will be a wash basin, with hot and cold running water, in each compartment and two toilets in each coach. British Railways hope to bring the new vehicles into service on the routes between London and the north of England and Scotland in the autumn.

SYMPOSIUM ON CORROSION OF BURIED METALS.—A symposium on the corrosion of buried metals is to be held at the Iron and Steel Institute, 4, Grosvenor-gardens, London, S.W.1, on Wednesday, December 12, under the chairmanship of Sir Charles Goodeve, O.B.E., D.Sc., F.R.S., Director of the British Iron and Steel Research Association. It is being organised by the Iron and Steel Institute in conjunction with the B.I.S.R.A. and the Corrosion Group of the Society of Chemical Industry, and will be open to all interested in the subject, though intending participants are requested to complete part A of a reply form which is obtainable from the secretary of the Iron and Steel Institute. The papers, which will be presented in abstract, are as follows: "Tests on The Corrosion of Buried Iron and Steel Pipes," by Mr. J. C. Hudson and Mr. G. P. Acock; "Investigations on Underground Corrosion," by Mr. K. R. Butlin, Mr. W. H. J. Vernon and Mr. L. C. Whiskin; "Cathodic Protection," by Mr. K. A. Spencer; "Cathodic Protection of Buried Metal Structures," by Mr. M. R. de Brouwer; "Corrosion of Buried Copper and Ferrous Strip in Natural and Salted Soils," by Mr. G. Mole; and "Tests on the Corrosion of Buried Aluminium, Copper and Lead," by Mr. P. T. Gilbert and Mr. F. C. Porter.

ANNUALS AND REFERENCE BOOKS.

Ship and Boat Builder Year Book, 1951.—This is the second edition of a publication which is designed to appeal to the owners as well as builders and repairers of small craft. The foreword by Mr. D. T. Oxton, past-President of the Ship and Boat Builders' National Federation, indicates that the size of craft covered ranges up to 180 ft. in length, though we should have thought that this overlapped considerably the field of the large shipyard, as commonly understood. However, the scope of the book, in its contributed articles, its reference sections, and its advertisements and classified lists of suppliers of equipment, conforms to no very rigid demarcation, but is clearly designed to be serviceable to the greatest number of potential users. To single out only one feature: the section on "Marine Engine Specifications" contains a great deal of information on makers' standard ranges of petrol and oil engines, conveniently arranged in tabular form. It is followed by a similar section on outboard motors. The book is published by John Trundell (Publishers), Ltd., Temple Chambers, Temple-avenue, London, E.C.4, and costs 25*s*.

Kempe's Engineer's Year-Book for 1950-1951.—Though *Kempe's* is normally published annually, production delays prevented the publication of the 56th edition in 1950, which has therefore been described as "for 1950-1951." No engineer—in this country, at least—needs to be introduced to *Kempe's*; nor will those who buy it annually wish to be told how the 56th edition differs from the 55th; but there must be many who continue with a well-thumbed pre-war edition, and for their benefit it may help to point out the changes that have been made in recent years. Comparing the latest edition with that for 1936, for example, the most obvious change is the division of the book into two volumes, a step necessitated by the increased number of pages, from 2,664 to 2,954. In the mathematical section, the inclusion of trigonometrical tables and tables of logarithms, squares, cubes, etc., is particularly welcome since the previous omission was an annoyance to anyone who liked to regard his *Kempe's* as the prime source for day-to-day references. The arrangement of the material generally has been revised, so that now the fundamental concepts and sciences—units of measurement; mathematics; mechanics, statics, etc.; heat, optics, etc.; acoustics, vibration and noise; hydraulics; thermodynamics; measurement of power; etc.—come first and lead logically to various branches of civil engineering, mechanical engineering and electrical engineering. The most important new section is that on gas turbines—in 1936 there was a page on "internal-combustion turbines"—and several sections, notably on aircraft and aero-engines, lubricants and bearings, have been almost completely rewritten. Certain other sections have also been revised for the latest edition. The volumes continue to be revised and edited under the direction of the editor of *The Engineer*, and are published at a price of 65*s*. net. (postage, 1*s*. 6*d*.) by Morgan Brothers (Publishers), Limited, 28, Essex-street, Strand, London, W.C.2.

The Colliery Year Book and Coal Trades Directory.—The present issue of this well-known reference book is the 29th, which is sufficient guarantee that the compilers are aware of the peculiar needs of the industry that they serve, and have taken due steps to meet those needs. Since the previous issue, the National Coal Board have abandoned the practice of numbering their various Divisions, and this change is reflected in the index of mines, which is an important part of the *Year Book*. Features of the 1951 issue include a list of headquarters-controlled establishments, a complete list of members of the National Council of Coal Traders, and of the Seaborne Coal Traders' Association, and the main points in the "Plan for Coal," proposed by the National Coal Board, which was the subject of some editorial comment in our columns at the time of its introduction by Lord Hyndley. Of the many regular features that have been tested by experience in previous years, one of the most useful is probably the "Bibliography of Periodical Literature in the Technology of Coal Mining." We would suggest, however, that this might be still more useful if either the titles of the periodicals were given in full, or a key were provided to the somewhat arbitrary abridgments: for example, there may be many people interested in the design of brakes for haulage gears who would not recognise the *Bergbau Rundschau* in the abbreviation "Bergbau Rdsch." The *Year Book* is published by the Louis Cassier Company, Limited, Dorset House, Stamford-street, London, S.E.1, at the price of 30*s*. net.

ROYAL STATISTICAL SOCIETY.—The library and reading rooms of the Royal Statistical Society, 4, Portugal-street, London, W.C.2, will be closed from August 4 to September 1, inclusive.

THE HEAT TREATMENT OF WELDS IN PIPELINES.*

By A. H. GOODGER, M.Sc.Tech., A.R.I.C.

(Concluded from page 158.)

THE measurement of temperature during the normalising of small pipes is readily done by means of a suitable colour card, using the card to indicate the colour of the hot pipe rather than its luminosity. For thicker pipes, optical pyrometers or thermocouples, attached to the pipe near the edge of the zone to be heat-treated, are more satisfactory. Thermocouples should be clamped (or, better still, welded or peened) into small holes in such a way that they do not read higher temperatures than the actual pipe walls. Thermocouples should not be brazed on to pipes, as the copper or brazing metal frequently causes cracking of the pipe during heating or during subsequent welding. Temperature-indicating crayons or paints are satisfactory, but, in some cases, the crayon has to be applied repeatedly to give continued temperature readings. Crayons will give temperature readings which are accurate to 1 per cent. The crayons that give a streak which melts on reaching the temperature are probably the best type for welded joints.

Preheating temperatures cannot be judged by colour, and the only satisfactory methods are the use of temperature-indicating paints or crayons, or thermocouples attached to the pipe wall. Most crayons fail to indicate by how much the specified temperature is being exceeded; if it is necessary to know this, two crayons giving a range must be used. Fortunately, there is a wide margin allowable on preheating above the minimum required, provided the welder does not feel discomfort.

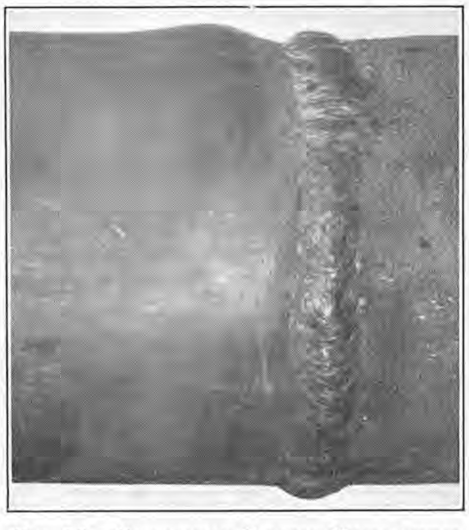

FIG. 16. DISTORTION DURING NORMALISING DUE TO THRUST.

The temperatures for stress relief cannot be measured by colour cards and, where simplicity is desirable for small piping, a crayon or paint must be used. The use of base-metal thermocouples is the most satisfactory method and, where very important joints are being treated, a recording indicator is desirable, as it is unwise to exceed the maximum temperature by more than a small margin. The same precautions must be taken as in normalising to ensure that the correct temperature of the pipe is being read. Whatever method is used, it should be such as to ensure that the band of desired width is heated to the required temperature.

For most welds where preheating is necessary, it is best to maintain the temperature during the whole of the welding operation. It may only be necessary to watch the temperature, once welding has started, and to resume heating only if the temperature of the joint tends to drop. In normalising oxy-acetylene welds, the time during which the joint is held at the required temperature is all that matters, the time for heating-up being unimportant. The joint must be soaked through, and when this is done the time need only be short. For pipes up to 4 in. bore, not less than 2 minutes is sufficient; for over 4 in. bore, the time should be not less than 5 minutes. After normalising, the heated joint should be covered with a muff or asbestos cloth to allow of cooling free from draughts.

Relief of stress takes longer than normalising, as the action takes place mainly by a process of creep. The usual rule is one hour per inch of thickness, with a minimum of half an hour. The time should not greatly exceed what is required. Reference should be made to the British Welding Research Association's memorandum on stress relief for what is considered good practice. Cooling should be slow, and uniform enough to prevent re-introduction of stress by uneven cooling. In both normalising and stress-relieving, it is desirable to close the open ends of the pipes to prevent circulation of air by convection, which would prolong the heating unnecessarily and cause a marked difference in the temperature of inner and outer surfaces.

Where cold pull has been used in a pipeline, the pull should be maintained by mechanical means during the heat-treatment of the closing joint. Where no pull is intended, care should be taken that there is no pull or thrust put into the line unwittingly before normalising, as distortion may occur. Fig. 16, herewith, shows a pipe joint which bulged because of undue thrust during normalising.

Where heat-treatment is considered necessary, it should be applied to all butt joints, branch welds and compensation welds. Logically, all flanges on piping for similar conditions should also be heat-treated, but there is a very great variation in British practice. A rule which has been suggested is to stress-relieve when the depth of the weld grooves in the flanges exceeds $\frac{1}{2}$ in.

In Tables III & IV particulars are given of recommended good practice for the heat-treatment of oxy-acetylene and metallic-arc pipe welds, respectively.

* Paper presented at the summer meeting of the Institution of Heating and Ventilating Engineers held in Buxton, on June 19, 1951. Abridged.

TABLE III.—RECOMMENDED GOOD PRACTICE FOR HEAT-TREATMENT OF OXY-ACETYLENE PIPE WELDS.

Material.	Conditions of Service.	Wall Thickness.†	Heat Treatment.		Time.
			Preheat.	Postheat.	
Mild steel up to 0·26 per cent. C. max.	Up to 250 lb. per sq. in. and/or 425 deg. F.	$\frac{3}{8}$ in. max.	None	None	
Mild steel, 0·26 per per cent. C.	Over 250 lb. per sq. in. and/or 425 deg. F.	Up to $\frac{7}{16}$ in. $\frac{7}{16}$ in. to $\frac{11}{16}$ in. $\frac{11}{16}$ in. to $\frac{7}{8}$ in. Over $\frac{7}{8}$ in.	None 100 deg. C. 200 deg. C. 300 deg. C.	Normalise 900-950 deg. C.	Up to 4 in., o/d for 2 mins. Over 4 in., o/d for 5 mins.
Medium carbon, 0·26 per cent. C. to 0·4 per cent. C.	As above	As above	As above	Normalise 870-920 deg. C.	As above
Molybdenum steel, 0·5 per cent. Mo.	As above	As above	As above	Normalise 950-975 deg. C. for carbon up to 0·12 per cent.; 925-950 deg. C., for carbon above 0·12 per cent.	As above
Chrome molybdenum 0·6-1 per cent. Cr, 0·5 per cent. Mo.	As above	As above	As above		

† For oxy welding of thicknesses greater than $\frac{7}{16}$ in., preheating is essential to assist in obtaining good root fusion on pipe welds, and this is independent of the temperature or pressure conditions.

TABLE IV.—RECOMMENDED GOOD PRACTICE FOR THE HEAT-TREATMENT OF METALLIC-ARC PIPE WELDS.

Material.	Conditions of Service.	Wall Thickness.	Heat Treatment.		Time.
			Preheat.	Postheat.	
Mild steel up to 0·26 per cent. C.	Up to 250 lb. per sq. in. and/or 425 deg. F.	$\frac{3}{4}$ in. max.	None	None	—
Mild steel up to 0·26 per cent. C. As above	Over 250 lb. per sq. in. and/or 425 deg. F. As above	$\frac{3}{4}$ in. Over $\frac{3}{4}$ in.	None Optional if high restraint 200 deg. C. min.	Stress relieve 600-650 deg. C. As above	One hr. per in. of thickness. As above
Carbon steel, 0·26 per cent. to 0·4 cent. C.	As above	All thicknesses	200 deg. C. min.	As above	As above
Molybdenum steel, 0·5 per cent. Mo.	As above	As above	As above	As above	As above
Chrome molybdenum steel, 0·6 to 1·0 per cent. Cr, 5 per cent. Mo.	As above	As above	As above	As above	As above
Chrome molybdenum steel, $2\frac{1}{4}$ to 3 per cent. Cr, 1 per cent. Mo.	As above	As above	300 deg. C. min.	630-680 deg. C.	One hr. per in. of thickness.
4 to 6 per cent. chrome, $\frac{1}{2}$ per cent. molybdenum. Titanium addition	As above	As above	300 deg. C. min.	Normalise at 850-870 deg. C.	15 min. per in.; cool in air, protected with asbestos blanket.
4 to 6 per cent. chrome; 0 per cent. molybdenum; no titanium	Over 250 lb. per sq. in. and/or 425 deg. F.	All thicknesses	300 deg. C.	Normalise at 870 deg. C. if possible without cooling from welding	One hr. per in.; thickness. Cool at 50 deg. C. per hr. to below 700 deg. C.
Molybdenum-vanadium steel‡	As above	As above	250 deg. C. min.	Stress relieve at 690 to 700 deg. C. max.	Not less than 2 hr. slow cooling.
Chrome-molybdenum vanadium	As above	As above	250 deg. C.	Stress-relieve 690-710 deg. C.	Not less than 4 hr. slow cooling.
Austenitic steel, 18/1-12/1 Cb	As above	As above	None	None	—

‡ The heat treatment of welds in molybdenum-vanadium steel is a compromise, as the piping is originally normalised at 975 deg. C. and tempered at 700 deg. C. for four hours. This treatment is necessary to obtain high impact resistance and low notch-sensitivity. If such a treatment is applied locally to a weld, the temperature gradient resulting is liable to produce a zone, a little distance from the weld, of low impact and high notch-sensitivity.

TRADE PUBLICATIONS.

Cranes and Winches.—Illustrated leaflets giving brief particulars of their wharf winches and mobile jib cranes have been issued by Ransomes and Rapier, Ltd., Ipswich.

Enamelled Plates for Factory Notices.—We have received from J. A. Whitehead, 33, Blackfriars-street, Manchester, 3, a price list of electrical, factory, workshop and power-station notices on enamelled metal plates.

Grain Conveying.—A well-illustrated brochure, describing pneumatic grain conveying and bin drying plant for use on farms has been published by the Sturtevant Engineering Co., Ltd., Southern House, Cannon-street, London, E.C.4.

Technical Books.—H. K. Lewis and Co., Ltd., 136, Gower-street, London, W.C.1, have issued two catalogues, one concerning books on mathematics, physics, astronomy, and meteorology; and the other giving particulars of books on electrical engineering, radio, and electronics.

Clutches and Brakes.—The Rapid Magnetting Co., Ltd., Lombard-street, Birmingham, 12, have issued an illustrated catalogue describing the construction, and operation of their electro-magnetic clutch, brake and clutch-brake units.

Pumps.—A Buyers' Guide has been published by the British Pump Manufacturers' Association, 94-98, Petty France, London, S.W.1. It includes a list of members, an alphabetically-classified guide to manufacturers of various types of pump, and some tables of useful data.

SHIPS' STRUCTURES: A CENTURY OF PROGRESS.*

By R. B. SHEPHEARD, C.B.E., B.Sc.

(Concluded from page 28).

THE introduction of welding marks a further revolutionary stage in shipbuilding history. This differs in nature from the earlier transition from wood to iron in that it has not resulted from a change in constructional material, but from a method of connection. It is, therefore, more subtle in its implications, and it is of the greatest importance for progressive development that these shall be fully appreciated.

The first all-welded sea-going ship was probably the coaster Fullagar, 150 ft. in length, built by Cammell Laird and Company in 1919. Her structural design followed generally that of a riveted ship, and included many overlapped joints, but the efficiency of the welding was thoroughly proved during her service life, which included heavy distortion by stranding. The Peter G. Campbell, a longitudinally-framed tanker of 180 ft., built in 1933 by Swan, Hunter and Wigham Richardson, Ltd., through the initiative of Mr. N. M. Hunter and in collaboration with the British Corporation, is an outstanding instance of early all-welded design and construction in this country.

The process developed in many shipbuilding countries, and, while a number of smaller ships were entirely welded, a steady change-over took place to welded connections, both in internal structure and at the butt of shell and deck plating, with appreciable saving in weight; particular advantage being taken of the improved tightness at bulkheads and tank boundaries. The years since the war, with the return to individual rather than "standard" construction, have shown a universal reorganisation of shipyard equipment and layout for increased welding, particularly for tankers. This unmistakable trend, dictated by the economic and technical advantages of the new mode of construction, does not, however, imply that most new ships will be entirely welded—at least for some years to come.

Early shipbuilding practice for riveted connections was largely based on the work and experience of bridge builders and boilermakers. Under the early Iron Rules of Lloyd's Register, rivets in the plating butts, which were strapped and double-riveted, were spaced 3 to 4 diameters apart, with 8-diameter spacing in the transverse frames to the plating. Butt straps were to be fitted "with the fibre of the iron in the same direction as the fibre in the connected plating." The rivets were to be punched from the faying surfaces and to be countersunk through the outer plating; they were to fill the holes completely and their points were to be round or convex and not below the plating surface. Butts and edges of outside plating were to be "truly fitted, carefully caulked and made watertight."

These early requirements have not been subject to major changes. The number of rows of rivets in end connections has been increased as the width of plates has grown. With the introduction of steel and consequent reduction in plating thicknesses, the size of the iron rivets was not reduced. The relation between rivet diameter and plating thickness still remains greater than in the days of iron ships. Extensive experiments on double-riveted joints, undertaken by the Institution of Mechanical Engineers and reported in 1885, included information on slip.† Montgomerie, in his work carried out for Lloyd's Register, investigated the elastic properties of riveted overlap joints. He observed a falling-off in slip stress for the heavier connections and the improvements in the latter resulting from high-class workmanship and hydraulic riveting. Experiments in the United States on double-strapped double-riveted joints in ¾-in. plating gave lower slip values. Results of tests on individual riveted joints must, however, be applied to the complete hull structure with great discretion and in relation to practical experience.

John Grantham, in 1860, expressed the opinion‡ that "a bulkhead boundary angle punched a row of holes in a direct line round the ship, thus unconsciously making a partial severance of the whole structure. The persistence of this belief resulted in the fitting of diamond plates at transverse bulkheads in way of outside strakes well into the present century. Students of naval architecture were long taught that, in computing the section modulus of the hull girder, a deduction should be made for the loss of area in way of rivet holes in the fibres under tension. They have also devoted much study to the "efficiency" of riveted joints in ships. Experience has, however, consistently shown that, where the main structure of a riveted ship has failed by tension, due to stranding or other causes, the fracture has followed neither a transverse line of rivet holes nor riveted butts.

Recent experiments employing improved techniques and taking account of local bending stresses in the plating have shown that, at least under static conditions of loading, "overall" stresses and deflections in the hull girder of both riveted and welded ships closely correspond with values calculated on beam theory from known bending moments, allowing the full area of longitudinal material without deduction of rivet holes in the modulus of section, and adopting the normal E value for mild steel. The results from the sea-going tests on the Ocean Vulcan* and the associated still-water tests are expected to provide valuable additional information on this subject.

In early experiments on welded joints, much attention was naturally given to the development of adequate tensile strength, but it was found that while, with reasonable workmanship, this could be attained, ductility and toughness in the weld zone were also of prime importance. While fractures in welded structures may originate in defects at welds, experience has shown that, except in cases of gross defects in craftsmanship, these fractures show no tendency to follow the line of welded joints. The belief that these joints represent a line of weakness and that, consequently, welded butts should be shifted as in riveted practice, has been largely dissipated. This has permitted major advances in building method and the adoption of large panel connections extending in one continuous line over several plate widths. The importance of this breakaway from riveted tradition has been fittingly recognised in the citation of the award to David Arnott of the David W. Taylor Medal in 1947.

While the "overall" behaviour of riveted and welded hulls under service loadings would seem, therefore, to be very similar, the differences between the two types of connection are nevertheless fundamental and their understanding of the greatest importance. Stress concentrations inevitably abound. The flexibility of riveted joints provides relief at these positions, though sometimes at the cost of impaired tightness. Welded connections cannot so yield, and unless the closest attention is given to their geometric form, and to the maintenance of high standards of welding, "hard spots" will result and local fractures develop. These cannot be arrested by a convenient rivet-hole, and relief, if widespread tearing is to be avoided, is dependent on the ability of the steel to absorb energy and thus to dissipate the stress concentration. These characteristics must constantly be appreciated in design and drawing offices and in the shipyard. The properly designed welded structure must be free from abrupt discontinuities and framed with easy contours. A slavish repetition of riveted detail is neither sound nor æsthetically satisfactory in the welded ship. The shipbuilder is alive to the importance of careful preparation of material and systematic control of all welding operations; and the increasing use of radiography indicates that thorough supervision pays.

Great advantage can be taken of the improved fixity of welded compared with riveted end connections. This fixity significantly reduces both the stress and deflection under load in welded stiffening members; consequently, appreciable reductions in scantlings are possible at welded bulkheads, for example, in addition to the elimination of faying flanges and with resulting improvements in tightness and efficiency in service. Most useful data in this direction have been provided by the tests initiated through J. L. Adam at Glengarnock and now under the direction of British Shipbuilding Research Association, the experimental work being carried out by Lloyd's Register.

Disturbing major structural failures in certain welded ships built during the war in the United States led to immediate and exhaustive investigations by shipbuilding authorities, both in that country and in the United Kingdom. These fractures developed in a sudden brittle manner, apparently quite uncharacteristic of the ductile mild steel which, over long years, had proved its reliability in riveted ships. The investigations early disclosed that a major factor in the failures was insufficient notch-toughness in some of the material used in these ships at the temperature prevailing at the time of casualty. The fracture in mild steel in the presence of a notch changes from the "ductile" mode, with high energy absorption, to the "brittle" mode with low energy as the temperature is lowered, the transition being usually clearly marked and rapid. Increase in thickness of material also tends to increase the susceptibility to brittle fracture. It is apparent, therefore, that shipbuilding steel in the full range of thicknesses required should possess a low transition temperature and adequate notch-toughness at all service temperatures. The factors influencing these properties in material complying with the usual tensile and ductility tests are most complex, and may be affected by the processes of manufacture at all stages, from the chemical composition to the dimensions of the finished product. The problem is challenging, and is being tackled with close collaboration between metallurgists and the shipbuilding interests in many countries.

The design of ships must be related to experience. A particular responsibility of the classification society is to examine the behaviour of hull structures under service conditions in various states of loading and especially in bad weather; and to study critically all evidence of defects or failure. This constant analysis of sea-going experience, essential to a progressive revision of general and local standards of strength, focuses attention on problems calling for specific research. The naval architect, handicapped by the difficulty of assessing the loads applied under the constantly changing conditions at sea, has been compelled to rely largely on a comparative approach in determining strength; yet these methods, if applied judiciously and with full appreciation of other significant factors, have proved their reliability as between reasonably similar structures.

The later stages of the programme framed by the Admiralty Ship Welding Committee laid emphasis on the direct measurement of sea forces. Tests were made on the welded cargo ship Ocean Vulcan over a long period of North Atlantic trading. Through the related static trials under controlled conditions of loading on this ship and on a riveted sister-ship, the Clan Alpine, stresses and deflections in each structure were to be deduced under known applications of loading at sea. The programme, involving the use of specially designed instruments, was carried out in 1946-47, and analysis of the recorded data is now approaching completion. This promises to throw much light not only on the stress response in the main structures to known applied forces, but also on the intensity of stress concentrations at discontinuities and local bending stresses in plating.

Great progress has been achieved through the welded ship, which has come to stay. Experience from this second and rapid revolution in ship construction has clarified the essential differences from riveting. These call for modification of many construction features acceptable with riveting, the reduction of stress concentrations by appropriate design, both basic and detailed, the easing of discontinuities, and the minimising of notch effects—for which a high standard of workmanship is essential. The structural material must possess adequate toughness to absorb energy in the presence of inevitable notches, particularly at low service temperatures and in thick plating.

In his paper read before the Institution of Naval Architects in 1860, John Grantham said: "The perfection of a structure such as a ship is to be seen in the scientific disposal of the materials to give the greatest possible strength with the least amount of weight." We still strive towards this perfection, and with vastly enhanced scientific knowledge and facilities. True progress in the design and building of ships will be dependent on the proper application of scientific method, related to practical experience, but unfettered by undue reliance on tradition.

* Paper presented at the International Conference of Naval Architects and Marine Engineers, London, on June 26, 1951. Abridged.

† *Proc. I. Mech. E.*, 1885, page 236.

‡ "The Strength of Iron Ships," *Trans. I.N.A.*, vol. 1, page 57.

* "The Measurement and Recording of the Forces Acting on a Ship at Sea," by F. B. Bull and Professor J. F. Baker. Part I. *Trans. I.N.A.*, vol. 91, page 29 (1949).

BOOKS RECEIVED.

The Hashemite Kingdom of the Jordan: Report on the Proposed Extension of Irrigation in the Jordan Valley. by Sir Murdoch MacDonald and Partners. Crown Agents for the Colonies, 4, Millbank, London, S.W.1. [Price 30*s*.]

World Power Conference: Annual Report 1950. Central Office of the World Power Conference, 201-2, Grand Buildings, Trafalgar-square, London, W.C.2. [Price 1*s*. 6*d*. post free.]

The Birmingham Tame and Rea District Drainage Board: Deputy Engineer's Report on a Visit to Sewage Purification Plants in the United States of America. 19th September to 31st October, 1950. Engineer's Office, Birmingham Tame and Rea District Drainage Board, Rookery Park, Erdington, Birmingham, 24.

The Industrial Use of Flash Welding, Dealing in Particular with Ferrous Materials. British Welding Research Association, 29, Park-crescent, London, W.1. [Price 2*s*. 6*d*.]

Architectural Design Data for Solid Fuel. Coal Utilisation Joint Council, 3, Upper Belgrave-street, London, S.W.1. [Price 7*s*. 6*d*. net.]

Office Systems. Vol. I. Office Management Association, Management House, 8, Hill-street, London, W.1. [Price 7*s*. 6*d*.]

University Research Potential: A Survey of the Resources for Scientific and Engineering Research in American Colleges and Universities. The secretary, Engineering College Research Council of the American Society for Engineering Education, 77, Massachusetts-avenue, Cambridge 39, Massachusetts, U.S.A.