HOLLOW STEEL PROPELLER BLADES FOR AIRCRAFT.

(*Concluded from page 194.*)

THE assembly of the core tube and shell, the filling compound and the root closure of the de Havilland hollow steel propeller blade, and the milling of the ball races on the root end of the core tube, were described in the second part of this article, in last week's issue.

To provide adequate resistance to wear, it is necessary to deep-harden the ball races which have been milled on the relatively soft surface of the core tube, which has a Rockwell C hardness value of 28. High-frequency induction heating is clearly most suitable for this purpose, since the current induced in the workpiece, and thereby the heat, is confined to the immediate vicinity of the inductor coil, and the depth and intensity of the heat can be closely controlled by regulating the power and the time during which it is applied. A specially-designed high-frequency generator, believed to be the largest of its type in Europe, has therefore been supplied by Messrs. Philips Electrical, Limited, Century House, Shaftesbury-avenue, London, W.C.2. The generator, which employs an oscillator valve of the type used for radio transmission, operates at a nominal frequency of 275 kilocycles per second, and has an intermittent 15-minute rating of 225 kW with a maximum continuous output of 150 kW; it is supplied from three-phase 50-cycle mains at a voltage between 380 and 440.

Fig. 22, herewith, shows the generator, beside which is a blade set up for hardening. A supply contactor and a radio-interference suppressor, not shown, are supplied with the generator. For ease of transport, the generator was built on two separate frameworks which were assembled together on the site on a common plinth. The frameworks carry all the components except the high-tension transformer, which weighs just over 2 tons and is supported on a steel sheet on the floor. The heavier components, such as the high-tension transformer, the filament transformer, and the oscillator condenser assembly, which carries two cooling fans, are mounted on runners and are removable. Access to a gangway in the interior of the generator, for servicing, is through a door midway along the right-hand side; all the components of the oscillatory circuit are grouped to the left of the gangway, and the supply circuits are on the right. A light inside the generator comes on automatically when the door is opened. Opposite the door, and accessible through a panel on the other side of the generator, is a compartment containing the contactors and relays, overload circuit-breakers, fuses, links for automatic timing mechanisms, and monitoring meters recording the total life of the valves.

Motor-driven cooling-air fans are built into the unit for cooling many of the components; in addition, water-cooling is provided for those conductors carrying high currents, such as the oscillator valve and the high-frequency transformer. To maintain the glass-to-metal seal of the oscillator-valve anode at a constant temperature, an air blast is directed at this area. The oscillator valve is a CAT-14-type valve working in a Hartley circuit; it is illustrated in Fig. 23, which shows the interior of the generator to the left of the gangway. The large variable high-frequency transformer can also be seen; this component, which is motor-driven, allows the high-frequency output to the working coil to be adjusted quickly, either manually or automatically, should it be required, during a hardening operation, over a power range of ten to one. In addition to the variable transformer, the output current can be adjusted by a series of condensers which can be placed in series or in parallel with the working coil.

The alternating-current mains supply is fed to an oil-cooled supply transformer, the secondary coil of which is provided with a tap-changing switch enabling the high-tension voltage to be set at 6 kV, 9 kV, 12 kV, or 15 kV; the de Havilland Company work at the maximum setting. The high-tension voltage is converted to direct current for supplying the oscillator valve by a full-wave rectifier comprising six hot-cathode mercury-vapour rectifiers, which are air-cooled to ensure that they work in an ambient temperature of 10 deg. to 50 deg. C.

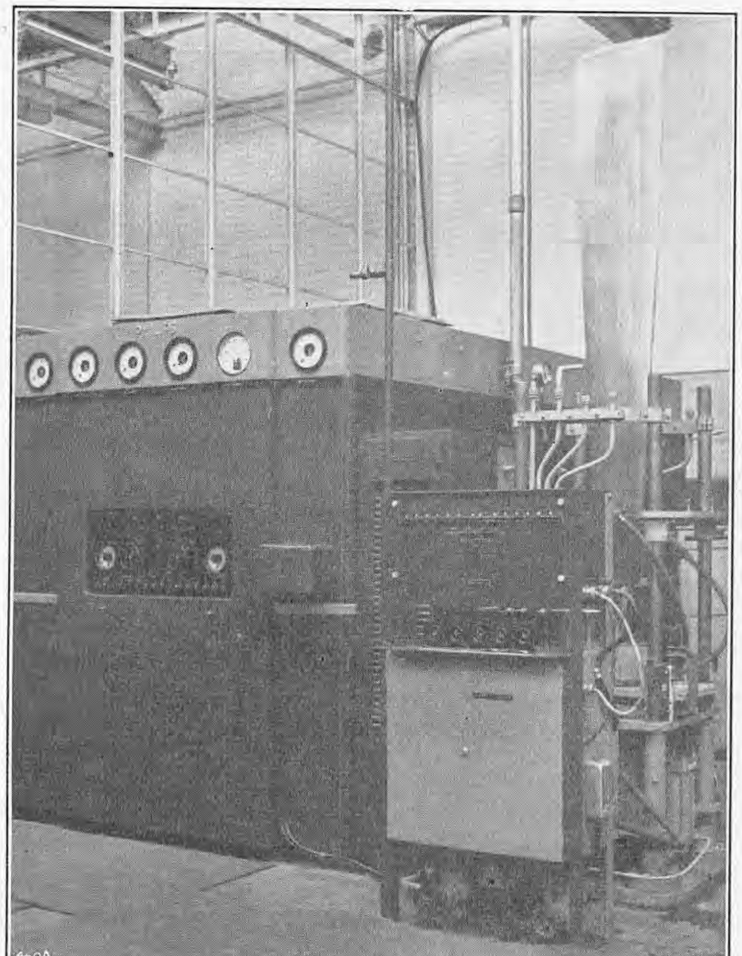

FIG. 22. PHILIPS HIGH-FREQUENCY INDUCTION-HEATING GENERATOR.

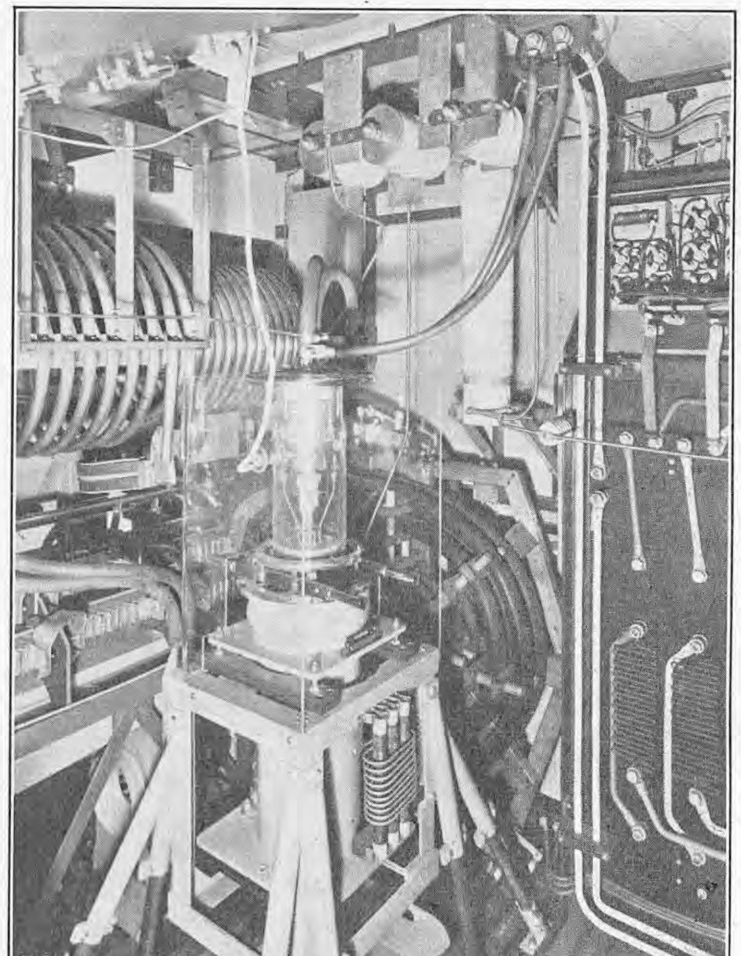

FIG. 23. COMPONENTS OF THE OSCILLATORY CIRCUIT OF THE GENERATOR.

Special precautions have been taken to protect the apparatus, and the personnel using it, from accidents. In addition to overload relays or fuses in every circuit, there are manually-preset overload switches protecting the main high-tension transformer supply, the oscillator-valve filament and the anode current. The main circuit-breaker is tripped by gate switches when either of the doors on the generator housing is opened. To ensure that the valves and condensers do not become overheated, the water and cooling-air supplies also operate safety trips when they fall below a pre-set level.

Apart from the outside supply circuit-breaker, all the control switches and indicators are grouped on a panel at the front of the generator. Operation of the mains circuit-breaker push-button turns on the cooling-water supply and switches in the filaments of the rectifiers and the oscillator valve, which are coupled to the mains supply through low-tension filament transformers. The oscillator-valve filament voltage is applied in three stages—15 volts, 27 volts, and 30 volts—by automatic delay switches. Further increase of the filament voltage up to full voltage is carried out manually; the filament voltage is kept constant by an automatic motor-driven regulator. It is not possible to apply high voltage to the rectifiers until the filaments have warmed up and this is accomplished by two delay switches, comprising a clockwork timing mechanism which operates, after 15 minutes, a solenoid actuating a mercury switch which closes after a further two minutes delay, and causes a green indicator lamp on the panel to light up, showing that the filaments are ready. Operating the "H.T. Voltage," push-button actuates a contactor in the primary of the high-tension supply transformer, and applies high-tension rectified voltage to the oscillator anode. The radio-frequency power to the working coil is switched on by switching in the grid of the oscillator valve, by means of a triode valve used as a variable grid resistance, thereby enabling a high-power circuit to be switched on using a low-power circuit. The output current can then be varied by a handwheel which controls the motor for setting the high-frequency transformer. Two

HOLLOW STEEL PROPELLER BLADES FOR AIRCRAFT.

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Fig. 24.

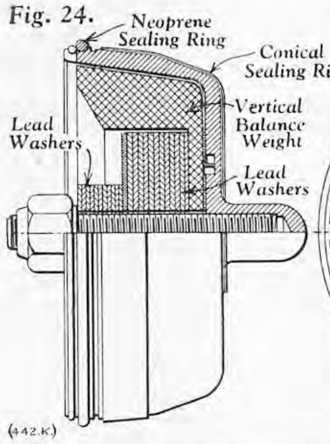


Fig. 25.

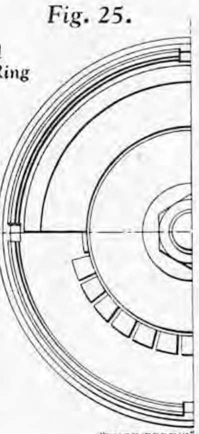
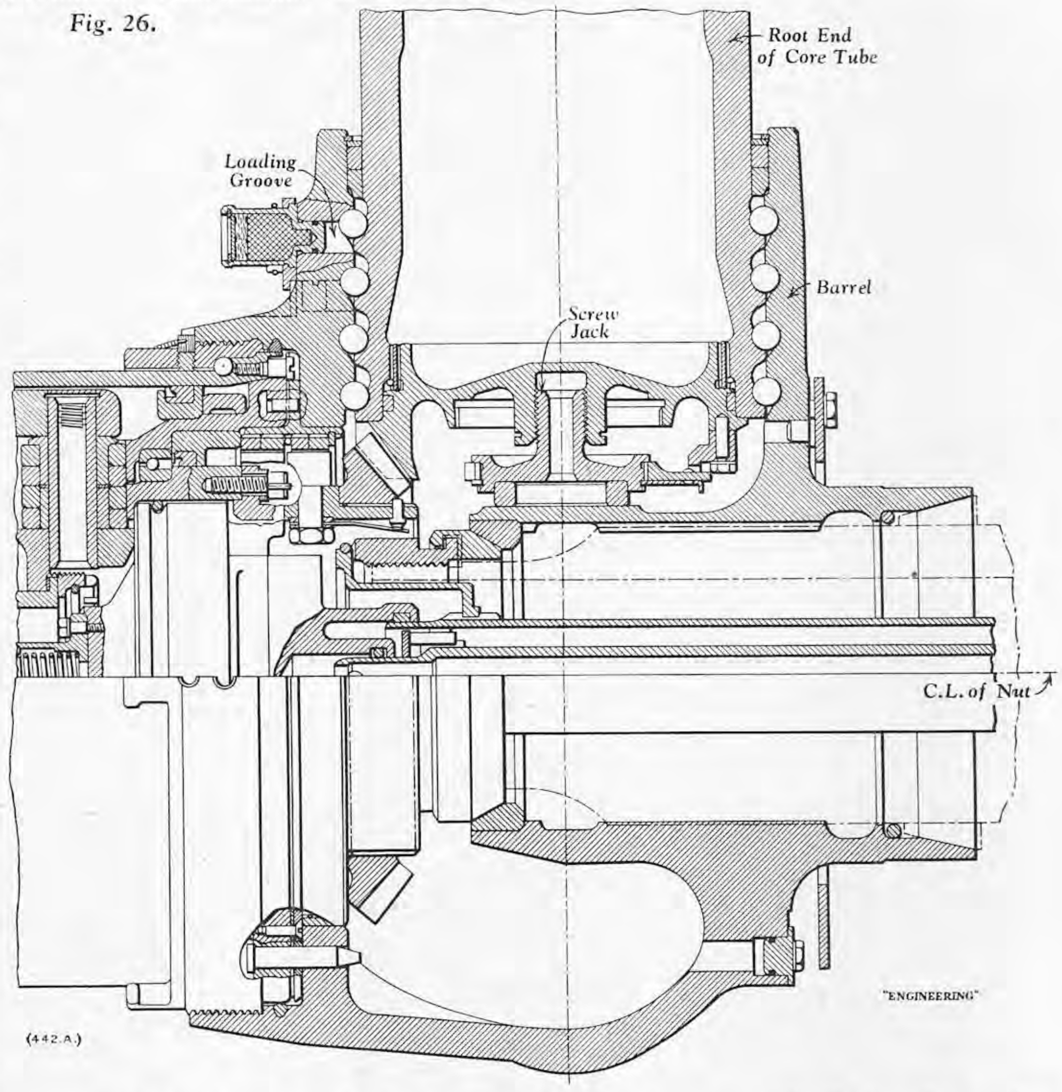


Fig. 26.



automatic timers, with ranges from 0 to 10 and from 0 to 100 seconds, are provided for switching off the output power after a predetermined interval; alternatively, manual control can be selected. Pilot lights are provided to indicate water supplies on, forced-air cooling on, and thermostat cut-outs, in addition to the time delay for the rectifier filamenus already mentioned.

The wiring for the control circuits for switching on power is taken to a terminal board in the generator, to enable a remote control station to be used. Such a station has been constructed by de Havillands, and is shown on the right of Fig. 23, immediately in front of the blade being hardened, for giving completely automatic control of the heating and quenching sequences by means of adjustable cam-operated switches, the camshaft being driven by a clockwork-controlled mechanism.

For the induction-hardening process, the high-frequency working coil and the concentrator, which concentrates the magnetic flux over the required area of the workpiece, are mounted on a framework vertically above the centre of a turntable. The blade is set up vertically, through the concentrator and work coil, with its root placed over a central spigot on the turntable. The spigot, which has holes bored in it for spraying cooling water, carries a sealing ring at its lower end which is tightened against the blade root to form a watertight seal; the water is used for controlling the heat treatment, not for quenching, which is done by air. Before the power is switched on, the turntable is raised by compressed air to bring the blade root into the concentrator; it is then rotated at a speed of about 25 r.p.m., and the power sequence is initiated. For hardening the ball races on the blade, de Havillands start heating at a low power and increase it in two stages, at 60 seconds and 100 seconds; the total heating time is 140 seconds. By this means, the desired hardness pattern, varying from 0·03 in. at the shallowest part to ⅜ in. on the areas which carry the bearing loads, as shown on the specimen illustrated in Fig. 27, on Plate XVII, is obtained. Starting at a low power allows a certain degree of penetration without overheating the surface, and the power increase in the later stages of the cycle compensates for the loss of magnetic permeability as the steel heats up. Immediately the power is switched off, the workpiece is quenched by high-pressure air jets which pass through holes in the wall of the concentrator. The blade root is cooled to room temperature within approximately 15 sec. This hardening of the ball races, to a Rockwell C hardness value of 58, is followed by a stress-relieving treatment at 135 deg. for six hours in a small furnace; during this treatment the moulded-rubber root closure is continuously sprayed with cold water so that the temperature does not exceed 80 deg. C. Final grinding of the hardened races is the next process.

Fig. 28, on Plate XVII, shows the hub in which the blades are mounted; the procedure at present is to harden the bores of the barrels before grinding the ball races. When more experience has been gained in using the equipment, this procedure will be reversed and the hardening will be applied around the contour of the ball races to a depth of 0·09 in. A rotating fixture has been developed for successively heating each of the four barrels of the hub, in conjunction with an internal induction coil and concentrator.

The hub is mounted on a horizontal spigot which is supported at each end in bearings on the extended side members of a wheeled carriage; the carriage is wheeled on to the turntable, where it engages in grooves on the surface, so that the centre line of one of the barrels is aligned with the centre of the barrel concentrator and the work coil, which in this case are mounted high on the turntable framework. The turntable is raised to bring the bore of the barrel over the concentrator, and, as before, it is rotated during the heating and quenching sequence. Since the hardness pattern to be imposed on the barrel bore is free from peaks and valleys, a shorter heating period—60 seconds—of greater intensity can be used. The outside of the barrel is surrounded by three water-spray rings, the centre one of which is brought into action 10 seconds before the high-frequency power is switched off, to control the heat penetration at this point where the concentration of heat tends to be greatest. Immediately the high-frequency power is switched off, the other two water-cooling rings operate and a high-pressure air blast through rows of holes in the concentrator quenches the bore of the barrel. The turntable is then lowered and the hub is rotated through 90 deg. about the spigot to bring the next barrel into position for heat treatment. After the four barrels have been hardened, the carriage is wheeled off the turntable, and the whole hub receives a stress-relieving treatment.

After the hardening and stress-relieving treatment, the bore of the blade is finally milled and ground; Fig. 29, on Plate XVII, shows the ball-race grooves receiving their final grinding, after which serrations are cut in the bore for securing the pitch-changing gear.

The blades are now zinc-plated to give a protective coating and to provide a further means of correcting unbalance. From the recorded history of each blade, a close estimate can be made of the amount of plating required to bring the blade within the required balance tolerance. The horizontal balance is corrected by graduating the thickness of the zinc deposit from the root to the tip; firstly, the area not requiring deposition is protected by painting with a special lacquer; the remainder of the blade is then plated, and finally, after removing the lacquer film, the blade is plated all over. Correction for vertical balance is made by suspending the blade horizontally and submerging either the leading edge or the trailing-edge chord partly into the solution. During this process the blade is given a slight vertical oscillation by a motor and eccentric drive to produce a diffused edge to the zinc deposit.

The final balancing of the blade is effected by inserting a steel cup, illustrated in Figs. 24 and 25, herewith, which carries several removable lead balance weights for adjusting horizontal balance and an eccentric lead mass which can be adjusted about the centre line for vertical balance. The cup, which is fitted in the core tube at the root end, is provided at its outer end with a conical sealing ring formed of three layers of resin-impregnated fabric which seats on a taper formed in the bore. After screw-jacking the balance cup into position, heat is applied and the resin flows to form a liquid-proof seal; a shoulder groove is provided in the balance cup to accommodate any surplus resin. Below the shoulder groove, a Neoprene seal is fitted between the skirt of the balance cup and the root bore. The blade is now ready for assembly in the hub. The pitch-changing bevel-gear mounting-ring is splined to the bore; this ring provides a fine adjustment for setting the

(To face page 226.)

HOLLOW STEEL PROPELLER BLADES FOR AIRCRAFT.

DE HAVILLAND PROPELLERS, LIMITED, HATFIELD.

(*For Description, see Page* 225.)

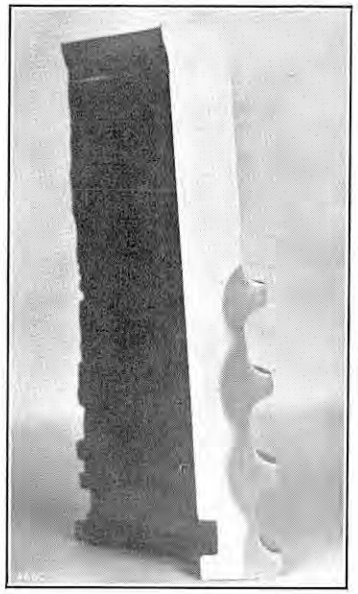


Fig. 27. Hardness Pattern.

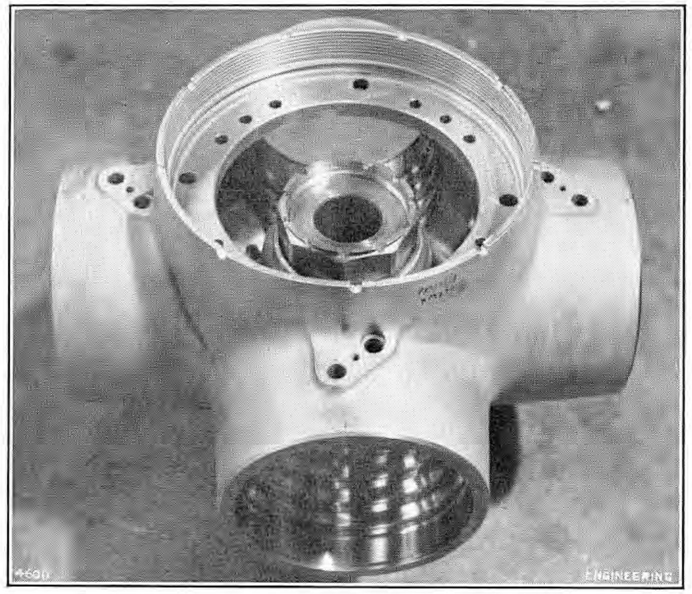


Fig. 28. Propeller Hub.

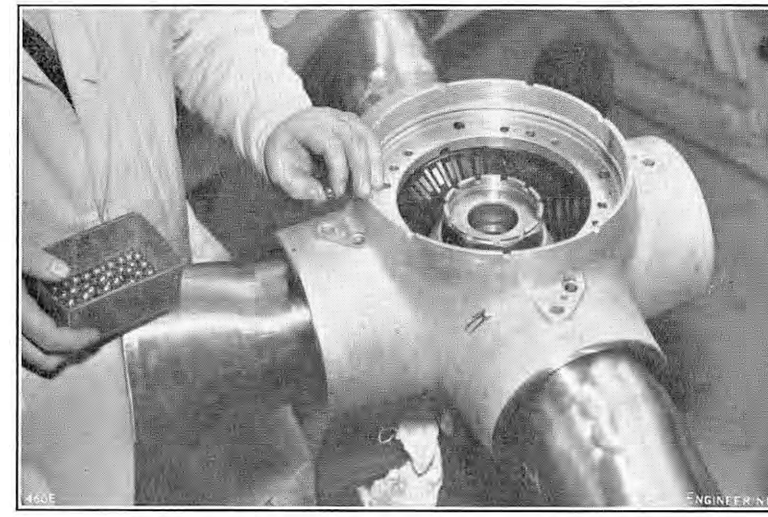


Fig. 30. Inserting Balls in Races.

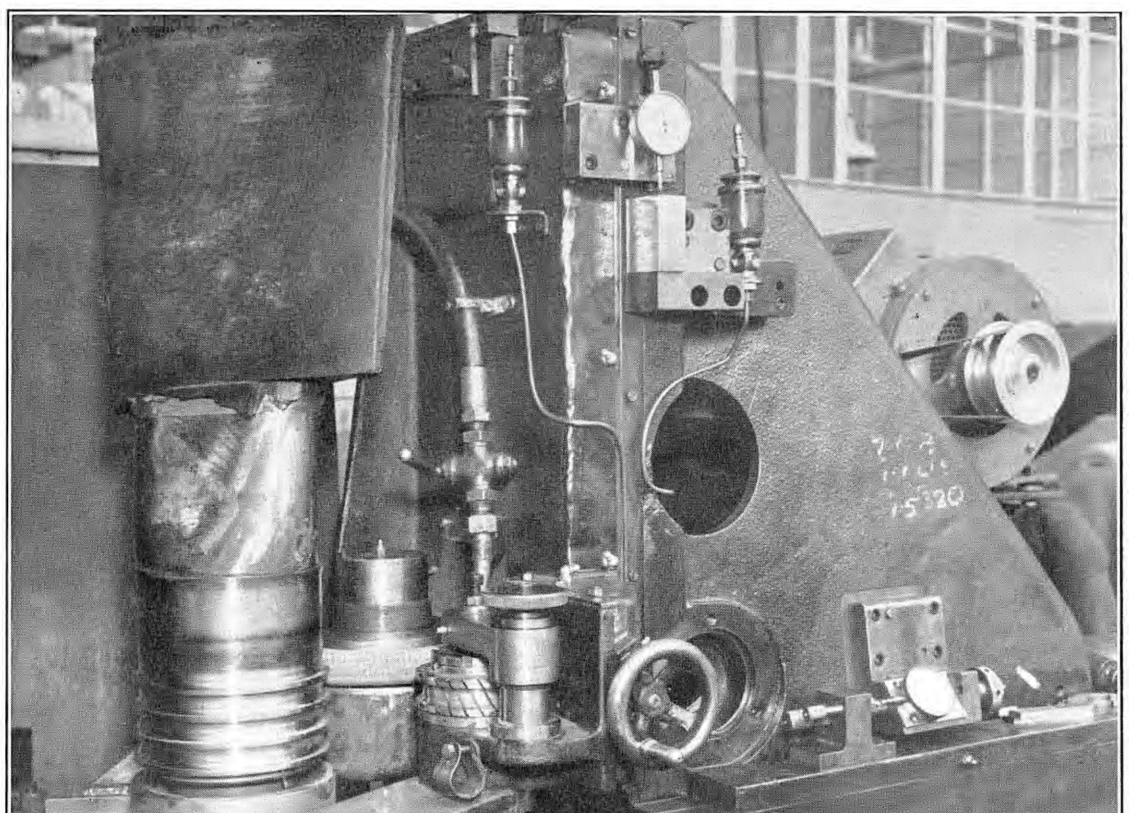


Fig. 29. Grinding Ball Races on Blade Root.

Fig. 31. Propeller on Test Rig.

gear accurately in relation to the master pitch-changing gear in the hub. The centre of the pitch-changing gear in the blade is threaded to receive an assembly screw-jack carried in the barrel.

The method by which the ball races are assembled may be understood by referring to Fig. 26, from which it will be seen that the ball grooves in the blade root and in the barrel are wider than is necessary to accommodate the balls. Communicating slots connect each barrel groove to the outside of the barrel. The blade is screwed down into the barrel, which is horizontally mounted on a spigot, by the assembly jack until the ball tracks on the blade root are aligned with the slots in the barrel. As may be seen in Fig. 30, on Plate XVII, the balls are fed to the tracks through the slots, and the blade is rotated so that the balls are rotated into position; the blade is then jacked to the outboard position until the torsional resistance, measured by a loading bar attached to the blade, reaches a predetermined value. The ball-loading slots are then filled with blanking plugs to prevent the ingress of dirt and moisture. It will be appreciated that the loading slots, which are machined before the induction-hardening process takes place, penetrate through the hardened surface of the barrel. Normally, such an interruption of the surface layer by a hole or slot would seriously distort the hardness pattern, and it has been found necessary to seal the loading holes during induction heating with a tightly-fitting copper-plated steel plug, which provides an effective current path across the hole and an undisturbed heat pattern. After hardening, the plugs are driven out. Finally, the complete propeller is balanced as a unit, and any corrections are made by inserting lead wool into cupped extensions of the ball-filling-hole blanking plugs.

The first aircraft which are likely to be fitted with de Havilland hollow steel propellers are the Saunders-Roe Princess flying boat and the Bristol Britannia air liner, both of which are in an advanced state of construction. It may be recalled that the Princess has ten Bristol Proteus propeller turbines, arranged in four double units and two single outboard units; when equipped with hollow steel propellers, each Proteus unit will drive a 16-ft. 6-in. diameter four-bladed propeller, those fitted to the double units being arranged to rotate in opposite directions. The Britannia will be powered by four Proteus propeller turbines each driving a 16-ft. diameter hollow steel propeller. Figs. 1 and 2, on page 161, *ante*, show the layout of such a blade. The basic diameter of the de Havilland design of hollow steel blade is, actually, 17 ft., but at present there is no application for this size; the 16-ft. 6-in. and 16-ft. diameter blades are cropped versions of the basic size.

The first complete four-blade hollow steel propeller constructed in this country has already been subjected to a series of power, vibration and over-speed tests at various blade settings at the Royal Aircraft Establishment, Farnborough. On completing these tests, it was returned to Hatfield where it was stripped down and examined, and found to be completely satisfactory. The propeller has now been reassembled and, as shown in Fig. 31, on Plate XVII, it is at present fitted to a Bristol Centaurus 22 SM engine in the de Havilland engine and propeller testing rig, where it is undergoing a 25-hour "special category" test prior to flight testing. During this test, it will be operated at a sequence of engine speeds and powers to simulate those occurring in flight. When the 25-hour test has been passed, the propeller will be installed on one of the Centaurus power units of an Airspeed Ambassador aircraft to be tested thoroughly in flight before being submitted for its type-approval trials on the bench.

NEW MOTOR TORPEDO-BOAT.—The first of a new type of motor torpedo-boat, M.T.B. 5701, was launched on August 18 at the yard of Messrs. J. S. White and Company, Limited, Cowes, Isle of Wight. The machinery will be novel in that she will have Metropolitan-Vickers gas turbines in combination with Diesel engines. The installation of the machinery is being completed by Messrs. J. S. White and Company, who are also building the hull. M.T.B. 5701 will be 120 ft. in length and 25 ft. in beam. The armament will consist of four 21-in. above-water torpedo tubes and one small gun.

THE INTERNATIONAL CONFERENCE OF NAVAL ARCHITECTS AND MARINE ENGINEERS.

(*Concluded from page* 200.)

As previously stated, the technical sessions in London of the International Conference of Naval Architects and Marine Engineers concluded on the afternoon of Thursday, June 28. The morning and afternoon of the following day were devoted to visits to places of (non-technical) interest in the Home Counties and, in the evening, the delegates and members met at Grosvenor House, Park-lane, W.1, for the official dinner, at which the Institution of Naval Architects and the Institute of Marine Engineers were the joint hosts. On Saturday, June 30, a visit was arranged to Stratford-on-Avon; and on the Sunday the Conference transferred itself officially to Glasgow.

In Glasgow, there were no technical sessions, but a full programme of visits to works, and to places of scenic and historic interest, had been arranged by the Institution of Engineers and Shipbuilders in Scotland, and their organising committee. In the unfortunate absence, through illness, of the President of the Scottish institution (Professor Gilbert Cook) and, as it happened, of all the other Presidents of the collaborating societies, the Conference was temporarily without an official head; but, as the Lord Provost was absent also from the reception that he gave to the members of the Conference in the City Chambers, it may be said that a state of equilibrium was restored. Monday, July 2, was spent in visits to works and shipyards, and (by the ladies especially) in exploring the Trossachs and Edinburgh by motor coach; and July 3 in cruising down the Clyde in the pioneer turbine passenger vessel King Edward—50 years old, but more comfortable than many a younger ship, and still capable of a good turn of speed, as she demonstrated on the Skelmorlie measured mile on the return trip. Her speed on the mile was stated to be about 16¼ knots, but, as only the one run could be made, the allowance for the tide, running at about half ebb, had to be guessed. Our own estimate was that the speed through the water was nearer to 16¾ or even 17 knots.

On the morning of Wednesday, July 4, a coach tour of Glasgow was well patronised by the members, who re-assembled in the Grosvenor Restaurant for a luncheon at which they were the guests of the Institution of Engineers and Shipbuilders in Scotland; then, at 2.30 p.m., they left by their special train for Newcastle, which was reached in the early evening.

The proceedings in Newcastle began on the following morning in the hall of the Literary and Philosophical Society, where Sir Philip B. Johnson, B.A., President of the North-East Coast Institution of Engineers and Shipbuilders, made the members welcome, and presided over the concluding technical session of the Conference, at which two papers were presented. These were on "U.S. Fleet Maintenance and Battle Damage Repairs in the Pacific during World War II," by Captain Ralph K. James, of the United States Navy; and on "Stresses in Propellers and Propeller Shafting Under Service Conditions," by Dr. S. F. Dorey, C.B.E., F.R.S.

BATTLE DAMAGE REPAIRS IN THE PACIFIC.

Captain James, in presenting his paper, practically ignored his printed text; but evidently he had little need of it, for he proceeded to give a summary of the paper that was so obviously the fruits of experience, and so ably delivered, that it was received with an enthusiasm rarely accorded to a paper before a professional society. He explained how the outbreak of the war found the United States Navy with repair facilities that were quite inadequate for the conduct of a major war in the western Pacific. The shipyards in the United States were fully occupied with new construction, so plans were formulated to provide the fleet with advanced bases on the Pacific islands, as it advanced towards Japan. It was doubtful, said Captain James, whether the combined productive capacity of the United States and the Allies could have built, equipped and repaired ships in sufficient numbers to defeat Japan if it had been necessary for the ships to return to United States bases for maintenance and repairs. An important feature of the advanced bases was the fleet of floating docks; during the war, 158 of these docks were acquired or built, with lifting capacities ranging from 400 tons to 100,000 tons. In one period of twelve months, towards the end of the war, the floating docks docked 7,000 vessels, of sizes from motor torpedo-boats to battleships of the Iowa class. A large fleet of repair ships supplemented the docking facilities; these were variously fitted with equipment including machine shops, Diesel-engine overhaul shops, blacksmiths' shops, plate shops for hull repairs, and, in some cases, a foundry capable of producing castings up to 3,000 lb. in weight. The need for such greatly increased repairing resources was indicated by the fact that, between 1941 and 1945, the United States Navy increased tenfold, the additions including six battleships, 15 cruisers, 19 aircraft carriers, 157 destroyers and 860 auxiliaries. In one year, battle-damage repairs were effected to 20 capital ships, and miscellaneous repairs (including minor battle damage) to 1,800 other vessels. Much work was done to improve fire-fighting arrangements on board ships, to such effect that, whereas a single torpedo hit on the cruiser Erie, in the early days of the war, started a fire which burned for five days, a torpedo hit on a petrol tank holding 2,500 gallons, in the Houston, was extinguished in 15 minutes.

Sir Lawrence Edwards, who opened the discussion, welcomed the paper as evidence of careful and efficient planning for the maintenance and repair of the United States Pacific Fleet, backed by stupendous resources of labour and material. It is appropriate, he added, that the paper should have been presented in Newcastle, on the bank of the Tyne, where the tradition of ship repairing was deeply rooted. As one who was associated with the national organisation of ship repairs in Great Britain during the war, he felt some jealousy when hearing of the numbers of men that were available for ship repairs, even at a United States advanced base in one theatre of operations. In the United Kingdom, there were fewer available for the construction and maintenance of the Royal Navy and the merchant navies of Britain and the Allies than there were in the Pacific Fleet's advanced bases; yet Britain, during the war years, managed to repair some 19 million tons gross of American merchant shipping. He wondered greatly where the United States Navy found those vast numbers of essentially skilled men to man the advanced bases; for much more initiative was required for ship repairing than for doing the repetitive work of shipbuilding. Captain James had drawn attention to the expansion of the United States Pacific Fleet by ten times, from the beginning of the war to the end of hostilities, and had shown that the repair facilities were extended by many times more. That was obviously necessary to keep pace with maintenance in war time, when there were not only normal marine hazards, but the hazards of enemy action.

Mr. D. E. J. Offord, R.C.N.C., observed that Captain James had referred to the importance and usefulness of the American battle damage reports, and had stated that they followed the pattern of similar reports issued by the British Admiralty. He (Mr. Offord) had had the honour of leading the team responsible for the British reports, from the beginning of the war until the middle of 1943. Captain James had referred also to the improvements achieved in the shock-proofing of machinery. One of the first, if not the first, of the British reports dealt with a ship which had suffered crippling shock damage. Several other ships were similarly affected. A concentrated study of the subject followed and was still continuing, and it was no secret that very considerable advances had been made in the shock-resisting properties of machinery and equipment. Such properties were now a specification requirement for all warships, and he urged that shipbuilders and shipowners should consider seriously something similar for merchant ships. The requirement did not lead, as a rule, to increased weight or space, and need not lead to increased costs; in most cases, all that was required was a closer attention to detail, which usually resulted in a more elegant design and one that was more efficient from every point of view. There was one important lesson to which Captain James had not made specific reference, namely, that a warship's function in war time was to be at sea, in all respects ready to fight. Any time spent in port for repairs, or going to and from a port for such a purpose, was a waste of time, and another warship had to take her place in the war zone. Therefore, the shortening of the time spent out of action virtually increased the effective size of the fleet. The entire paper indicated most clearly the vital importance of designing warships to have the maximum possible resistance to damage. Moreover, if they were damaged, the extent and nature of it should be such as to render repairs simple and expeditious. To obtain the knowledge requisite to execute such designs, research should be conducted in peace time; so that, in war, ships were ready and efficient, and it was not necessary to learn of their defects by the costly, and often disastrous, process of war-damage experience. It had come to be generally recognised that research into warship design was no less important than research into weapon design; the most perfect weapons counted for nought if the ships carrying them could not bring them within range of the enemy. The Conference was concerned primarily with merchant ships, but, in war, merchant ships were no less subject to attack than warships, therefore, the fewer ships damaged and the less the damage suffered, the more effective was the mercantile marine; it was important that merchant ships should make every use of improved fabrication technique, and that those concerned with Service and civilian ships should work in the closest harmony.

Mr. R. Chipchase, who followed, said that, as a ship repairer associated mostly with commercial vessels, he thought that the decision to send the repair bases abroad over such distances and in such mass was a very valiant one, and vital to the eventual issue of the war. In Britain, repairers were concentrating on carrying out their work under war-time conditions of black-out, and shortages of labour and materials; but they did as well as could be expected, and some very surprising figures could be given in that respect. They had a problem under consideration, namely, how, without skilled salvage craft and personnel, they could save lame ducks by covering a breach in an emergency; it was demonstrated very satisfactorily. There was also under consideration a system of "plastic surgery," involving the use of reinforced concrete to cover up breaches in vessels either afloat or ashore. Fortunately, the rapid fall of Japan made those aids unnecessary, but it would be interesting to know whether, in America, anything of that sort was envisaged.

Another problem was that of de-fouling without docking. Particularly after the fall of Singapore, many vessels could not put to sea, and others were too slow to maintain convoy speed. The problem was difficult, because ships varied so much in size, and nothing either mechanical or electrical could be evolved to meet the requirements without holding up items of prime importance for the fighting Services. However, the problem was tackled satisfactorily. The method adopted had to be foolproof, so that it could be used by native labour. Hundreds of vessels were cleaned in dozens of ports throughout the world, and, even in the Mediterranean campaign, the vessels were able to serve, being de-fouled without having to dry-dock. That work was done on Tyneside.

The chairman, after thanking Captain James for his paper, then called on Dr. S. F. Dorey.

Stresses in Propellers and Propeller Shafting.

The object of his paper, Dr. Dorey said, was to describe a number of problems encountered by Lloyd's Register of Shipping, the solutions of which were due largely to the application of electronic methods; and to indicate further fields in which knowledge was still uncertain, but in which rich dividends might be expected to result from the adoption of those methods. The paper also included some examples of failures, the causes of which were diagnosed by more conventional means. The difficulties of measuring stresses in marine propeller blades in service were considerably greater than those encountered in the parallel problem for aircraft propellers; partly because tailshafts in merchant ships were usually solid, and because of the need to waterproof the strain gauges. The lack of an axial hole in the shaft, through which to take the leads, was met, in the case of the 32-ft. cabin cruiser used to develop a suitable experimental apparatus, by using an armoured rubber hose, fixed in a curved steel protecting tube, the lower end of the tube being located in a water-lubricated bearing inside a special boss provided on the propeller. The other end of the tube extended up over the cruiser stern to the slip-ring gear on deck. The strain gauges were mounted radially on the blades. The success of the experiments with the cabin cruiser appeared to offer good prospects of equally satisfactory results in ocean-going vessels, and the possibility that knowledge of such problems as the effect of aperture fairing and blade clearances, in relation to blade vibration and "singing" phenomena, might be considerably clarified and extended. Already, tank experiments were being made in collaboration with the National Physical Laboratory to ascertain the effect of aperture changes on blade stresses and shaft exciting torques. Other problems awaiting solution included the measurement of blade stresses during torsional or axial vibration of the shafting, and shaft and blade stresses under conditions of partial screw immersion and when the propeller was racing at sea. Most tailshaft failures occurred, however, in single-screw ships with balanced rudders, and to elucidate these it might be necessary to await the co-operation of some owner or organisation, willing to afford facilities for experiment with a hollow-bored tailshaft, provided with slip-rings at the inboard end. Of all the war-built tonnage, the geared-turbine "Victory" type of ship had the worst record, with 63·3 per cent. of tailshaft renewals. In general, experience had amply demonstrated that, whatever the type of machinery, the maintenance of the maximum possible propeller immersion when in ballast was a fundamental requirement for maximum tailshaft life.

In opening the discussion, Mr. A. R. Gatewood, chief engineer surveyor of the American Bureau of Shipping, said that it was especially interesting that Dr. Dorey considered that the use of strain gauges in association with a hollow-bored shaft would be the most satisfactory method for exploring the shaft strains between the stern tube and the propeller boss. In the United States, they had arrived at the same conclusion, and the Machinery Committee of the American Society of Naval Architects and Marine Engineers had only recently completed such tests at sea, using a hollow-bored shaft and strain gauges. The tests were carried out on a single-screw 10,000-h.p. tanker of the T2-SE-A2 type. The object was to determine, by direct measurement under service conditions, the stresses occurring in propeller shafts in the critical region between the propeller and the stern-tube bearing. Preliminary results indicated that, when the ship was operating at normal service speed, reversed bending at propeller-blade frequency considerably exceeded the static bending moment due to the cantilevered mass of the propeller, and was somewhat greater in the "light ship" condition than when fully loaded. This propeller-blade frequency bending-moment was believed to be due to eccentricity of thrust. In addition, bending moments were measured at various frequencies which were multiples of the propeller-blade frequency. The results were being studied in relation to the natural frequencies of the propeller shafting system in lateral vibration, which were determined while the ship was in dry dock by means of a vibration generator attached to the propeller boss. The natural frequency for motion in a horizontal plane was found to be substantially less than the natural frequency for motion in a vertical plane, both in the dry and in the immersed conditions. Analysis of the film records of the tests would be a somewhat lengthy affair, but when they were completed it was expected that a full report will be published. The nature of a considerable number of the fractures indicated that the principal stress could be in bending, and this much, at least, had been verified by the tests at sea. Tests by the American Bureau of Shipping on propeller-shaft material also proved that there had been no reduction in the quality of the material. It was their view that, once accurate information was available about the actual service stresses, it would be much simpler, and certainly more economical, to carry out further research by using models. For example, so far as was known, no tests had been carried out to study the possible effect of the fretting action of a solid bronze propeller fitted on a steel shaft, as compared with a cast-iron hub fitted on a steel shaft. The entirely different characteristics of the two materials might prove to be of much more significance than had been supposed previously. In the United States, the tests were made possible only by a genuinely co-operative effort, to which a large number of individuals and organisations contributed. He hoped that Dr. Dorey would receive the co-operation for which he had asked, for, in Mr. Gatewood's opinion, a completely independent check on the American results would be valuable.

Dr T. W. F. Brown thanked Dr. Dorey for having advocated so much the development of electronic instruments for measuring deflection, strain and similar factors. Without measurement, very little progress could be made. They were still in the empirical stage of trying to decide the causes from first principles, and, if there was one thing that the paper had shown more than another, it was the complex nature of so many of the phenomena examined. Dr. Dorey had made several remarks about the use of the M.I.T. oscillograph, the Bell-type multi-channel recorder using films; but why use films, when there were so many direct-recording electronic graphical methods with pen recorders available? With them, it was possible to see the record as quickly as the measurements were taken, without having to wait until the film was developed and then to do extensive projection work. He congratulated Dr. Dorey on his use of the recording tape, which represented a great advance over film work. Having tailshafts drilled seemed a useful method of measuring strains in full-size ships. In high-speed transmission shafts, whirl was a factor to be considered.

Dr. S. Livingston Smith, Director of Research, British Shipbuilding Research Association, noted that, for the cast-iron propeller mentioned in the section of the paper dealing with stresses in propeller blades, the calculated stresses at the blade root exceeded the recommended safe limit for the material. The stress values obtained by the calculation given in an appendix to the paper, which was similar to the method recommended by the B.S.R.A., could only be considered as very approximate; various unknown factors rendered absolute accuracy improbable, but the case quoted by Dr. Dorey demonstrated that it could be used as a guide to the safety of any particular design. The author stated that the service speed of the coaster concerned coincided with a major one-node torsional critical speed, and he gave a calculation to substantiate that; it would be interesting to know how that calculated value compared with the actual value, and also the allowance made in the calculation for entrained-water effect. For ocean-going vessels, the use of a hollow trailshaft would appear to be preferable for conveying the leads from the strain gauges, and he hoped that opportunity would be found to extend that work in the near future. The case of the Great Lakes oil tanker brought out a number of interesting points, particularly in regard to the relative immunity of the starboard shaft. It was suggested that the machining and fitting of the keys might have played a large part in preventing rapid failure by reducing the stress-concentration factor. This might be so, but it seemed hardly likely that all the port replacement shafts had some machining defects. The point would be given careful consideration in tests which were to be carried out by Lloyd's Register on behalf of B.S.R.A., into the fatigue strength of the propeller assembly. It appeared that the fatigue strength of the tailshaft at its weakest point, namely, at the forward end of the propeller boss, could be greatly influenced by the standard of workmanship and the care taken in assembly. Because of the unfavourable conditions under which the work had often to be carried out, it was difficult to ensure the most favourable operating condition for the shaft. It was hoped, however, to obtain some information on the relative importance of the variables concerned by the fatigue tests referred to in the paper. Many members would learn with surprise that the type of vessel having the worst record in regard to tailshaft failures was the geared-turbine "Victory" ship. He hoped to hear more of the method of recording torsional fluctuation by the magnetic-tape method. If it was possible to improve the accuracy of that apparatus, it should be a valuable tool for that type of investigation. He agreed with the author regarding the importance of shafting alignment on bearing performance. Apparently, insufficient attention had been given to the positioning of lineshaft bearings, particularly at the after end, where the loading of the bearings could be altered radically by wear-down of the stem bush. That problem was being given some attention by the B.S.R.A. In addition to the bending moments resulting from the dead-weight of the shafting, etc., and from misalignment, in some reciprocating-engine installations bending of the shaft immediately aft of the crankshaft resulted from the flexure of the crankshaft itself; thus, when running, the load on the foremost plummer block was constantly varying.

Mr. A. Hiley asked Dr. Dorey's opinions on the impact and the yielding qualities which were required by virtue of the forces of torsion, bending, etc., on the tail shaft. The stresses and torsions could be so finely determined, not only by calculations, but also by check experiments, that the magnitude of the torsional forces on the shaft were fairly well known, and he thought that the knowledge might be applied to design a tailshaft to have a measurable yield at the extreme end, just forward of the propeller.

Professor E. V. Telfer said that he was much impressed by Dr. Dorey's remark that it was generally in ships with balanced rudders that tail-shaft trouble occurred. That was an excellent line of investigation, and he hoped that it would be followed up. From his own experience, balanced rudders were more frequently associated with tail-shaft troubles than was the ordinary type. It was interesting to see how Dr. Dorey had analysed the propeller on which the blades broke three times. It was a criticism of the practice of engineers that the propeller blade had to break three times before it was finally made satisfactory. Could Dr. Dorey say just what was done on the last occasion which enabled the blade to remain on the shaft in a healthy condition? Anyone with experience of propellers would have diagnosed at once that the propeller itself was faulty, and instead of the blade being 3¼ in. thick, it should have been 4½ in. The calculation showed that the maximum tensile stress on the blade always occurred at the trailing edge. Fracture never occurred there, however, but always somewhere near the centre of the blade, on the driving face. He thought that Dr. Dorey was a little ambitious in trying to measure stresses at sea on propeller blades. More could be learned in the laboratory on whether a force applied to a model propeller would produce a stress of a certain character in a certain place with a certain degree of accuracy. Having solved that problem, he could then be more ambitious and go to sea.

Mr. H. G. Yates said that the paper contained so much particularly valuable information, drawn from practical experience with installations actually in service, that it was a little unfortunate that the first example quoted was a good deal less convincing than those which followed. The shaft alignment indicator, referred to in the paper, was of great interest to him because an instrument using exactly the same principle was brought out at the Pametrada research station, for aligning two shafts connected by flexible couplings without the necessity to break the coupling and rotate the shaft independently.

Mr. P. Jackson commented that the ingenuity with which the people who specialised in electronics and those who built the instruments applied them and obtained readings was really surprising. Up to about 1944 or 1945, he had tried to keep pace with those things, but he began to think that he would be doing nothing else if he persisted in that effort. In view of his own experiences, he had become sceptical, and would like to know Dr. Dorey's opinion on electronic measurements and strain-gauge measurements.

Dr. Dorey said that he hoped to deal in due course with all the points raised. Comments had been made with regard to the materials and the engineer. It had generally been the practice for engineers quickly to condemn a material. In his experience, however, the material stood up to the job very well, and it was the engineer who was to blame, in that he did not know enough about the stresses in the part concerned. He thought that, by means of the apparatus now available, it would be possible to learn more of what went on in the parts under actual service conditions. He was glad that Mr. Gatewood had mentioned the tests carried out with the hollow shaft; the information which is to be published in due course would be of great value. It was extremely difficult to measure those stresses, and a great deal of work had to be done to produce results. Strain gauges required to be fitted with a reasonable degree of accuracy, and the results read properly. In merchant ships, it was not usual to have hollow shafts, whereas the Navy wanted to keep down weight and so always had hollow shafts; it would be much easier, therefore, to obtain results in naval ships than in merchant ships. The work had indicated how necessary it was to obtain greater knowledge of the single-screw cargo ship, which had to sail loaded or in ballast. He had tried to emphasise how necessary was proper ballasting, so that the propeller was adequately immersed. The tests described cost a lot of money and time. They wanted to develop the technique so that tests can be made on a much bigger scale when the funds were found for the purpose. Mr. Jackson had doubts concerning the use of electronic means. Like everything else, it was a question of gaining experience. There was no doubt that collaboration and checks were essential in that class of measurement. Another point he would emphasise was that, while they wanted information about behaviour in heavy weather, they could not keep people going around the world seeking it. He hoped that, in time, there would be suitable apparatus fitted on ships, and a competent person on the engineering staff who would be able to take records when the opportunity arose, so that advantage can be taken of the apparatus without unduly high cost. Professor Telfer had referred to the model propeller. They had one about 18 in. in diameter, with which they hoped to obtain considerable information under conditions approximating to those which a propeller would meet at sea. More information was required on the effect of shear stresses on propeller blades, particularly near conditions of cavitation, when there would be a considerable difference of pressure between the two sides of a blade.

SOCIAL EVENTS.

As previously mentioned, Dr. Dorey's paper concluded the technical business of the Conference, and the rest of the time was devoted to social events and visits to works, etc. On the afternoon of July 5, there was a visit to Durham Castle, where the members and ladies were entertained to tea by the Warden (Sir James Duff) and the Council of the Durham Colleges. In the evening, they were the guests of the North-East Coast Institution of Engineers and Shipbuilders at a banquet in the Old Assembly Rooms. Sir Philip B. Johnson, B.A., President of the Institution, with Lady Johnson, received the guests, who included the Lord Mayor of Newcastle (Alderman W. McKeag) and the Lady Mayoress. Sir Philip presided at the banquet, and the Lord Mayor proposed the toast of "Our Guests from Overseas," which was acknowledged by Mr. J. H. King, President of the Society of Naval Architects and Marine Engineers, New York, and Ingeniör H. Sjöholm, President of the Naval Architecture and Aeronautics Section of the Svenska Teknologföreningen.

On Friday, July 6, parties visited various works and shipyards during the morning, and also King's College, where they were received by the Rt. Hon. Lord Eustace Percy, Pro-Vice-Chancellor, and were conducted over the College by Professor L. C. Burrill, who occupies the chair of Naval Architecture. In the afternoon, there was a general excursion to the Roman Wall under the guidance of Dr. Ian Richmond, Professor of Romano-British Archæology. As frequently happens along the Wall, the weather left something to be desired, but the conditions were not sufficiently adverse to interrupt Professor Richmond's exposition of the Roman station at Housesteads, which was the most important item in the programme. Many of the members dispersed on that evening, the remainder returning to London by special train on the following day.

ECONOMIC DESIGN OF HEAT EXCHANGERS FOR GAS TURBINES.

By M. RUDDICK, B.Sc., Wh.Sc.

LARGE stationary gas-turbine plants for power generation have only recently been constructed and, as yet, varied experience of heat-exchanger performance is not available. Methods of calculating the dimensions of a heat exchanger for a given performance are known, as this subject is suitable for theoretical investigation and the problem is not greatly different from some other applications. The major difficulty at present is to decide for what performance the heat exchanger should be designed so as to give the optimum financial return. Practical experience will ultimately determine the solution, but for the first plants a surer guide than an intelligent guess is required, since a large financial outlay is involved.

A heat exchanger is added to a gas turbine only to reduce the cost of fuel for a given output, so the choice of performance should be regulated by economic considerations. It is apparent that changes in heat-exchanger resistance and thermal ratio will considerably affect the overall efficiency of the plant and thus the quantity of fuel saved over the life of the machine. The saving in fuel cost may be found for a given heat exchanger and compared with the cost of the heat exchanger and its upkeep expenses. When this has been done for a wide range of heat-exchanger performances, the best design point for the cycle considered may be chosen from an economic viewpoint. As an example, consider the determination of optimum heat-exchanger performance for a 10,000-kW plant using the cycle illustrated in Fig. 1, on page 230. In this plant the high-pressure turbine supplies the power output and also drives the high-pressure compressor. The low-pressure and medium-pressure compressors are driven by the low-pressure turbine through a separate shaft. There is reheat, also two stages of intercooling and a heat exchanger. This arrangement enables very great power to be obtained from a single plant, with high efficiency and good part-load performance.

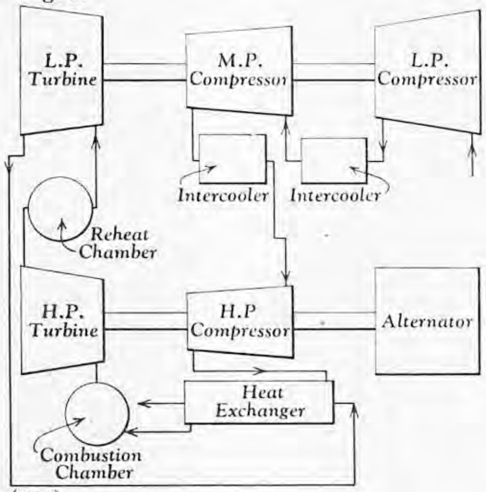
Two factors are normally used to define the performance of a heat exchanger. The first is thermal ratio, which is the ratio between the difference in temperature of the inlet air and inlet hot gas, and the temperature rise of the compressed air. The other factor is resistance, which is given as a percentage of the absolute pressure at which the resistance or fluid pressure drop occurs. This enables the air-side and gas-side resistances to be added to determine the effect on plant performance with only small inaccuracy.

For any gas-turbine cycle with given component efficiencies there is an optimum compression ratio. A change in heat-exchanger thermal ratio or resistance would alter this optimum compression ratio, but this variation with heat-exchanger performance is small over the range of practical importance. It is sufficiently accurate to estimate a heat-exchanger thermal ratio and resistance as close as possible to the unknown design values and use this performance to determine the cycle optimum compression ratio. It is then necessary to prepare a complete heat-exchanger design for costing at this chosen performance.

The type of heat exchanger and its cost depend on the individual designer. In the present case, a circular-section contraflow unit with straight tubes, as shown in Fig. 2, page 230, was used. Detailed

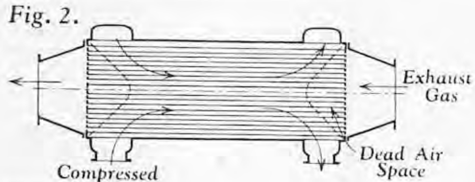
HEAT EXCHANGERS FOR GAS TURBINES.

Fig. 1.



(397A)

Fig. 2.



(397.B)

Fig. 3.

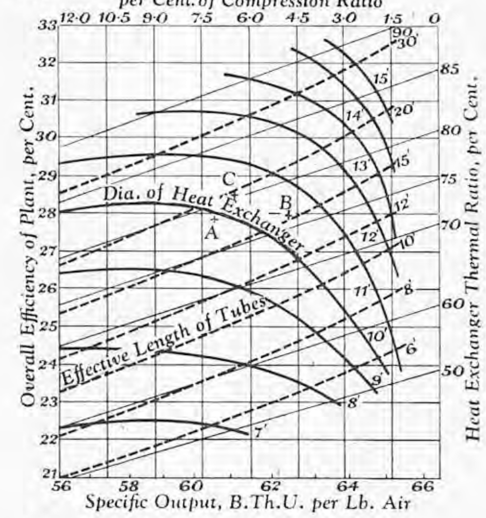


Fig. 4.

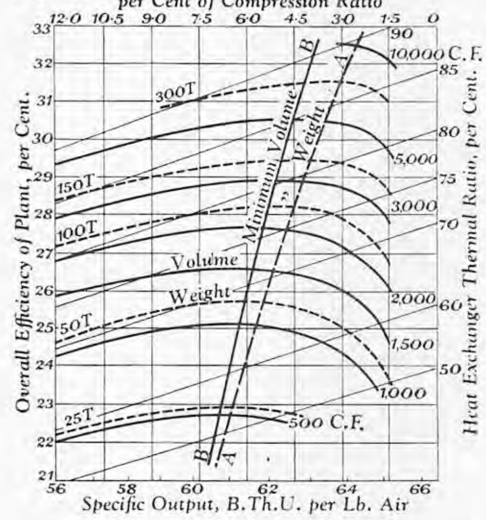
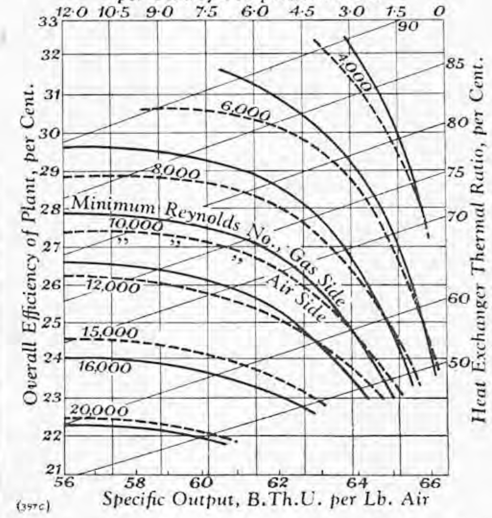
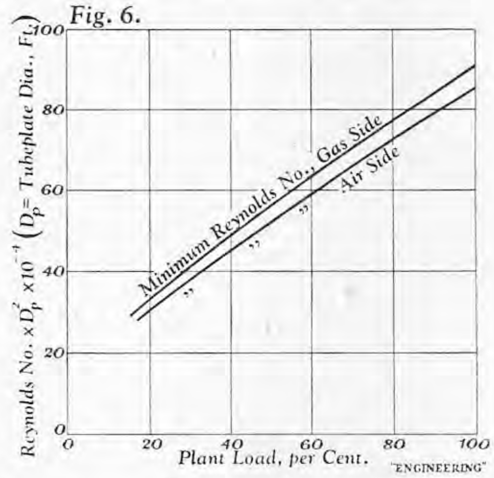


Fig. 5.



(397C)

Fig. 6.



consideration is not given here to the factors influencing the design of a heat exchanger as they do not affect the present investigation, which is applicable to any design. A clear presentation of heat-exchanger factors influencing the performance of a gas turbine may be made on a "background" graph of a type first used by Mr. C. E. Iliffe. This shows, simultaneously, the effect of a given factor on plant overall efficiency, plant specific output, heat-exchanger thermal ratio and resistance. On this background, the influences of heat-exchanger overall diameter and tube length are shown in Fig. 3. Allowance has been made for the ineffective areas of the tubes at inlet and outlet and for decreased heat transfer due to sooting and ash deposits. The results shown are of considerable interest where the size of the heat exchanger is limited by site area or fixed cost, as they give directly the influence of heat-exchanger dimensions on the plant overall efficiency and specific output. It may be noted that, over the narrow range considered, for a given thermal ratio, the tube length remains comparatively constant and only the overall diameter changes considerably for a decrease in resistance.

The next factors to be considered are overall weight and volume, which are of importance in the site and building costs. These dimensions, which are given in Fig. 4, include the headers. Heat exchangers are designed on the assumption of turbulent convection for heat transfer, for which a Reynolds number greater than 2,100 is required. If the Reynolds number of either the gas or air side falls below this value, the performance of a heat exchanger would be considerably lower than that indicated in Fig. 3, as a different heat-transfer relationship would apply. To determine the limiting range of dimensions and to find the way in which lines of constant Reynolds number run, the results given in Fig. 5 were calculated. These apply with the plant at full load, but it is necessary to have high efficiency at part output, so the heat exchanger must also be efficient down to about 20 per cent. of full load, requiring a heat-exchanger minimum Reynolds number of at least 2,100 at this value. Exhaust and compressed-air temperatures, compression pressure and air mass flow vary in a complex way with change in load, and these factors control the Reynolds numbers. Considering these effects, the variations with load of both air- and gas-side Reynolds numbers have been found and are shown in Fig. 6, in which D_p is the tubeplate diameter in feet. From this it may be seen that the full-load Reynolds number on the air side must be at least 6,000 for effective part-load operation.

Relative economy is the ratio of overall financial saving, due to the heat exchanger, to the fuel cost without a heat exchanger, and is a directly comparable factor. The overall saving is determined by the fuel saved over the life of the plant, this last being normally fixed by the turbine design, and the heat-exchanger costs, including first cost, cleaning, upkeep, and an annual percentage of the first cost as financial interest. From Fig. 7, opposite, in which relative economy (100 per cent. cost) is plotted on the base graph, it may be seen that there is an optimum relative economy in the practical range of construction. If it is necessary to design a smaller heat exchanger than that with the maximum relative economy there is a wide range of dimensions for any given lower value. In such a case it is desirable to use the design involving least outlay. The locus of such designs is given as a broken line in Fig. 7. If a given sum is available for the heat exchanger, the design on this line involving such a cost gives the greatest financial return. The actual heat exchanger cost as a percentage of an arbitrarily chosen value is given in Fig. 9, opposite. It is from this diagram that the minimum cost line is taken, and it may be seen how a heat exchanger designed for the wrong performance involves a considerable financial wastage.

While the point of maximum relative economy gives the maximum overall financial return, it is advisable to consider how effectiveness of outlay varies with overall cost; or, more simply, does a sum spent on a small heat exchanger get a greater return than a similar sum spent to make the heat exchanger larger? To consider this question the financial saving is plotted against outlay in Fig. 10, opposite, for the minimum cost locus of heat exchangers. This line is denoted 100 per cent. outlay. It may be seen that there is a sharp "elbow" in this line, above which a large increase in outlay is required for a small overall return. If point A is chosen for the final design, the outlay is half that for the optimum relative economy, while the overall saving is decreased only by about 6 per cent. The slope of the line gives the effectiveness of the outlay at any position, and below A the slope is high, so it would be uneconomical to move to a lower cost than this. Point A, which is also marked in Fig. 3, is the best compromise for a heat-exchanger design. It is within the limiting range of Reynolds number, and a heat exchanger of the given dimensions may be constructed in a number of parallel units. Point B is marked on Fig. 3 to show the minimum heat-exchanger weight for the same relative economy, but this movement involves only a small saving in weight.

The cost of the heat exchanger plays a part in deciding the final design size. To determine the magnitude of this effect the relative economy variations for heat-exchanger costs 75 per cent. of the previous values have been calculated, and are shown in Fig. 8. The total financial saving on the minimum cost line is marked 75 per cent. outlay in Fig. 10, and the final design point is designated C. Point C is also shown on Fig. 3, from which it may be seen that heat-exchanger manufacturing cost does not greatly influence the design point. This is because the cost is small compared to the overall saving.

CONSULTING ENGINEERS AND THE BRITISH ELECTRICITY AUTHORITY.—The British Electricity Authority desire it to be known that, while their own staff are carrying out the designs for the majority of the new power stations, a proportion of this work is being entrusted, as a matter of policy, to consulting engineers. Long-term agreements have therefore been entered into with Messrs. Merz and McLellan, Messrs. Kennedy and Donkin and Messrs. Ewbank and Partners, which cover the complete engineering and supervision of a number of future stations. Similar agreements for certain stations have also been made with Messrs. Preece, Cardew and Rider and Messrs. Strain and Robertson. Specialist consultants and architects will also be employed on civil engineering work.

HEAT EXCHANGERS FOR GAS TURBINES.

(For Description, see Opposite Page.)

Fig. 7.

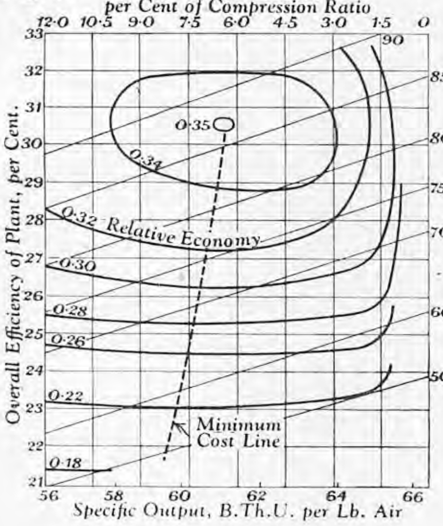


Fig. 8.

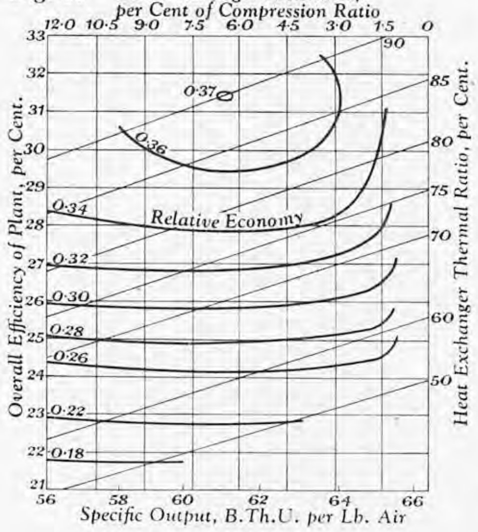


Fig. 9.

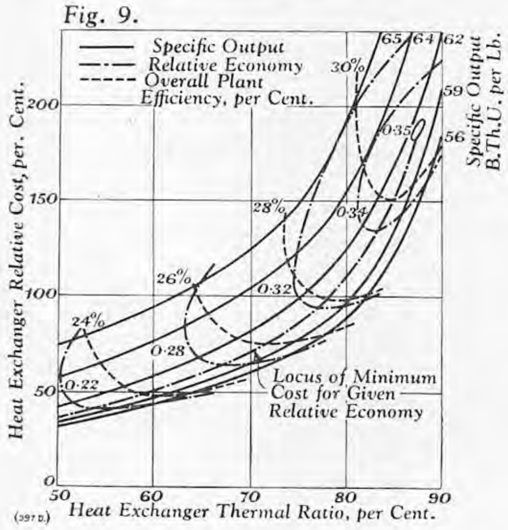


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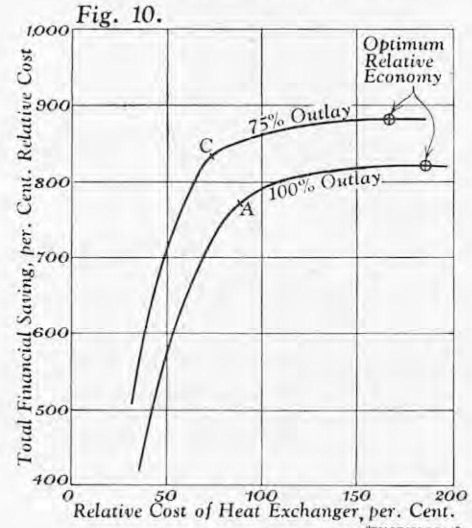
Fig. 10.



THE JOINT ENGINEERING CONFERENCE, LONDON.

(Concluded from page 202.)

WATER supply, mining and electric cables were the three subjects discussed at the Joint Engineering Conference on Thursday, June 14. The papers and discussions are reported below.

WATER SUPPLY TO TOWNS.

Mr. R. C. S. Walters, B.Sc. (Eng.), M.I.C.E., took the chair at the meeting in the Institution of Civil Engineers at which Mr. H. F. Cronin, C.B.E., B.Sc. (Eng.), gave a paper on "Some Considerations on the Water-Supply to Towns, with Special Reference to Consumption and Waste."

To show the progress that had been made in the past 100 years, Mr. Cronin drew attention to the Reports and Proceedings of the Duke of Buccleuch's Royal Commission of 1844 on the "Health of Large Towns." In 1850, it was the practice in many towns and cities to furnish an intermittent supply by turning the water into the service pipes for a few hours during the day and, sometimes, only on certain days of the week. Great controversy raged over the merits and practicability of affording a constant supply, but in due course, Thomas Hawksley, J. F. Bateman, James Simpson, and others, laid the foundation of present-day water-supply systems. The principal systems, the development of which Mr. Cronin outlined, were upland sources, impounding reservoirs, lowland rivers and streams, and underground sources. Developments in the treatment of water, apart from filtration, included chlorination, coagulation, softening, ozone treatment (an attractive process, not much employed in Great Britain), the removal of iron, manganese and other objectionable matter and algal control. Great advances had been made too, in pumping and distribution, and by the introduction of the bacteriological examination of water. Mr. Cronin then gave tabulated information on the water supply and consumption of 20 big cities in the world. From 1900 to 1949 the aggregate population of these cities had grown from 24,703,000 to 43,000,000 persons, i.e., a 74 per cent. increase; the total consumption in the areas of direct supply had risen from 1,539 to 3,640 million gallons a day—an increase of 137 per cent.—and the average consumption per head per day, which was 62 gallons in 1900, was now 85 gallons.

It was very necessary, Mr. Cronin continued, that, consistent with the maintenance of public health, there should be the greatest economy in the supply of water. The metering of domestic supplies had been advocated, but various social and political reasons (which he enumerated) made it unlikely that a method of charging based on metering would be introduced in this country. A serious matter, affecting underground supplies from fissured rocks, was the possibility of pollution due to the spread of building over the countryside. A question to which no satisfactory answer could be given for some time was the effect of land drainage on both overground and underground water. With increasing demands for electricity, upland water was now required for power generation; was it, then, beyond the bounds of possibility that some large combined water and electricity scheme could be arranged, and was it too fantastic to suggest that, in off-peak periods, electrical energy might be used to pump water through the aqueduct and so enable its size and cost to be reduced? Finally, Mr. Cronin referred to water softening (which involved heavy capital expenditure and the disposal of the sludge), and the possible extended use of prestressed-concrete pipes for distribution and of plastic pipes for interior work.

DISCUSSION.

Mr. J. A. Banks, who opened the discussion, remarked on the curious fact that the gross consumption per head in Glasgow was twice what it was in Birmingham—cities of almost the same population; this was true in 1900 and again in 1949, though in the interval the quantity per head had doubled. Regarding the amount that should be assumed for future schemes, he said that an overall allowance of 80 gallons per head per day, say 50 years hence, was already being anticipated, and he inclined to the view that in the course of the next 100 years the demand might rise to 100 gallons. Mr. Cronin had mentioned the possibility of combined water and electricity schemes; he (Mr. Banks) would suggest that high-head storage be reserved for hydro-electric power, and water for primary purposes pumped from lower-level sources in the off-peak period.

Mr. G. Baxter said it was quite true that so far no roll-filled dams had been constructed in the United Kingdom for waterworks purposes; he thought that was largely due to lack of research and of the failure to apply the principles of soil mechanics in civil engineering practice until comparatively recent years. He thought it was permissible to advance the view that chlorination had gone a little too far; indiscriminate chlorination meant that there was no merit or virtue in the water of Thirlmere or Loch Katrine, compared with that of the Thames. Domestic metering, he thought, was impracticable owing to the high capital cost; in any case, only relatively few people were careless in the use of water. A saving of 5 gallons a head had been made by one undertaking by reducing the night pressure from a head of 200 ft. to 100 ft.

Mr. G. G. Marsland said that the standard of water in lowland rivers was steadily deteriorating. An Oxford don to whom he spoke some years ago had made a comment that the land drainage which was now practised had brought about progressive "flashing" on the ground water levels, and he had added that within his own lifetime he had seen a complete change of flora in certain districts. He (Mr. Marsland) did not quite understand the author's advocacy of a national testing station for fittings, but thought it would be an excellent idea if only British Standard fittings were permitted.

Mr. C. W. Cassé referred to Indian and African experience and said that water supplies abroad had been greatly handicapped by the tendency to follow the principles of British legislation, making unrestricted supplies available on the basis of rateable value of property. Supplies were insufficient in most tropical countries and had therefore to be restricted; Africans paid one cent for four gallons from a public water kiosk. In this country, metering would have to be applied in the future; otherwise, where was the water coming from, where were the schemes to provide for increasing consumption, and where was the money coming from?

Mr. F. Grundy suggested that the study of hydrology required developing in this country so as to link up the dry-weather flow of rivers, when the demand was acute, with the availability of ground water.

Mr. E. G. Kimsey asked the author whether he had considered the supply of non-drinking water for fire-fighting, garden-watering and street cleaning.

Mr. H. R. Lupton called for greater consideration, on the part of the electricity authority, for the special requirements of the water authorities, and also for the encouragement of research for the common good of water authorities.

Mr. W. M. Lloyd Roberts remarked that during the past few years there had been two factors which had kept down water consumption in London, namely, the weather and the shortage of coal, etc., for domestic water heating.

Mr. Cronin, replying to the discussion, said that Dublin had a combined water and electricity scheme. He also referred to investigations that had been undertaken in connection with additional water supplies for London; one of the advantages of the idea of putting a dam across the Enborne valley, above Newbury, was that the water could be let into the River Kennet, thereby avoiding pipelines to London; but the Thames Conservancy advisers had opposed the scheme.

ENGINEERING PROGRESS IN COAL MINES.

A session of the conference dealing with "Gas Industry Plant, Mining and Steelworks Plant," was held at the Institution of Mechanical Engineers on Thursday morning, June 14, Mr. A. C. Hartley, C.B.E., B.Sc.(Eng.), M.I.C.E., M.I.Mech.E., occupying the chair. The paper presented dealt with "A Century of Engineering Progress in British Coal Mines (1851-1951)," and was by Mr. B. L. Metcalfe, B.Sc. (Eng.), M.I.Mech.E., M.I.E.E., who stated that by 1850 the problems of pumping in the mines had been overcome by the early inventions of Savery, Newcomen and Watt. Steam power was available on a general scale. The introduction of the use of coal for metal smelting, in the latter half of the eighteenth century, had brought down the price of iron and had given an enormous impetus to the application of machinery built to the designs of these early pioneers and others, such as Trevithick and Smeaton. The most serious problem facing the engineer was ventilation, and many accidents occurred owing to the explosion of firedamp, particularly where only one shaft was used. After the disaster at New Hartley Colliery in 1862, when 201 lives had been lost, amended legislation had made two shafts obligatory. In subsequent years, great improvements were made in fan installations, methods of coal winning, winding engineering, coal-face lighting and coal-cutting machinery, and for a long time past methods of improving the safety of men underground had been under constant revision.

Emphasis in the future would be on the improvement in the output per man-shift on the one hand and in the safety of the men on the other, and these two improvements must be reconciled and progress must run on parallel lines. In considering some of the trends in development, the most noticeable change would be the improvement in surface layout. Pit-head baths, washeries, colliery offices, winder houses, substations, workshops, ambulance rooms, lamp rooms and covered walking ways between the lamp room and headgear would all be designed to harmonise with each other with a functional unity seldom achieved in the past. At existing collieries which had to be modernised and reconstructed to increase output, it would not be possible to achieve the same pleasing result, but a great deal of attention would be paid to the surface layout to maintain a smooth and efficient flow of men and material. In introducing new machinery, the impact on the men must be carefully studied. The difference in a man's attitude—albeit subconscious—towards a machine which determined the rate at which he must work was vitally important and understandable.

DISCUSSION.

The discussion was opened by the reading of a written contribution from Sir Andrew Bryan, by the chairman, Mr. A. C. Hartley. Sir Andrew wrote that some measure of the success of a century of progress was reflected in the accident figures. During the period 1851-1951 the fatal-accident rate had fallen from 4 to 0·7 per 1,000 persons employed, despite the fact that the physical difficulties had progressively increased on account of the ever-growing need of exploiting thinner and deeper seams with working faces at much greater distances from the shafts. The development of coal-getting machines of a type which reduced dust formation to a minimum was an urgent necessity and a start had been made with machines of the "plough" type, which wedged or levered off the coal rather than cut it.

Mr. Harold Watson-Jones said that whether it was due to conservatism on the part of those controlling the industry in the past, or to lack of progressive ideas in engineering development, or, perhaps, to the age of the industry itself, the result had been that much machinery installed 100 years ago was still existing and, in some cases, continued to give satisfactory service. Development in coal-face equipment, however, particularly for power loading and stowage, was proceeding rapidly. The task of the craftsman and technician, in the past, had been largely one of breakdown repair rather than planned maintenance. A more scientific approach to the development, periodic inspection and planned maintenance of all coal-producing machinery, however, would ensure that defects would be detected before possible breakdown, and the continuity of coal production thereby assured.

Mr. I. G. E. Leek said that one interesting point concerning the application of machinery to coal faces was the introduction of the coal cutter with curved jib, as illustrated in the paper. With the very large increase in mechanisation which was taking place at collieries, both underground and on the surface, it had become necessary to attract to the mining industry the best and most highly qualified mechanical and electrical engineers. The next speaker, Mr. A. E. Crook, stated that slowly, as the years passed, it had been realised that one of the most, if not the most, important problems in industry was the safe and efficient handling of materials and that, with proper mechanical equipment, a workman could move a load of 100 tons as easily as a load of one ton.

Mr. G. W. Alexander said that this country, without doubt, had always been in the lead in the design and manufacture of hoisting machinery, due, in part, to the fact that power-driven vertical hoists had been in general use in the coal-mining industry many years before their adoption in other parts of the world. One point which had arisen during the last few years and should be carefully watched was the tendency towards over-elaboration in the control of hoisting machinery. The main objective should be to maintain the wheels turning, not to make them turn round a little faster with the risk of probable stoppages. The next speaker, Mr. A. E. McClelland put in a plea for the creation of a National Mining Museum which might be housed on the South Bank. Such a museum, he said, could be a permanent, live and instructive exhibition of modern mining machinery and methods, of new ideas and trends, and of safety measures and devices.

Mr. D. R. Love said that the author had mentioned 11-kV winders. These were still a new requirement and were due mainly to the National Coal Board establishing a standard of 11 kV as a system of primary distribution in the collieries. They possessed obvious advantages. The next speaker, Mr. D. Frost, said that mention had been made of the use of electrically-controlled locomotives underground. In the South African gold mines there was no need to worry about flame-proofing; electric trolleys and locomotives were used extensively and many were over 10 years old. Mr. J. Vaughan Harries, who spoke next, said that the person who had dominated mining engineering for the first half-century under review had been the mechanical engineer, and, until quite recently, no instance could be recalled in which the services of a recognised civil engineer had been engaged in one particular area. If a civil engineer had been employed, collieries now 50 or 60 years old would have been less unsightly, and, possibly, underground structures would have been built to more generous dimensions and be of a more permanent character. Looking ahead, it should be emphasised that no other industry lent itself to larger measures of standardisation than did the coal industry and standardisation lowered costs and speeded the completion of schemes.

Mr. F. C. Swallow stated that, during the last five or six years of the period under review, the industry had profited from public attention more than in the whole of the previous 94 years. Another point was the growing emphasis placed on the importance of human beings and on questions of dust suppression, comfort and safety, rather than merely on mechanical appliances. Mr. T. H. Petch, who spoke next, said that the post-war years had seen considerable application of the ideas of closed-loop servo systems to electric winding engines. In particular, that type of control would be put into service in this country at about the end of the present year for controlling dynamic braking on alternating-current winders and haulages. It had already been applied to the control of a Ward-Leonard winder and it was also used for other applications, such as the control of power factor on synchronous motors driving generator sets. Mr. C. L. Layland, who closed the discussion, said that the deep mines on the Kolar Gold Field, South India, were ventilated by means of air-conditioning plants, installed on the surface, which delivered saturated air into the mines at a temperature of 40 deg. F. Under the prevailing climatic conditions on that field, the need for cool air became imperative at a depth of 7,000 ft. The improved performance of the miners after its provision had been astonishing.

Mr. B. L. Metcalfe, in reply, said that in British mines some kind of air conditioning would be used before the end of the century, if not sooner, on the new coalfields which were being exploited in the Manchester district and in North Staffordshire. It was under consideration by the National Coal Board to strengthen their civil-engineering staff, particularly in view of the reconstruction undertakings to which they were committed. The question of 11-kV winders had been mentioned, and, with the increasing size of the motors, it would be an advantage to standardise on 11 kV. A number of problems, such as the suppression of dust, needed to be tackled energetically. The value of an exhibition on the South Bank would be doubtful; it should perhaps be nearer the coalfields.

GAS-PRESSURE CABLES.

"The Development and Use of Gas-Pressure Cables for High-Voltage Systems in Great Britain" was the title of a paper presented by Messrs. S. E. Goodall and D. B. Irving at a meeting at the Institution of Electrical Engineers on Thursday, June 14. Mr. J. Eccles was in the chair. The first experimental installation using high gas pressure to suppress ionisation, the authors said, passed satisfactory tests in November, 1931; and the first commercial installation in the world was completed in the following year between Hackney and Walthamstow, a distance of $2\frac{1}{2}$ miles. It operated at 66 kV and had given satisfactory service even under severe bombing conditions. Details of the construction of compression gas-filled and mass-impregnated gas-pressure cables were given; and it was pointed out that there were two basic designs of sealing-end in use, one in which porcelain resisted the gas pressure and the other which incorporated a synthetic resin bonded paper or a porcelain internal pressure retaining tube. One of the problems was to ensure that the joint between the sealing end and the cable was gas-tight and in the latest designs this had been solved by the use of flanged joints.

At the present time some 46 miles of gas pressure cable, working at 132 kV, were in use in Great Britain, as well as 93·5 miles at 66 kV and 58·5 miles at 33 kV. In addition, 28 miles for operation at 132 kV, 2·5 miles at 66 kV and 20 miles at 33 kV were being installed. These figures showed that, while the proportion of gas cable was still relatively small, considerable progress had been made. Between 1932 and 1939 only two cables were installed. This was due, in some measure, to objections to the steel pipe, objections which had been overcome by the use of better anti-corrosion servings. A standard specification was adopted by the Central Electricity Board towards the end of the 1939-45 war and was now being amended in certain minor particulars. Closer collaboration on a national basis and between the principal cable manufacturers was now possible and there was every reason to suppose this would be extended into the gas-pressure cable range. While the highest transmission voltage at present in service in Great Britain was 132 kV, a certain amount of gas-pressure cable for higher voltages had been supplied for export and at the present time designs suitable for use on the 275-kV grid were being considered.

DISCUSSION.

Mr. D. P. Sayers said that although the object of the gas in both the main types of cable was to suppress ionisation in the voids, the mechanism of the process was different; and it might be thought that a cable in which means were taken to ensure that the gas more or less completely filled the dielectric would be the more effective. The main difference between the pre-impregnated and mass-impregnated types of cable was that there was little free compound in the former and on hilly routes there would therefore be little or no migration from higher to lower levels; and the characteristics would remain substantially constant. He was not sure whether experience had yet shown what happened with regard to migration in a mass-impregnated cable. He did not think the stage had been reached where it would be wise or safe to standardise rigidly on gas-pressure cables, but he would like to plead for more standardisation of accessories and fittings. At the same time there should be some scope for experimentation. Otherwise there was a risk that standardisation would become stagnation. Solid cables were quite satisfactory at 33 kV, and the reason for choosing a gas-pressure cable for that voltage was in order to secure the maximum possible rating per circuit. There had been no case of a gas-pressure cable failing owing to ionisation of the dielectric, but there had been considerable trouble from gas leaks, and in one or two cases serious trouble with sheath corrosion. If the armouring weakened, the lead sheathing might burst under the internal gas pressure. To use a double lead sheath would be expensive at the present time, and for that reason a combination of aluminium sheathing and gas pressure offered a valuable opportunity for economy.

Mr. E. L. Davey said that E. A. Watson's work in 1909 was the basis of all gas-pressure cables and it had been left to the British manufacturers to produce practical designs therefrom, with the encouragement of the Central Electricity Board. During the period of development, knowledge and new techniques had been acquired and had been applied to the improvement of more ordinary products. The introduction of the gas-pressure cables had, in particular, allowed much higher stresses and temperatures to be used, and in the majority of these cables the risk of ionisation had been eliminated up to about twice the working voltage. At 275 kV the dielectric losses were important, not only from the economic point of view but because they had a pronounced effect on the rating of the cable. The standardisation of accessories and joints was both possible and desirable; and at the lower voltages cables, too, could be standardised. At the higher voltages standardisation of the cable should not be carried too far.

Dr. R. C. Williams was disappointed that aluminium sheathing had not been mentioned in the paper. He agreed that they wanted to standardise as far as they could, but it should not be pressed too far at the present time. As knowledge increased, designs would become more precise and the "factor of safety" would be converted into some form of tolerance. The manufacturer should not be discouraged by the fact that there was a small demand for the higher voltage cables in this country; there was plenty of scope abroad.

Mr. P. C. Barnes asked the authors to give their views on the relative merits of the two types of reinforcement used on the mass-impregnated gas-pressure cable and to describe the tests made on the coverings to assess their service life. He would also like to know why it was necessary to reinforce the lead sheath of the pipe line compression cable, which was subjected to external gas pressure.

Mr. G. J. Sutton said that a dielectric consisting only of oil and paper had a much higher electric breakdown strength than where gas was introduced. That was one of the greatest weaknesses. More co-operation was required from the manufacturers of raw materials, as well as from mechanical and electrical engineers. At 275 kV it was necessary to use steel pipe, which could easily be bent and welded and could be employed with all types of design. Corrosion problems no longer existed. Unless care was taken there would be more leaks on the automatic gas system than from the whole cable.

Mr. S. E. Goodall, in reply, said that there had been no example of migration of compound in the pre-impregnated type of cable. They had not yet had sufficient experience to say that any of the types of cable could be dispensed with in the interests of standardisation. They were all interested in the use of aluminium, but corrosion difficulties had not yet been overcome. He agreed that standardisation was possible at the lower voltages, but they should go carefully at 132 kV in order not to stifle development.

Mr. D. B. Irving, who also replied, said that no installation which had passed the impulse tests had given any trouble in service. The standardisation of 33-kV joints and accessories was under active consideration.

Three technical sessions were held on the morning of the concluding day of the Conference—Friday, June 15—when papers on sewerage and sewage disposal, mechanical engineering in the iron and steel industry, and progress in electric lighting, were presented and discussed.

Sewerage and Sewage Disposal.

At the Institution of Civil Engineers, with Mr. H. Cliffe, B.Sc. (Eng.), M.I.C.E., in the chair, Mr. David M. Watson, B.Sc., M.I.C.E., presented a paper on "Sewerage and Sewage Disposal." Reviewing historical developments, he said that the modern centrifugal pump, as compared with the old reciprocating pump, was cheaper, required less attendance, could be used for relatively small flows of sewage and could be operated automatically. The utilisation of the fertilising properties in sewage, as well as the desire to clarify and purify the liquid so that pollution of rivers would not be caused, had apparently engaged the attention of many men from the earliest days of water-carriage of sewage, probably at the time of the early Public Health Acts of 1848 and 1858. One of the milestones in the history of sewage purification had been the appointment, in 1898, of the Royal Commission on Sewage Disposal, which issued nine reports over a period of 17 years; these reports, though old, still guided and influenced modern methods and standards.

During the 1920's, it was realised that the merging of several drainage districts of an urbanised character could often be economical, since they could be dealt with as one co-ordinated system with one large sewage works. Ten years' experience of the Mogden sewage works, which replaced 28 sewage works in West Middlesex, had shown that the high standard of results achieved had warranted the large capital expenditure. The establishment of the Water Pollution Research Laboratory had laid an excellent foundation for reducing the harm done to rivers by discharges from trade premises, and the educational value of the laboratory's work was an important factor in the intelligent study of river pollution and sewage and trade-wastes purification. The proportion of trade wastes of a "difficult" nature to domestic sewage varied greatly, and a knowledge of the best means of treating wastes which predominated was invaluable. Filters appeared to have given better service than the activated-sludge process where troublesome wastes occurred.

Consideration of the possible trend of development in the future showed that the scope was impressive. Would the greatest changes take place as a result of economic considerations or be brought about by the need to treat rivers better than they were being treated at present? In some cases the latter was a real need, and in all cases the economic aspect of operating sewage-purification plant as cheaply as possible was a matter of increasing importance. Great advances towards complete mechanisation had been made and would continue. Even if it had not already arisen, there would arise sooner or later a general desire to improve the quality of sewage effluents to a standard higher than the generally accepted normal standard of the Royal Commission; to eliminate nuisance by smell; and to make use of all sludge. The conflicting demands of increased abstractions of water from British rivers and the larger pollution loads on rivers could only be reconciled by higher standards of sewage-works effluents, trade-waste discharged, and storm-water overflows, and a greater pride in the rivers of this country on the part of all riverside dwellers.

Mr. Watson then described the work undertaken at Luton to ensure that the effluent discharged into the River Lee, which at that point has usually no flow, is consistently better than the normal standard. Dealing with sewerage problems generally, he said, "What is required and what can be achieved is unified consideration of all the problems in a watershed, intakes, and outfalls, and ability of the river to yield water for domestic use, without too seriously impairing its ability to perform its complementary duty of draining the watershed to the sea and without too great a sacrifice of amenity. A proper balance between these two primary duties of a river may not always be easily attainable, but it must be done if national life is to have the best conditions to thrive in this crowded island."

Discussion.

Mr. E. A. Calvert, who opened the discussion, said that it seemed to him almost a tragedy that the work of the Royal Commission came to a conclusion during the 1914-18 war. Regarding sludge treatment, for many years the prevailing method of disposing of sludge had been on sludge-drying beds, and to-day they had a development of that in the introduction of sludge digestion. At the Colne Valley sewage works they also had works under construction for drying and combustion. The great difficulty in this country was the cost of chemicals for sludge conditioning. If the chemicals were cheaper in relation to general prices, as they were in America, he believed that there would be a big development in other methods of sludge treatment.

Mr. Hal Gutteridge referred to the great development which was now taking place in all countries in composting sewage screenings or sewage sludge with town's refuse to produce a first-class organic manure. It would achieve the useful purpose of returning to the soil that which had been taken from the soil. In composting, sewage and town's refuse were complementary to each other; the former providing mainly the bacterial element, and the latter the structural side of the organic manure.

Mr. David Currie said he believed that a great deal of the pollution of the streams and water courses, particularly in larger cities and towns, came from storm-water overflows. Undoubtedly, most of the storm overflow chambers in the country at the present time were obsolete, and he felt that this would be a very useful subject for research in order to achieve the right type.

Mr. R. E. D. Bain, referring to his experience in Northern Ireland, said he wished to make a plea that anyone who was connected with the designing of a small sewage works should not neglect the instructions to be issued to the caretaker. Moreover, he suggested that, when the engineer was designing his works, he should insert a clause in the contract documents in respect of small works to the effect that the contractor should be responsible for the maintenance of those works for the first six months. The caretaker would be selected by the contractor and he should stay on after the termination of the contract.

Mr. Stanley Brassey-Edwards said that if they were to clean up the rivers of this country they must start at the beginning and not allow people to put factories in certain places and then wake up to find that they had a trade effluent to get rid of which might cost a small fortune at a sewage works or if the firm had to put down a plant of its own. In his opinion, town-planners did not give sufficient consideration to drainage matters when they were siting new towns and new factories.

Mr. M. R. Atkins remarked that joint schemes for rural areas were very few at present and they were very expensive. Going about the country, one realised the local objections to small sewage treatment work. It had occurred to him that in such cases a tank installation might be located near the villages and several tank effluents from different small works might be piped under hydraulic gradient, by pumping, if necessary, to one central filtering installation where the process could be continued under far better supervision than could be obtained at the smaller works, and at some point where the nuisance would be minimised.

Mr. J. A. Banks described conditions on the Clyde and the Forth, and said that, in the latter, there was nothing to prevent the discharge of untreated sewage, and that was in fact what took place right from Stirling downstream. Schemes were being prepared, however, by the authorities in both of the areas to which he had referred. It was of fundamental importance, even in the case of the smallest works, that there should be attendance, and he would go so far as to say that, where grants were given, a condition should be made that the grant would not be given unless that superintendence was guaranteed. That pointed strongly to the advantage of combining small works in an area, in so far as it was reasonably practicable to do so, even if it entailed some extra expense.

Mr. A. L. Fielding spoke of conditions in Australia, with particular reference to New South Wales. First, however, he referred to certain special cases where underground works and works in excavated cliffs had been undertaken. Many of those present had, no doubt, visited the wonderful job of work which had been done in Stockholm. That had been accomplished by means of excavation in solid granite. He also wished to refer to works at Bondi, Sydney, in the case of which the excavations were carried out in Hawkesbury sandstone, which had presented special problems because the machinery and equipment had to be designed and fitted into the span of natural support of that material, as it was not considered economic to line the excavation or to support it in any way if it could be accomplished by other methods. At Coudramunda the effluent was being discharged by pumping it into a field, and poplar trees were growing in that field for the purpose of absorbing the effluent quickly. The effluent was encouraging the rapid growth of the trees, which were placed in line with the prevailing winds, towards the town a few miles away, and the leaves acted as a deodorant.

Mr. C. W. Cassé recalled experience in India and Africa. Trade wastes did not concern them very much in India, he said; the chief trouble in that respect arose from the sugar factories. It was often thought that labour was cheap in the tropics, but that was becoming a fallacy. Labour was dear because so many people were required there to do the work which one man would do in this country. It seemed to him that the original systems of sewers in many of the large towns in India were not designed to suit the climatic conditions there, and it appeared that the solution was an entirely separate system and plenty of small pumping stations. More recently, schemes had been worked out on that basis. Tropical storms were usually more severe in effect owing to the higher rainfall intensity and it was quite uneconomical to provide against all possible flooding.

Mr. K. A. Pope said that the idea of composting could not really be measured in monetary values, because the health and fertility of the land which were obtained by the use of pure manure as distinct from chemical manure was, in his opinion, rather unpredictable.

Mr. Watson, replying to the discussion, said that in his opinion there was an enormous amount of work to be done on composting. He was aware that the London County Council and various other authorities had done a lot about it, but he believed that there was still a very great deal to be done. He agreed with Mr. Currie that in many cases storm-water overflows could be improved, but he would go a little further than that; he believed that they could do quite a lot by examining and merely bringing up to what was to-day's practice a great many of the storm-water overflows which were behaving improperly. He wondered if Mr. Bain had considered the practicability of adopting a centralised system of servicing rural sewage works, with men and equipment who went round the small rural sewage works day by day and helped the one man who was in charge. Mr. Atkins had raised a difficult question about the localised tanks for arresting sewage in rural districts and centralised sewage works for filtration. He would be creating sludge problems wherever he had tanks and he would have to spend money on labour at those places; and one of the things that he had to watch was costs.

Mechanical Engineering in the Iron and Steel Industry.

At a session on "Gas Industry Plant, Mining and Steelworks Plant" held on the morning of Friday, June 15, at the Institution of Mechanical Engineers, with Mr. A. Roebuck, M.I.Mech.E., in the chair, a paper by Mr. W. F. Cartwright on "Mechanical Engineering in the Iron and Steel Industry" was presented. In this, the author stated that the rapid development of the iron and steel industry in the last 50 years had had two aspects, namely, an improvement in quality which had been mainly due to the efforts of metallurgists, and an increase in quantity, which had been largely facilitated by the application of mechanical engineering principles. Mechanical engineering had brought about a large reduction in the labour required to produce a ton of steel. Very little mechanical engineering had been employed even in the manufacture of pig-iron until the development of an effective steam engine by James Watt in 1775. At the end of last century, there was at Dowlais a blower operating at a steam pressure of 100 lb. per square inch with steam cylinders 36 in. by 64 in. and blowing cylinders of 88 in. diameter. In 1900, the charging of blast furnaces had become a limiting factor in the speed of production. The first step had been the use of some form of lift for the barrows, and this had been followed by the principle of the skip hoist, a method still widely used.

The handling of raw materials to and from the furnace had been responsible for many major engineering problems. The unloading of ore ships, the dumping of iron-ore wagons, and the handling of molten iron and molten slag had resulted in many ingenious developments. The Hulett ore unloader was a striking example; it was an enormous piece of mechanical-engineering equipment only suitable for the special ore ships of the Great Lakes. There were 66 of these machines at work throughout the world, carrying up to 20 tons of ore in a grab. American railways had progressed to the point at which wagons carrying more than 100 tons of ore were used in conjunction with wagon tipplers. The capacity of iron ladles had grown to 200 tons, with an axle load of over 40 tons.

Looking to the future, the pitch of efficiency in rolling mills had already reached such a high level that there seemed but little room for improvement except in detail, although, in the wide-strip business, surely a continuous cold mill would soon be constructed in which the coils were changed without stopping the mill. Several continuous annealing furnaces had been built for the tin-plate industry, and it seemed highly likely that this principle would be extended eventually to sheets. The iron and steel engineers of to-day were more fully aware of what was going on in other industries than they had been in the past, and they did not hesitate to adapt techniques from these to their own industry, so that it could be expected that iron and steel works of the future would be more refined than in the past and that they would make use of every possible development in mechanical engineering, such as special hydraulic applications, higher steam pressures, and new link motions and gear designs.

Discussion.

Mr. W. A. Johnson, who opened the discussion, said that a fully-integrated iron and steel works in which the only fuel supply was that to the coke ovens tended to become an economic necessity. Much, however, could be done in improving the overall heat balance for non-integrated steelworks. If full use were made of waste-heat steam from open-hearth and reheating furnaces such works could be largely self-sufficient in respect of electricity and steam. For instance, waste-heat steam production from open-hearth furnaces and soaking pits could amount to about 1,500 lb. per ingot ton. Of that quantity about 400 lb. per ton were required as steam for atomisation, oil heating, the gas producer plant and other applications. The overall electric power consumption of such a works was approximately 110 kWh per ingot ton, and a substantial proportion of that power could be generated from surplus waste heat.

Mr. M. A. Fiennes stated that the author had referred to the method of driving roller tables in a rolling mill and had said that, generally speaking, the practice had become, at the heavier end of the mill, to concentrate on bevel gears and at the lighter end of the mill to have motor-driven rollers. The conclusion had been that the reason for that was to keep the electrical equipment away from the heat as far as possible. That, however, was not the principal reason. The main reason was that, at the heavier end of the mill, the material was shorter and was therefore carried on fewer rollers. In order to move it and reverse it a very much larger motor was required for individual drive at that stage. At the finishing end of the mill, where the stock was generally greater in length, it was carried, on a much larger number of rollers and could, therefore, be moved by individual motor drive of much smaller power. The author had suggested that weight reduction was one of the problems which must be tackled in order to reduce cost; he entirely agreed. One of the most potent factors in the reduction of weight and cost was the greatly-extended use of fabricated welded components as against steel castings and this was likely to continue.

Mr. L. F. Case said that in Australia a system of production bonuses for operating staff in the rolling mills had been established when the equipment used had been inadequate to produce a sufficient quantity of steel unless this incentive payment was made. At present there had been an improvement in the equipment, but the men were still being paid production bonuses. A good deal of industrial trouble had arisen because the leading hand, the mill foreman, who, ten years previously, had been receiving a wage far above that of the ordinary mill hand, was now often earning a salary below that of the mill operative who received the production bonus on the very high output obtained with modern equipment.

Mr. F. B. George said that, at present, one of the great difficulties was that a long time elapsed before a plant which had been planned was completed and working, and there was always the fear that by the time the plant was on the ground it would be already out of date. The change that had taken place in recent years in the industry, which, previously, had been a conglomeration of ill-assorted and poorly-integrated units, had been wholly to the good. There was not the least doubt that the industry had become conscious of the need for proper plant and adequate maintenance, the suitable control and location of spares and the importance of lubrication.

Mr. T. Jenkins said that the American Iron and Steel Institute had found, as the result of investigation, that for every ton of steel produced some 60 or 70 tons of materials had to be handled. That was to say that a works producing 15,000 tons of steel a week (an ordinary figure nowadays) had to handle one million tons of materials. Modern rolling equipment, comparatively speaking, was very reliable, and if it were manned by an efficient maintenance crew it would give good results. In one particular steelworks, there had been an output of 667,000 tons in a year in the cogging mill and about 475,000 tons in the continuous mill. The total stoppages due to mechanical breakdowns had been under 50 hours in duration.

Mr. C. H. Williams stated that it was still common for furnace designers to install high-grade instruments and find that the works concerned had insufficient personnel having the requisite skill, or the time, to service these instruments. Although the instruments generally were most ingenious and highly efficient in many respects, it was to be hoped that they would be simplified and made more robust.

Mr. W. F. Cartwright, in the course of his reply to the discussion, said that while Mr. Fiennes might be right in some respects concerning individual electric roller drive on rolling mills, several blooming mills had been built in which individual roller drives had been used right up at the front. Whenever he had visited these places, one or other of the rollers was "dead" on account of electric trouble due to the insulation not having been able to stand up to the conditions imposed. When writing his paper, he had put to a rolling-mill manufacturer the simple question: If there were a real saving in weight in mill machinery, would it effect a considerable saving in the capital cost? The reply had been that the saving of weight would not be a big factor in cutting down costs but that a real saving would be made by cutting out complication. With proper incentive payments, there was sometimes double and even treble the output from a machine compared with the production when no incentive payments were given. The question of the time which elapsed between the planning and the operation of a plant had been mentioned. This was certainly a distressing matter. In the United States, a strip mill had been built in 10 months from the day of cutting the first sod to the day when the mill was running. Furthermore, the site had been on marshy ground which had been flooded twice during the construction of the mill. That kind of achievement had never been matched in this country.

PROGRESS IN ELECTRIC LIGHTING.

A meeting was held at the Institution of Electrical Engineers on Friday, June 15, with Mr. A. N. Irens in the chair, at which a paper on "Progress in Electric Lighting" was read by Mr. R. O. Ackerley. Each major step in lamp development, said the author, had given the lighting engineer fresh scope, but had, at the same time, revealed new problems in the sphere of luminous reactions for the research worker to solve. He illustrated this argument by showing the influence of each new lamp on lighting practice and discussed the interior lighting of to-day with special reference to the problems of brightness, balance, colour rendering and desirable values of illumination. Modern methods of street and airport lighting were also briefly reviewed.

As regards the future, in the sphere of lamp development it was difficult to visualise any discovery which would revolutionise lighting practice as the gas filled and fluorescent lamps had done. Any development in the field of specialised projection apparatus was likely to be towards the improvement of the colour rendering of mercury lamps and in reducing their cost. Higher ratings might well appear, thus increasing the value of these lamps in street lighting and industry. For general service lighting, low-brightness large-area fluorescent sources gave satisfactory general lighting of an area and high-brightness small-area tungsten sources the directional and concentrated lighting of a feature. It did not seem possible that fluorescent sources of sufficiently small area and high brightness would be produced to make them satisfactory for the latter purpose, although their efficiencies would probably be improved, relative costs decline and control circuits be simplified. Plastics had the strength to replace metals and the light-transmission characteristics to replace glass for fittings. They were light in weight and could be fabricated inexpensively, besides being non-conductors and chemically inert. They might possibly, therefore, bring about almost a revolution in design technique for fluorescent lamps.

The first task of the future in the field of interior lighting was to make high-illumination installations more comfortable to work in. The second great problem related to colour rendering, which involved not only the colour appearance of certain objects, but the whole question of interior decoration. It would not be sufficient just to give enough light on the visual task and to make the balance of brightness comfortable. Correct modelling and emphasis, which involved the question of flow of light at all points in the interior, must be contrived. In this task, lighting, decoration colour and form were all interrelated and the flow of light must be such as to create a sense of coherence between all parts of the scene.

DISCUSSION.

In opening the discussion, Mr. L. J. Davies said that the curiosity stressed by the author had enabled us to take fluorescent lamps up to the coal face and to see how they could be used for street lighting. It had also resulted in employing the mercury-vapour lamp with a little cadmium in it for making colour films. Certainly, manufacturers had produced lamps with a range of brightness, shape, colour and reliability that would have been unthought of a few decades ago; and the consumer seemed to be satisfied. While illumination engineers had displayed great ability in using light sources up to a certain point, they did not seem to be able to fit them into the psychological and subjective picture, which occupied the strange country between the acceptable and the comfortable.

Dr. J. W. T. Walsh thought it was rash for the author to say that a fundamental basis for general illumination value appropriate for different tasks had now been reached. Although this might be true to-day it might cease to be true when social conditions changed. The whole matter depended upon the relative costs of light and labour; and the author must, therefore, not be surprised if, in ten years' time, the present values, which some people already found high, were amended. As regards colour, although the difference between tungsten light and daylight was greater than between fluorescent light and daylight, the difference was continuous throughout the spectrum. With the fluorescent light, on the other hand, it was irregular, and therefore very trying to the eye.

Dr. R. G. Hopkinson said it was now becoming common to think of lighting in terms of the whole environment, so that the engineer had to plan not only for the working plane, but for all planes in the field of view. He also had to think of the brightness of the field of view. An important recent development had been the increase in the interest of the user in lighting problems. A joint team of architects and engineers was working on the problems of lighting design at the Building Research Station and was trying to determine the physical factors giving such things as sparkle, brilliance and gloom which could not be measured directly, and thus to define them in terms of precise engineering design.

Mr. J. M. Waldram criticised the design of lighting fittings, the first requirement of which was that they should be decorative. For this reason, it was the practice to hang them in the middle of the interior, although there were then limits to what could be done with light distribution. In this position, moreover, the fitting interfered with the architecture, and, more important, with the flow of light, so that there was a galaxy of shadows. More study should therefore be devoted to the surfaces that ought to be lighted, how they should be lighted and where the light should fall if they were to be properly revealed. To achieve the desired end, earlier co-operation between the engineer and the architect than was customary at present was essential.

Mr. E. S. Calvert thought that what was wanted in a room was horizontal and vertical "streamers" with plenty of light and shade paths. Sparkle was necessary in order that visual judgments could be made at short range. It was important in airport lighting to enable the pilot to locate a runway with a smooth glazed surface and no texture.

Mr. H. C. Weston was not sure that the author had been rash in saying that the Illuminating Engineering Society's code was approaching finality. He did not think that the maximum values of the illumination range would need to be much increased.

TRANSMISSION FEEDERS AT HOLME MOSS TELEVISION STATION.

THE two stand-by feeders which have been constructed for the Holme Moss television station by the Telegraph Construction and Maintenance Company Limited, Greenwich, London, S.E.1, are designed to carry loads up to 20 kW at a frequency of about 50 megacycles. The inner conductor of these cables consists of a solid copper wire of rather more than ½ in. in diameter and the insulation of a series of interlocking semi-cylindrical thimbles of moulded Telcothene (polythene). These thimbles form a smooth cylindrical surface on the outside of the core and provide support for the conductor at frequent intervals. The outer conductor is a seamless extruded tube of high conductivity aluminium, which was applied to the core by the Johnson and Phillips process. It acts both as a return conductor and as a screen at all radio frequencies, besides serving as a watertight sheath for protecting the semi air-spaced insulation. It is covered with servings of bituminised paper and hessian as a protection against corrosion. Owing to its robustness and light weight the cable can be installed on masts without the usual steel armour.

Tests on the cables, which are similar to those already installed at Alexandra Palace and Sutton Coldfield, show that the propagation characteristics are electrically uniform, a point which is of importance in broadband transmission such as television. It was also found from tests on a 280-yard length of cable that, with a correctly terminated load, the voltage standing-wave ratio would not be worse than 0·98 over a 10-megacycle band centred on 60 megacycles.

The Alexandra Palace stand-by feeder incorporates a joint which was designed by the British Ermeto Corporation, Maidenhead, in collaboration with the Telegraph Construction and Maintenance Company. This simulates the cable construction very closely and is therefore substantially free from reflections. A mechanical joint to the outer sheath is used. The pressure-tight ceramic terminations were developed in collaboration with K.L.G. Limited, Putney.

PRE STRESSED-CONCRETE TANKS AT HARTLEPOOL.

FIVE tanks recently completed at the Palliser Works of the British Periclase Company, for the Ministry of Supply, two of them with a capacity of 2,000,000 gallons each, are stated to be the first to be constructed in this country in prestressed concrete. The Magnel-Blaton system of prestressing was employed. The tanks are used in the manufacture of seawater magnesia, which is later processed into magnesium metal and into dead burnt magnesite for refractories for the steel industry, seawater and dolomite being the principal raw materials. Two are "half-tide" storage tanks, each 106 ft. in diameter and 41 ft. deep; one is a sand-trap tank 50 ft. in diameter and 46 ft. 6 in. deep; and the other two, both reaction tanks, are 30 ft. in diameter and 36 ft. deep. The manufacturing process is continuous. First, the seawater is pumped into the sand-trap tank and is passed over a circular weir into an elevated annular launder, and then on through flumes into the half-tide storage tanks, which normally are filled and emptied twice a day, since pumping of seawater can only take place between full and half-tide. Mixed with dolime, the seawater enters first the Dorr hydrotreators, where the calcium compounds are removed, and then passes into reaction and settling tanks where the magnesium hydroxide is collected, ready for filtering and calcining in rotary kilns.

Because these were the first prestressed-concrete tanks to be built in this country, it was considered desirable to make the walls thicker than was actually required from considerations of working stresses in the concrete, in order to permit the concrete to be easily and properly placed and compacted; thus the stresses in the walls are much lower than are generally used in prestressed-concrete design. Experience has since shown, however, that thinner walls can be satisfactorily concreted, and thus higher stresses may be used. The walls are prestressed horizontally and vertically so that, under all conditions of loading, not only can no tensile stresses occur in the concrete, but there always remains a compressive stress at all points. The vertical cables were prestressed first, thus ensuring that the tensile stresses due to the temporary vertical moments caused by the horizontal stressing operation were counteracted by the vertical prestressing, and no horizontal cracking could occur. The horizontal cables are composed of groups of four high-tensile wires 0·200 in. in diameter for the upper cables, and 0·276 in. in diameter for those near the bottom of the walls. The ultimate tensile strength is 95 to 100 tons per square inch. The wires lie in a layer, one wire thick, against the external concrete surface; they are supported in position prior to tensioning by a series of 1 in. by 16-s.w.g. mild-steel vertical strips, with notches cut in them to ensure the correct spacing of the cables throughout the height of the wall. When the horizontal cables had been tensioned a light steel reinforcing mesh was fixed to them, and a one-inch coat of mortar was applied pneumatically over the whole outer surface of the walls as a protective covering.

The vertical prestressing was carried out with ordinary Magnel-Blaton cables, which were located at mid-thickness of the walls. For the storage and sand-trap tanks these cables were composed of sixteen 0·200-in. wires; for the reaction tanks 8-wire cables were used. The cables were placed in position prior to concreting and the lower anchorage was then cast in with the first lift of the wall. From 1 ft. 6 in. above the lower anchorage the cables are in ducts, made by a tubular former through which the cables passed. After each lift of concrete had been completed the former was withdrawn and raised to the correct position for the succeeding lift; thus the cables are in a continuous duct above a point 1 ft. 6 in. higher than the built-in anchorage. At the bottom of the duct a communicating hole was cored through the outer surface of the wall. After the cables had been tensioned, colloidal grout was pumped into this hole to fill the space surrounding the wires, the pump being powerful enough to force the grout the full height of the tank wall until it enveloped the sandwich-plate cable anchorage at the top (Fig. 1, on page 236) and spilled over, thus ensuring complete filling of the duct and sealing of the cable. All the tanks were designed with a sliding joint between the walls and base, formed by constructing a groove in the base and then casting the wall in it.

Because of the number of large pipes which pass into the storage tanks at floor level, it was decided to design the base and bottom 6-ft. height of the wall, together with the low-level launder which surrounds these tanks to collect overflow, in normal reinforced concrete. The floor was also designed in normal reinforced concrete; it comprises a 5-in. reinforced slab laid on a 3-in. screed course. The whole of the floor and internal surface of the 6-ft. high reinforced-concrete stub wall was finished with a ¾-in. layer of asphalt, laid in three courses. At the top of the stub wall, a 4-in. deep groove was formed, in which the prestressed-concrete shell rests. The lower surface of the groove was steel-

PRESTRESSED-CONCRETE TANKS.

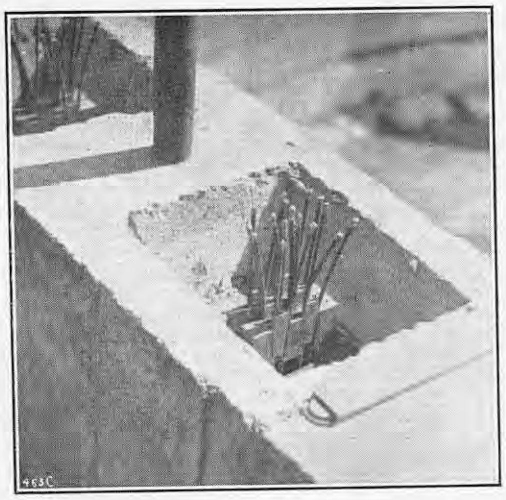


FIG. 1. TOP ANCHORAGE OF VERTICAL CABLES.

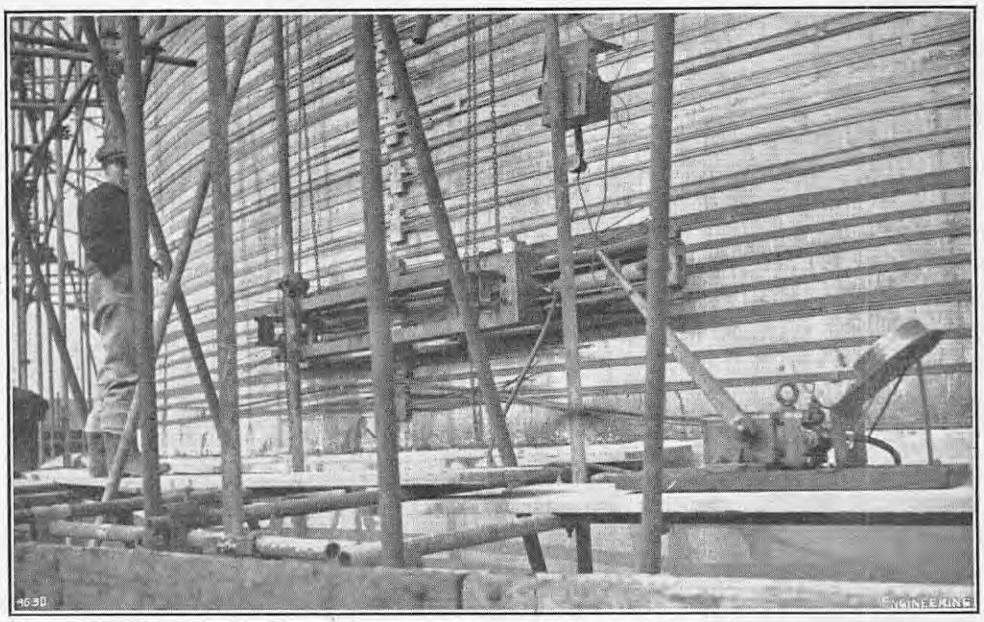


FIG. 2. TENSIONING HORIZONTAL CABLES.

trowel finished and then coated with hot bitumen to form the sliding joint surface. The space between the prestressed shell, a cross-section of which is shown in Figs. 3 and 4, and the sides of the groove in which it is formed, is sealed with a rubber-impregnated bitumen. The outer space was also filled to prevent it from becoming packed with blown sand, which would restrict the free movement of the shell. The inner surface of the prestressed concrete in all the tanks is without protective coating of any kind. The steel outlet flumes discharge at the level of the top of the tanks. The two storage tanks are interconnected by a levelling pipe.

The sand-trap tank also has a reinforced-concrete floor, in the centre of which there is a drain for scouring off the accumulated sand. Round the periphery of the floor there is a groove for the prestressed shell, as in the storage tanks, and near the foot is a 2 ft. 6 in. manhole (Fig. 7, page 240). The vertical prestressing cables pass on either side of this opening. The horizontal prestressing force is carried across the opening by a steel frame to which the horizontal cables are anchored. The frame encircles the manhole and was placed after concreting had been completed. Four 18-in. inlet pipes enter the tank at about mid-height through holes in the tank wall. Here, also, a steel frame, embracing all four pipes, transfers the horizontal prestressing force, and the vertical cables are spaced so that they pass between or outside the holes. On the top rim of the tank there is an annular trough-shaped launder, as shown in Fig. 3. The inner wall forms the circular weir over which the water discharges from the sand trap. The launder is designed as a reinforced-concrete collar and is simply supported on the tank wall, with a copper water bar through the bearing surface. The reaction tanks also have a reinforced-concrete floor with a groove for the shell. Several pipes pass through the walls, the same method of transferring the forces across the opening being employed. In addition, each has a structural-steel bridge supported on the top of the wall.

The lower anchorage for the vertical cables comprises a short mild-steel bar, to which are welded several ½-in. mild-steel links. Each high-tensile wire in the cable passes from the top anchorage, around this bottom anchor bar and back to the top. The upper anchorage comprises the standard sandwich plates and distribution plate, as shown in Fig. 1, and tensioning of the cables was carried out by the normal Magnel-Blaton jacking equipment, as shown in Fig. 6, on page 240. The cables have only one grille or spacer near each end to locate the wires. The 0·200-in. wires are of 100 to 110 tons per square inch ultimate tensile strength and they were tensioned to 140,000 lb. per square inch. Magnel-Blaton sandwich plates are machined steel blocks with trapezoidal grooves cut in them; a wedge in each groove anchors two wires.

The anchorages for the horizontal cables are the opposed-type sandwich plates which have their four grooves arranged so that when the eight ends of the wires are secured the plate is in equilibrium and lies flat against the tank surface. Tensioning was carried out by the Magnel-Blaton tank jack, which straddles the sandwich plate and simultaneously pulls two wires from each direction around the tank, as shown in Fig. 2, herewith. When the calculated extension had been induced in the wires the wedges were secured in the grooves of the sandwich plate. Since the wires touch the surface of the concrete all round the tank there was some loss of force while they were being tensioned, due to the friction between them and the concrete. This friction causes the stress in each wire

Fig. 3. SAND-TRAP TANK

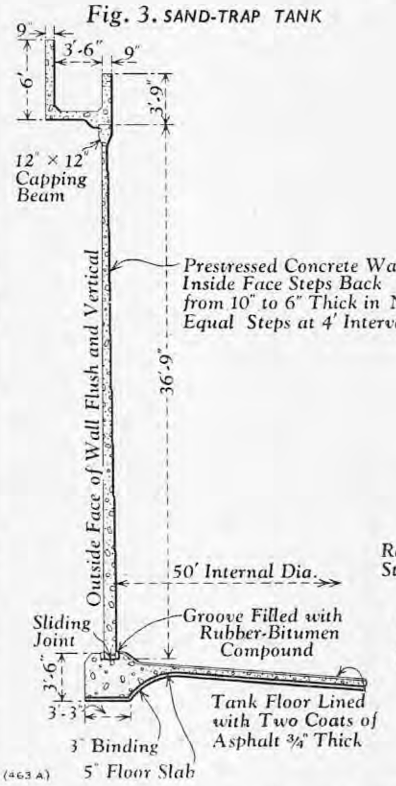
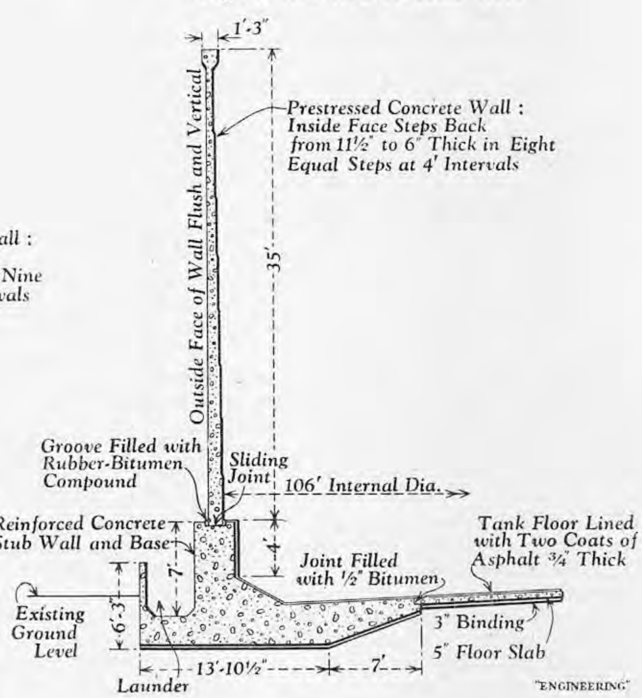


Fig. 4. HALF-TIDE STORAGE TANK



to vary from a maximum adjacent to the tensioning point to a minimum at the point farthest away from it. The variation in stress, which does not follow a linear function, was allowed for in the design. It can be controlled to any desired degree by tensioning each pair of wires simultaneously at several points round the circumference of the tank. At each tensioning point there is an anchorage. The number of tensioning points in the full circle to give the most economical result therefore depends upon the relative costs of labour, high-tensile wire and anchorages. In the present tanks it was a requirement that there should be only one layer of horizontal prestressing wires at any point on the tank. This was easily fulfilled in the most highly-stressed position near the bottom of the storage tanks by tensioning and anchoring the 0·276-in. wire cables simultaneously at four points 90 deg. apart. Only near the bottom of the large tanks was four-point tensioning employed; in all other cases the wires were tensioned at two points 180 deg. apart. The anchorages of adjacent cables are spaced at intervals around the circumference to provide a uniform effective prestress.

Construction followed the usual practice for water-retaining structures as far as the concrete work was concerned. The mix specified was a nominal 1 : 1½ : 3 with a water-cement ratio of 0·45. Shutter vibrators were employed to compact the concrete in the prestressed walls and launders, immersion vibrators being used for the reinforced-concrete stub walls and bases. Normal Portland cement was used, and throughout the contract the average 28-day test-cube strength was approximately 6,500 lb. per square inch. The floors and the stub walls of the storage tanks were concreted on the alternate-bay method to reduce shrinkage effects. The prestressed shells were cast in lifts of 4 ft., each lift being cast full-circle in a continuous operation and completed before the succeeding lift was commenced. The horizontal construction joints between adjacent lifts were not provided with water-bars. The joints were made by striking off the scum and laitance from the concrete a few hours after casting by means of a powerful water spray. The surface was then kept damp until just prior to placing the concrete of the next lift, when a layer of mortar was spread on it and tamped. During the prestressing operation three dial gauges were mounted on the tanks between the foot of the shell and the base. Readings showed quite reasonable correspondence with the calculated elastic contraction under prestressing. Readings taken when the tanks were being emptied and filled showed that the prestressed shell moved freely in the joint.

The contractors were Costain-John Brown, Limited; the prestressing equipment was provided by Stressed Concrete Design, Limited, Lynton House, 54, South Side, Clapham Common, London, S.W.4; and the agents for the Ministry of Supply were the British Periclase Company, whose chief development engineer is Mr. P. J. Metcalf.

4-6-4 LOCOMOTIVE FOR VICTORIAN GOVERNMENT RAILWAYS.

NORTH BRITISH LOCOMOTIVE COMPANY, LIMITED, GLASGOW.

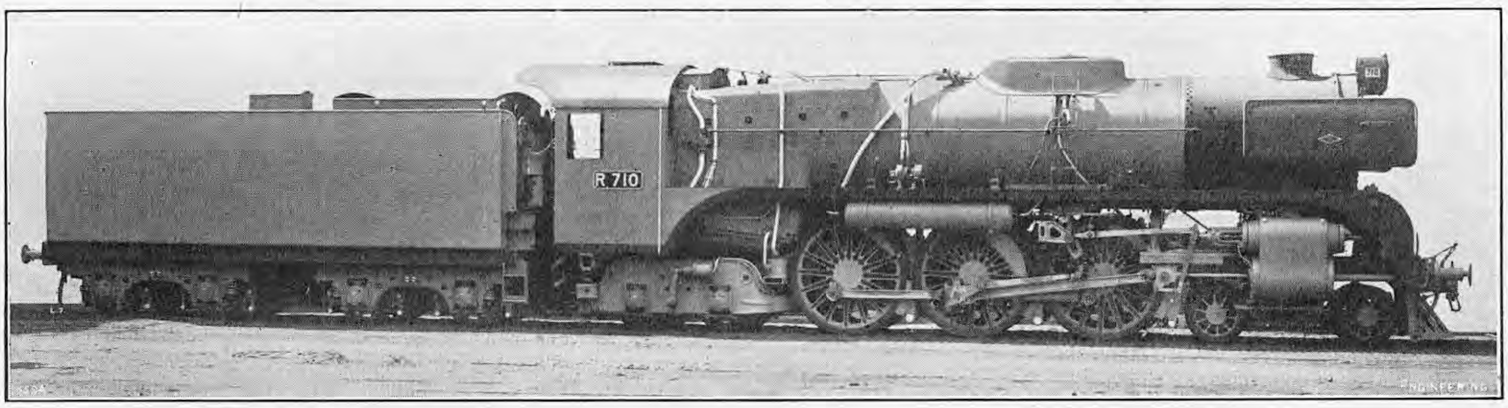
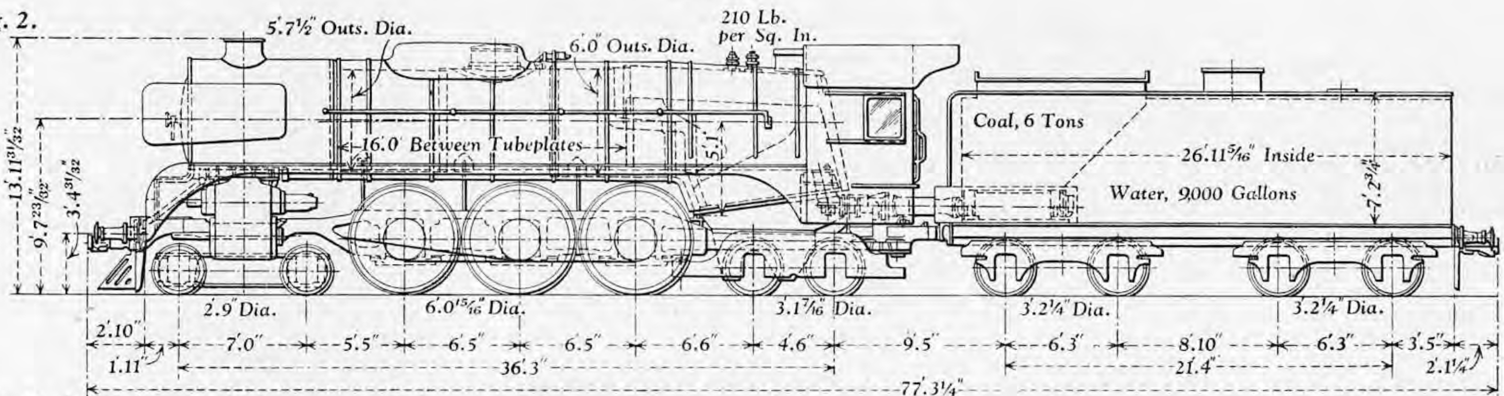


FIG. 1.

Fig. 2.



Weights in Working Order, Tons 23·2 19·5 19·5 19·5 25·9 38·4 41·4

(459.B.) *Total Weight of Engine and Tender in Working Order, Tons 187·4* "ENGINEERING"

4-6-4 LOCOMOTIVES FOR VICTORIAN GOVERNMENT RAILWAYS.

The North British Locomotive Company, Limited, 110, Flemington-street, Glasgow, N., have under construction for the Victorian Government Railways, Australia, 70 4-6-4 locomotives of a new "R" class. The engines are being built to suit the 5 ft. 3 in. gauge, but are suitable for conversion at a later date to 4 ft. $8\frac{1}{2}$ in. gauge; the main frames will then remain unchanged, as distance pieces have been provided at the cylinder seatings to the frames, between the central connections of the cylinders, slidebar bracket and the trunnion and reversing-shaft brackets. The design includes a combustion chamber and thermic syphons, a mechanical stoker, roller-bearing axleboxes and Scoa-P wheel centres. The boiler pressure is 210 lb. per square inch; the cylinders are $21\frac{1}{2}$ in. in diameter, 28 in. stroke; the coupled wheels are 6 ft. $0\frac{15}{16}$ in. in diameter; the tractive effort at 85 per cent. boiler pressure, and assuming a wheel diameter of 6 ft., is 32,080 lb.; and, as the adhesive weight is 58·5 tons, the adhesive factor is 4·04. Fig. 1, herewith, shows a general view of one of the locomotives and tenders, and Fig. 2 gives some of the principal dimensions and weights. The locomotives are to the design and requirements of Mr. A. C. Ahlston, chief mechanical engineer, and inspection is being carried out at the builders' works by Messrs. A. E. Turner and John Coates and Company, Limited, Victoria House, Melbourne-place, London, W.C.2.

The boiler barrel, with external diameters at front and rear of 5 ft. $7\frac{1}{2}$ in. and 6 ft., respectively, consists of three rings with the middle ring tapered. There are 30 superheater flue tubes of $5\frac{1}{4}$ in. outside diameter and 155 small tubes of 2 in. outside diameter. The heating surfaces are: tubes, 1,958 sq. ft.; firebox, including syphons, 285 sq. ft.; total evaporative, 2,243 sq. ft.; superheater, 462 sq. ft.; and total evaporative and superheating, 2,705 sq. ft. The grate area is 42 sq. ft. The firebox is of the Belpaire type and has a steel inner box of all-welded construction, with a long combustion chamber and two thermic syphons which support the brick arch. Roof stays are of Longstrand steel, with flexible stays fitted in the breaking zones and round the combustion chamber.

The boiler is supported at the front of the firebox by expansion shoes attached to the foundation ring and bearing on slides fixed to the front end of the frame cradle casting. Frame deflection plates are located at the front of each of the coupled wheels to reduce bending stresses in the frames. A breathing plate is fitted between the foundation ring and the hind end of the cradle casting. The smokebox is equipped with a self-cleaning spark arrester and the smokebox floor is cemented with a mixture of cement, coke and sand. Smoke-deflection wing plates are fitted on each side of the smokebox. The regulator valve is of the balanced type and is fitted with a pilot valve. Two tangential steam driers are provided in the dome and steam is supplied through a 7-in. steam pipe to a 30-element Melesco superheater. The Standard Stoker Company's type MB 1 stoker unit is fitted to each locomotive; it delivers coal under the firebox to the firing table in the centre rear of the box. A hand-operated Waugh-type firegrate is arranged for rocking and dumping in two sections, with fixed sections on each side of the firing table. Sliding doors are fitted to each ashpan hopper and are operated by means of an air cylinder. An air-operated Franklin firedoor is fitted to the firebox. Asbestos mattresses are applied to the boiler barrel and throat plate, but the firebox is lagged by asbestos sprayed on the inner surface of the clothing. General steam fittings include two Nathan non-lifting injectors; two Coale safety valves (one muffled and one plain); and two blow-off cocks of the Railways Department's standard pattern, with separators fitted at the front of the firebox sides.

The main frames are of the bar type, cut from rolled slab and finished to a thickness of 5 in. A cast-steel headstock incorporating the buffer beam and dragbox is fitted at the front end, and the back end of the frame consists of a one-piece cradle steel casting attached to the main frames at the rear of the coupled wheels. The frame horn shoes and wedges are of phosphor bronze and the horn clips are of cast steel. S.K.F. self-aligning roller-bearing axleboxes are fitted to all coupled axles and are grease-lubricated. The coupled-wheel laminated springs are overhung and compensation is arranged between the driving and trailing coupled wheels. Side buffers are fitted at the front of the engine and the rear of the tender, and distance pieces are provided under the buffers to maintain the proper relation between buffers and couplers during the transition period. An automatic Alliance coupler is fitted into a pocket casting on the front engine headstock and a "transition" screw coupling is also provided. The cast-steel wheel centres are of the "Scoa-P" type (described in our issue of June 29, on page 803), and the revolving masses only are balanced. The cylinders, incorporating the smokebox saddle base, are of cast steel and are fitted with renewable cast-iron liners in the steam-chest and cylinder barrels.

Walschaerts valve gear actuates 11 in. diameter piston valves, which have a maximum travel of $6\frac{1}{2}$ in. and a cut-off of 75 per cent. in full forward gear. The connecting rods and coupling rods are forged from manganese-molybdenum steel and are of fluted section. Adjustable brasses are fitted to the connecting rods, and the coupling-rod bushes are solid, lined with whitemetal. The piston consists of a $3\frac{1}{2}$ per cent. nickel-steel forged centre with a cast-iron bull ring riveted to the centre and fitted with two cast-iron piston rings. Lubrication of valves and pistons is by means of a Nathan six-feed mechanical lubricator. Oil feeds are taken to the steam pipes and to the top and bottom of the cylinders; they are controlled by terminal check valves, and atomisers are provided for the feeds to the steam pipes and the tops of the cylinders. Lubrication of the engine bogie centre, trailing-truck pivot and coupled-wheel axlebox horn faces is by another Nathan six-feed lubricator.

The leading bogie frame consists of steel bars with a cast-steel transom and cast-steel end bars cast integral with the outer horn cheeks. The inner cast-steel horns are joined together transversely by steel frame stays. The horns are fitted with hardened-steel liners and are tied by forged horn stays. Spring beams carrying the laminated bearing springs rest on top of the axleboxes and the bogie load is transmitted to the springs through spring seats attached to the underside of the side frame bars. S.K.F. roller-bearing axleboxes are fitted. The centring device consists of heart-shaped rockers having an initial and constant resistance of $33\frac{1}{3}$ per cent. The trailing bogie is of the four-wheeled delta type, with an all-welded frame. S.K.F. roller-bearing axleboxes are fitted. The centring device consists of heart-shaped rockers having a constant resistance of 20 per cent. Westinghouse brake gear is provided, the tender being fitted with automatic hydrostatically-controlled variable-load brake equipment.

The tender, with double four-wheeled bogies, has capacities of 9,000 gallons of water and 6 tons of coal. The bogie frames and transoms are of mild-steel plate, flanged and welded into box section, and the end bars are of mild-steel plate, flanged and welded into position. Hardened steel liners are provided at the horns and the horn stays are steel castings. Laminated bearing springs with equalising beams are fitted above each axlebox and housed within the side frames. The cast-steel bolster is suspended from the transoms by means of swing-links and trunnions.

NOTES FROM THE INDUSTRIAL CENTRES.

SCOTLAND.

THE LATE SIR JAMES M. RITCHIE, C.B.E.—Sir James Martin Ritchie died in Glasgow on August 16, aged 77. Sir James was managing director of Andrew Ritchie and Son, Ltd., paper-box manufacturers, Bridgeton, Glasgow, and, on the merging of their interests with the Eburite Corrugated Containers Co., Ltd., London, in 1944, became chairman of the reconstituted board of directors. He was created a C.B.E. in 1926 and knighted in 1939.

SCOTTISH SHIPBUILDING ACTIVITY.—Five vessels—four tankers and one ore carrier—to be launched from Clyde shipyards during the second half of this month will add nearly 60,000 tons gross to the launching figures of the river. This will bring the total for the first eight months of the present year well above that of 1950. Speaking at Dundee on August 16, Mr. Edgar P. Brown, chairman of the Caledon Shipbuilding and Engineering Co., Ltd., said that there was no lack of new orders; the main anxiety was whether sufficient steel would be forthcoming for them to be executed promptly.

DEEP PILE-DRIVING AT GRANGEMOUTH.—On the site of the new factory that is being constructed at Grangemouth for Forth Chemicals, Ltd., a steel foundation pile was driven on August 14 to a depth of 161 ft. 6 in. before the solid subsoil was reached. Since work began in April, over 200 piles have been driven to an average depth of 120 ft. It is stated, also, that Forth Chemicals, Ltd., have applied to the Grangemouth town council for a daily supply of 2,000,000 gallons of water for process work. This represents an increase of 25 per cent. over the quantity now supplied to local industries.

THE MECHANICAL ENGINEERING RESEARCH STATION.—Two buildings of the Mechanical Engineering Research Station at Birniehill, East Kilbride, have been completed, and the third is well advanced. Plans for the construction of a fourth building are now being considered and the site is being prepared.

CARGO STEAMER SERVICES ON FIRTH OF CLYDE.—Plans for the resumption of a cargo steamer service linking Campbeltown with Arran, the Clyde ports and Stranraer are under consideration. All freight to and from Kintyre at present has to go by road. Provost R. Wallace Greenlees, of Campbeltown, said on August 10 that for some time he had been trying to attract industry to the area, but had repeatedly met the objections that no steamer service was available and that freight costs were high.

PRIORY COLLIERY, BLANTYRE.—The National Coal Board and the National Union of Mineworkers, in agreement with an opinion expressed by H.M. Divisional Inspector of Mines, have decided that Priory Colliery, Blantyre, will be made a new central pumping station serving the other collieries in the Clyde Valley sub-area. The colliery was closed on April 10, following an inflow of water.

SUBMARINE TELEPHONE CABLE IN KILBRENNAN SOUND.—The submarine cable ship, Iris, has been commissioned to lay a telephone cable nine miles long in Kilbrennan Sound from Ardnacross, north of Campbeltown, to Blackwaterfoot, Arran. The new cable will provide an alternative route in case of need and in the event of faults occurring in any of the other lines to Glasgow.

JOY-SULLIVAN, LTD.—In our issue of August 10, on page 175, *ante*, reference was made to the removal of Messrs. Joy-Sullivan, Ltd., to a new factory at Cappielow, Greenock, in terms which might be read as indicating a complete removal. Messrs. Joy-Sullivan inform us, however, that only part of their factory and offices has gone to Cappielow, and that the rest will remain at Battery Park.

THE LATE MR. HENRY ROBB.—The death occurred in Edinburgh on August 17 of Mr. Henry Robb, M.I.N.A., founder and managing director of Henry Robb, Ltd., shipbuilders, of Leith. Mr. Robb, who was a native of Ayr, was 77 years of age.

CLEVELAND AND THE NORTHERN COUNTIES.

PRICE INCREASES IN IRON AND STEEL.—The long-expected substantial rise in fixed market values of iron and steel, announced last week, to cover heavy production costs occasioned by the big upward movement in prices of raw material, wages and transport charges, was no greater than had been anticipated for some time in North-East Coast commercial circles. As yet the increases have had little effect in the industrial areas between Tees and Tyne. Buyers are prepared to discuss the terms of new contracts but sellers have little tonnage to dispose of. Prices of North-East Coast products are still below those of Continental materials.

CLOSURE OF SOUTH DURHAM MALLEABLE STEEL PLANT.—The Iron and Steel Corporation of Great Britain have closed down the malleable steel plant of the South Durham Steel and Iron Co., Ltd., at Stockton-on-Tees, on account of shortages of raw materials. Some 350 employees of the company are understood to have been paid off on August 10, but Mr. Benjamin Chetwynd Talbot, chairman and managing director, said that it would be the policy of the company to endeavour to offer, to men whose services were dispensed with, alternative employment at their other works. Developments at their Cargo Fleet, Middlesbrough, and West Hartlepool works were well advanced. He hoped that those for whom alternative employment could not be provided would secure work at some of the engineering firms in the district or on the large enterprises near Stockton.

COLLISION AT NEWCASTLE CENTRAL STATION.—A collision occurred on the morning of August 17 between two electric trains, one entering and the other leaving the Central Station at Newcastle-on-Tyne. The driver of the incoming train and a woman passenger were killed, and another passenger subsequently died from injuries received. Forty-two other passengers were injured, eight of whom were detained in hospital. The electric line to South Shields was blocked for about six hours, but the line to the coast via Benton was not cleared until the evening.

MIDDLESBROUGH TRANSPORTER BRIDGE.—For the first time for many years, the transporter bridge over the River Tees at Middlesbrough, was out of action during the evening of August 12. A fire which occurred in the power house was quickly put out by the local fire brigade, but it was subsequently found that an electric motor had been rendered inoperative. A new motor was substituted and the bridge resumed working after a delay of about two hours.

LANCASHIRE AND SOUTH YORKSHIRE.

FOUNDRY REORGANISATION IN SHEFFIELD.—Samuel Osborn & Co., Ltd., state that the output of their foundry has been doubled as a result of reorganisation and re-equipment undertaken after visits to the United States by their managing director, Mr. Frank A. Martin, as a member of the team sent to America under the auspices of the Anglo-American Productivity Council, and, subsequently, in a private capacity.

OPENCAST COAL ALLOCATION.—The scarcity of pit coal is making it necessary to increase the proportion of opencast coal in the domestic coal allocation. The view is held by Yorkshire coal merchants that the percentage may yet be as high as 25 per cent. In Sheffield, already about 16 per cent. is coming from opencast sites, compared with about 10 per cent. last winter. At Chesterfield, opencast coal comprises about 37 per cent. of the allocation.

GERMAN COMPETITION.—Sheffield cutlery manufacturers are concerned about the growth of German competition, and it is stated that, unless protection is afforded to the industry, there may be acute unemployment in the near future. Imports of German cutlery into the United Kingdom, in June, were three times greater than those for the whole of 1938. One advantage which German cutlery manufacturers enjoy is an adequate supply of nickel for cutlery components, whereas, in Sheffield, the shortage of nickel makes its use virtually prohibitive. British imports of cutlery from Italy have also increased.

THE MIDLANDS.

THE EDGE-TOOL TRADE.—Shortages of certain types of steel are causing difficulties in the Midland edge-tool trade. The Wolverhampton firm of W. G. Birkinshaw & Co., Ltd., have closed their pick and mattock department temporarily, transferring the men normally employed there to other work. Similar action has been taken by John Perks & Sons, Ltd., of Wolverhampton, and there are other firms in Dudley, Birmingham and Oldbury who will be placed in the same position unless steel is forthcoming. In the meantime, valuable export orders, which account for a large proportion of the trade in picks and mattocks, cannot be executed.

INDUSTRIAL STUDY VISIT TO SWEDEN.—A visit to Sweden for representatives of Midland industrial concerns has been arranged by the Industrial Welfare Society. The party will travel to Stockholm on September 2, and the programme includes visits to factories and to the Swedish Employers' Federation conference and study establishment. Midland engineering firms sending representatives include Accles and Pollock, Ltd., Oldbury, British Industrial Plastics, Ltd., Birmingham and Ernest N. Wright, Ltd., Wolverhampton.

NEW MOTOR-CAR FACTORY AT KENILWORTH.—Wilks, Mackie & Co., Ltd., of Dorridge, near Birmingham, are to build a factory at Kenilworth for the manufacture of the "Marauder" motor car. The Marauder car is a sports model, utilising an engine and certain other parts made by the Rover Co., Ltd. Several cars have been built experimentally, and the firm now have sufficient orders to enable them to go into production, and to keep them busy for some time.

A SURVEY OF DUDLEY.—A survey of the borough of Dudley, Worcestershire, which has just been published by the University of Liverpool Press under the title of "Aspects of a Town Development Plan," is largely concerned with social matters, but the industrial section contains some conclusions of interest, not only to Dudley, but to the whole of the neighbouring Black Country. The survey points out that since Dudley, which developed as a centre of heavy industry, has lost its coal and iron trades, the town has ceased to be an industrial centre, and that more than 40 per cent. of its population are employed outside its boundaries. The view expressed in the survey, that the future of the town will be to act as a dormitory for the surrounding industrial area, has aroused opposition. Mr. R. H. Gibbons, borough engineer and surveyor, has stated that, while it is no doubt true that there will be no revival of heavy industry, the Council's plans are designed to attract lighter trades, particularly light engineering. Provision is being made to accommodate new factories in the parts of the town zoned for industry.

ELECTRICITY PLANS FOR THE WINTER.—The question of how the electricity load requirements are to be met in the coming winter is under discussion in the Midlands. There is clearly no likelihood that there will be sufficient power to meet all requirements, especially if the weather should be severe, and any measures introduced will have to take this fact into account. Firms which can generate their own power, or can provide alternative means of driving machinery, will be encouraged to do so. A suggestion that staggering of working hours should be re-introduced has already met with opposition from both sides of industry.

SOUTH-WEST ENGLAND AND SOUTH WALES.

COLLIERY CASUALTIES.—The report of Mr. T. A Rogers, H.M. Inspector of Mines for the South Western Division, issued last week, shows that 94 miners were killed in the pits in the Division in 1950, one more than in 1949. Of this number, 83 died in accidents underground. The number of accidents increased by two, from 412 in the previous year to 414. The Division, states the Inspector, was shown in 1949 to have a pit accident rate "worse than the average." More than half of the accidents, in the opinion of mine inspectors, could be avoided by following the rules and exercising ordinary care. On a man-power basis, one person was killed in the pits for every 1,082 employed and one in 250 suffered serious injury.

SALE OF CARBONISATION PLANT.—The low-temperature carbonisation plant opened 12 years ago at Heolycyw, six miles from Bridgend, Glamorgan, has been purchased by R. S. Hayes, Ltd., engineers and machinery merchants, Bridgend. The purchase has involved the entire freehold property occupying a site of about 50 acres and comprising extensive railway sidings, workshops and offices and a considerable quantity of ferrous metals. The low-temperature carbonisation plant itself is not part of the purchase, but is being transferred to the North of England. The plant was shut down several years ago on Government orders.

SEVERN BRIDGE PROJECT.—Sir Percy Thomas, consultant architect of the Severn Bridge project, said last week that surveys had been made and that the plans for the suspension towers had been passed by the Fine Arts Commission. All that remained now was for Treasury permission to go ahead, but that seemed a long way off. The proposed bridge will have the third longest span in the world.

WATER SUPPLY AT TENBY.—Tenby Corporation hope to receive a Government grant towards the cost of their Preselly water scheme, which is estimated to cost more than 200,000*l*. Ratepayers have been apprehensive that the scheme, undertaken on orders from the Ministry of Health, would be an additional burden on the town, where the rates—nearly 30*s*. in the £—were the highest on record. The town council have decided to press their case for a grant.

UNEMPLOYMENT STATISTICS.—Wales remains a "black spot" for unemployment. In June, 20,484 operatives were registered as out of work, comprising 13,340 men, 487 boys, 5,946 women and 711 girls.

NOTICES OF MEETINGS.

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

Incorporated Plant Engineers.—*London Branch*: Tuesday, September 4, 7 p.m., Electric Light Manufacturers' Association, 2, Savoy-hill, Strand, W.C.2. "Storekeeping," by Mr. J. Barrett. *Peterborough Branch*: Thursday, September 6, 7.30 p.m., Eastern Gas Board's Demonstration Theatre, Church-street, Peterborough. "Cutting-Tool Dynamometry as an Aid to Machine-Tool Maintenance," by Mr. J. Purcell.

LAUNCHES AND TRIAL TRIPS.

Light Vessel No. 11.—Built by Philip & Son, Ltd., Dartmouth, for the Corporation of Trinity House, London, E.C.2. Nineteenth light vessel built for the Corporation. Main dimensions: 130 ft. by 25 ft. by 15 ft.; gross tonnage, 350. The lantern contains six 500-watt lamps giving a beam visible for 10 to 12 miles in clear weather. Launch, August 15.

S.S. "Deptford."—Single-screw collier, built by S. P. Austin & Son, Ltd., Sunderland, for the British Electricity Authority, London, W.1. Second vessel of a series of three. Main dimensions: 257 ft. by 39 ft. 6 in. by 18 ft. 6 in.; deadweight capacity, about 2,700 tons on a draught of 17 ft. 1 in. Direct-acting triple-expansion engine of reheat design, developing 800 i.h.p. at 78 r.p.m., constructed and installed by George Clark (1938), Ltd., Sunderland, and one coal-burning forced-draught boiler. Service speed, 10½ knots. Launch, August 16.

M.S. "Sunnaas."—Single-screw oil tanker, built by the Caledon Shipbuilding & Engineering Co., Ltd., Dundee, for Iver Bugge, Larvik, Norway. Main dimensions: 470 ft. between perpendiculars by 64 ft. by 35 ft. 6 in.; deadweight capacity, 13,500 tons on a draught of 28 ft. 5 in.; gross tonnage, 9,500. Vickers-Doxford four-cylinder opposed-piston Diesel engines, developing 4,400 b.h.p., constructed by Vickers-Armstrongs Ltd., Barrow-in-Furness. Speed, 13½ knots. Launch, August 16.

S.S. "British Talent."—Single-screw oil tanker, built and engined by R. and W. Hawthorn, Leslie & Co., Ltd., Hebburn-on-Tyne, County Durham, for the British Tanker Co., Ltd., London, E.C.2. Main dimensions: 643 ft. overall by 81 ft. by 44 ft. 6 in. to upper deck; deadweight capacity, about 28,100 tons. Steam turbines with double-reduction gearing, developing a maximum of 13,750 s.h.p. Launch, August 17.

M.S. "Nordvard."—Single-screw cargo vessel, built by Short Brothers, Ltd., Sunderland, for the Klosters Rederi A/S, Bygdøy, near Oslo, Norway. Main dimensions: 425 ft. between perpendiculars by 58 ft. 9 in. by 37 ft. 9 in. to shelter deck; deadweight capacity, about 9,400 tons on a draught of 26 ft. 1 in. N.E.M.-Doxford four-cylinder opposed-piston oil engine, constructed and installed by the North Eastern Marine Engineering Co. (1938), Ltd., Wallsend-on-Tyne. Service speed, 13¼ knots. Launch, August 17.

M.S. "Margaret."—Single-screw tug, built by Cochrane & Sons, Ltd., Selby, Yorkshire, for Charrington, Gardner, Locket (London), Ltd., London, E.C.3. Main dimensions: 70 ft. between perpendiculars by 18 ft. by 8 ft. 6 in.; gross tonnage, 66. Six-cylinder Diesel engine, developing 450 b.h.p. at 300 r.p.m., constructed by British Polar Engines, Ltd., Glasgow, and installed by Charles D. Holmes & Co., Ltd., Hull. Launch, August 18.

M.S. "Jean-Helene."—Single-screw trawler, built and engined by Chantiers et Ateliers Augustin Normand, Le Havre, France, for the Armement Pannequin, Boulogne, France. Main dimensions: 105 ft. between perpendiculars by 23 ft. by 13 ft. 3 in.; fishroom capacity, 4,450 cub. ft. M.A.N. six-cylinder four-stroke single-acting Diesel engine, developing 450 h.p. at 207 r.p.m. and a speed of 10½ knots. Launch, August 18.

Equipment for Students of Gas-Turbine Technology.—Since moving to Farnborough in 1950, the School of Gas Turbine Technology has been adding steadily to its range of instructional sectioned gas-turbine engines, and now claims to possess the best collection in the country. The present range of sectioned jet engines includes examples of the Power Jets W2/700, Rolls-Royce Derwent I and III, de Havilland Goblin, Metro-Vick Beryl, and Junkers Jumo engines. Turbo-propeller types on show include the Rolls-Royce Trent, Dart and Clyde engines, and the Bristol Theseus, Armstrong-Siddeley Mamba, and Napier Naiad engines. In addition to the sectioned engines, two engines are kept for test purposes at the Napier test beds in Acton, London. At present, these are a W2/700 and a Naiad. They are used by the students themselves to obtain performance data. It is hoped to increase the range of gas-turbine engines in the near future.

CONTRACTS.

Ferranti, Ltd., Hollinwood, Lancashire, have received an order from the Aluminum Co. of Canada, Ltd., for power transformers totalling 400,000 kVA, to operate at 300,000 and 275,000 volts. These transformers are to be installed at the new hydro-electric stations at Kemano and Kitimat in British Columbia.

Cellactite & British Uralite, Ltd., Cellactite House, Whitehall-place, Gravesend, Kent, have received an order from the London Midland Region of British Railways for 36-in. diameter protected-metal extract roof ventilators for the machine shop and north and south erecting shops, at Crewe Locomotive Works.

Crypton Equipment, Ltd., George-street, Bridgwater, Somerset, have received a large order from the Near East covering the supply of 12 Crypton B.100 motor analysers, 40 "Portatest" portable electric test sets, 12 multi-range electrical test sets, four heavy-duty electrical test benches and three new distributor analysers.

Marconi's Wireless Telegraph Co., Ltd., Chelmsford, Essex, state that the television equipment ordered by the Municipality of Bogota, Colombia, briefly referred to on page 207, *ante*, will consist of a 5-kW vision transmitter, a 3-kW sound transmitter, a television studio including telecinė apparatus, and a specially-constructed vehicle which will contain all the equipment necessary for televising special functions such as public ceremonies, theatre plays and open-air events.

The Birmingham Railway Carriage & Wagon Co., Ltd., Smethwick, Birmingham, 40, are the main contractors for the construction of 14 Diesel-electric locomotives of 955 b.h.p. for general service on the 3-ft. 6-in. gauge Central Australian Railway. They will build the mechanical portion and deliver the complete locomotives. We are informed, however, that technical responsibility is vested in Sulzer Bros. Ltd., and that the locomotives are to be known as the Sulzer type. The Diesel engines are to be supplied by Sulzer Bros. (London) Ltd., 31, Bedford-square, London, W.C.1, and the complete electric transmission and control equipment is to be supplied by Crompton Parkinson Ltd., Chelmsford, Essex.

BRITISH STANDARD SPECIFICATION.

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

Methods for the Sampling and Testing of Mineral Aggregates, Sands and Fillers.—A complete revision of the 1943 edition of B.S. No. 812, which covers the sampling and testing of mineral aggregates, sands and fillers, has now been issued. The publication has been entirely re-arranged so as to allow all tests of a similar kind to be grouped under one heading. In the section dealing with particle-size analysis, methods of sieving are specified in greater detail than has hitherto been the case, separate requirements being given for coarse, fine and all-in aggregates and for fillers. A new section, comprising a glossary of rock and mineral names, terms of origin and textural terms, has been added. [Price 6*s*., postage included.]

Ban on Uses of Nickel Postponed.—The Ministry of Supply and Board of Trade announce that, following representations by industries affected by the Nickel (Prohibited Uses) Orders, it has been decided that the date from which the nickel-plating of articles listed in the Second Schedules to the Orders will be prohibited, shall be October 1, 1951, instead of August 22, 1951. It has also been decided that the disposal of articles containing controlled material, or which are nickel-plated, shall be permitted without licence up to December 31, 1951. These changes are being made to allow manufacturers more time to turn over to alternative methods of production and to dispose of existing stocks.

Courses in Photoelasticity.—A course of 15 lectures and demonstrations on the practical application of photoelastic methods to the investigation of two-dimensional stress distributions will be held on Mondays, from 5 to 6 p.m., commencing on October 8, in the Faculty of Engineering, University College, London. A course of ten lectures and demonstrations on recent developments in the photoelastic investigation of three-dimensional stress problems will be held on Mondays from 5 to 6 p.m., commencing on February 18, 1952. The fee for the first course is 8½ guineas, and for the second, 6 guineas. There are, moreover, a few vacancies for students desiring to do practical work in the photoelastic laboratories. The fee for one day a week, throughout the session, is 10 guineas. Students wishing to attend the courses should communicate with the secretary, University College London, Gower-street, W.C.1.

PERSONAL.

Professor C. A. Coulson, Ph.D., M.A., D.Sc., F.R.S.E., who has occupied the chair of theoretical physics in University of London, King's College, Strand, W.C.2, since 1947, has been appointed Rouse Ball Professor of Mathematics in the University of Oxford, as from January 1, 1952.

The Council of the Institution of Mining and Metallurgy, Salisbury House, Finsbury Circus, London, E.C.2, have unanimously elected Mr. Vernon Harbord, A.R.S.M., F.R.I.C., F.I.M., President of the Institution for the session 1952-53, in succession to Sir Lewis L. Fermor, O.B.E., D.Sc. (Lond.), A.R.S.M., F.R.S.

Dr. Edwin Glaister, M.Sc. (Eng.) (Lond.), A.M.I.Mech.E., has been appointed to the University of London Readership in Mechanical Engineering, tenable at the Imperial College of Science and Technology, South Kensington, London, S.W.7. He will enter upon his new duties on October 1.

Mr. J. P. S. Clarke has relinquished the chairmanships of Stephenson Clarke Ltd. and Associated Coal and Wharf Cos. Ltd., and his membership of the management committee of the Powell Duffryn board for reasons of health, but is remaining a director of these companies and of Powell Duffryn Ltd. Mr. E. W. Ganderton is succeeding Mr. Clarke in the appointments he is vacating. Sir Henry Wilson Smith, K.C.B., K.B.E., has been elected a director and vice-chairman of Stephenson Clarke Ltd., and has joined the board of Associated Coal and Wharf Cos. Ltd. Powell Duffryn Ltd. announce that as from August 21 their registered office is 19, Berkeley-street, London, W.1. (Telephone: GROsvenor 3801). The previous registered office, at 40, Lime-street, London, E.C.3, remains the City office of the company and the transfer office continues at 17, Overton-road, Sutton, Surrey.

Rear-Admiral J. H. F. Crombie assumed the posts of Flag Officer Commanding in Scotland and Northern Ireland and Admiral Superintendent, Rosyth Dockyard, on August 14, in succession to Vice-Admiral Sir Angus Cunninghame Graham, C.B.E.

Mr. W. E. Loveridge, M.I.N.A., M.I.Mar.E., is retiring on September 30 from his active capacity as engineering director at the Hartlepool works of Richardsons, Westgarth & Co., Ltd., but retains his seat on the board. Mr. Loveridge has been appointed a director of London and Overseas Freighters, Ltd., and will act as consultant and adviser on technical matters.

Mr. I. C. Green, who has been manager of the Finnieston Diesel-Engine Works, Glasgow, of Messrs. Harland and Wolff, Ltd., for many years, has retired for reasons of health, and Mr. Ernest F. Souchotte has been transferred from the company's Belfast Works to take charge of the Finnieston Works. Mr. W. C. Crawford has retired from the managership of the firm's Scotstoun Works, Glasgow, also for health reasons, and has been succeeded by Mr. Frederick H. Duncan, who has been assistant manager for a number of years.

The London Transport Executive, 55, Broadway, S.W.1, announce that Mr. A. C. Edrich, A.M.I.C.E., who has been senior assistant to the permanent-way engineer (railways) since 1944 has now been appointed permanent-way engineer (railways) and will report to the assistant civil engineer (permanent way). Mr. A. R. Purves, B.Sc. (Eng.), A.M.I.Mech.E., A.M.Inst.Pet., who has been assistant works engineer (Charlton) since 1945, has been appointed an officer of the Executive with the title of engineering superintendent (road services). Mr. T. C. Ball, A.M.I.Mech.E., M.Inst.F., F.G.S., who became assistant plant engineer in the early part of the present year, has been appointed plant engineer (omnibuses and coaches) and will report to the works manager (omnibuses and coaches).

Mr. H. Streets, formerly chief technical engineer to Richard Sutcliffe, Ltd., Universal Works, Horbury, Wakefield, Yorkshire, has been made technical director.

Mr. N. I. Bond-Williams, B.Sc., has been nominated to fill a vacancy for an ordinary member of Council of the Institute of Metals caused by the death of Mr. Harry Davies, F.I.M.

Mr. W. C. Johnson, A.M.I.C.E., M.I.W.E., is now water engineer to the City of Winchester; he was formerly water engineer for Douglas, Isle of Man.

Mr. Peter Wrightson, O.B.E., deputy managing director of Head, Wrightson & Co., Ltd., Thornaby-on-Tees, has been elected to a seat on the north-eastern district board of Martins Bank, Ltd.

Mr. P. G. Liversidge, secretary of Spear and Jackson Ltd., Savile-street East, Sheffield, 4, has retired after 50 years of service with the firm. He became secretary in 1935.

Strain and Robertson, consulting engineers, 154, West George-street, Glasgow, C.2, announce that their telephone number has been changed to DOUglas 8941-2.

PRESTRESSED-CONCRETE TANKS AT HARTLEPOOL.

(*For Description, see Page* 235.)

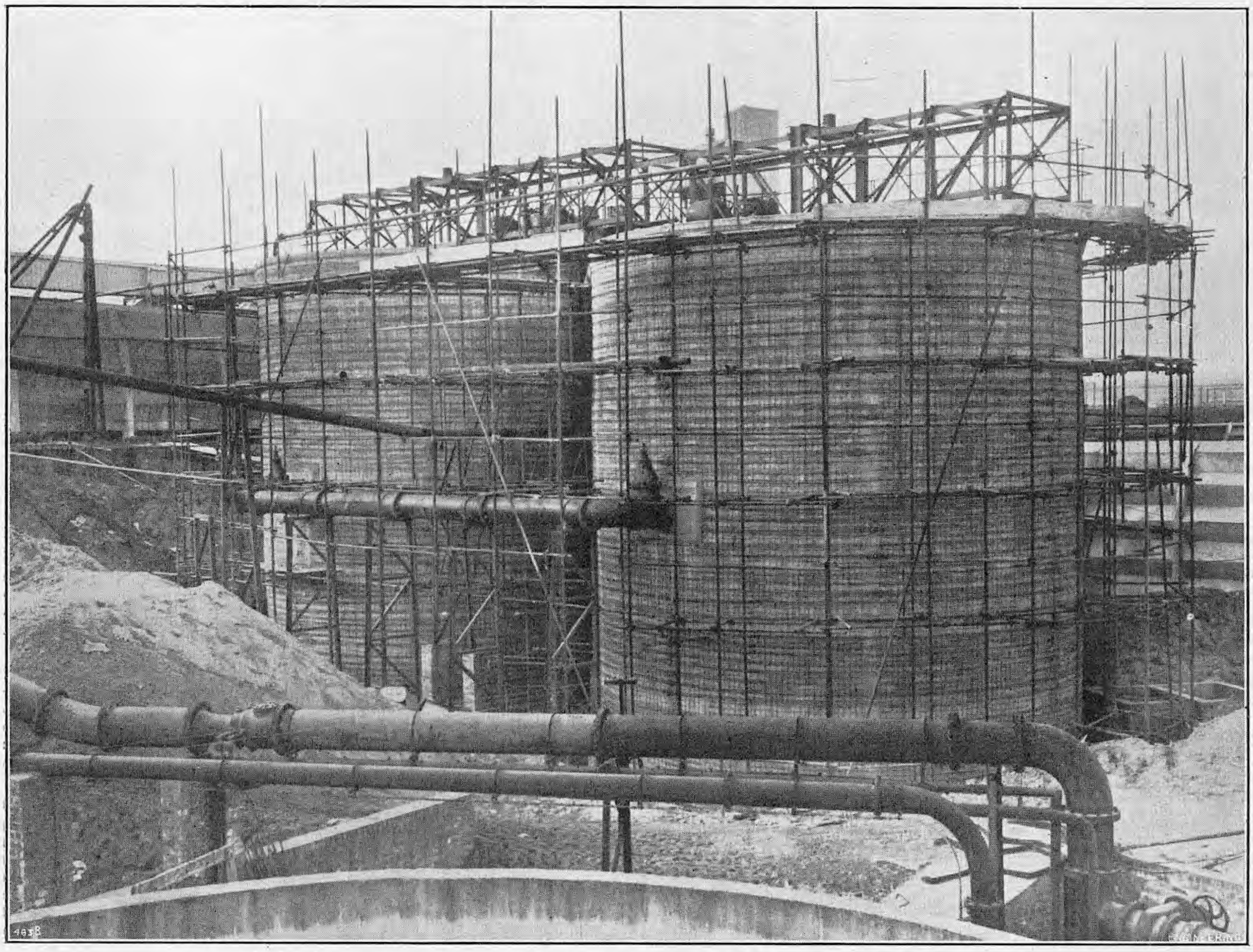


FIG. 5. REACTION TANKS; PRESTRESSING COMPLETE.

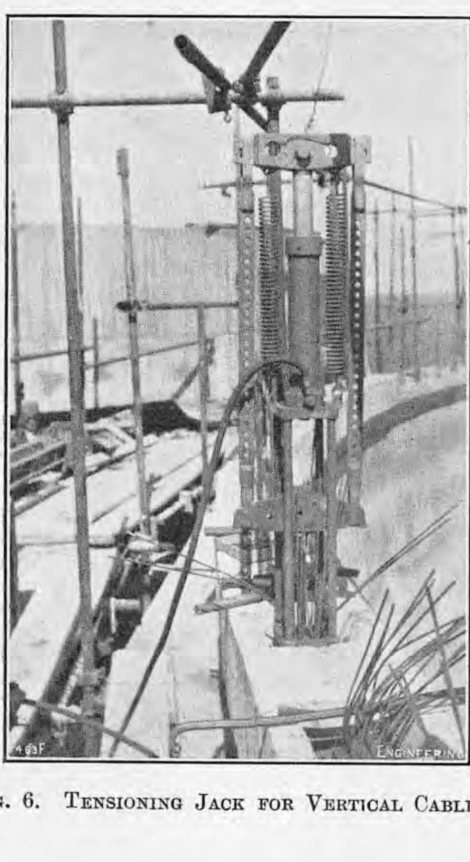


FIG. 6. TENSIONING JACK FOR VERTICAL CABLES.

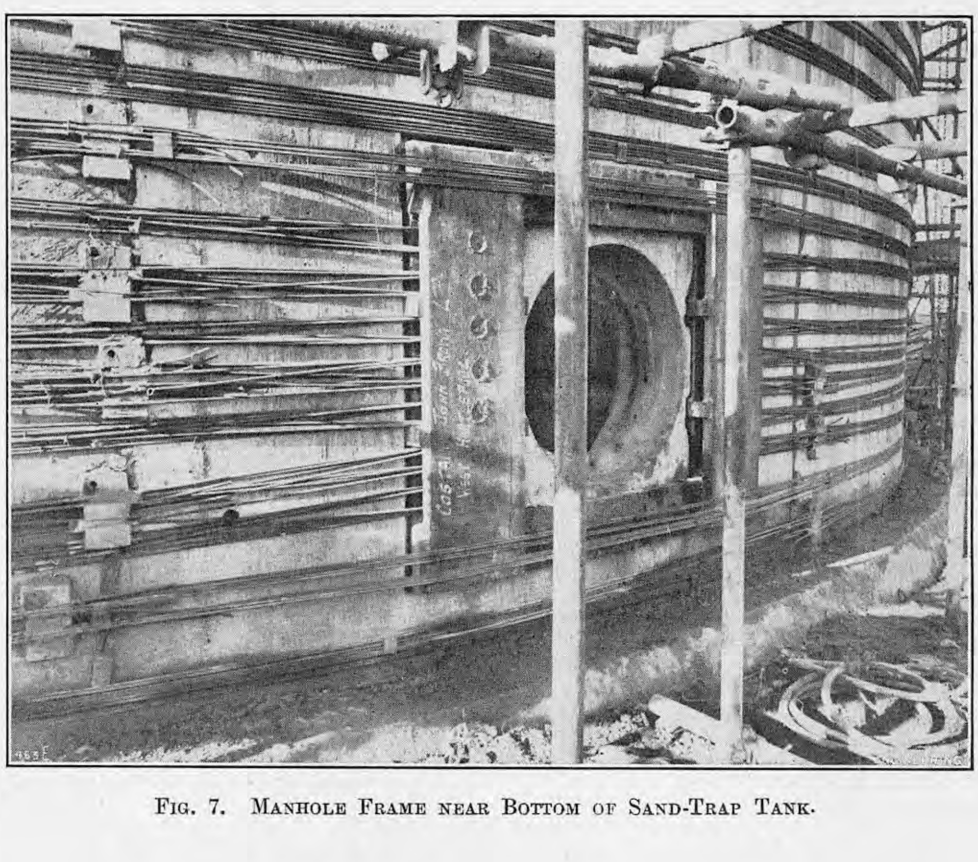


FIG. 7. MANHOLE FRAME NEAR BOTTOM OF SAND-TRAP TANK.

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Telegraphic Address:
"ENGINEERING," LESQUARE, LONDON.

Telephone Numbers:
TEMPLE BAR 3663 and 3664.

All editorial correspondence should be addressed to the Editor and all other correspondence to the Manager.

Accounts are payable to "ENGINEERING" Ltd. Cheques should be crossed "The National Provincial Bank, Limited, Charing Cross Branch." Post Office Orders should be made payable at Bedford Street, Strand, W.C.2.

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ENGINEERING

FRIDAY, AUGUST 24, 1951.

VOL. 172. No. 4465.

THE NEGLECT OF SCIENCE.

DURING the last ten years of the Napoleonic wars the expenditure of Great Britain averaged 84*l*. millions per year; in 1814, it was 106*l*. millions and at the end of the wars the country was carrying a debt three times the size of the national income. The fact that this situation was successfully faced and dealt with was mainly due to the great industrial expansion fostered by, and, indeed, based on, the mechanical developments and applications of steam power made possible by the genius of a chain of inventors and workers whose names are honoured in the history of engineering and mechanical science. Lecky, the historian, wrote that "England might well place the statues of Watt and Arkwright by the side of Wellington and Nelson."

On a more formidable scale, Great Britain is faced, in 1951, by a situation of the same type as that ruling in 1815. Although the sums concerned are vastly greater, it is not the financial aspect which presents the greatest difficulty. The relation between the national debt and the national income is probably not greatly different from that of 1815, but the lead in manufacturing ability which carried the country through the earlier crisis is no longer held. Much has been said and written about the undesirable social conditions induced by the industrial revolution, but, at least people did work hard in those days; there was undoubtedly much suffering and an unfair distribution of the profits from labour, but the cardinal fact is that the nation's difficulties were surmounted and an era of prosperity inaugurated. The social conscience of to-day would not permit a return to the conditions of a century or more ago, but at least it would appear desirable, and even necessary, that an effort should be made to recapture something of the devotion to work which characterised those earlier days.

This desideratum, it is to be feared, is contrary to the spirit of the welfare state, but in the long run, and possibly not a very long run either, it may be found that the amenities which are now being enjoyed cannot be sustained in any other way. Britain now holds no lead in manufacturing ability and is dependent on overseas trade, not only for the maintenance of the present standard of living but for very existence. There is no lack of demand for British products, mainly due to world shortages caused by the war and the disruption of the industries of many Continental countries, but these temporary conditions will pass. There appear to be two ways in which the foundations of a more enduring prosperity could be laid. The first is a frank acceptance by organised labour of the possibilities of modern labour-saving appliances and a willingness to use them to the full; this is the basis of American industrial leadership. The second is proper utilisation of the scientific ability, which has never been lacking in this country, by ensuring that the advances made possible by investigations in laboratories and research departments are fully applied. To ensure a prosperous Britain both methods are necessary.

The Duke of Edinburgh, in his Presidential address to the British Association, quoted Sir Henry Tizard to the effect that the weakness of this country was not in fundamental research, but in its applications in practice. In a recent book,* Professor F. E. Simon makes the same point. He gives two reasons for the present state of affairs; the first is that "British industrial firms have in the last fifty years largely changed into financial undertakings, being run by financiers and accountants"; the second is that this country is gravely lacking in institutions providing higher technological education. In connection with the first reason he points out that technical and scientific experts are seldom placed in positions of full authority in British industry or the British Civil Service. They are available for consultation by non-scientific boards and directors, but are not themselves appointed to positions in which they can control policy. This matter has been discussed on a number of occasions in these columns in the past. The most hopeful thing to be said about it at the moment is that there are evidences of a change of heart and that the appointment of technical directors is now common, although it is to be feared that in many cases they may be out-voted by the non-technical.

It is generally admitted that in pure science this country need fear comparison with no other, but the point has frequently been made that the results of scientific work have not been applied in practice to the extent they might have been. Professor Simon quotes the well-known case of aniline dyes and states that "More recently the production of penicillin has also been allowed to slip out of our hands." He admits that the attitude of industry towards science and scientific research has improved somewhat as a result of lessons learned during the war, but contends that matters are still far from satisfactory. Although the many research departments and associations are having important influences on the general attitude of industry towards research it is probable that, for many years, industrial firms will continue to be largely controlled by "financiers and accountants." It would not be possible, or, perhaps, desirable, to turn these people into scientific men, but it would be of great value if in some way they could be instructed in the scientific point of view. Professor Simon quotes a scientific member of the House of Lords as saying "I am sure if the ordinary scientist knew as little about history and literature as the ordinary arts man knows about science, he would be certified and locked up within a fortnight."

An incident bearing on the same point was given by the remark of a world-famous historian to the

* *The Neglect of Science. Essays addressed to Laymen.* By F. E. Simon, C.B.E., F.R.S. Basil Blackwood, 49, Broad-street, Oxford. [Price 8s. 6d. net.]

effect that his knowledge of the fact that water expanded when it froze, so that ice floated, greatly impressed his own academic circle; it was concluded that he had added scientific to his historical attainments. Professor Simon does not suggest any method by which some rudimentary notion of scientific method can be given to the laity, though his own book is a useful contribution. It is a reprint of a series of articles in *The Financial Times*, which were probably read by many non-scientific people. The suggestion has been made, though he does not mention it, that a useful idea of the broad principles of science might be given to arts undergraduates by requiring them to study the elements of some scientific subject during their first two years. It has, of course, always been the purpose of the British Association to spread a knowledge of science more widely, and it is stated that 4,000 people attended the Edinburgh meeting; unfortunately, they were probably mostly the converted. The relative appeal of science to the general public, as compared with some other matters, is illustrated by the fact that 250,000 people are expected to attend the Festival of Music and Drama.

The ill effect of the ignorance of scientific matters of many non-technical boards of directors has possibly been somewhat overstated by Professor Simon; research departments are now a common feature of British industry. The second reason which he gives for backwardness in the commercial application of scientific advances probably has more substance. The advertisement columns of this journal and others furnish evidence of the demand for scientifically-trained engineers, and the reports of research asociations frequently refer to the difficulty met in recruiting technical staff. Professor Simon's explanation of this state of affairs is that there are not enough educational institutions. Various committees have reported on this matter, but he considers that their recommendations fall far short of the requirements. He states that "the latest lukewarm report of the Advisory Council on Scientific Policy is very disturbing . . . the setting up of one or more new Institutes of Technology is obviously regarded as too big an undertaking."

The type of foundation to which Professor Simon refers is represented by the Zürich Technische Hochschule, the Institute of Technology at Delft, and various institutions in America, such as that at Massachusetts. He thinks that the nearest approach to an institute of this kind in the United Kingdom is the Imperial College in London. The Zürich Hochschule has nearly 100 full-time professors, about the same number of associate and assistant professors and 150 assistants for an undergraduate body of roughly 2,000. The position of this country is "now similar in many ways to that of Switzerland" and in view of the relative populations "this country ought to possess ten 'Zürich' institutes." Professor Simon is quite satisfied with British universities and their scientific departments; what he is calling for is more technological education. In pure science, we are behind no one, but for its application we are short of trained men. Illustrations of the value of a plentiful supply of scientifically-trained technologists were furnished by the remarkably quick development of methods for the manufacture of the atomic bomb, and the large-scale production of penicillin, in America. Another point put forward is that scientific workers are not paid adequate salaries in this country; there has been an improvement recently in the universities, but it is stated that research workers are still underpaid. It may be contended that Professor Simon's aims are impossible of attainment owing to the financial issues involved, but this is entirely a matter of a sense of proportion. The question is whether enormous State expenditure on social services and Government offices is a better insurance for the future than the proper cultivation of the scientific ability latent in the country.

ELECTRICITY SUPPLY IN SOUTH AFRICA.

In the latest report* of the Electricity Supply Commission of South Africa it is stated that "the problem of power shortage is world-wide. Besides the war losses, the world went short of normal replacements during the years when every major country's energies and resources were concentrated on the manufacture of arms. At the war's end, time was needed for reconversion from war to peace production, and now production is retarded by a 'partial reversal of this process, caused by the rearmament of the great Powers and the consequent shortage, for industrial purposes, of plant, labour and materials.' The universal shortage of power has a cumulative effect: for instance, power cuts in the United Kingdom affect the manufacture of plant for South Africa." It is clear that the present international situation is having an unfavourable effect on non-military activity, though, as far as the United Kingdom is concerned, it does not appear that the arms programme is responsible for the power shortage which is affecting industry and the public generally. Shortage of generating plant has been an acute problem ever since the termination of hostilities.

The statement in the report that "the problem of power shortage is world-wide" suggests that this country is not the only one in which influences other than military preparations are responsible for delays in the provision of adequate power services. How far these influences may operate in South Africa it is not necessary to consider here, but, as that country is dependent on Britain for a major part of its power plant, conditions here are at least partly responsible for the situation there. In January, 1943, Mr. Churchill, then Prime Minister, circulated a note to the Cabinet on the subject of promises about post-war conditions. He stated that a dangerous optimism was growing up about the conditions it would be possible to establish after the war and wondered "whether we are not committing our forty-five million people to tasks beyond their compass, and laying on them burdens beyond their capacity to bear."† Subsequent events have justified Mr. Churchill's fears, and the "dangerous optimism" which has led to attempts to introduce all the amenities which were so glibly promised by politicians has created a situation in which doubts must arise about how long the country will be able to afford some of those that it has actually achieved.

Apart from these doubts, the "dangerous optimism" has led to a slackening of effort at a time when it should have been intensified. Reduction in the hours of work, and the payment of wages at levels having little relation to the value of the services rendered—in short, a policy of more money for less work—have created conditions with which the people of this country are only too familiar. It has no doubt had effect in a number of other countries, but referring only to South Africa, with which this article is primarily concerned, it is partly responsible for the fact that new connections in the Rand undertaking of the Electricity Supply Commission may be refused until more plant becomes available, and that restrictions in supply which have operated in connection with the gold mines since 1949 have been extended this year to all classes of consumer.

An aspect of the situation created by present policy is illustrated by the fact that the 424,000 kW of plant installed in the Klip power station of the Rand undertaking up to, and in, 1940, cost 15·4*l*. per kilowatt, but the 150,000 kW of plant planned for the new power station at Vierfontein, which is being built to serve the new goldfields in the Organe Free State, is estimated to cost 55*l*. per kilowatt. The South African pound was devalued in September, 1949, but this in itself is not sufficient to explain a considerably more than three-fold rise in costs, especially as sterling was devalued in the same month and the greater part of South African electrical plant is purchased in this country. The rise in the cost of raw materials, which is one of the items responsible for the rise in the cost of manufactures, is basically determined by labour charges, which have risen in many countries without output correspondingly increasing. The report does not give any particulars, but it states that even a moderate-sized power station cannot be completed in less than four to five years. This condition also rules in Great Britain and is again a function of labour productivity. Whether the standard of living which is being aimed at, and the material equipment on which it must be based, are attainable under present conditions the future will show, but it seems possible that people generally are being set "tasks beyond their compass."

The report of the Commission presents abundant evidence of the energy with which it is facing the problem which it has been set. The particular service with which it is concerned is both an amenity to the public generally and a necessity to modern industry, and if attainment of the standard of living which appears to be aimed at in most parts of the world is not achieved in South Africa the fault will not be with those responsible for the activities of the Commission. Its work covers the operation of eight undertakings. Some of these are contiguous and electrically interconnected, but six areas completely isolated one from the other are served. The nearest points on the Cape Western system, which covers an area in the neighbourhood of Cape Town, and the Border undertaking, serving the hinterland around East London, are more than 300 miles apart. Kimberley, the centre of the Cape Northern undertaking is 340 miles from East London. From the point of view of output the Rand undertaking, which in 1950 carried a maximum load of 939,000 kW, is by far the most important system. A major part of the output of this undertaking serves mining properties and there is also a heavy compressed-air load. In 1950, 573 million units were supplied to the Rand system from the Witbank undertaking which adjoins it. The other important systems are the Natal Central and the Durban. These are contiguous, the Durban undertaking serving the coastal area and the Natal undertaking the inland district extending up to and into the Orange Free State. The Sabie undertaking is a small hydro-electric system serving isolated mining properties in the north of the Transvaal.

Particulars about the output and performance of the 25 power stations owned by the Commission must be sought in the report. These comprise 13 steam stations, 5 Diesel stations and one hydro-electric station supplying electric power and 6 compressed-air stations. By far the largest steam station is Klip, with 424 MW of plant. The largest Diesel station is Port Shepstone, which contains four sets of a total capacity of 3,400 kW. Sabie, the only hydro-electric station, is equipped with three 450-kW sets. The aggregate installed capacity of the Commission's power stations at the end of last year was 1,513,975 kW and the energy being displayed in meeting, or attempting to meet, the demand, is indicated by the fact that plant under erection, or on order, will bring the total capacity up to 2,487,705 kW. Seven new power stations are being built. Without going into details, it may be mentioned that, on December 31, 1950, 29 turbo-generator sets were on order, ranging in size from 15,000 to 60,000 kW.

* *Twenty-Eighth Annual Report of the Electricity Supply Commission for the year ended* 31*st December*, 1950, *with a Brief Review of its Activities up to* 30*th April*, 1951. Electricity Supply Commission, Escom House, Rissik-street, Johannesburg.

† *The Second World War. Volume IV: The Hinge of Fate*, page 861.

NOTES.

RATIONING OF CARBON STEEL.

THE Ministry of Supply has announced that the control of the distribution of the main forms of carbon steel will be introduced on December 3, 1951, and that the new arrangements will be similar to those in operation up till May, 1950. As from December 3, no person will be allowed to acquire carbon steel in the form of ingot, billet, bloom, slab, tinplate or sheet, bar, plate, angle, round, sectional material, rail, sleeper, hoop, strip, tube, pipe, tyre, axle, wheel, blocks for forging or pressing, colliery arches, pit props, spring material, wire rod, wire, wire rope and wire strand, unless an "I.S. authorisation" has been obtained. These authorisations will be issued to firms to acquire specific quantities of steel for specific purposes. The authorisation will allow firms to acquire the steel direct or permit their sub-contractors to purchase steel to fulfil sub-contracts. These arrangements do not apply to building and civil engineering firms, who will receive a notice from the Ministry of Works giving them instructions on how to apply for the steel they need. Firms who, formerly received I.S. authorisations will shortly be asked by the appropriate department to send in applications for allocations of carbon steel. Ministry of Supply regional controllers will ask firms who formerly received I.S. authorisations from regional offices to apply to them. Steel-using firms, with the exception of sub-contractors, which will be requiring carbon steel and have not had an authorisation previously, should make application early in September. If the requirements are for more than 25 tons of steel a quarter, the firm should apply to the department with which it normally deals on matters of production. If the firm uses 25 tons, or less, a quarter (including not more than 10 tons of sheet), it should apply to the Ministry of Supply regional controller. I.S. authorisations will not be needed to buy small quantities of carbon steel (one ton a quarter, or less, according to the form of the steel). Iron and steel stockholders will need licences to acquire controlled types of steel for re-sale. A further announcement will be made concerning the distribution of alloy steel, but the present arrangements for controlling the distribution of sheet steel, tin-plate, terne plate and black plate will remain unaltered.

COMMEMORATION OF THOMAS NEWCOMEN, 1663-1729.

Thomas Newcomen, the inventor of the reciprocating steam engine, was born in Dartmouth, Devon, in 1663. He came of a Lincolnshire family, but his grandfather, the Rev. Elias Newcomen, had been presented in 1600 to the living of Stoke Fleming, a few miles from Dartmouth, and thereafter the family (or that branch of it) made Devonshire their home. Thomas is said to have been apprenticed to an ironmonger in Exeter, though no documentary evidence of this statement is known to exist; but it is known that he set up in business as an ironmonger in Lower-street, Dartmouth, and there he developed his steam engine—or, more strictly, atmospheric engine—the earliest known example of which was set to work in 1712 near Dudley, Staffordshire. He died in 1729, in London, and was buried in Bunhill Fields. Until 1929, there was no memorial to him in his native town or elsewhere, but in that year, as a result of efforts by a local committee, supported by the Newcomen Society and by the Devonshire Association, a memorial was erected in the Town Gardens at Dartmouth. It consists of a block of Dartmoor granite, bearing a plate with an inscription, and beneath it another on which is engraved a representation of a Newcomen engine. Annually, thereafter, a chaplet of laurel was laid upon the memorial, at the instance of the Newcomen Society, on August 5, the anniversary of Newcomen's death; but the local committee of commemoration was disbanded a number of years ago and the ceremony seemed in danger of losing its meaning for many of the younger townsfolk. Recently, however, through the activity of a resident, Mr. Percy Russell, F.S.A., steps have been taken to reconstitute the committee and to bring the annual ceremony into greater prominence; and this year, on August 16 (the eleven days "lost" from the calendar in 1751 having been added to the date, to keep it clear of the August Bank Holiday) the collaboration of the Dartmouth Rotary Club was obtained to bring the event into greater prominence. In the presence of the Mayor (Alderman A. M. W. Chapman), the President of the Rotary Club (Councillor F. C. B. Kirk), Mr. B. Magenis (secretary of the former Newcomen Memorial Committee, to whom the erection of the memorial was greatly due), and a number of guests, the chaplet was deposited by Mr. J. Foster Petree, a vice-president and President-elect of the Newcomen Society, after which the party proceeded to the Yacht Hotel, where they were the guests of the Rotary Club at luncheon. This was followed by an address on the economic consequences of Newcomen's engine, by Dr. W. G. Hoskins, reader in economic history at the University of Oxford. Mr. Petree then outlined the circumstances which led to the formation of the Newcomen Society in 1921, and the researches subsequently carried out by the members of the Society in the history of engineering in general and the Newcomen engine in particular. Mr. Percy Russell, in thanking the speakers, said that active steps were being taken to put the annual commemoration of Newcomen on a formal basis, adding that the Mayor had expressed his intention to call a meeting in the autumn, to discuss the formation of a standing Newcomen Committee.

INTERNATIONAL SYMPOSIUM ON ABRASION AT DELFT.

We have now received from the Rubber-Stichting, Delft, Holland, the detailed programme of the International Symposium on Abrasion which, as previously announced, is to be held from November 14 and 15 in the new building of the Rubber-Stichting, in the Oostsingel, Delft. The Symposium will be opened on the morning of Wednesday, November 14, by the President, Dr. Ir. R. Houwink, who is Director-General of the Rubber-Stichting ("Rubber Foundation"), and the Director of Research, Dr. H. C. J. de Decker, as secretary of the organising committee, will present various communications. Papers will then be delivered by Dr. F. B. Bowden, reader in physical chemistry at the University of Cambridge, on "The Friction of Solid Surfaces" and by Ir. H. Blok, research chemist in the Royal Dutch-Shell Laboratory at Thornton, Cheshire, on "Principles of Wear Prevention." The members will be entertained to luncheon by the Rubber-Stichting, after which there will be a demonstration of apparatus for the measurement of abrasion and wear. In the afternoon, two more papers will be presented, these being on "The Chemistry of Wear," by Professor Ir. J. J. Broeze, Director of Research, Royal Dutch-Shell Laboratory, Delft; and on "Morphological Aspects of Abrasion and Wear," by Dr. Ir. G. Salomon, of Delft. On Thursday, November 15, the morning session will be devoted to two papers, namely, "Abrasion and Wear of Rubber," by Mr. J. M. Buist, of the Rubber Service Laboratory of Imperial Chemical Industries, at Manchester, and "Studies in the Abrasion of Rubber," by Dr. A. Schallamach, of the British Rubber Producers' Research Association, Welwyn Garden City. In the afternoon, Dr. N. A. Brunt, of the Paint Research Institute, Delft, will present a paper on "The Abrasion Resistance of Paints," and Dr. R. D. Stiehler, Chief of the Testing and Specifications Section of the United States National Bureau of Standards, will contribute one on "Some Factors Influencing the Road Wear of Tyres." Dr. Decker will then present a general survey of the symposium, which will be formally closed by Dr. Ir. Houwink. A programme of excursions, mainly to industrial and Government laboratories, is to be arranged for the two following days, but particulars of these are not yet available. Forms of application to take part in the symposium may be obtained from the secretary, at the Rubber-Stichting, Postbox 66, Delft, and the completed forms should be returned not later than September 30. It is pointed out that the number of participants must be limited to 150; it is our intention, however, to reprint the papers in ENGINEERING as soon as possible after the symposium.

THE "MODEL ENGINEER" EXHIBITION.

The *Model Engineer* Exhibition opened at the New Royal Horticultural Hall on Wednesday, August 22, and will remain open daily from 11 a.m. to 9 p.m. (Sunday excepted), until Saturday, September 1. The opening "ceremony" was unusual in that it was performed by a radio-controlled model, 4 ft. long of a Churchill tank, constructed by Mr. A. T. Tamplin, of Birdham, Chichester: it will respond to 16 different radio "orders," and inaugurated the exhibition by bursting through a large poster screen. A message from the Rt. Hon. Winston Churchill, which was read, contained the statement that "Model engineers play a part in our industry in war and peace, and help to preserve our heritage of craftsmanship," the concluding claim in which is amply demonstrated by the models displayed. The entries seemed to be rather less numerous than in some former years, but there is no diminution in the standard of workmanship, which reaches levels that few professionals could improve upon. Having remarked, in connection with a previous exhibition, on the rarity of models of Cornish engines, we were pleased to note a good example, the work of Mr. R. F. W. Jarvis, of High Wycombe. Ship models, which are numerous, run much to type, but it is notable how many are now radio-controlled. A model of some historic interest is one of the Great Eastern, lent by the Telegraph Construction and Maintenance Company; it is claimed to be over 100 years old, having been made before the ship was built. She was laid down in 1853. Another loan exhibit is an ingenious engraving machine. The most numerous section of competition entries is that of "sailing models of any period," in which there are 35; the next largest, small locomotives and rolling stock, etc., and working model steamers, have 28 each. There are some striking exhibits on the stands of various clubs; and, in the trade section, some notable displays of machine and hand tools, and of work. Of particular interest, too, are the demonstrations of craftsmanship in action, including practical blacksmithing. Finally, mention may be made of the large tank, in which radio-controlled boats, and one that is sound-controlled, are periodically exercised; and a motor-racing track, on which scale-model Grand Prix cars are operated, three at a time.

THE "AMERICA" CUP.

A nautical centenary which appears to have escaped the attention of entrants in the competitions of the *Model Engineer* Exhibition, mentioned above, is that of the yachting "classic," the original race for the America Cup, in August, 1851. The schooner yacht America, of 170 tons, and designed on the general lines of the Sandy Hook pilot boats then in use, had crossed the Atlantic under sail earlier in the season and, against what seems to have been a not very skilful opposition, carried off a 100*l*. cup offered by the Royal Yacht Squadron for a race round the Isle of Wight. The syndicate of American yachtsmen who owned the America presented the cup to the New York Yacht Club, some six years later, as an international challenge cup. In the hands of that Club it has remained, in spite of repeated attempts to win it back; and appears likely to remain until either the rules governing competition for the cup are altered materially, or British taxation policy is amended drastically to enable a class of wealthy amateur yachtsmen to develop again. The America was designed by George Steers and built by W. H. Brown; well built, evidently, because she sailed in later years to the Mediterranean and to Australia, was used as a blockade-runner in the American Civil War, was scuttled in a Florida creek, raised, and saw further service as a picket-boat, a training ship for midshipmen, and a patrol vessel. In 1870, she was fitted out as a yacht again, remaining as such for many years; and eventually was roofed over and used as a floating yacht-club house. Now, we understand, she is preserved as a maritime museum. A builder's half-model in the headquarters of Lloyd's Register of Shipping, at 71, Fenchurch-street, London, bears the date August 22, 1851, as that of her historic race; but the authoritative *Memorials of the Royal Yacht Squadron*, by the Hon. Montague Guest, formerly librarian of the R.Y.S., and W. B. Boulton, gives it as August 23.

THE BRITISH ASSOCIATION MEETING AT EDINBURGH.

(*Continued from page* 214.)

Contra-Flow Heat Apparatus.

When the proceedings were resumed in Section G, session A, on Monday morning, August 13, the chair was occupied by Professor R. N. Arnold, vice-president of the Section, who called on Mr. C. E. Iliffe to deliver his paper entitled "Recent Developments in the Methods of Proportioning Contra-Flow Heat-Exchange Apparatus." This paper is reprinted on page 252 of this issue of Engineering.

The first speaker in the discussion which followed the reading of the paper was Mr. J. M. C. Dunlop, who asked whether the method described by the author could be applied to the case of water flowing through the tubes of a heat exchanger with a condensing fluid on the other side. He also wished to know if it were possible to verify by measurements the performance of a heat exchanger of the type discussed and, if so, what form of measuring instrument was used. He had always understood that it was very difficult to measure accurately small changes of temperature in large flows of gases and liquids. Mr. Iliffe replied that the method he had described could not be applied exactly as it stood to the case of a condenser with water on one side and a condensing fluid on the other, even if of the contra-flow type. The calculations he had given were at present being checked in connection with the regenerative type of heat exchanger. A large amount of checking remained to be done on cooling towers, but in the case of the contra-flow recuperator the method had given the thermal ratios actually obtained in practice.

Mr. C. W. Marshall, who followed, said the cooling tower was a feature of the landscape which was not altogether popular nowadays, and it was interesting to note that the area occupied by the cooling towers in many cases was much greater than that required for the rest of the station; but it must not be forgotten that the cooling tower rendered great service to the country in making it possible to build reasonably efficient generating stations near the load. The situation of the cooling towers was a matter of great concern to the people living near the generating station. It had been found that the specific volume per unit of heat dissipated was very variable, and it had soon become apparent that but little fundamental study of the thermodynamics of cooling towers had been made. In the examination of the problem, however, a theory of cooling had been evolved which had enabled tests to be made under any weather conditions. In his view, the next important point was that the velocity of the air passing up through a tower varied from zero at the circumference to a maximum at the centre; there might be two maxima, due to the form of construction. His colleagues hoped to publish a paper which would, at least partly, remove the existing ignorance on cooling towers. They had been examining the question of the use of the splash bar and had come to the conclusion that the cooling should be done entirely by film.

In replying, Mr. Iliffe said that with regard to the area occupied by cooling towers, he believed the old wooden towers passed about 80 gallons per square foot per hour and that the concrete towers now passed nearly double that amount. Consequently, the latter occupied a much smaller ground area. On the other hand, the height had increased. He agreed with Mr. Marshall that film-type cooling was preferable to drop-type cooling, but pointed out that drop surface was cheap, whereas film surface was expensive. Tests were being made on cooling towers, but we still lacked for the splash type the data available for the film type, which had recently been dealt with thoroughly by Carey and Williamson. They had tested particular types of splash bars, but it was difficult to say what the optimum arrangement of bars would be; but a start had been made. With regard to wasted space, presumably Mr. Marshall had in mind that a tower might be 200 or 300 ft. high and that the water entered at a height of 30 or 40 ft. above the ground. He supposed that was inevitable in the case of the natural-draught tower, but more consideration should be given to the use of the forced-draught tower, which would be smaller.

Mr. S. Weinberg, who continued the discussion, said that in heat-transfer apparatus fixed temperature differences were usually involved, and he did not think enough consideration had been given to the possibility of largely increasing heat-transfer coefficients. In conventional heat-transfer apparatus, such as that using water, and in the cases of steam and hot-gas cycles, speeds of a few feet per second were generally considered in the first case and of perhaps 100-200 ft. per second in the second case; but a new field had been opened up in the study of the enormously high-speed injection engines in rockets, combustion turbines, and so on. In those cases, gas speeds could reach 4,000 or 5,000 ft. per second, and great quantities of heat had to be transferred across a comparatively small area of a correspondingly small bulk. It would be interesting to know how the first two equations of the first group the author had given should be combined so that, as the speed increased, the relative importance of one or other of the dimensionless groups became less and less in favour of one factor, such as the friction factor. It was known in practice, without recourse to the latest heat exchanger in use, that steam nozzles in turbines which had seemed to be going up to Mach numbers of perhaps $1\frac{1}{2}$-2 could apparently lose something like 10 per cent. of the initial energy in a manner which was associated with heat transfer through the walls. It would be interesting to hear what the author had to say about the possibility of using very high speeds and correlating the dimensionless data to produce heat-transfer coefficients sufficiently large to avoid that trouble. In power-station apparatus, one of the limitations was fouling and it would be necessary to use a fouling factor which became increasingly significant at times of cleaning, for instance. He asked how it would be possible to use a method of design in which the overall heat-transfer coefficient was a combination of several factors, one of which was a compromise.

In reply to Mr. Weiner, Mr. Iliffe said he could not discuss the question of high gas speeds if supersonic effects, etc., had to be considered, but the heat-transfer and friction factor would hold for very much higher speeds than were used in heat-exchange apparatus. He referred to the contra-flow recuperator, and said the purpose of the method he had outlined was to find precisely what was the best speed to give the most economically suitable heat exchanger. The speed was automatically taken into account in solving the equations and getting the optimum value. The problem of fouling presented a wide scope for research. It was a very important point; but so far as the gas turbine was concerned, even if it did foul, it was very easily cleaned. The lengths of the parts were small and in the disc type only measured an inch or two; they could be cleaned quickly by air.

Mr. W. W. Campbell, discussing the economic proportioning of heat-exchanger surfaces, said it might be taken that for a given plant performance, η and λ were fixed. When there were variations of the constants considerable arithmetical work was involved. That was the approach adopted some years ago when designing steam condensers; and there was an almost legendary account of the number of calculations made before the Hams Hall cooling towers were designed. There was an alternative approach, consisting of partial differentiation of an expression for the total cost, including costs of variations in efficiency and coal consumption, in surface, in pumping power, in pressure loss, and so forth, partially differentiating the whole and dealing with the system of differential equations. That approach, in the case of steam condensers, was dealt with very fully in Bottomley's classical paper in 1942, and there was no reason why the same approach should not, *mutatis mutandis*, apply to other forms of heat-exchange surface. The cooling-tower issue was extremely complex, especially in the case of the natural-draught tower, which involved, to a very large extent, a meteorological problem. So far, it had not been possible to use some of the meteorological analytical methods owing to lack of data. The official tests on cooling towers were now fairly elaborate and maybe more reliable. They were quite complicated, involving the assistance of a good number of men, as well as inconvenience to the contractor and to the station staff; sometimes they were made in the middle of the night in order to secure better meteorological conditions. The data slowly accumulating, however, might now provide further information on the design of natural-draught towers than had been available in the past. It should not be assumed that mechanical-draught towers had not been considered. It did not follow that the mechanical-draught tower would solve completely the problem of height, because problems of re-circulation might arise, and in certain cases where mechanical-draught towers had been considered, it had been found necessary to increase the height of the towers considerably to avoid this effect.

Mr. Iliffe agreed that the method of recuperator design as he had described it would lead to the disadvantage Mr. Campbell had mentioned. He had adopted that method because it was the simplest, and also because it corresponded to the published data, so far as he was aware. He knew of the alternative partial-differential method, but he had never considered adopting it because, when using a method which was satisfactory, there was no particular reason to change; there were more important things to do. It did not surprise him that the economics of the forced-draught tower had been worked out, though he had not seen anything published on the subject; but the question of height needed to be looked into seriously from the point of view of the amenities of the locality. He had had practically no experience with forced-draught towers, but thought that re-circulation could be avoided more easily by the use of induced-draught. If the height of towers could be reduced considerably, even if not as much as had been hoped for, it was well worth while.

Dr. Ezer Griffiths, O.B.E., F.R.S., raised the question of full-scale experiments; and, in regard to instrumentation, said he understood that the author had had difficulty in measuring small temperature differences. He asked what the difficulty was. Mr. Iliffe replied that full-scale experiments had been carried out on many forced-draught towers, but he had not heard of any such experiments on natural-draught towers. With regard to instrumentation, he would not say that the temperature differences were small. The temperature rises involved in measuring the thermal ratio of a heat exchanger were quite large; of the order of 200 deg. or 300 deg. F. The measurement was made by traversing a thermocouple.

Mr. T. D. Patten asked if the author had considered the initial warming-up period, and whether it depended on the heat-conducting efficiency of the metal in the regenerative type of heat exchanger. He also raised the question of the allowance for entry pressure. To this, Mr. Iliffe replied that he had not considered the initial warming up. So far as recuperators were concerned, there were many empirical data on warming up, but he had not made a detailed investigation. To allow for conductivity in the regenerative type of heat exchanger would be entirely complicated. In the type of matrix used to-day, the transverse conductivity effect could be more or less ignored. With regard to longitudinal conductivity obviously, as the length of the material increased, the longitudinal conductivity had more effect; but he believed that in all likely designs the loss due to that cause could be kept below one per cent. In his method, he had allowed for the entry pressure; he took it as a number of velocity heads. Schmidt had introduced a factor, but the speaker was not clear whether it was meant to cover entry loss.

No other member wishing to speak, the Chairman closed the discussion, with a vote of thanks to the author.

Heat Transfer during Condensation of Steam.

He then called on Mr. A. Hampson to present his paper on Heat Transfer during Condensation of Steam, which we reprinted on page 221 of our issue of August 17. After delivering the paper, Mr. Hampson showed a cinematograph film which illustrated in a very effective manner the development and coalescence of drops in drop-wise condensation and also showed the effect of the addition of solvent "promoters."

The discussion which followed the reading of the paper was opened by Mr. S. Weinberg, who said the general object of studying heat transfer during condensation was a negative one; what we were really interested in was how little of the metallic area we needed to cover the condensation. In design, we required to know how much of the metal surface was free from condensation, and we could then assess roughly the total heat transfer. To that end it would be better to have large hemispherical drops rather than small ones. It seemed that the use of a solvent promoter which reduced the local surface tension would tend to defeat the object by producing small drops rather than large ones. He believed the drops formed suddenly at a definite size, and that microscopic study at a great magnification would reveal that they did not become infinitely small. He asked why the promoters which had been used all tended to reduce the surface tension of the water. To this, Mr. Hampson replied that the principal operation going on was probably coalescence; it was not known what was formed on the surface; it was desirable to know what happened between the drops. He was afraid, however, that it was not very clear what was going on. His impression was that the process was unstable, and that minute droplets were formed; but he did not think that was of great importance because the operation was so rapid. There was a good deal of heat going through the minute drops; large drops were not wanted necessarily, but tiny drops.

Dr. I. G. C. Dryden spoke on the action of the promoters. We were considering, he said, a soap firmly fixed to the metal surface. As to drop size, the larger drops must be formed from smaller ones. It seemed from the film and the slides shown by the author, that, after 24 hours or so, the effect of a mono-layer was gradually decreased. He asked if that ruled out the use of fatty acids for the purpose, or whether there was a regenerative effect.

Replying, Mr. Hampson said he had tried injections into the steam. There was then a rather long period, of half an hour or more, of excess promoter, in which the heat transfer would balance, so that it was necessary to inject the promoter at the period of no load in the condenser. After the period mentioned, however, there was a gradual recovery and, depending on the fatty acid used, the effect would continue for two or three hours, or more. When using benzyl mercaptan the change from mixed to drop-wise condensation could be fairly rapid; but the benzyl mercaptan had features which were not desirable. It had, however, given ten days' continuous operation on a copper surface.

The next speaker, Mr. J. R. Appleton, said the phenomenon of drop-wise condensation had been known for a number of years; it was referred to about 20 years ago in some work initiated by Professor Gerald Stoney. The author had not mentioned the method of calculating the actual coefficient of heat transfer. Reference had been made to the rates of the water flowing down the plates as being much in excess of that over the bottom tubes of a condenser. Surely, he said, at the bottom of the condenser the amounts of water falling would be considerably in excess of the water running off the plate. He believed it was 20 to 30 in. per hour, which must in effect give, with the flooding of the falling water from the higher tubes, something like film condensation at the bottom. Obviously, drop-wise condensation was not the whole point in a steam condenser. Guy and Winstanley had obtained various values of heat-transfer coefficients from selected tubes in a steam condenser, and their results ranged from something like 2,000 down to almost zero, although the figures could never go down to zero; but he believed the actual temperatures used were not correct. Finally, he felt that the boilers, or steam generators, would suffer from the injection of promoters; there would be drop-wise evaporation on the boiler tubes, which he did not think would be desirable, apart from any chemical reactions that might take place.

Mr. Hampson replied that the effect of drop-wise condensation was noted by Spoelspra, in the first case, even earlier than the work of Professor Stoney. The calculation of heat transfer coefficients required the measurement of the temperature drop on the steam side, i.e., from the actual surface of the metal plate to the body of steam across it; for the steam there was an automatic check between pressure and temperature. It was only possible to measure the plate temperature slightly below, say, 0·020 in., the surface, and estimate the surface temperature from that. If the surface were interfered with, its nature would be changed. The heat-flow rate could be obtained from the water side or steam side and the check between the two varied by less than 2 per cent. The effect of a non-condensable gas was shown in Fig. 8, and it could be seen how serious it was. He wished to point out that with 0·1 per cent. of gas in the steam, and with drop-wise condensation, the surface coefficient was still three or four times what it would be for film-wise condensation. About the heat-transfer coefficient of the tubes of the condenser, he said he had not the faintest idea. There were many effects which were quite intangible. In regard to practical applications, he agreed that appreciable quantities of oleic acid would be undesirable, but he did not think the small quantities he had been using would give rise to much trouble; the quantities required were minute. If, however, a promoter was used in the boiler water there would be film-wise evaporation, which was undesirable; what was wanted was nuclear boiling.

Mr. W. W. Campbell asked whether it was possible to determine from the change of volume of the drop the amount of heat transferred in a particular time; to which Mr. Hampson replied that he and his colleagues had tried to do that four or five years ago, but the results had not been satisfactory. They had worked first with a horizontal plate, but with drops on a vertical plate they could not achieve the necessary accuracy.

No other member wishing to speak, the chairman closed the discussion, with a vote of thanks to the author, and adjourned the meeting.

HIGH-VOLTAGE POWER TRANSMISSION.

In session B, where Sir Claude Gibb presided, two papers were read on electrical engineering subjects. The first of these was "The Development of High-Voltage Power Transmission with Particular Reference to Hydro-Electric Projects," by Mr. T. G. N. Haldane, which will be found reprinted on page 249 of this issue of ENGINEERING. Mr. Haldane having delivered his paper, the chairman, after referring to the many points of importance in it, called upon Sir Harold Hartley, K.C.V.O., to open the discussion.

Sir Harold said he was not qualified to discuss the details of the rival techniques which the author had described but he felt strongly about the future importance of transmitting large blocks of power because, as he hoped he had made clear in his Presidential Address the previous year, the world's future depended more on supplies of energy than on any other single factor. The potential water power in the world was roughly equivalent to the total world consumption of energy to-day, but only a small proportion of that water power was being tapped. The rising costs of fuel and its limited supply gave added importance to the need for utilising fully hydro-electric power in the future. As the author had stated, a large proportion of the available water power was at very great distances from what seemed likely to be centres of consumption, and although in Britain the prospect of requiring to employ direct current transmission might be small, from the points of view of its probable importance in the world as a whole and the future of Britain's export market, the subject merited careful study.

The chairman said he believed that a consumption of electricity in Great Britain equivalent to five times the level of present production would still not amount to demand saturation. The fact that Britain was short of energy, whether it be from coal, coke, gas, electricity or petroleum, was the most certain indication that the standard of living had increased since before the war, and the one thing that had not kept pace with the improvements in the application of electricity and power generally to the service of man, to increases in productivity, and to improvements in the standard of living, was the output of fuel. He foresaw a glum future, at least for the next ten years, and, unquestionably, every possible alternative source of power should be utilised. This would inevitably involve the use of long-distance extra-high-voltage transmission.

Professor R. O. Kapp said that the author had produced a paper which all those concerned with transmission would welcome, cherish, and refer to frequently. It was impossible to criticise the matter but attention might be drawn to a point that was implicit and might be of interest, namely, the limitations on long-distance transmission. Those who had grown up with the lower voltages tended to believe that if one required to increase the distance one increased the voltage. That might be said to be the result of thinking in terms of direct current, but, with alternating current, one reached a limit, which at 50 cycles per second was 930 miles, and then ran into another set of difficulties. It was wrong to believe that greater distances could be reached merely by increasing the voltage, or by changes in the line construction. The two limiting factors at long distances were what was known as the Ferranti effect, namely, the rise of voltage on switching off, and the phase displacement between the ends of the lines, the theoretical limit of which was 90 deg. Both these could be shown to be functions of distance, frequency, and the velocity of light, over which one had no control! The author had mentioned that one reduced the line reactance by using a multiple conductor; it was worth remembering that if one increased the capacitance, the product of the two, which was a pure function of the velocity of light, was not affected. That was inescapable and that was the reason why, if, in addition to increasing the voltage, one wished to increase the distance beyond, say, 400 or 500 miles, there was nothing for it but frills like shunt reactors and series capacitors.

Mr. Winfield said that the consumption of the earth's resources had proceeded on a "plum" policy, but the plums had now largely gone. Every year, power was having to be sought farther away and it was well known that it must be handled in larger blocks than before for reasons of economy. The cost of transmission was the major issue in any development of water power. In alternating current transmission the cost per unit had to be kept down and, in consequence, the transmission voltage had been pushed up over the past 60 years until at present nearly 400 kV had been reached and the authorities now saw themselves being caught in the toils. At those higher voltages, costs were rising very steeply and it was becoming difficult to keep down the cost per unit. The lines, as they stretched further, in effect became of reduced capacity, so that not only did the cost per mile increase but the capacity was less. Some compensation was possible, but it generally amounted to expedients designed to keep the line capacity up. What lay ahead, therefore, was still larger schemes at still greater distances with the costs of transmission per unit tending to rise all the time, and he could not see any easy solution. With the rising cost of coal some of the dams were now becoming "plums" but most of the plums in water power throughout the world had been worked out.

Direct-current transmission was, therefore, of great importance but it could not be considered for small plants owing to the heavy cost of the terminal equipment. Furthermore, over small distances, direct current could not complete with alternating current. For long distances, however, direct-current transmission offered an inherently cheaper line without many of the disadvantages of alternating current. In the field ahead, therefore—that of larger outputs at greater distances—it appeared that direct-current transmission could help to keep down transmission costs and assist the development of water power. He did not think anybody could say with certainty if it could be done, but the Swedes, Germans and Swiss, in particular, had been working on the problem for ten years or more. Britain lagged behind, probably owing to the war, and had gone into the matter only during the past three or four years, but it could be said that in all four countries transmission engineers had reached the stage where they agreed that they saw no technical difficulties in direct-current transmission which could not be surmounted by an extension of the present methods, and were satisfied that, so far as preliminary estimates could show, direct current had economic advantages compared with alternating current. On the other hand, they were all agreed that much costly development was required before it would be possible to proceed on a large scale. They could try out the scheme on a small scale but could not be certain of the validity of the conclusions until they had experimented on a large scale. The position had been reached where the world demanded that they should prove or disprove the case for direct current, but that required a lot of money.

The underground cable had many possibilities, of which Mr. Haldane had mentioned a few, such as crossing the Channel, and in the last few weeks he had heard of an enquiry from Canada in a similar connection. In Eastern Canada there was no coal readily obtainable and it was impossible to import coal owing to the cost. The Canadians, therefore, were looking to the Hudson Bay coal, many miles away. Recently, it had been pointed out that the transmission lines could be shortened considerably by cutting across the Hudson Bay, and the Canadians had asked if a direct-current scheme was practicable. Similar examples could be found in many parts of the world. Furthermore, the power stations in the Thames estuary were becoming saturated and economic considerations were forcing the authorities to consider burning coal in the Midlands for London and transmitting something like 1,000,000 kW overland. That would be all right until 1960, but by 1970, 5,000,000 kW would be required and there would be considerable opposition to overhead lines. The alternative to unsightly overhead lines was a cable. There was undoubtedly a clear case for making investigations into direct-current transmission but money was required.

Mr. T. Lawrie said he felt sure that everyone present shared the doubts expressed by Mr. Haldane about the prospect of getting enough coal in the future, but it should be emphasised that one of the obvious ways of saving coal was to electrify more and more. If the thermal efficiency of power stations were increased from 20 per cent. to 25 per cent. they would give double the amount of power for very much less than double the amount of coal. If the extra power were put to good use in factories it would provide a more efficient form of power than at present, and there would be a further saving because fewer factory chimneys would be belching black smoke as a result of the incomplete and inefficient combustion of coal. If the railways were electrified, it would probably save 9,000,000 tons of coal a year, and if the coal mines were electrified it might save a further 6,000,000 tons. These were substantial amounts, not perhaps in the coal budget of the country as a whole, but at least in the budget of the electricity industry, and if, in the next few years, the supply industry could show such great savings in coal consumption, there need be no apprehension about the construction of the power stations which were so greatly needed.

Mr. A. Feiner expressed the view that there was an increasing probability that instead of having to take the power to the people it would be necessary to take the people to the power. Dealing with the question of line-charging capacities, particularly with very high alternating voltages, he said that one of the difficulties facing the designer of a water-turbine generator was the production of stable line-charging currents at limiting power factors, and he would welcome some information on the line charging capacity per mile of a 275-kV or 375-kV single circuit system as compared with one of 132 kV. Secondly, he had been associated with alternating current convertors for some time and he assumed that an invertor would be used for transforming direct into alternating current but, at one time, the difficulty of inverting had been considerable and he would like to know if that had been overcome.

Mr. C. Cherry said that Mr. Haldane had not mentioned the possible influence that recent research on materials of high dielectric constant and high dielectric strength might have on transmission in the future. He asked if such work might not be of great assistance in the transformation of direct-current and if the use of such materials might not affect the design of high tension transmission lines?

Mr. Haldane, in his reply, said he entirely agreed with Sir Harold Hartley on the extreme importance of ensuring supplies of energy and, therefore, on the importance of direct-current transmission in order to make available the more distant energy resources. His only comment on Mr. Winfield's remark on the great importance of pushing ahead with research on direct-current transmission in this country was that the canalising of research was highly beneficial. If one started off without a clear idea of what one wanted to achieve progress was likely to be slow. That was why he wished to concentrate efforts for the time being on the definite idea of getting interconnection with the Continent. Sir Claude Gibb had referred to the coal shortage, and with that he agreed wholeheartedly, being convinced that Britain was on the verge of a really acute coal shortage which would present a far worse problem than the present shortage of generating capacity. However, the 275-kV grid which the British Electricity Authority were about to develop would have an important effect not only in meeting the shortage of generating plant but also in connection with the coal shortage, because it would enable generation to be concentrated in the highly economic stations. In that way surprisingly large quantities of coal would be saved. Mr. Haldane also thanked Professor Kapp for his complimentary remarks on the paper and for drawing his attention to the limitations on long distance transmission. He could not agree with Mr. Lawrie, however, that greater electrification was going to solve the coal shortage problem, although he thought the speaker had probably not intended to imply as much. His own view, after trying to assess the probable shortage in 1961, was that after taking into account the possibility of a certain amount of new electrification, the electrification of the coal mines, and power stations achieving higher thermal efficiencies, the consumption of coal for generation purposes was going to be far higher than was generally thought and certainly higher than the CoalBoardthought, and there would be a shortage of coal. He could not answer Mr. Feiner's question about the charging capacity offhand and could only say it was very high. He agreed with Mr. Cherry about the importance of research on materials of high dielectric constant.

The chairman thereafter proposed a formal vote of thanks to Mr. Haldane, which was carried with acclamation.

(To be continued.)

ENGINEERING IN THE FESTIVAL OF BRITAIN.*

X.—SCIENTIFIC EXHIBITS IN THE DOME OF DISCOVERY AND SCIENCE MUSEUM.

THE exhibits in the Dome of Discovery at the South Bank Exhibition have been selected to illustrate the general theme that an outstanding trait in the British character has always been initiative in discovery and invention. This task they perform sufficiently well, although it may be wondered whether their large number and great variety may not cause the wood to be obscured by the trees. The story is told in eight sections—the land, the earth, polar regions, sea, sky, outer space, the physical world and the living world, but the allocation of the exhibits to these sections often appears to be a little arbitrary.

On an external podium, in addition to the 275-kV oil circuit-breaker, described on page 696 of our 171st volume (1951), an ancient table engine is exhibited by Messrs. Smith Kendon, Limited, 132, Borough High-street, London, S.E.1. This has been in the possession of the firm for over 100 years and was in operation until three years ago. Modernity is represented by the Railton car on which Mr. John Cobb made the world's land-speed record and by a main undercarriage of the Brabazon aircraft. A Rotaprest head, 12 ft. 6 in. diameter and $1\frac{3}{4}$ in. thick, is exhibited by Messrs. G. A. Harvey and Company (London), Limited, London, S.E.7. This was spun from a flat chrome Colclad disc, 15 ft. 10 in. in diameter and weighing $5\frac{3}{4}$ tons; and is of a type used for the ends of pressure vessels in the oil and chemical industries. An exhibit of engineering interest, which, however, falls outside the classification mentioned above, is the three-dimensional admittance diagram, designed by Mr. D. C. Johnson, Department of Engineering, University of Cambridge. This consists of a graph, which has been constructed to demonstrate the theory that a tuned damper can be used to reduce the torsional vibration of a crankshaft. Since the motion possesses two components, one in phase and one in quadrature with the force, the admittance lines employed become space curves. These components are represented as displacements along perpendicular axes, while a third axis represents the frequency. The graph is constructed for a damper, which is isolated from the crankshaft. The admittance lines for the crankshaft are drawn on a sheet of paper, which is placed beneath the base of the other graph and the admittance of the damper and crankshaft combined, at any particular frequency, can be obtained by measuring the distance between the damper line and the crankshaft line in the plane corresponding to the frequency.

Perhaps the most impressive exhibit in the Dome is the 74-in. reflecting telescope, which is being made by Sir Howard Grubb, Parsons and Company, Newcastle-on-Tyne, for the Mount Stromlo Observatory of the Australian Commonwealth. This instrument is designed on Newton's reflecting principle and is generally similar to that at the Radcliffe Observatory, Pretoria. The star-light in the form of parallel rays passes down a skeleton tube, at the bottom of which is a paraboloidal mirror. It is thus reflected up the tube and falls on a Newtonian flat mirror, opposite which is a holder for a camera or eyepiece where provision is also made for spectrographic examination. By substituting a convex mirror for the flat mirror the light is reflected back towards the base of the tube and through a hole in the main mirror, where it is brought to a focus at the Cassegrain focus. The focus can also be brought to the coude focus just outside the lower bearing of the polar axis.

The main mirror of the telescope is 76 in. in diameter, 12 in. thick and weighs 2 tons. The front face of the glass is hollowed out and was polished to form a paraboloidal surface, which is coated with a film of aluminium. The tube is pivoted on a declination axis which, in turn, is pivoted on a polar axis at right angles to it. To control the steady angular movement about the polar axis, which is necessary to counteract the effect of the earth's rotation, the drive is transmitted through an 8-ft. diameter worm-wheel with 960 teeth.

In the Land Section of the Dome the principal exhibits of engineering interest are a model of the Tekapo power station in New Zealand and of an impulse turbine, both of which are shown by the English Electric Company, Limited, Kingsway, London, W.C.2. Models of a steel bridge for Middle Harbour, Sydney, are exhibited by the Cleveland Bridge and Engineering Company, Limited, Darlington, and of various types of aircraft, including the Viking and the Speedbird Stratocruiser, by the British Overseas Airways Corporation. The exhibits in the earth section are designed to show what has been done by digging, boring, experiment and scientific reasoning to explore the earth's crust and what has resulted therefrom in the way of the discovery and use of metals. The equipment required by those who explore those parts of the earth where the climate is extreme forms the principal theme of both the polar and the sea sections.

In the Sky Section the displays summarise what is now known about the weather and deal with the air masses which envelop the earth and with the three main layers of ionised vapours, which exist at heights between 70 and 250 miles. The process by which these layers are ionised is exhibited, as are their diurnal changes of intensity. Their effect on radio propagation is demonstrated on an animated wall diagram, which shows the way in which the waves become deflected and illustrates skip and other reception phenomena. The effect of sunspots

* 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.

on the earth's magnetic field and the intense convection which results is shown on another model. A complete weather forecasting unit is in operation which indicates how the information obtained with meteorological appliances is collected, recorded and analysed. Illuminated wall maps show the positions of the weather reporting stations in the Northern Hemisphere and illustrate the radio and teleprinter networks over which coded weather reports are sent to the Central Forecasting Office at Dunstable. These maps indicate the positions of the floating meteorological stations in the Atlantic (of which the United Kingdom maintains two) and of other stations where Radiosonde and flight investigations are carried out. In this part of the Dome, there is also a representative collection of present-day meteorological appliances for indicating and recording pressure, temperature and humidity. These include the Radiosonde in which the necessary measuring and telemetering equipment is carried aloft by a balloon. The indications of these instruments during the ascent are translated into electrical signals in the audio-frequency band and are used to modulate a radio frequency transmitter which, in turn, radiates them to a ground station. As a contrast, a model is shown of Merryweather's tempest prognosticator, which was displayed at the 1851 Exhibition. This consisted of glass tubes containing leeches, which were suspended from radial arms attached to a central column. With the approach of certain weather conditions the leeches were supposed to climb the neck of the tube and by their position to act as meteorological prophets.

The Outer-Space Section of the Dome is designed first to illustrate how astronomy is used for the accurate determination of time and then to present a summary of what is known about a number of heavenly bodies. Among the exhibits is a reconstruction of the Greenwich time ball, which used to be dropped at 1 p.m. every day to enable ships in the Thames to regulate their chronometers. A number of early chronometers and escapements are shown, among them being a Fifteenth Century alarm clock and a striking clock movement by Fromanteel dating from about 1675. Of the later clocks mention may be made of the standard sidereal clock, constructed by Messrs. E. Dent and Company to the specification of Sir George Airy between 1868 and 1872 and used at Greenwich until 1920. This is said to be one of the most accurate clocks ever constructed. Modern equipment is exemplified by a phonic-motor clock controlled by a quartz crystal, which has an error of only one second in three years.

What is known of the working of the solar system is demonstrated by an orrery devised by the Sondes Place Research Institute. This consists essentially of a clock movement in which a sphere, representing the sun, is mounted on a central pivot and other spheres, representing Pluto, Uranus, Jupiter, the Earth, Venus, Mars, Saturn and Neptune, on the ends of arms of different lengths. The lengths of these arms represent the radial distances of the planets from the sun on a logarithmic scale which has been modified to reduce the distance of the most remote planet (Pluto) to 16 ft. The diameters of the sun and the planets are also scaled down logarithmically and further arbitrary reduction factors have been employed, except to the Earth, Mars, Mercury and Venus. The distances of the satellites (which are also shown) from their planets have been scaled down empirically, so that they can pass both each other and the satellites of neighbouring planets. The speeds of the planets round the sun have been scaled up linearly, as also have been the revolutions of the planets on their own axes.

Owing to the small ellipticity of their orbits the planets are arranged to follow concentric circles round the sun. The orbits of the satellites are also made concentric. As it is not known whether Pluto revolves on its own axis it was made stationary, but the rise and fall of its elliptical orbit round the sun above and below the ecliptic plane has been reproduced. Saturn's rings are represented by a transparent plastic collar placed round its equator and marked with dots of fluorescent paint. As the orbital speed of Mars' innermost satellite, Phobos, is greater than that of the planet, its speed has had to be reduced considerably to prevent persistence of vision. The spheres representing the sun and planets are of copper or aluminium sheet and those of the satellites of solid brass and steel. They are coated with fluorescent paint and are displayed under ultra-violet light, the arrangement being such that a three-dimensional effect is obtained.

The mechanism is driven by a $1\frac{1}{2}$-h.p. motor through a V-belt and worm gearing. The output shaft of this gear is directly coupled to the shaft of the sun, which is $\frac{1}{2}$ in. in diameter and runs at 27 r.p.m. The planets are driven from this shaft through hollow spindles of seamless steel tube, which are keyed to turntables consisting of circular ribbed plates of cast aluminium. Arms, consisting of two beams of T-section aluminium alloy, 3 in. by $1\frac{1}{2}$ in., set at an angle to each other and sheathed on the top surface with No. 16 gauge aluminium sheet, are bolted to the turntables. In all but three cases, these arms carry base castings which support turrets housing the driving mechanism for the axial rotation of the planets and the orbital rotation of their satellites. Mercury, Venus and Jupiter are, however, belt driven directly from the turntables of the planets above them, while each of the other six planets is driven, at the correct speed, from the turntable through bevel gearing and a clockwork train in the turret. The inclination of the axes of the Earth, Mars, Uranus and Neptune to their orbits has been reproduced by mounting the gearing in their turrets at the requisite angle and fitting universal ball joints to the vertical drives. The complete mechanism is mounted on a steel cradle which is fixed to an angle-iron frame. This frame stands on channel members which are connected to the display stand and are arranged so that the ecliptic plane is at an angle of 45 deg. to the floor.

EXHIBITION OF SCIENCE AT SOUTH KENSINGTON.

The Exhibition of Science at South Kensington may be regarded as a supplement to the displays in the Dome of Discovery, although its theme is more limited since it is devoted to illustrating present-day knowledge of the inner structure of matter, both living and inert. It occupies the ground floor of the centre block of what will eventually be an enlarged Science Museum but which for the moment consists of a basement, ground and first-floor, with a temporary roof over the central well. Completion of the construction of the new building to this stage was hastened by the Ministry of Works, so that it would be available in time for the Festival.

The exhibition is arranged in three parts dealing, respectively, with the physical and chemical nature of matter, the structure of living things and, under the heading of "stop press," with some of the latest research work that is now being done. In the first part it is shown how matter is made up of one or more of 90 elements and how those elements, which are similar in their use and action, form regular groups. The way in which these elements make up the earth's crust and the inner structure of the atoms themselves are also illustrated, as are the constitution of rocks and crystals and the chemical behaviour of elements and their combinations. It is pointed out, however, that few of these elements are ever found alone. Usually, several are combined into one rock or mineral and each influences the colour, weight and texture of the compound. There are many thousands of these compounds, and a display is given to illustrate their uneven distribution in the earth's crust.

Considerable space is devoted to advancing evidence that matter is made up of separate particles, as shown for instance by the Brownian movements, and that the atom itself consists of a heavy central nucleus with electrons moving round it in such a way that they are more likely to be found in some places than in others. The link between atoms and electricity is illustrated by a number of exhibits describing the early work of J. J. Thomson, while the investigations of Aston into the existence of isotopes, and of Rutherford, Cockcroft and Walton on the structure of matter are similarly demonstrated.

Since, however, physicists are not only concerned with matter, but with radiation, the opportunity is taken to show how this extends from the longest radio waves through heat waves, light waves and X-rays to the shortest and most penetrating γ-rays, which are given out by radioactive materials. The nature of these radiations is illustrated by examining those which make up ordinary light, and it is shown how they travel and can be deflected, reflected, diffracted and used in telescopes and microscopes of both the optical and the electron types. In another section, the relation of the process of chemical combination to the physical structure of the atom is illustrated by displays showing how compounds formed by the transfer of the outer electrons of the constituent atoms usually arrange themselves in crystals and how the distribution of the atoms in a crystal can be worked out from the patterns discovered by Lave and used by Bragg. The exhibition contains an interesting display of crystal patterns, including one showing how mica consists of a complicated structure built up of aluminium, potassium, silicon, oxygen and hydrogen atoms. On the other hand, the outer electrons of metals are not firmly held by their nuclei, but form a loose cloud which links the latter together. A model shows how this cloud can easily be set in motion by heat or electricity, so that it drifts through the whole mass of the metal and arranges itself in one of three crystal patterns. The crystalline pattern of alloys is also illustrated by similar models. Finally, the third way in which elements can combine by sharing the outer electrons between two atoms, so that the latter remain neutral and no charge ions are formed, is shown. Since all carbon compounds are of this kind, these displays form a natural introduction to the exhibits showing the leading role which this element plays in plants, animals and all living organisms.

In the "stop press" section of the exhibition, displays are given to indicate how the knowledge we have acquired, and which is illustrated in the preceding sections, is being used either through the aid of the five human senses, or by such "sixth senses" as the effect of light on a photographic plate or the conversion of radio waves into sound or luminescence, to make further discoveries. A particular feature is made of the instruments which are being employed for these purposes, including a cathode-ray oscillograph shown by Mullard Electronic Products and a mercury discharge lamp with a black glass bulb, so that only ultra-violet radiation is emitted, which is exhibited by the Electric Lamp Manufacturers' Association. A projection microscope is shown by the Hummel Optical Company and a Blackett cloud chamber by the Physical Laboratories, University of Manchester. How calculating machines can be used to relieve the human brain of many mechanical tasks in calculation is illustrated by the "Nimrod" computer, which is being shown by Messrs. Ferranti, Limited, and is attracting a great deal of attention. Considerable space is devoted to murals and other means of illustrating what is being done on cosmic rays and to investigate the constitution of outer space.

THE SCIENCE MUSEUM, PAST AND FUTURE.

Another exhibition which, although distinct in organisation from the Festival of Britain, also illustrates the advances that have been made during the past 100 years, is that arranged in No. 1 gallery of the Science Museum, under the title of the "Science Museum—Past and Future." The main purpose of this exhibition is to display representative scientific and engineering objects from the collection in the museum, many of which have had to be stored for many years owing to lack of space, and some of which have not previously been shown publicly. The exhibition also endeavours to portray the history of the Museum, which is adequately described in a pamphlet compiled by Mr. F. Greenaway. Among the pictures displayed are three, one depicting the museum as it was in 1857, another showing from the air the area now occupied and a third giving an artist's impression of the new designs envisaged for future development. Among the models are some of the earliest and latest forms of mechanical power-transmission equipment, while other sections are concerned with early civil engineering, navigation and transport. There is also a section on industrial chemistry, including a model of an ancient woad mill and working models of Nineteenth Century fire-fighting equipment.

ANNUALS AND REFERENCE BOOKS.

Technical Reference Book of Compressed Air Terms and Standards.—This almost-book but much more than brochure, first published in 1932 and now, in its third edition, considerably enlarged, is issued at 10*s.* 6*d.*, including postage, by the British Compressed Air Society, 94-98, Petty France, London, S.W.1, who describe it as "an official work of reference for the Compressed Air Industry, to establish definite standards for Manufacturers and Users of Air and Gas Compressors, Exhausters, Pneumatic Tools and Appliances." It contains, *inter alia*, the relevant British Standard Specifications, advice on the installation and maintenance of pneumatic plant, and numerous tables, graphs and data relating to compressed air and gases, the operation of rock drills and other pneumatic tools, pipe-line losses, etc., as well as conversion factors, logarithms, etc.; all useful information, though the logarithms might have been omitted. Also included, however, are numerous "definitions" which, we suggest, are much in need of revision; for some (e.g., "absolute temperature") must be sufficiently familiar to anyone competent to take a practical interest in the compression, exhaustion or use of air, and many more are not definitions at all, but descriptions, sometimes so loosely worded as to be hardly worth the space that they occupy. For example, the "definition" of a displacement pump refers to it only as a device for pumping water, though some of its more important uses are in pumping acids and other corrosive liquids; while that of the air-lift pump—so worded that it would apply as well or better to the displacement pump—makes no reference whatever to its basic principle of operation, namely, the creation of an artificial difference in density between a column of liquid which has been aerated and another (usually surrounding it) which has not. These are only two instances out of many that invite criticism. It may be that most users of the book, being themselves in the industry and so not requiring definitions of the appliances that they make and use, seldom refer to these pages; but there must be many others who would benefit by a greater precision.

An International Bibliography on Atomic Energy.—Some indication of the rapidity with which knowledge of atomic energy is accumulating is provided by this monumental volume of 880 pages which contains over 24,000 references to books, research reports, technical papers and articles in scientific and technical journals on the purely scientific aspects of the subject. It is the second volume of two prepared by the United Nations Atomic Energy Commission, the first, published in 1949, having dealt with the political, economic and social implications of the development and use of atomic energy. In this second volume, the information is listed under five main headings and numerous sub-headings, and all the main "chapters" are prefaced by a short introductory essay or essays written by persons distinguished in the field. Thus, in the first chapter, Professor Pierre Auger writes on fundamental nuclear science, and the references on this subject are listed under twelve main sub-headings and numerous subordinate headings. The second chapter on the physics and engineering of nuclear reactors is prefaced by an essay by Sir John Cockcroft. This, like the others, was written for an earlier publication of the information in parts, and is dated December, 1948. It seems a pity that, in all these cases, an opportunity was not taken before issuing the material under one cover to have the essays revised and brought up to date. To do so in the case of the lists of papers would, of course, have been an impossible task and, presumably for the reason that the references do not extend beyond 1949 and are far less complete for both that year and 1948 than for earlier years, the editors preferred to retain the essays in their original form. The other main sections of the book deal with the biological and medical effects of high-energy radiations, isotopes in biology and medicine, and applications of radioactive tracers in non-biological sciences and technology. All the main headings are so well subdivided that the finding of references to specific subjects should present no difficulty, while the work of particular authors may be located quickly by means of the index of authors printed as an appendix. The United Nations Organisation is to be congratulated on providing this most useful guide to the vast literature of atomic energy, which will be welcomed by all those engaged on the subject or seeking information concerning it. The book carries the United Nations Publications' sales number 1950.IX.1 and is obtainable from H.M. Stationery Office, P.O. Box 569, London, S.E.1, at the price of 75*s*.

HEAT TRANSFER DURING CONDENSATION OF STEAM: ERRATUM.—We regret that in our reprint of Mr. H. Hampson's British Association paper on the above subject an error occurred in the expression in the penultimate paragraph on page 223, *ante*. The differential *dD* with which the expression terminates should be deleted.

LABOUR NOTES.

SOME noteworthy changes in the outlook and policy of the Trade Union Congress are recorded in the annual report of its General Council, which was published on Tuesday last. This rather long document, of nearly 250 pages, will be presented to the 83rd annual congress of the T.U.C., which is due to be held at Blackpool during the week commencing September 3. The pleas of the General Council during recent years for the exercise by trade unions of some restraint in the presentation of demands for wage increases are replaced by suggestions that the unions should endeavour to maintain the level of real wages, by demanding fresh increases for their members. At the same time, the Government is urged to establish "a new and more stable" level of prices as soon as possible. The General Council's policy of wage restraint was far from popular with some of the affiliated unions, which, in practice, largely ignored it, and its rejection by a majority vote at last year's congress was a severe reverse.

Although, in the present situation, trade unions must endeavour to maintain real wages by pressing for increases, the General Council realises that such maintenance is unlikely to be possible for workpeople as a whole and that only some of the more favourably-placed sections may be able to achieve it. In fact, the increasing demands of the rearmament and export programme will result, in the immediate future at any rate, in a decline in the community's standard of living. This could only be avoided, the General Council considers, if there were to be a considerable increase in production. In this connection, the possibility that production may be jeopardised by shortage of raw materials and the conversion of plants to rearmament projects emphasises the need for both sides of industry to co-operate as fully as possible in increasing the efficient use of all available resources and in eliminating wasteful methods.

A period of considerable social and industrial strain is forecast by the General Council, owing to the present apparatus of price and production controls and of profits and income tax being insufficient to prevent wage increases from being offset by price increases, now that the relative wage-price-dividend stability of the last few years has broken down and everything is in motion. The General Council considers that the resulting spiral of incomes and prices is not likely, in this country, to result in any runaway inflation of a catastrophic nature, although it is dangerous, and, if carried too far, could have a damaging effect on the nation's oversea trade balance. The efforts of the trade unions to increase wages cannot prevent, by themselves, a reduction in the standard of living, but they may mitigate it to a greater or less extent. There is a warning that the activities of certain extremists, who seek to utilise existing economic difficulties to further their own ends, might not only wreck the nation's chances of obtaining stability, but could also set back the whole trade-union movement for many years.

On the question of profits, the General Council refer to a statement by Mr. Harold Wilson, when President of the Board of Trade, that it was necessary for there to be a "reasonable return" on capital employed in industry, if adequate supplies were to be forthcoming. If that return were reduced below a certain level, it would be easy for industry to evade price-control arrangements by, for example, lowering the quality of the articles produced or by causing the whole administrative machine to stall. Price control in a largely private economy requires a certain amount of willing consent from manufacturers. The General Council recognises also that price control can, for the most part, deal only in terms of average costs. In spite of this, the General Council believes that more could have been done by the Government to reduce the permitted return to manufacturers, if necessary by reintroducing some of the associated physical controls which have been abandoned in recent years.

The General Council states that it has reviewed the practicability of limiting profits by statute and that it has rejected the idea. The control of each firm would introduce "a disastrous rigidity into industry" and would "break down under its own weight." It is pointed out that 60 per cent. of all profit is taken away by the Government in the form of taxation. While this represents a large proportion, many firms could probably stand more, but, the General Council adds, other firms, particularly the smaller ones, could not. It has to be remembered, it is stated, that if all personal incomes above 2,000*l.* a year were to be taxed away completely, so that the person concerned had no income, the total yield would be no more than 230 million pounds. On the other hand, the General Council expresses its concern at the continuing increases in profits and dividends. It will consider the practicability of a capital gains tax. Nearly eight million workpeople belonging to 195 trade unions are affiliated to the Trades Union Congress.

Retail prices increased slightly during the month ended July 17, according to an announcement by the Ministry of Labour on Monday last. The interim-index figure for all items stood at 126 at that date, compared with a level of 125 on June 19; for food only the figure was 137 on July 17, against 136 on June 19. The comparative figures for mid-January, 1951, were 117 for all items and 127 for food only. During the two months between mid-March and mid-May last, there was a rise of five points in the index level for all items, and of seven points in the level for food only. The Ministry records that the latest rise was due mainly to the higher prices of potatoes, milk and sugar, but there were also increases in the prices of many other articles. This index measures the average changes, each month, in the United Kingdom prices of goods and services which entered into the expenditure of working-class households before the war. It was commenced on June 17, 1947, the level at that date being taken as 100 for all items and 100 for food only.

The joint committee of representatives of the Railway Executive and the three principal railway unions, which was set up to improve the efficiency of the railway services and to effect economies in working, held its tenth meeting in London on Monday last, but little further progress appears to have been made. Beyond agreements providing for the reduction of knockers-up and of van guards in the London area, there has been little to show for the committee's efforts. The main issues before the committee at recent meetings have been the proposals of the Executive for an increase in the number of lodging turns, and for the extension of the eight-hour roster by one hour's overtime in some instances. The adoption of either of these proposals would enable more economical use to be made of train crews.

These changes in working conditions, although apparently accepted by the trade-union leaders as not unreasonable, are extremely unpopular with the drivers and firemen concerned, and it is to this opposition by the rank and file that the difficulties which the joint committee has encountered are largely due. Possibly with the object of avoiding a complete deadlock between the two sides of the committee, the Executive made new proposals regarding lodging turns at the committee's meeting last Monday. While these may not involve any drastic change in principle, they are understood to have been presented in a form more likely to secure the men's co-operation in the proposed changes. The unions have undertaken to consult their memberships regarding the Executive's new proposals. These principally concern the Associated Society of Locomotive Engineers and Firemen, to which train crews belong. No date has been fixed for another meeting of the committee.

The arguments in favour of the joint claim of the three principal railway unions, for a wage increase of 10 per cent., were presented by the general secretaries of the unions to the Regional representatives of the Railway Executive, at a meeting of the Railway Staff Conference in London on Tuesday. Some 450,000 employees of British Railways are affected by these claims, which are estimated to cost the Railway Executive between 17 and 18 million pounds a year, if granted in full. Parallel claims have also been submitted formally on behalf of the members of the three unions who are in the service of the other Executives of the British Transport Commission. This is the first occasion for many years that the three unions, the National Union of Railwaymen, the Associated Society of Locomotive Engineers and Firemen, and the Transport Salaried Staffs' Association, have united to present a joint wage demand.

The case for the unions rested principally on the argument that the wage increase of $7\frac{1}{2}$ per cent., conceded in February last, had been more than offset by rises in the cost of living during recent months and that, as a result, railway employees were now no better off than before the February increase was granted. It was pointed out that the figures of the interim index of retail prices had advanced by nine points during the first six months of the present year. Reference was also made to the existing shortages of man-power on the railways and it was urged that wage levels must be raised substantially if the railway service was to obtain the new recruits it needed. The representatives of the Executive undertook to consider the union's arguments and to call another meeting of the Railway Staff Conference, when the Executive's case will be presented. This meeting will probably be held in about three weeks' time.

DEVELOPMENT OF HIGH-VOLTAGE TRANSMISSION WITH PARTICULAR REFERENCE TO HYDRO-ELECTRIC PROJECTS.*

By T. GRAEME N. HALDANE, M.I.C.E., M.I.E.E., F.A.I.E.E.

WHEN the public supply of electricity commenced in the early 1880's, the main object was to provide a new means of lighting superior to gas. All the earlier Acts of Parliament dealing with electricity supply were termed " Electric Lighting Acts " and it was not until many years later that electricity became an important means of providing electrical power. Transmission distances were severely limited by the low voltages available in the early days of electricity supply, and the size of areas supplied was correspondingly small. As this restriction became less severe with the development of higher alternating-current voltages—so largely due to the pioneer work of Dr. S. Z. de Ferranti—there arose controversy between the advocates of the " central " station and those who took a more parochial view of electricity supply. This was the dominating theme in discussions on electricity supply up to about the beginning of the second decade of this century. Those who urged the central-station idea wished to see each town, or portion of a large city, supplied by one central station carrying a wide variety of load and benefiting by the consequent diversity of peak demands. As the central-station idea caught on, and as transmission voltages continued to rise, this theme was extended to the interconnection of a number of central stations covering, collectively, a large area comprising a multiplicity of cities, towns and rural districts. A large-scale policy of this sort was first adopted in the development of the North-East Coast area and marked a milestone in the history of electricity supply. Another milestone was the creation of the British grid system, following the passing of the 1926 Act.

With still further increase in transmission voltages, the scale of interconnection has steadily increased until to-day it has reached international proportions. At this stage, the problem is tending to become more political than technical, particularly in Western Europe. In parallel with this development, and also closely connected with increasing transmission voltages, was the search for sources of power other than coal. From the beginning, some countries which had no coal sought to develop their water power; and in other countries the increasing cost of coal has led to the use of water power even where located at considerable distances from the load centre. Apart from the economic incentive, there is now a growing consciousness, to which Sir Harold Hartley referred in his presidential address last year, of the obligation to explore, for the benefit of future generations, the non-expendable sources of energy, before our expendable resources have been used up.

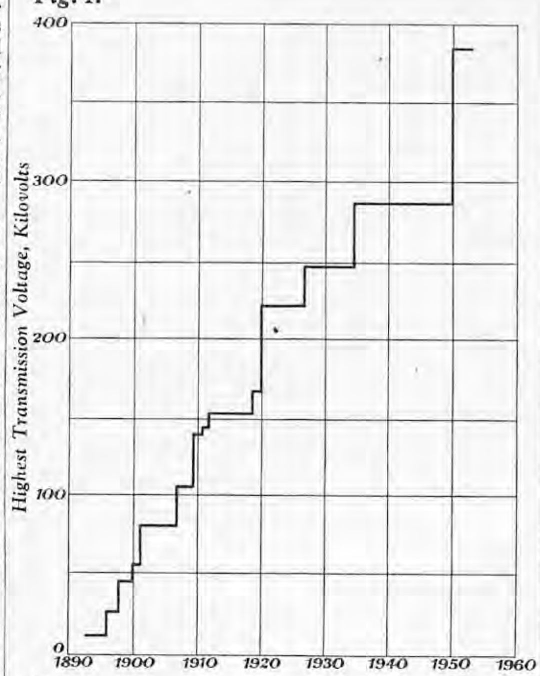
Of the several ways in which we can reduce our dependence on coal or other expendable resources, for the world at large the most important is to make greater use of water-power resources, and to do so involves transmission of large blocks of power over greater distances than ever before. At the present time, the world's greatest water-power transmission system is that from Boulder Dam to Los Angeles, a distance of 270 miles, over which some quarter of a million kilowatts are transmitted at 287,000 volts. If the great water-power resources of Norway are to be made available to Western Europe, this might involve a transmission distance of between 500 and 1,000 miles. In several parts of the world there are very large sources of water power which may lie up to 1,000 miles from the nearest large load centre; in fact economic transmission of large blocks of power up to a distance of nearly 1,000 miles would appear to be the goal of present development. The nearest immediate approach to this distance will be the Swedish 600-mile transmission now in construction which, at a voltage of 380,000, will make available the water-power resources of the extreme north of Sweden.

The urgency of the problem to which I am referring is not perhaps sufficiently appreciated. Although there are vast resources of coal still available in many parts of the world, the difficulty and cost of producing coal, particularly in the European countries, including Great Britain, have been steadily increasing. The National Coal Board has estimated the total demand for British coal at 240,000,000 tons per annum in the period 1961 to 1965. To meet this demand will require considerable effort and a further large capital investment in the coal-mining industry. A study of the rate at which the consumption of electricity has been increasing, and the rate at which thermal efficiency is improving, suggests that the coal required for power generation will be appreciably higher than the amount which appears to be included in the Coal Board's estimate. Bearing in mind the relatively low degree of mechanisation and of comfort standards in this country as compared with the United States, it seems very probable that an additional 10 million, or more, tons per annum will be required during the period 1961 to 1965, which may not be available. It does not appear that we can reckon on power from nuclear fission in any large quantity by that date.

In this paper I propose, first, to make a general review of the position which high-voltage transmission has reached to-day and its prospects for the future; and then to make special reference to some of the difficulties in choosing the best transmission system for a given task. The superiority of alternating current for transmission and distribution purposes has been maintained since it emerged some 50 years ago as the victor of the " battle of the systems." This superiority has been retained by constant development to meet the rapidly increasing demands upon it.

When long-distance transmission by overhead line first came to be considered, the load which could be carried was found to be limited mainly by the reactance. This caused not only drop in voltage, but ultimately, as the load was increased, instability, a situation in which the phase displacement between voltages at the beginning and end of the line is so great that a disturbance such as a fault, or even a switching operation, may " shake " the driving and driven machines out of step. The obvious answer was increase of voltage, and in Fig. 1 is shown the consequent rise of voltages caused by this striving for higher capacities. The 380-kV line, which is shown as the present highest voltage, is not yet actually in operation but probably will be next year. As already mentioned, it will, by transmission of some 300 MW over a distance of 600 miles, make available the water-power resources of the extreme north of Sweden.

Fig. 1.



With ever-growing requirements as to loads and distances it next appeared that a practical limit to increase of transmission voltage might be set by the size of conductor necessary to avoid excessive losses due to the ionic discharge known as corona. A voltage of 300 kV requires a conductor about 1·4 in. diameter and anything larger than this is found to be difficult to manufacture, transport and erect in reasonable lengths. This limitation also is in process of being removed by the introduction of the multiple or " bundle " conductor which, although first suggested about 1910, has only recently been actually developed. This consists of two or more conductors connected in parallel and spaced apart at a distance fairly large as compared with the diameter of the components but still small as compared with the inter-phase spacing. A multiple conductor behaves electrically like a single large conductor, the corona starting voltage being much higher than that of an equivalent single conductor of cross-section equal to the sum of the cross-sections of the components. The diminution of corona loss in wet weather with multiple conductors is very marked, as the majority of the drops of water hanging from the conductor are not in a region of maximum electrostatic stress and so do not form points of discharge. It appears probable that the requirements of lines up to 400 kV will be satisfactorily met by the use of twin conductors, at least where the system neutral is solidly earthed. Twin conductors are being used for the Swedish 380-kV lines and the French 400-kV lines and for the 275-kV lines of the British Electricity Authority. On the projected German 400-kV lines it was intended to use quadruple conductors, but probably only because it was first intended that they should be earthed through arc-suppression coils.

Although the primary reason for adopting multiple conductors is to minimise corona, there is another very noteworthy advantage. The larger effective conductor diameter decreases reactance and increases capacitance, and since line reactance is a big factor in problems relating to system stability, this makes greater power transmission possible with the same degree of safety. The increase is of the order of 10 to 20 per cent. for twin conductors and 30 to 40 per cent. for quadruple conductors.

Much thought has been and is being given to the development of economic methods of counteracting, as opposed to reducing, line reactance. One obvious possibility is the neutralisation of line reactance by the use of series capacitors, but theoretical investigations indicated that the danger of over-voltages being set up across the capacitors by faults and switching surges was considerable. It has been left to Swedish engineers to make the first practical demonstration of the scheme. In January, 1950, a capacitor was installed at the Alfta substation of the Swedish State Power Board at the mid-point of a 300-mile 220-kV line. The capacitor is designed to compensate 20 per cent. of the line reactance and thus to increase the load transfer capacity by about 25 per cent. Theoretical investigations, confirmed by experiments on models, show that, by subdividing a line with series capacitors and adding shunt reactors connected between line and earth to limit voltage rise at times of low load, stability problems on the longest lines contemplated can be satisfactorily solved.

It appears that, at least during the next 20 years or so, any transmission requirements likely to be encountered in Europe can be satisfactorily dealt with by the alternating-current system at voltages not exceeding 400 kV. Objections to the use of substantially higher voltages are the very high cost of the transformers and switchgear at the line terminations, and—a point sometimes overlooked—the very large amount of space required by the substations. We may then regard 400 kV as a practical limit of alternating-current transmission for some time to come, although the use of still higher voltages is not likely to present any insuperable technical difficulties.

Switchgear and transformer problems are too specialised to come, in full detail, within the scope of this paper. Circuit-breakers for very high-voltage use must of course have the desirable qualities common to all types of switchgear, including high speed and ability to handle large fault power. On very high-voltage lines, the additional complication and expense of features which improve stability, such as single-phase switching and automatic reclosing after transient faults, are fully justified and will no doubt be widely used. As to type, in Europe the air-blast breaker is tending to monopolise the high-voltage field, while in America the conventional tank-type oil switch is more in evidence. On the British 275-kV system, to which reference is made later, both types will be used.

The problems associated with transformers for very high voltages are largely concerned with considerations of size and weight and, particularly in the case of remote hydro-electric stations, it is often necessary to install single-phase units. This has the incidental advantage that provision of one spare single-phase unit is often considered adequate cover against breakdown. For the interconnection of the 380-kV and 220-kV systems in Sweden and the 275-kV and 132-kV systems in England, auto-transformers are to be used, these having the advantages of lower cost, losses and impedance as compared with double-wound transformers. Use of auto-transformers involves the application of direct earthing which, although it has been British practice on the 132-kV grid since the beginning, has not been general European practice. However, while there may be scope for some difference of opinion as to whether arc-suppression coils are worthwhile at 132 kV, it is now generally recognised that for all higher voltages their advantages are outweighed by the extra cost of insulating equipment, the difficulty of keeping the arc-suppression coils tuned, and their effect of aggravating the corona problem.

The use of high voltages for transmission has necessitated a large amount of experimental work, not only to ensure satisfactory operation, but also to determine the most economical sizes and arrangements of conductors with a view to minimising capital costs and losses. The three most extensive research installations associated with high-voltage transmission are at Tidd, near Brilliant, Ohio, on the system of the American Gas and Electric Company; at Chevilly, near Paris, owned by Electricité de France; and our own B.E.A. research station at Leatherhead, Surrey. All these

* Paper read before Section G of the British Association at Edinburgh on Monday, August 13, 1951. Abridged.

installations have test lines on which experiments may be made at voltages up to 500 kV. At Leatherhead, the line, some 800 yards long, is carried on gantries instead of normal transmission towers and is specially designed to facilitate modifications of clearances to earth and between phases. The line has been used since November, 1949, mainly for tests at 275 kV with twin conductors as proposed for the B.E.A. super grid.

By virtue of the insulation level necessary to meet normal service conditions, insulation and spacing between conductors need not be increased in proportion to voltage, and there are two important inducements to studying the lower limits of these features; first, the reduction in capital cost, and secondly, the reduction in line reactance, which both vary with interphase spacing.

The assessment of corona losses is a matter of considerable complexity, as many variables are involved and results obtained in one country may not be exactly reproduced in another; in addition, the accurate measurement of corona loss presents great difficulty. For this reason, authorities contemplating the use of voltages greater than 132 kV have generally preferred to carry out their own experiments rather than to rely on published data; and a great deal of work is being carried out in this connection. A further matter which has been the subject of investigation is the possibility of interference to radio and television services by discharge from lines. At Leatherhead, it has been shown that a television receiver could be operated within ten yards of a 275-kV line with negligible interference. As shown in Fig. 2, which gives the probable line outages per 100 circuit miles per annum for Great Britain, high-voltage lines are relatively free from lightning trouble.

Looking now specifically at the British grid, considerable progress in thought has recently been made, culminating in the decision to proceed with a 275-300 kV super grid. The British system is amply large enough for statistical analyses to be reasonably reliable and studies have shown both that a much greater degree of interconnection was justified as a result of savings due to diversity of various sorts—diversity of loads, diversity of estimating errors, diversity of weather conditions and diversity of breakdowns—and that these benefits, plus the reduction of the rupturing capacity needed in the switchgear, could best be obtained by superimposing a distinct new higher voltage system on the existing grid. A voltage of 275 to 300 kV has been chosen for this; it is hoped that the first portions will be in operation by 1955, and that the subsequent more effective use of the available generating plant will have an important effect in reducing load shedding.

The new 275 to 300-kV grid will be combined with circuits provided for the direct transmission of power generated in the cheap coal areas, for instance the Midlands, to the densely-populated London area. Some of these transmission circuits may, in fact, be designed for future operation at 380 kV. Up to a few years ago it had been thought that it was generally cheaper to transport coal than to transmit electricity even over comparatively short distances. Although this may still be true as regards sea transport of coal, it is now accepted as no longer true with regard to rail transport of coal over distances up to about 150 miles. This change is due to the rising cost of rail transport and the development of extra-high-voltage transmission. It is also due to the increasing scale of the bulk transmission required. Fig. 3 shows an approximate comparison of the costs of transporting coal by rail as compared with transmitting the equivalent electrical energy. The coal is assumed to have a calorific value of 11,000 B.Th.U. per pound and to be converted into electrical energy at an efficiency of 26·5 per cent. Electrical energy is assumed to be transmitted at 300 kV over a distance of 125 miles. Present rail costs are of the order of 2*d.* per ton-mile.

While the ease with which alternating current can be controlled and transformed to any desired voltage makes that system the natural choice for the great majority of transmission and distribution systems, there are exceptional situations where direct-current transmission would have technical and economic advantages if suitable converting and switching apparatus were available. The possibilities of direct-current transmission have therefore once again begun to engage the attention of engineers. The cases in point are the transmission of large amounts of power over very long distances and transmission by cable where overhead lines are impracticable, such as across considerable expanses of water. The main advantage of direct-current transmission is that problems associated with the reactance and capacitance of the line or cable disappear, so that the costly compensating devices which have to be inserted at intervals in a long alternating-current line would be unnecessary. Direct-current transmission permits of greater power per conductor for the same insulation level than alternating current; alternatively, the same power can be transmitted with fewer conductors while retaining the same voltage to ground. On the other hand, there is no method of stepping the voltage up or down in any way comparable in efficiency, simplicity and cheapness with the alternating-current transformer; in addition, switching presents considerable difficulty, as the alternating-current principle of breaking the circuit as the current passes through zero is not available.

No review of direct-current transmission possibilities would be complete without reference to the installation based on the constant-current system of Thury in France, which only went out of service in 1937 after some 40 years in service, but all present-day developments are based on the conventional constant-voltage system. In the few direct-current transmission proposals which show promise of practical development, alternating-current generators would be used, the power being converted to direct-current by mercury-arc or valve rectifiers. At the receiving end, similar

Fig. 2.

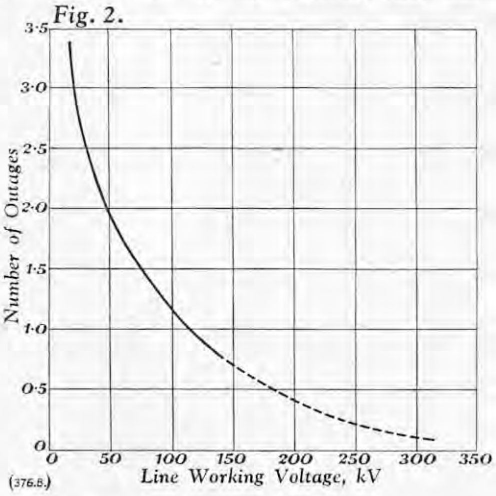
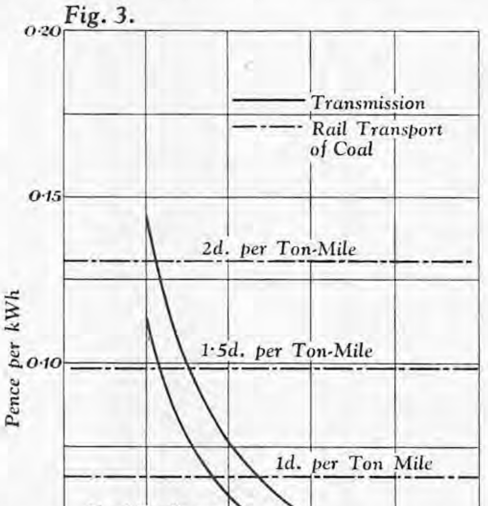


Fig. 3.



devices would be used as inverters to transform the power back to alternating current for distribution. It is considered that there would be no insuperable difficulty in developing this method for use at the voltages required for very long distance transmission, say, 500 kV, except the very high cost of the development work, much of which would necessarily have to be carried out on an actual system. It seems likely that attention will be specially devoted to the most advantageous use of direct current represented by the second case mentioned above, namely, the transmission of power by underground, or more often under-water, cable. For various reasons, including lower peak voltage, ionisation and dielectric losses, a high voltage direct-current cable requires less insulation than the equivalent alternating-current cable and this, together with the elimination of the capacity charging current, makes direct current an attractive proposition for transmission where cables are essential.

A project of great interest is the proposal to connect the island of Gotland with the Swedish mainland, a distance of about 60 miles, by a direct-current cable. The scheme has proceeded so far that it is to be put up to the Swedish Parliament during the current year for authorisation and will probably go into service about 1954. First a single cable working at 100 kV will be laid, the sea and earth being used as return; later, a second cable will be laid, the voltage across the two cables being 200 kV and the power transmitted 40 MW.

The maximum transmission distances in Great Britain are comparatively small and are less likely to justify the use of direct current except where the loads to be transmitted are very large. On the other hand, there is the very important possibility of linking the great thermal system of Great Britain with the whole Continental system, which is about half thermal and half water power. To do this, we should require to transmit very large blocks of power by submarine cable across the Channel, a distance of a little over 20 miles. Such transmission might be technically possible using alternating current, but would involve very serious difficulties due to the huge charging currents involved at very high voltages. It might be possible to provide reactive compensation, but this would be very costly. Consequently, direct current would have great advantages in this particular case and it seems that research on direct-current transmission carried out in this country should be directed primarily to the provision of a direct-current submarine link between Great Britain and the Continent. This is a matter referred to in the author's presidential address to the Institution of Electrical Engineers some years ago, when it was suggested that the economic advantages of the interconnection of Great Britain and the Continent should be studied. Since then there has been contact between the British Electricity Authority and Electricité de France, and the necessary study has been put in hand. The matter is, however, extremely complicated and involves many different factors. There is, for instance, the diversity in peak demand due to differences in habits, weather, climate and time. Apart from this there is the difference due to the fact that the Continental system is largely dependent on water. All such diversities and differences tend to create arguments in favour of interconnection which are similar in character to the arguments which have led the B.E.A. to decide on interconnection of the various parts of this country by a new 275 to 300-kV system. For cross-Channel interconnection it will be necessary not only to prove the economic case but also to solve the technical difficulties before large-scale direct-current cable transmission becomes commercially feasible.

Whereas the cross-Channel interconnection might be regarded as the primary objective, direct-current research in this country may also become of importance for certain Commonwealth transmission projects. A case which is somewhat similar to the cross-Channel project, though on a smaller scale, is the laying of a cable across the Cook Strait between the North and South Islands of New Zealand. The hydro-electric resources in the North Island are nearly fully utilised, but there is surplus in the South Island, which is less densely populated. The laying of a cable across Cook Strait, which at the narrowest part is some 16 miles wide, might effect great savings in the future in the amount of very expensive coal which would otherwise have to be burnt in thermal stations, unless geothermic stations can be developed.

Control of transmission, principally control of frequency, power flow and reactive current, presents many problems, except in cases of simple point to point transmission. The difficulties are more acute where the system is a loosely-knit one, the largest example of which is the Combined South Atlantic and Central Areas Group in the United States, with a peak load of 20 million kW. However, in view of the fact that in Western Europe there are already 50 transmission lines crossing international frontiers, Europe itself may in some sense be regarded as in process of becoming such a loosely-knit interconnected system with a total load approaching 30 million kW. In this country, and also in the second great interconnected system in the United States, namely the Pennsylvania, New Jersey and Baltimore, Washington Group, the system is much more tightly knit and represents what may properly be called a grid system. Speaking in general terms, in such systems the multiplicity of bilateral agreements is replaced by a single obligation on a controlling body to get the best out of the system. This, coupled with the fact that the existence of many cross connections makes the application of automatic equipment very difficult, has justified the continuance of a large degree of manual control in such systems.

The economics of transmission is a subject which may easily be over-simplified to the point of being quite misleading, and the danger of this happening is particularly great if the performance of the transmission system is considered apart from the generating system. Transmission studies must be related to the electrical system as a whole if the effect of the many relevant factors is not to be overlooked, and such fundamental facts or assumptions as coal price, life of equipment, rates of load growth, probabilities of

COSTS OF HYDRO-ELECTRIC PROJECTS.

Fig. 4.

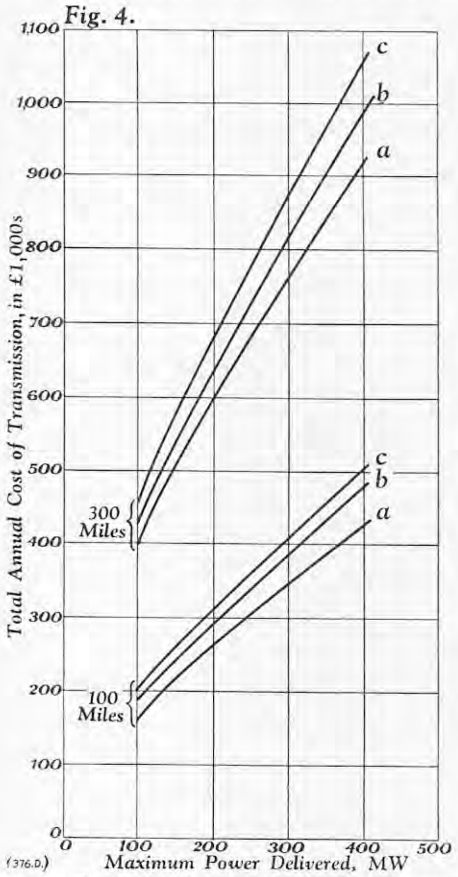
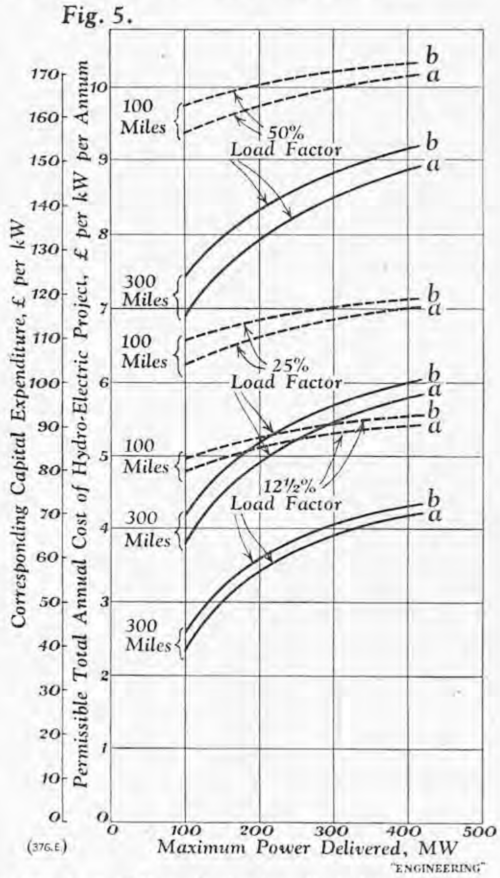


Fig. 5.



generating-plant outage, etc., can all affect the results considerably, although none of them is specifically associated with the transmission system. As far as the lines themselves are concerned, even the apparently simple question of the cost per mile is frequently subject to a wide margin of error in the planning stages of a project because the line may traverse wild and hitherto inaccessible country. In fact, the best we can truthfully say of the most careful study is that it enables us to eliminate all definitely bad alternatives, leaving the final choice largely a matter of judgment and experience combined with policy considerations.

When hydro-electric projects come to be considered it is more than ever necessary to study generation and transmission costs as one whole. In the design of the hydro-electric scheme, not only is there likely to be relatively long transmission, but there is also almost certain to be a degree of freedom in choosing the load factor, and the choice of load factor affects, and is affected by, the transmission costs. The fundamental decision to be made in connection with any particular hydro-electric scheme is, should it be proceeded with now, or postponed in favour of some alternative? The alternative may be some other hydro-electric scheme but, provided it can be assumed that fuel is available, there is always one basic alternative with which the scheme can be compared—that of thermal generation at or near the load. Thus, what may be called the "thermal yardstick" is a measure to which useful comparisons may always be made, although, needless to say, it is a yardstick which has different dimensions in different parts of the world and at different times. For the purpose of the comparisons made later, the thermal yardstick is taken to be a generating cost of 5*l*. per kilowatt of installed plant per annum and 0·35*d*. per kilowatt-hour. These figures are consistent with a present capital cost of about 55*l*. per kilowatt installed for a high-efficiency thermal station and with coal costing about 60*s*. per ton. For comparison with this, the total combined cost of the hydro-electric scheme and its associated transmission must be evaluated, but subject, of course, to policy considerations regarding coal conservation.

Clearly the variation of load factor possible in the hydro-electric scheme itself (which is reflected in the load factor of the transmission line), the variation in line voltage and number of lines, and other electrical parameters, lead to many alternatves and some of these must be resolved by preliminary study before progress can be made. One way of making such a preliminary study is to evaluate total line costs for various loadings and load factors, including for this purpose as line costs all extra generating costs caused by transmission-line losses. These extra costs are of two kinds, that due to the power loss at time of peak and that due to the average energy loss over the year. The first of these is clearly reflected in plant capacity while the second is reflected in additional consumption of fuel or water. In most hydro-electric projects it is possible to vary the daily peak output with but little change in civil engineering costs, so that the power losses can be provided for by installing slightly more generating capacity, a typical incremental cost for this being about 27*l*. per kilowatt, i.e., about half the cost of providing the same extra capacity in the form of steam plant. In considering the second, the kilowatt-hour losses, two cases must be distinguished, one in which the river flow (for most of the year at least) is in excess of requirements, when the kilowatt-hour losses obviously cost practically nothing; the other in which all the available water is used, when the losses definitely result in greater expenditure of fuel in the system as a whole and must be costed accordingly. The first of these cases seldom applies to hydro-electric projects in this country; the second case is usually appropriate to Scottish conditions.

Fig. 4 gives the results of such a preliminary study, showing the least total transmission cost for a variety of loads and load factors. Each curve is really the lower envelope of a series each representing a particular voltage and number of lines. In all cases one spare line is included, i.e., one more line than is needed to transmit the maximum power, but for the purpose of calculating the energy losses all lines are assumed to be in use practically all the time. Fig. 4 brings out the influence of the kilowatt-hour losses, the curves *a* applying to a situation in which the losses are of no importance, while curves *b* and *c*, applying to 25 per cent. and 50 per cent. annual load factor, respectively, include the cost of replacing kilowatt-hour losses by thermal generation at a cost of 0·35*d*. per kWh. In all cases the kilowatt losses are assumed to be made good by increased capacity at the sending end and costed accordingly. The curves also show that the total costs are by no means proportional to distance. For instance, at 300 miles the costs are only about twice the corresponding figures at 100 miles. This is due to the relatively high cost of the end-stations with short lines.

The amount which can be economically invested in a hydro-electric project is clearly a function of the difference between the transmission costs shown in Fig. 4 and the cost of thermal generation at the load, the "thermal yardstick" mentioned previously, and in Fig. 5 this difference is shown for the same range of loads and distances, and for three alternative load factors. The ordinate of Fig. 5 has two scales, and of these the permissible annual cost per kilowatt of maximum capacity is more fundamental. The other, the permissible capital cost per kilowatt, is based on an arbitrary capitalisation at 6 per cent. Whether this is valid for a particular project depends, of course, not only on the rate of interest on capital but also on the life assumed for various parts of the hydro-electric installation. It should be noted, in connection with Fig. 5, that the kWh losses are not charged for curves *b*, but for curves *a* they are charged at 0·35*d*. per kWh. The kW losses are charged in all cases on a basis of 27*l*. per kW capital cost.

As might be expected, the load factor of the project is much the most important variable, and the effect is such as to indicate the advantage of low load factor development, having in mind the relatively low incremental cost of additional installed capacity. The variation of permissible cost per kilowatt is seen to be appreciable, affected also by the size of the project, and the transmission distance has a substantial effect but by no means *pro rata*. On a large project at 50 per cent. load factor, trebling the distance only reduces the amount expendable on the hydro-electric scheme by 15 per cent. The effect of having surplus water to cover kilowatt-hour losses is most noticeable at 300 miles and 50 per cent. load factor, when it makes a difference of some 5 per cent. in the amount which can economically be invested in the hydro-electric scheme.

It must be remembered that these figures are the result of measurement with a yardstick which relates to our own present-day British conditions and do not necessarily apply elsewhere. Moreover, they relate to one particular stage of development. For our conditions, this does not introduce any difficulty because we are developing our hydro-electric resources at an advanced stage of general electrical development. Our existing electrical load is therefore very large in relation to any possible hydro-electric scheme, and thus the scheme can be fully developed at the start, with full assurance that its whole output will be immediately absorbed. Very different conditions may exist in other parts of the world. Many countries which have hitherto been largely agricultural are now anxious to develop industries and supply them with cheap power. Hydro-electric projects started in these circumstances may have to go through a prolonged period of "growing-up," during which a project, ultimately highly profitable, may accumulate substantial losses during the early years while the potential output is only partly absorbed. As an alternative to postponement of such a project in favour of thermal generation local to the growing industries, financial stringency may well restrict the choice of transmission system to one cheaper than is known to be justifiable on a long-term view. The study of transmission economics, including the choice of voltage, is a difficult and complicated matter and in general it is not possible to arrive at a definite answer by pure calculation. Calculation should be used as far as possible, but we must always be aware of its limitations due to the inevitable uncertainties in the assumptions on which the calculation is based. In most cases, it is necessary to make some forecast of future, and largely unknown, conditions. This calls for sound judgment as well as vision, which qualities are in fact the essence of all engineering.

With each upward step of transmission voltage, new technical problems are presented, the overcoming of which not only requires time and experience but also involves heavy cost. It must not, therefore, be too readily assumed that any voltage level, however high, is merely a matter of time. It may be some considerable time before 400,000 volts is exceeded, but, nevertheless, we are probably within sight of the half million volt mark enabling blocks of a quarter of a million kilowatts to be transmitted per circuit over distances not far short of 1,000 miles, though whether such transmission will be economic is another question. Direct-current transmission may eventually supersede alternating-current and increase this limit, but it would appear more probable that, for economic reasons, direct current will be used initially for the submarine-cable transmission of very large blocks of power.

THE ENGINEERS' GUILD.—We note that, of the 11 members nominated for the Metropolitan Branch committee election in the Engineers' Guild, eight are employed by nationalised or other public authorities. Of the 11 candidates, six belong to the Institution of Civil Engineers, four to the Institution of Electrical Engineers and only one to the Institution of Mechanical Engineers. The ballot papers are to be returned by noon on August 27. The election will take place on September 30.

NEW FOUR-JET BOMBER AIRCRAFT.—The second British bomber aeroplane propelled by four Rolls-Royce Avon jet engines, the SA/4, constructed by Messrs. Short Brothers and Harland, Limited, Seaplane Works, Queen's Island, Belfast, Northern Ireland, recently made its first flight. It may be recalled that the first four-jet bomber aircraft, the Vickers-Armstrongs Valiant, which is also propelled by Avon engines, made its first flight in May this year. No details of performance have been released on either of these aircraft.

THE PROPORTIONING OF CONTRA-FLOW HEAT-EXCHANGE APPARATUS.*

By C. E. Iliffe, M.A., A.M.I.Mech.E.

In general, the design of heat-exchange apparatus may be presented as the solution of three problems. The first of these problems is that of determining the laws governing heat transfer between a fluid and a surface or between two fluids direct, and the accompanying skin friction. The second is to formulate the relation between the temperatures of the fluids and the heat-transfer coefficients and apparatus dimensions. The third problem is that of combining the solutions of the first two, so as to obtain the best possible proportions for the apparatus. An expression for the temperatures of the fluids is obtained as a result of solving the heat-balance relation between heat-transfer rate and rate of gain in enthalpy of the fluids. In the case of contra-flow apparatus, to which this paper is confined, this relation may involve only one independent variable, namely, distance along the path of one of the fluids. It is not surprising, therefore, to find that considerations of optimum proportions have been carried farthest in such cases.

The velocity of a fluid flowing over the surface of a body is in general of the same order as that of its mass mean velocity except in a layer adjacent to the surface, the "boundary layer," in which the velocity falls rapidly to zero. The thickness of this layer increases with distance travelled by the fluid over the surface. The effects of fluid flow over a body, such as heat transfer and skin friction, are thus expressible in terms of the least number of dimensions on which the thickness of this layer depends. The effects of fluid flow over a solitary thin plate, for instance, can be expressed in terms of its length in the direction of flow. In the case of flow between parallel flat plates, a limit is set to the growth of the boundary layer by their pitch. In this case, therefore, the effects of the flow must be expressed not only in terms of length as before, but of pitch as well. Finally, if the plates are very long in the direction of flow, the fluid effects on them may be expressed in terms of pitch alone.

In the case of heat-exchange apparatus, heat transfer and skin friction can almost invariably be expressed in terms of a single characteristic dimension, depending on the shape and arrangement of heat-transfer surfaces employed. If

D denotes this characteristic dimension,
h „ heat-transfer coefficient,
σ „ skin friction,
k „ conductivity of the fluid,
c_p „ specific heat of the fluid at constant pressure,
ρ „ density of the fluid,
μ „ viscosity of the fluid,
v „ mass mean velocity of the fluid,

then dimensional analysis gives:

$$\frac{h\,D}{k} = \psi\left(\frac{\rho\,v\,D}{\mu}\right)\phi\left(\frac{c_p\,\mu}{k}\right) \quad . \quad . \quad (1)$$

$$\frac{\sigma}{\frac{1}{2}\rho\,v^2} = f\left(\frac{\rho\,v\,D}{\mu}\right). \quad . \quad . \quad . \quad (2)$$

The three ratios appearing in equation (1) are respectively, from left to right, the Nusselt number, Reynolds number and Prandtl number, while that on the left-hand side of equation (2) is termed the "friction factor."

In general, the functions ψ, ϕ and f can be written as power functions. Furthermore, if the exponent of Reynolds number in equation (1) is then n, the corresponding exponent in (2) is commonly found to be $n-1$, a phenomenon which finds a theoretical basis in Reynolds well-known analogy between heat transfer and skin friction. In the case of given fluids, the designer of a given type of heat exchanger is at liberty to vary only the velocities of the two fluids and the corresponding characteristic dimensions. Since the exponent n is invariably a positive number less than unity, it follows that the heat-transfer coefficient can be increased only at the expense of increased skin friction, and therefore with increased power losses in driving the fluids through the apparatus. It is, however, seen to be more profitable to obtain higher heat transfer through a reduction in characteristic dimensions than by an increase in fluid velocities.

The degree of heat exchange effected by a heat exchanger is generally measured by the ratio of the heat actually transferred to that which would be transferred if the heat-transfer coefficients were infinitely great. When the water equivalent flow is the same for both the hotter and colder fluids, this ratio becomes merely the temperature change of either of the fluids divided by the difference in their entry temperatures, and is then often referred to as the "thermal ratio." The condition of equal water equivalent flows is substantially fulfilled by gas-turbine plants, and it is in connection with such plants that interest in heat exchangers has lately been renewed.

The contra-flow recuperator employs a series of parallel ducts which perform the dual function of keeping apart, and transferring heat between, two fluids in opposite directions. The ducts are commonly plain round tubes, in which case the apparatus is referred to as a "shell-and-tube" type heat exchanger. Shell-and-tube type exchangers have recently received considerable attention, particularly in connection with industrial gas-turbine installations. In such applications, the water equivalent flow W is the same for both the hotter and colder fluids, so that if these two fluids are respectively denoted by single and double primes, then the thermal ratio of such an exchanger of length L is

$$\eta_r = \frac{1}{1 + \frac{1}{L}\left(\frac{W'}{h'\,P'} + \frac{W''}{h''P''}\right)} \quad . \quad . \quad (3)$$

where P denotes the wetted perimeter, and $W' = W'' = W$.

For flow inside the tubes, D may be taken as the tube inside diameter, so that

$$D = \frac{4\,W}{c_p\,\rho\,v\,P}. \quad . \quad . \quad . \quad (4)$$

For flow outside the tubes, it is usual to accept the same form of equations (1) and (2), with D given by equation (4) and referred to as the "hydraulic diameter."

If p denote the pressure of either fluid, and Δp its pressure drop through the heat exchanger, it can be shown that, for the same thermal ratio, the performance of the plant is unaffected provided that the quantity

$$\lambda = \frac{\Delta p'}{p'} + \frac{\Delta p''}{p''}. \quad . \quad . \quad . \quad (5)$$

remains unchanged. If only pressure drop due to tube skin friction be considered, then

$$\Delta p = 4\,\sigma\,\frac{L}{D} \quad . \quad . \quad . \quad (6)$$

Finally, the weight, bulk, cost or any other limitation on the size of the exchanger may be written symbolically

$$S = F\,(L, D', D'', P', P'', t) \quad . \quad . \quad (7)$$

where t is the tube thickness.

If the tube inside diameter and thickness are fixed, then so also are either D′ or D″, and P′ or P″, so that there remain the eleven unknown quantities v', v'', h', h'', σ', σ'', L, $\Delta p'$, $\Delta p''$, D′ or D″, and P′ or P″. For a given plant performance, η_r and λ will be fixed. Since equations (1), (2), (4) and (6) may be written for both the hotter and colder fluids, these equations, together with equations (3) and (5), provide 10 relations from which all but one of the 11 unknowns may be eliminated. Equation (7) then enables S to be plotted against this one unknown quantity and the dimensions for a minimum value of S to be determined.

This procedure corresponds to that described by D. G. Shepherd before the American Society of Mechanical Engineers in 1947. Professor E. Schmidt has presented a similar analysis to the Institution of Mechanical Engineers in 1948, in which equation (5) is replaced by

$$\frac{N}{G} = \frac{\Delta p'}{\rho'} + \frac{\Delta p''}{\rho''},$$

and $\frac{N}{G}$ kept constant instead of λ. Professor Schmidt, in effect, pointed out that his theory could be adapted to correspond to constant λ instead of constant $\frac{N}{G}$, but did not make this adaptation.

In the simplest form of contra-flow regenerator, the hotter fluid enters at one end, the "hot" end, with a constant upper temperature, gives up part of its heat to a heat-storing body or "matrix" on its way through, and leaves with a variable lower temperature at the other end, the "cold" end. The supply of hotter fluid is then shut off and the colder fluid enters at the cold end with a constant lower temperature. The colder fluid flows through the regenerator in the opposite direction, while absorbing heat from the matrix, and leaves at the hot end with a variable upper temperature. The supply of colder fluid is then shut off and the cycle of operations repeated.

Equations (1), (2), (4), (5) and (6) given above for a recuperator may be applied almost identically to a regenerator, while equation (7) requires only slight modification. Once an expression for the thermal ratio has been obtained, therefore, an optimum design of gas-turbine regenerator may be obtained on similar lines to that of a recuperator.

Such an expression may be obtained on the basis of the following assumptions:

(a) The thermal conductivity of the matrix is zero in a direction parallel to that of the gas stream and infinite in a direction at right angles thereto.

(b) The water-equivalent flows, heat-transfer coefficients, and velocities for the two gases may be different, but do not vary during a reversal period.

(c) The entry temperature of either gas is constant.

For a matrix of water equivalent M per unit surface, through which the hotter and colder gases pass for lengths of time t_p', t_p'', respectively, dimensional analysis shows that the thermal ratio

$$\eta_R = \Phi\,(\Pi', \Pi'', \Lambda', \Lambda'') \quad . \quad . \quad (8)$$

where $\Pi = \frac{h\,t_p}{M}$ and $\Lambda = \frac{h\,L\,P}{W}$.

Π and Λ are respectively referred to as the "reduced period" and "reduced surface."

The calculation of η_R received considerable attention by H. Hausen and W. Nusselt some 20 years ago. Hausen produced a set of curves of η_R against Λ for different values of Π for the case

$$\frac{\Pi'}{\Pi''} = \frac{\Lambda'}{\Lambda''} = 1,$$

that is, for "thermally symmetrical" regenerators. Hausen's method of calculation was extremely complicated, the accuracy of the result increasing with the number of simultaneous algebraic equations used to represent a pair of simultaneous integral equations. In a paper presented to the Institution of Mechanical Engineers in 1948, the author described a modification of this method giving a more rapid convergence, and used it to derive curves similar to Hausen's for the cases

$$\frac{\Pi'}{\Pi''} = \frac{\Lambda'}{\Lambda''} = 2, \qquad \text{and} \qquad \frac{\Pi'}{\Pi''} = \frac{\Lambda'}{\Lambda''} = 3.$$

The equality of $\frac{\Pi'}{\Pi''}$ and $\frac{\Lambda'}{\Lambda''}$ follows from that of $W't_p'$ and $W''t_p''$ which corresponds closely to the gas-turbine case.

In a communication on the same paper, R. W. Corbitt put forward the formula

$$\frac{\eta_R}{\eta_r} = 1 - \left(\frac{\Pi}{3\,\Lambda}\right)^2 \quad . \quad . \quad . \quad (9)$$

where η_r is found from equation (3).

This formula was found to agree closely with the author's results over the range

$$0{\cdot}8 \leqslant \eta_r \leqslant 0{\cdot}98$$

$$0 \leqslant \frac{\Pi}{\Lambda} \leqslant 0{\cdot}6,$$

which corresponds to that of greatest practical utility.

Mention should also be made of a paper by Professor O. A. Saunders and S. Smoleniec, read before the VIIth International Congress of Applied Mechanics in 1948. These authors employed a relaxation form of calculation and gave design curves for thermally symmetrical regenerators which considerably amplified those of Hausen in the region of greatest interest.

The cooling tower presents an example of contra-flow heat exchange apparatus involving direct contact between the two fluids together with change of state of one of the fluids. As might be expected, the heat exchange process is in this case more complicated so that progress has been slower. Nevertheless, it now seems to be firmly established that this process fairly well satisfies the relations:

$$w\,d\theta = K\,(i - I)\,dV = G\,dI \quad . \quad (10)$$

where

w denotes mass-flow of water per unit of tower cross section,
G denotes mass-flow of air per unit of tower cross section,
V denotes volume of effective portion of tower per unit of tower cross section,
K denotes overall transfer coefficient,
θ denotes water temperature,
i denotes enthalpy of moist air saturated at temperature θ, and
I denotes enthalpy of actual moist air.

In the *A.S.R.E. Journal* for November, 1916, B. H. Coffey and G. A. Horne gave a step-by-step numerical solution of equations similar to (10) except for the replacement of enthalpy by a closely proportional quantity which they termed "cooling potential." The present form was given to equation (10) by F. Merkel, in an article appearing in *Z.V.D.I.*, January 23, 1926.

In the absence of an analytical expression for i in terms of θ, equations (10) cannot both be integrated. The fraction $\frac{K\,V}{w}$, however, is seen to be the water

* Paper read before Section G of the British Association at Edinburgh on Monday, August 13, 1951.

temperature drop divided by the harmonic mean of $i - I$. Approximating to this harmonic mean by an arithmetic mean, Merkel was able to integrate equations (10) completely and prepare a diagram connecting the top and bottom water temperatures with the moist-air enthalpy at entry, and the quantity $\frac{1}{2}\frac{w}{G} + \frac{w}{KV}$. The accuracy of this diagram is generally sufficient for a preliminary estimate of performance.

Although the thermodynamic aspect of cooling tower behaviour is now well understood, there still remains a wide field for research into the relation of K and pressure drop through the tower to the dimensions of the fill and conditions of operation. It is unfortunate that published data bearing on this relation are often insufficiently complete. Extremely comprehensive results have been published, however, on a particular forced-draught tower under widely varying operating conditions by A. L. London, W. E. Mason, and L. M. K. Boelter in the *Transactions* of the American Society of Mechanical Engineers, January, 1940, and on a different tower in the same *Transactions* for October, 1943, by J. Lichtenstein. Results equally comprehensive, under less widely varying conditions of operation, however, have been published for different types of fill by W. F. Carey and G. J. Williamson in 1950, in the *Proceedings* of the Institution of Mechanical Engineers, together with valuable data on pressure drop.

In the case of natural-draught towers, the air flow is automatically determined by the design of the tower and the other conditions of operation. This feature suggests the use of Merkel's approximate method in which the ratio of air rate to water rate and the overall transfer coefficient are combined into a single function of the water rate. Such use of Merkel's method was made by W. T. Bottomley in 1940 in the *Transactions* of the North East Coast Institution of Engineers and Shipbuilders with encouraging results.

HYDRO-ELECTRIC SCHEMES: MODERN TRENDS IN CIVIL ENGINEERING.*

By T. A. L. PATON, B.Sc., M.I.C.E., M.Am.Soc.C.E.

THE use of the income energy of the world in the form of water power has, in the past, not developed as rapidly as the capital energy in the form of power derived from coal, oil and other fuels. According to recent estimates, only 4 per cent. of the estimated potential water power of the world at mean flow has been developed, excluding the power of the tides, but advance in the transmission of power over long distances, the linking up of generating stations by means of a Grid, the diminishing resources of coal and oil fuel, the lower rate of interest on capital and modern development in civil engineering have given considerable impetus in recent years to the development of hydro-electric power. As an example, the schemes in hand, or being surveyed, in the United Kingdom, principally Scotland, will increase the power available from hydro-electric schemes in Great Britain from 2 per cent., as at present, to 10 per cent. of the present total electricity demand of the country.

The available amount of water for any given scheme is the first consideration. The assessment of the mean yearly discharge is still largely a matter of judgment on the part of the civil engineer, based principally on observations over varying periods of years of rainfall, but also and increasingly on actual discharge of a given river. Elements of uncertainty are the percentage run-off from a given catchment, and the long-term variation. The deceptiveness of even long records may be appreciable; thus, for the River Thames, with 67 years of accurate records, successive 30-year periods differed from the present long-term mean by -10 per cent. and $+15$ per cent.

The statistical approach to this problem has exercised the minds of many over the past quarter century, but it is only of recent years that this method has become a useful supplement to the older methods to throw further light on this and indeed on many other problems. Attempts have been made to derive reliable weather cycles, related to sunspots among other variables, but without success. With so many variables involved, the theory of probability—based on the assumption that the run-off conforms closely to the Gaussian law—gives a valuable further weapon for the initial investigations. Economic considerations are so closely involved that any method of arriving at a more reliable estimate cannot be overlooked.

No longer, too, are catchment areas regarded in isolation: they are linked in many projects by means of tunnels, canals and aqueducts all to a common or to related reservoirs. This integration is carried still farther in the uses to which the water so obtained is applied. "Multipurpose" dams have shown the way to a more general outlook, and instead of benefits over and above those for which a scheme was designed being fortuitous, as in the past, every possible aspect is now being increasingly considered. Thus, water supply, production of power, flood control, navigation, irrigation, amenities, fisheries, bird life and public health are all duly considered in almost every case.

The war shortages of almost all materials, and also of man-power, with the large increases in costs of labour and materials all over the world has led to an orientation in outlook which looks for possible economies in every direction. This has influenced the aspect and line of approach to every project. The survey of unmapped areas in overseas countries may now be carried out to a large extent from the air. What once took years can now be achieved in months, once the organisation has been set up. The location of a site suitable for a dam, from the geological aspect, can sometimes be more rapidly assessed by geophysical methods in the early stages; although positive results can only be interpreted accurately by a proper geological section developed from the results of borings, nevertheless such methods may show rapidly whether a site is clearly unsuitable, and save the loss of many months spent in drilling unprofitable boreholes. It may help also to determine the type of dam most suitable for the site.

Turning to the dam structure itself, of the many types now in use, from earth fill and rock fill through the arch, the multiple arch, the buttress, the bull-head or T-head, reinforced or otherwise, the Ambursen, the gravity-arch, and the mass gravity, the emphasis has rapidly changed, though various types appear to prevail in different countries. In nearly all recent cases, the choice of dam has been wholly governed by the cheapest methods of construction combined with cheapest available material. Thus, in America, where large muck-shifting plant is available, and labour is expensive, the earth and rock-fill dams are achieving an ever-growing popularity, even for heights undreamt of until recently. The Stevens rockfill dam, or "Mud Mountain," as it was originally called, completed in 1942, was the chief forerunner of this type; it is 400 ft. from ground level, with a maximum base width of 1,620 ft. and a cubic content of just 2 million cub. yards. The growing knowledge and technique of soil compaction has rendered this possible, and indeed the addition of a puddled-clay or other type of thin impervious core is considered almost redundant for a properly graded and compacted earth dam. Where rock-fill dams are concerned, the core favoured is now the highly flexible impervious clay, of comparative narrow width, but protected from erosion or movement by a graded rock filter on both its upstream and downstream face, though over the former, while advisable, it is not strictly speaking essential. This core may be placed anywhere upstream of the central vertical position. Confidence in its stability is so great that it has been asserted to be safer than any other form of dam. One wonders, however, in the case of the all-earthen dam, whether burrowing animals may not in time induce harmful effects.

An interesting demonstration of the suitability of the rock-fill dam in areas subject to earthquake is the Cogoti Dam in Chili, 240 ft. above ground level. Completed in 1939, it was subjected to a horizontal accelerating shock computed at $0 \cdot 2g$ and the rock as a result settled about $1 \cdot 3$ ft.; it remained intact and no further settlement has since taken place. A somewhat novel innovation in the construction of a rock-fill dam (that of Harsprånget, Sweden) is the introduction of a solid block of concrete immediately behind the central cut off, enabling an inspection gallery to be introduced, from which drainage-well points have been drilled, acting as relief valves and enabling a watch to be kept on the imperviousness of the foundations. The central core requires special flexibility at its junction with the solid concrete, and without very special precautions might prove a source of weakness.

With increased knowledge and experience in concrete construction the concrete buttress dam is becoming increasingly popular, displacing the gravity structure. Its two outstanding advantages are that it solves the cooling problem for large masses of concrete and that it shows a saving in cost over the solid dam of from 20 to 30 per cent. Outstanding examples in the United Kingdom are the Haweswater dam in the Lake District and the Sloy dam near Loch Lomond. In Italy, in particular, where site conditions are eminently suitable, the arch variable-radius dam has been used extensively, the construction being marked by remarkably thin sections, even for very considerable height, at most reasonable costs. An instance of this type is the Lumiei dam of height 449 ft., and maximum thickness under 45 ft. In such cases it has been important to reduce the cost of transporting materials owing to the difficulty of access.

One of the difficulties involved in massive concrete structures is to reduce the heat of hydration in the setting of the cement. Unless this is done, there is a serious risk of contraction cracks developing as the structure cools. Low-heat cement has been used in this country on a number of gravity dams, and in America the present trend is to reduce the temperature of the crushed stone, sand, cement and water, before mixing. Another approach to this problem of reducing the risk of contraction cracks is the grouting of coarse stone aggregate placed *in situ*, commonly referred to as "prepact concrete." A "colloidal" mix of cement and sand is pumped through pipes into the interstices between the closely-packed stones, the pipes being gradually raised as the level of the mortar rises.

An all-important national aspect with regard to the design of dams is their safety in the event of war, when subject to aerial bombardment. It is probable that no dam could withstand a direct hit or near miss of an atomic bomb, but an earthen type primarily, and a rock-fill next, would suffer the least immediate disruptive effects. It was found, however, in the last war, that the destruction of arch dams by aerial torpedoes was no easy matter. The most vulnerable of all are undoubtedly the buttress or Ambursen types, though the damage would probably be local in the case of the buttress type and not necessarily accumulative except for very high dams; the Swiss defence authorities were so concerned with regard to one of their new dams under construction that they ordered complete filling in with concrete between alternate buttresses.

A new technique in dam design which awaits development is that of prestressing to obtain a better distribution of stress in a concrete structure and to prevent the development of contraction cracks. In one or two special cases this method has already been used, but it is unlikely to receive much favour in the case of large water-retaining structures until there is positive assurance that the tensioning wires or rods are fully protected from corrosion and ultimate failure.

The subject of dams cannot be closed without mention of the vexed question of uplift in design, since much has been written on it in the past few years. Opinion has varied widely as to what extent a masonry or concrete dam is liable to the vertical uplift pressure due to the water head. One thing is certain—100 per cent. uplift intensity does occur near the water face of the dam, and it is virtually nil at the downstream face. The linear rate of change in intensity, assumed between 100 per cent. and 0 per cent., with the modifications introduced by drainage galleries and boreholes along it is well known and is probably closely correct. But is this uplift intensity developed along the whole section effective over 100 per cent. of the area? This is the chief matter of controversy. The protagonists of 100 per cent. maintain that, since water penetration takes place between colloidal particles, the full area over which uplift takes place can be measured in depth by some microscopic amount, and therefore it is virtually effective over 100 per cent. What they do appear to ignore is, however, that these colloids themselves are bonded together, and therefore their strength of bond must be taken into account, which resists the effectiveness of the full area developing. It would appear, therefore, that the full uplift is subject to the reduction brought about by this internal resistance. What this amount is will clearly vary, but it surely holds the clue to the reason why some dams are stable which, on the full-uplift theory, should have failed.

Fish passes in this country have been of the conventional succession of pools or fish-ladder type, either with submerged orifices or overfall cross wall. Indeed, in most countries this is the case, though the United States first introduced a "lift" or elevator for salmon on the Baker River or Salmon Pass Dam, which was completed in 1926. Few appear to have been constructed since that date. Recently, however, a new hydraulic fish-pass elevator has been developed by a Scottish firm which is virtually a sloping tunnel, and one of this design has been successfully installed at Leixlip dam in Ireland. It is quite possible that this may replace the more lengthy fish-ladder type, especially where the site conditions are difficult. A new development in the fish pass at Pitlochry on the Tummel-Garry project is an observation chamber with glass windows where fish may be seen and counted on their way upstream.

Linked closely with the construction of reservoirs is the control of floods. Provided that reservoirs are partly empty, they will always exert a modifying influence on the incidence of floods; this may result in a reduction either of the peak or of the length of its duration. If the reservoir is full, its effect is much less pronounced, due to its reduced capacity as measured by its surface area only, plus any permissible flood rise. Where dams are required to store water for specific use, and where the incidence of rainfall is very uncertain, the storage water must be obtained by early filling, leaving little or no margin for later floods. Unless, therefore, special provision is made for dealing with floods at all times by keeping a reservoir low before a flood, and emptying after its occurrence, the influence of storage is inevitably haphazard, the benefit

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

received in floods varying appreciably. Proper insurance against floods cannot be obtained in these circumstances, though it is always questionable whether it is economically worth while or possible to give absolute safety against freak storms, which may occur only once in 100 years or more. With the expansion of population and the increase in land areas required, the protection against flooding assumes greater emphasis and importance, and so on certain projects special dams are now being built which when controlled in conjunction with others give additional security; whereas the main dams are in general on the main rivers, these flood-control dams are on tributaries.

The broader concepts of multi-purpose dams covering every possible use to which they can be put, and not confined solely to the two aspects mentioned, have thus arisen, but a sane balance must be maintained between expenditure incurred and total benefits obtained. The interests of the community may render a local project of national importance, requiring financing by the Government, wholly or in part.

Where control of flood discharge over the spillway is required, the Tainter gates appear to be losing popularity—there is always difficulty in staunching them effectively. For smooth discharge with automatic operation the drum gates (such as being used at Pitlochry dam) are hard to improve on, and where these conditions are not essential and the length of spillway is not constricted, the Stoney roller gates, operated from a platform above, have advantages. Needle valves with dispersers are still popular for small discharges under considerable head, and the Stoney gates, with their effective staunching, ease of operation, and recent improvements (removing largely the "chatter" under moderate heads) hold the field for sluices up to 100 ft. or more in depth.

With the raising of the height of dams to 500 ft. and over, the discharge of excess water safely without endangering the foundations downstream of the works becomes a difficult problem. Some means of absorbing the kinetic energy of the water is imperative. Where small amounts are concerned disperser valves can be used, but the real problem is to cope with floods when the reservoir is full. In narrow gorges, the French-devised ski jump, with the power-house roof forming the toe of the spillway, has probably come to stay. The arrangement at the Boulder Dam, where batteries of valves discharge through connecting tunnels on either side of the canyon, mutually destroying their energy, is an ideal which can seldom, if ever, be applied except to a limited extent. The most promising method for a concrete or masonry dam would seem to be the overflow spillway, with a kick-up or bucket at its extremity, giving a trajectory discharge well away from the toe of the dam, where any pot-hole formed acts as a cushion, without jeopardising the safety of the structure. This has not been tried yet on really high dams.

In recent years, increasing attention has been drawn to the problem of silt deposition, and statements in the United States technical Press to the effect that over 60 per cent. of their existing reservoirs had a useful life of under 100 years has seriously perturbed the complacency of the water engineer. Study is being directed to the mitigation of this menace, and every possible method of preventing soil erosion is being tried, such as contour irrigation, the silting up of eroded gullies, etc.; special interception dams have been constructed in some instances. The rate of deposition in Lake Mead was such that its total life was given as some 250 years, but recent measures taken have resulted in a revised figure of 425 years. In few cases is it possible to store water so favourably as at Aswan, Egypt, due to the regulating of the occurrence of flood water, enabling the silt-laden water to be passed almost undisturbed through the 179 low-level sluices, and only the relatively silt-free water being stored later. This silt problem is common to all reservoirs, and calls for eternal vigilance.

Recent new technique has changed the economics of tunnel-driving to a remarkable extent, reducing the cost of rock excavation and of lining tunnels so considerably that it has rendered feasible projects which might otherwise be debarred on account of their cost. This advance is largely due to Swedish developments, using drills with tungsten-carbide tips. Light high-speed drills weighing only 33 to 55 lb. can now be used, supported on portable airlegs for boring holes in rock to place the explosive charges. The steel is of only $\frac{7}{8}$ in. to 1 in. hexagonal section, with a 1·3 in. bit which can drill 70 ft. into hard granite at a rate of 1 ft. per minute without requiring to be reground. Each rod will do from 700 to 1,200 ft. before being discarded; the rate of drilling is 30 to 45 ft. per man-hour, inclusive of all other work implied, such as changing the drill rod. The advantages claimed for using such a rig are the reduction in men required, 30 per cent. less compressed air required, with length of headings from 3 to 5 miles; the holes around the perimeter of a tunnel can be much closer, reducing the amount of over-breakage in an 11-ft. diameter tunnel, for example, by about 25 per cent. as compared with previous methods. The amount of high explosive used is also reasonable, about $1\frac{1}{4}$ lb. per cubic yard of rock excavated. Because of the close tolerances to which excavation can be carried out, the cost of lining a tunnel is reduced appreciably.

Where tunnels are subject to considerable water pressure a new technique for lining circular types has been developed in parallel with excavation; the shell, of thickness $1\frac{1}{2}$ in. to 4 in., is built up of precast blocks, on which is superimposed a compressive prestress of 3,000 to 4,000 lb. per square inch, which, in addition to preventing cracks, reduces the amount of tensile steel required. There are two methods of carrying this out, either by using high-tensile steel wire hoops—the small access holes being grouted later—or by direct grouting, inducing a compression stress 50 per cent. in excess of the maximum tensile stress which may develop under working conditions. Savings over previous methods in the United States by this new technique are computed at 30 to 50 per cent. The direct consequence of these developments would appear to be that larger sizes of water-carrying tunnels will be economically possible for future construction. The present largest in Great Britain is the recently-completed Clunie tunnel, in connection with the Clunie power station on the Tummel-Garry project; its equivalent diameter is 23 ft. and its length 9,158 ft.

The manufacture of high-pressure pipes forming the penstock has been subject to a considerable advance in technique. Static heads on turbines have reached over 5,500 ft., and the previous costly method of strengthening pipes to resist such a head by reinforcing hoops at close intervals, shrunk on by heat-treatment similar to the method of renewing steel tyres on railway-carriage wheels, is being replaced by the much cheaper method of building the barrel with tensioned steel wire —somewhat analagous to the strengthening of a gun barrel. In this country, however, heads of such a high order are non-existent, and the greatest that can be developed is of the order of 1,000 ft. The increased reliability of welding for pipes up to $1\frac{1}{2}$ in. thick has extended its employment for the penstock pipes, affording considerable economy, with the added advantage of reducing rivet resistance to the flow of water.

While the changes already mentioned have a very pronounced effect both on design and the construction technique, the least spectacular and yet most noticeable change is that of the disappearance of the power house, hidden in a rock chamber. While Norway appears to have given the lead in 1921, it is only recently that there has been a rapid increase, with over 60 underground stations in operation or under construction.

So far as either head or capacity are concerned, there appears to be no restriction with regard to the use of underground power stations, though the scope of choice of site with greater heads must clearly be advantageous more often than not. While claims have been made that this method of construction for the power house is in many cases cheaper by 10 to 30 per cent. than an outdoor type, the saving in cost may easily be offset by a longer transmission line. There are two dominating considerations which override all others: firstly, the rock itself may be of any formation or type, but it must be sound and, secondly, there must be reasonable access for the supply or replacement of plant. Apart from the difficulty of access which is inherent in such a site, a further necessity is that of air conditioning. The technical advantages of underground power stations are the reduction of friction, since the intake length (which must be lined) is invariably shorter and the penstock can consist of a straight vertical or inclined shaft with branches to each turbine intake; the elimination of surge tanks and chambers, and penstock valves; maintenance and depreciation costs are low; in cold countries, ice interference is eliminated at intake and in the tail-race tunnel; and security against avalanches.

It has been found that the tail-race tunnel is often the most expensive item, since gradients require to be kept between the limits of about 0·05 and 0·025. In the siting of these power houses, there is a choice between two extremes. Firstly, the location may be as near the source of water supply as possible, giving a short penstock, thus reducing the friction losses, and so obtaining the maximum power. This may, however, involve difficult access, and a long tail-race tunnel which must be of liberal section, and probably a surge shaft to damp down waves. The tunnel need not be lined. The Swedes advocate this, and state that it is economical in good rock. Alternatively, the location may be near the tail race with a long penstock but easy direct access by tunnel, possibly along the tail race itself. In this case some power is lost and a surge chamber is essential. The power cables are easily taken to the surface, and the transmission line is normally shorter than with the other arrangement. With good rock, the first alternative is probably the best.

The outdoor power house itself is subject to changes in building technique, and reinforced-concrete portal construction with barrel roof has recently given a pleasing design. Its advantages are obvious in the unobstructed roof space made available, tending to reduce the overall height of the structure. Doubtless prestressing will be used in the near future, leading to a lighter type of construction; and ultimately a small reduction in cost, though at present there is little difference. Considerable economy in the construction of the power house can be achieved by adopting the outdoor station type, the superstructure being omitted. This type appears to be adopted to an increasing extent in the United States, and, although this climate would seem not to favour its use, it is believed to be under consideration for one of the new smaller stations. Its chief attraction is the economy achieved in the larger stations. A variant on the outdoor station is the semi-outdoor, which differs from the other only to the extent of having separate covers for each machine.

The rise in the cost of both labour and materials and the shortage of labour has led to the design and extensive use of labour-saving plant and the careful revision of methods of design, so that the best possible use can be made of materials available. Belt conveyors up to 30 in. in width are now used for transporting all types of materials to an increasing extent. Muck-shifting plant has been developed to an equal degree; present limits for units are 45-cubic yard trucks, 5-cubic yard shovels, and 6-cubic yard unit batch concrete mixers. Furthermore, many improvements have been made in the mixing and control of concrete, the latest type of plant performing the following functions: fast accurate automatic weigh-batching, automatic compensation for variations in moisture of sand and fine aggregate, instantaneous mix changes with a mix selector, interlocking operations to prevent errors, grouping of all controls at a central board, and complete recording of every batch poured. On one scheme, concrete output has reached a monthly total of 400,000 cubic yards and for a single plant 10,000 cubic yards a day. Speed in placing has been enhanced by conveying the concrete in pipe lines with compressed air. Similar methods are applied to the bulk storage of cement. Large mixers enable an increase in the size of aggregate up to 6 in. diameter.

This survey of the present position and trends with regard to the production of hydro-electric power cannot be completed without an attempt to dip into the future. The question arises as to the effect atomic energy may ultimately have on existing and potential hydro-electric plant when produced on a commercial basis. No opinion can be reached without an appreciation of the possible methods of producing power by such means. The only means of utilisation of atomic energy would appear to be by raising the temperature of water or a gas to a sufficiently high temperature to enable it to work a steam or gas plant. Among many difficulties are the selection of reliable parts normally subject to renewal which will stand up to the conditions involved, such as an efficient gland for a rotor controlling the circulation, and a lubricant which can be dealt with effectively; and, finally, protection against the radio-toxicity induced by atomic energy.

These problems are very big ones and will not be solved quickly; if, and when a solution is obtained, the indications are that atomic power will certainly not be cheap, and, in the initial stages at any rate, will be in no position to compete with present sources of energy. It is extremely doubtful whether its cost of production can ever be less than that prevailing at the present day; its great significance will be its substitution for the wasting asset of coal. It follows, if these premises are correct, that the hydro-electric station will always have a very positive value, at any rate, beyond any foreseeable horizon of time. It would, therefore, seem prudent to continue all possible development of this source of energy, including tidal power.

A further significant source of energy must also be mentioned which is full of latent possibilities, namely, the tapping of natural sources of heat in the form of steam (mostly 95 per cent.) and gas, at considerable depths in the earth's crust, akin to the energy source from which volcanoes are derived. The Italians between 1926 and 1949, have achieved remarkable success in producing energy at Larderello in Tuscany, with various depths of bores reaching a maximum of 4,800 m. (15,750 ft.); the pressures of the steam gases when reached have been from 15 to 18 atmospheres with a temperature of 140 to 215 deg. C. The amount of energy now produced per annum is over 1,000 million units.

Finally, a paper dealing with modern trends in civil engineering works would not be complete without a word on amenities, particularly applicable to the schemes in Scotland. There is no reason for such development to be an eyesore. The Galloway power scheme, completed in 1936, is a case in point where particular care was taken to avoid spoiling the amenities of the neighbourhood. Other important schemes where amenities were of special importance were Loch Sloy and Tummel-Garry. Much can be done to ensure that planning, design and maintenance are carried out in such a manner as to encourage tourists to visit and inspect modern hydro-electric schemes.

MARINE RADAR SCHOOL AT SOUTHEND-ON-SEA.

KELVIN AND HUGHES (MARINE), LIMITED, LONDON.

FIG. 1. SCANNER ON TOP OF PALACE HOTEL.

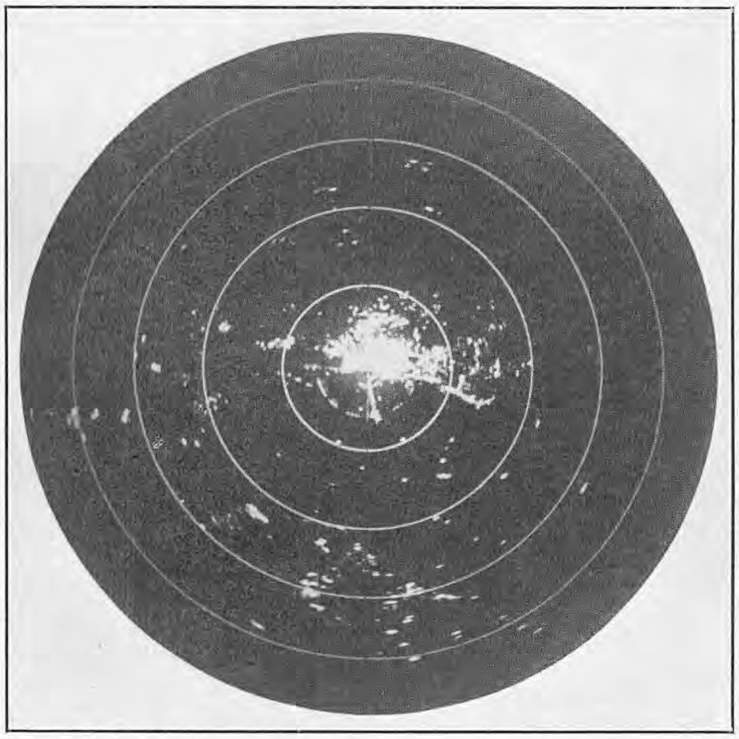


FIG. 2. RADAR SCREEN IMAGE OBTAINED FROM PALACE HOTEL.

KELVIN-HUGHES MARINE RADAR SCHOOL, SOUTHEND-ON-SEA.

IN order to instruct ships' officers in the use of their marine radar equipment, Messrs. Kelvin and Hughes (Marine), Limited, 107, Fenchurch-street, London, E.C.3, have recently opened a new and well-equipped school on the top floor of the Palace Hotel, at Southend-on-Sea, Essex. Formerly the firm operated a school at the head of Southend Pier, but this school is now closed and the apparatus installed there is employed for experimental and research work.

The Kelvin-Hughes system, which was shown in the Exhibition of Industrial Power at Glasgow and was referred to on page 168, *ante*, is relatively simple to use and to maintain, but it is obviously highly desirable that ships' officers who make use of the apparatus should understand its limitations as well as its capabilities; both are fully explained in the school and technicians are also instructed in the proper maintenance of the equipment.

The essential parts of the equipment are the scanner, transmitter, display unit, motor-generator and starter unit and monitor-signal unit. The scanner installed on the top of the Palace Hotel is illustrated by the photograph reproduced in Fig. 1. It is in the form of a truncated paraboloid, 5 ft. in width and 4 in. in height. The pulses, which have a wavelength of about 3 cm., are generated by the transmitter and are supplied to the centre of the scanner by a flared wave guide. The scanner is rotated continuously through a complete circle, by an electric motor, at a rate of 30 r.p.m., and as the pulses have a range of about 25 miles, a circle of 25 miles radius is covered. The pulses, which are of exceedingly short duration, recur at the rate of 2,000 per second; they have an angular width of 1·6 deg. in the horizontal plane and an angular depth of 27 deg. in the vertical plane. If a radiated pulse should encounter any material object, part of the energy is reflected back to the scanner, reaching it in the time interval between two transmitted pulses. During this short time interval the scanner is connected by an electronic switch to a receiving set the output from which is applied to the display unit. This incorporates a cathode-ray oscillograph designed so that the reflected energy appears in the form of a bright spot on a line radiating from the centre of the screen to the circumference. The line is made to rotate about the centre of the screen in synchronism with the rotation of the scanner and as the fluorescent material of the scanner is of the "after-glow" type, the bright spots resulting from the reflected pulses coalesce to form a small-scale map or plan, resembling a marine chart, of the area swept by the transmitted pulses. On this plan, a coast line, other vessels, buoys, and other objects of interest to a navigator appear in their correct relative positions, which are not affected by fog or other conditions of low visibility.

FIG. 3. DISPLAY UNIT.

The cathode-ray oscillograph of the display unit, or plan-position indicator (P.P.I.), is 12 in. in diameter. Its appearance is shown in Fig. 3, and also in Fig. 144, on page 167, *ante*. Fig. 2 is a reproduction of a photograph of the screen with an image of an area 10 miles in radius from the Palace Hotel, Southend-on-Sea. The pier and the adjacent shore can be readily distinguished. The radial distance between the circles, in this case, is two miles, but three other ranges, of 1 to 5, 15 and 25 miles, can be brought into use by a switch on the display unit; the small window near the bottom left-hand corner of Fig. 3 shows at a glance which scale applies to the image on the screen. It is possible, of course, to estimate the distance of any object visible on the screen from the known scale of the circles. To determine distance more precisely, a single circle may be made to appear on the screen and its diameter varied until it cuts the object the distance of which is required. The diameter of the circle is varied by the small knurled wheel partly visible under the window near the bottom right-hand corner of the display unit; above the wheel is an indicator on which the distance can be read directly in nautical miles and cables.

Careful inspection of Fig. 2 will show a light line to the left of the pier, also distinguishable by breaks in the circles. In a ship installation, this line is set parallel to the longitudinal axis of the vessel, and from this line the bearing from the ship's head of any object visible on the screen can be measured. The measurement is obtained by means of an illuminated cursor on an azimuth scale engraved on a ring which surrounds the screen.

The minimum range at which objects can be indicated on the screen obviously depends upon the height of the scanner above the water level, but, as usually mounted on a ship, the minimum range is 40 yards, and this is approximately the distance at which two objects on the same bearing but at different distances can be indicated separately on the screen. As the angular width of a pulse is 1·6 deg., separate objects which are closer than that in azimuth appear as one on the screen. These limitations, which are unavoidable, have little importance in practical navigation, though it is, of course, important that the navigator should be aware of them, and one of the functions of the school at Southend is to present them to the prospective user in their true proportions.

Notwithstanding the limitations mentioned, ships equipped with this apparatus have been able on many occasions to enter or leave a congested estuary in a thick fog when vessels not so equipped were at a standstill and to complete a long coastal voyage safely in conditions which rendered it impossible to take any visual bearings.

BOOKS RECEIVED.

Guide to the Coalfields. 1951. Edited by R. H. WALKERDINE and C. TREHARNE JONES. The Colliery Guardian Company, Limited, 30 and 31, Furnival-street, London, E.C.4. [Price 18*s*. net.]

Transients in Electric Circuits, Using the Heaviside Operational Calculus. By PROFESSOR W. B. COULTHARD. Second edition. Sir Isaac Pitman and Sons, Limited, Pitman House, Parker-street, London, W.C.2 [Price 32*s*. 6*d*. net.]

London County Council. Some Interesting Facts and Figures About the Council's Service. 1951. The Information Bureau, County Hall (South Block), Westminster-bridge, London, S.E.1; and Staples Press, Limited, Mandeville-place, London, W.1 [Price 6*d*. net, postage 1½*d*.]

Boiler Explosions Acts, 1882 *and* 1890. Report of Preliminary Inquiry (No. 3359). *Explosion from Water Tube Boiler at Cantley Sugar Factory, Norfolk.* H.M. Stationery Office, Kingsway, London, W.C.2. [Price 6*d*. net.]

Some Wallis and Steevens Traction Engines and Steam Wagons. By R. C. WALLIS and J. P. MULLETT. J. P. Mullett, Westcroft, Northchurch Common, near Berkhamsted, Hertfordshire. [Price 4*s*. 3*d*. post free.]

In the Workshop. By DUPLEX. Volume III. Percival Marshall and Company, Limited, 23, Great Queen-street, London, W.C.2. [Price 9*s*. 6*d*. net.]

THE TRACTIVE RESISTANCE OF TROLLEY 'BUSES.*

THE manufacturers of trolley-'bus electrical equipment who are members of the British Electrical and Allied Manufacturers Association have recently taken a valuable step towards standardisation by obtaining correct trolley-'bus tractive resistance curve, as shown in the accompanying graph. A comparison of the tractive-resistance figures previously used by the different manufacturers had revealed considerable divergence and it was found that few test data on the subject were available.

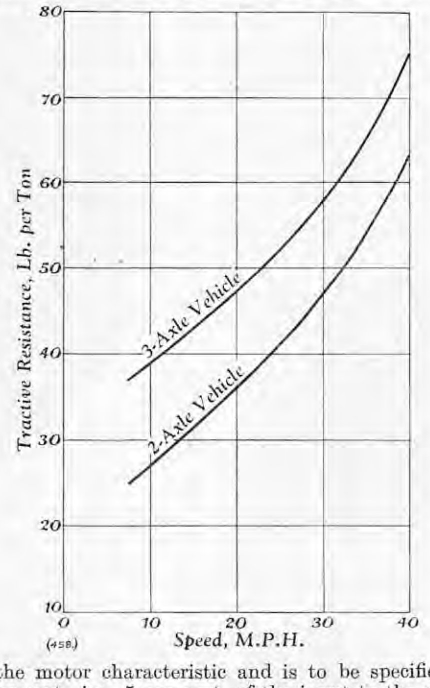
As the actual value of tractive resistance greatly influences performance, particularly the balancing speed, it is important that tendering companies should use accurate figures in order that the performance as shown by the calculated run curve can be obtained on the actual vehicles. It was therefore decided that all the companies concerned should combine to obtain resistance curves from actual tests. It was realised that no purpose would be served by making motoring tests, as all the necessary results could be obtained more simply and accurately from coasting runs, the reasons being as follows. It is possible to obtain only one point on a tractive-resistance curve by making a run at a balancing speed under power. A coasting run, however, gives points over the whole range of speeds through which the 'bus has coasted. Thus, a large number of motoring runs would have to be made to obtain a complete curve of tractive resistance, while only a few coasting runs are needed. Also, tractive effort cannot be measured directly without special apparatus; in fact, the electrical input to the motor must be measured and converted to tractive effort by means of the motor characteristic. This introduces the possibility of several errors, which are not present in coasting.

The first series of tests was undertaken on a two-axle double-deck trolley-'bus at Hastings, where there is a stretch of straight well-made level road along the sea front. Three forms of recording instruments were used to compare and, if necessary, obtain average values of tractive resistance. The instruments were a two-element cathode-ray oscillograph, a three-element Duddell oscillograph, and a paper strip recorder marked by means of intermittent sparks from two sparking coils. One spark was fired at equal intervals of distance covered by the trolley-'bus, and the other was fired at equal intervals of time. Distance impulses for the recorders were provided by means of a "fifth wheel" apparatus towed behind the vehicle. The variables recorded were speed, time and distance. Several runs were taken in each direction. There was no noticeable wind. The results obtained from the three recorders were remarkably consistent. The Duddell instrument proved to be the most useful in that photographic records of comparatively long runs could be made, whereas this did not prove possible with the other instruments.

The second series of tests was carried out in London, on the London Transport system between Kingston Bridge and Hampton Court, on a three-axle double-deck trolley-'bus. The Duddell recorder only was used, in conjunction with a "fifth wheel" apparatus. The road was sensibly level and straight and the surface good. Nevertheless, a survey was taken and due allowance made for the gradients in calculating the coasting retardation (a gradient of only 1 in 400, which is normally negligible in trolley-'bus work, will introduce an error of over 5 lb. per ton). Several runs were taken in both directions to nullify the effect, if any, of the slight wind. Oscillograph recordings were taken of speed, time and distance, the speed trace serving merely as a guide. On plotting the tractive-resistance figures obtained from the two series of tests as pounds per ton against speed, it was seen that there was a large difference between the curves for the two-axle and three-axle trolley-'buses, the latter curve being the higher. Probably the factors accounting for most of this are the difference in gear losses and the effect of the extra rear axle.

The loss in the gears can be split up into gear-face loss and oil-churning loss. The former is a function of power transmitted, but the latter is purely a function of speed. Thus, the gear-face loss is properly shown on the motor characteristic, and the churning loss is obviously incorporated in the tractive-resistance curve, as it is a considerable drag on the trolley-'bus and is included in the resistance measured in coasting conditions. In view of the fact that the power taken in driving the motor during coasting is very small, the gear-face loss is even smaller and can be neglected. The difference between the motoring tractive resistance and the coasting tractive resistance is the sum of the motor loss and the gear-face loss. This additional loss is accounted for in the traction-motor characteristic and should not be included in a motoring tractive-resistance curve.

Though the tests were made only on double-deck trolley-'buses, the curves obtained should in fact be applicable to single-deck trolley-'buses. Since the frontal area of a single-deck 'bus is smaller than that of a double-deck 'bus, the portion of the total resistance which is due to wind resistance will be less for the single-deck 'bus, which would give a slightly lower figure for the total tractive resistance in pounds per ton. This being so, the use of the test curves in calculating the performance of a single-deck 'bus will err slightly on the pessimistic side. As the gear loss has been divided in two, and the churning loss included in the tractive-resistance curves, the gear-face loss has to be included



in the motor characteristic and is to be specified at 5 per cent., i.e., 5 per cent. of the input to the gears. In motoring, this will be the output from the motor, and in rheostatic and regenerative braking the output from the axle(s). For predicting the coasting retardation a figure of 0·4 mile per hour per second should be used. It was felt that the range of speeds over which trolley-'buses normally coasted was so small that a fixed value was justified.

* Communication from the British Electrical and Allied Manufacturers Association, 36 and 38, Kingsway, London, W.C.2. Abridged.

TRADE PUBLICATIONS.

Contractors' Plant.—Chamberlain Industries, Ltd., Argall-avenue, London, E.10, have produced a catalogue of the contractors' plant, including bulldozers, compressors, concrete mixers, conveyors, cranes, hoists, lighting sets, pumps, tractors, winches, etc., which they have for sale and hire.

Industrial Locomotives.—The Yorkshire Engine Co., Ltd., Meadow Hall Works, Sheffield, 9, who are associated with the United Steel Companies, Ltd., have issued a catalogue of their standard industrial locomotives, which include two 0-4-0 and two 0-6-0 steam engines, and the 0-4-0 Diesel-electric locomotive which was the subject of an article in ENGINEERING, vol. 171, page 777 (1951).

Lubrication in Steelworks.—The latest addition to the Wakefield series of publications dealing with lubrication in industry is entitled "Steel Works Lubrication." As with others in the series, it is a substantial and well-illustrated book which gives extensive technical information on the subject. Complimentary copies are obtainable from C. C. Wakefield and Co., Ltd., Dept. P.D. 46, Grosvenor-street, London, W.1.

Tube Joints.—Some typical applications of the Simplifix compression joints for tubes are illustrated in a brochure issued by Simplifix Couplings, Ltd., 157, Victoria-street, London, S.W.1. The joints require no brazing or expansion of the tube, nor special tools; they are basically similar to a union joint, but the joint is made by a loose copper ferrule which is held in place by a collar and union nut. The firm have also published a price list of their brass and steel fittings for tubes.

Gauges and Tools.—The second edition of *Export Catalogue*, each copy in English, French and Spanish, has been prepared by the Gauge and Tool Makers' Association of Great Britain, 2-5, Old Bond-street, London, W.1. Most of the 137 pages are filled with illustrated advertisements of the member firms' products, the others containing indexes arranged alphabetically by products and firms, and a statement of the Association's aims, objects and export activities. The catalogue is free to addresses abroad, but price 5s. to home addresses.

NOTES ON NEW BOOKS.

The Gas Turbine Manual.

By R. J. WELSH, Wh.Ex., M.I.Mech.E., and GEOFFREY WALLER. Temple Press, Limited, Bowling Green-lane, London, E.C.1. [Price 25s. net.]

A BOOK that deals, in the words of the publishers' note, "with all forms of gas turbines other than those for aircraft," and is descriptive rather than mathematical, can afford to refer to almost every such gas turbine. In another 20 years, if the development of this type of engine proceeds according to plan, the situation will be different; meanwhile, this book serves a useful purpose, by dealing at some length with the general principles, in language that the non-specialist can readily follow, and giving short specifications of actual designs. The early history, which has been well covered in institution papers, is recounted in the first chapter. Thereafter, the authors deal with first principles of gas turbines, with basic metallurgy and thermodynamics, and with the different cycle arrangements that are possible. Compressors, turbines, combustion chambers, heat exchangers, intercoolers, and pre-coolers are described, with emphasis on the various forms they may take, and then there is a chapter each to gas-turbine locomotives, marine gas turbines, process gas turbines and power-station gas turbines. In the concluding chapters, brief descriptions are given of specific British and foreign machines in service or under construction, and two appendices are devoted to short specifications in tabular form and to a glossary of terms. The book is amply illustrated and the style of writing, in the main, suits the authors' approach to the subject.

The London, Tilbury and Southend Railway.

By H. D. WELCH. The Oakwood Press, Tanglewood, South Godstone, Surrey. [Price 5s., postage 4d.]

ANOTHER small volume to add to the Oakwood Library of Railway History, which now comprises eight books on some of the lesser railways of pre-amalgamation days. The London, Tilbury and Southend Railway was mooted nearly a hundred years ago, at a special meeting of the shareholders of the London and Blackwall Railway on November 24, 1851; the application to Parliament was made jointly with the Eastern Counties Railway. The Act received the Royal Assent on June 17, 1852, and the first section, from Forest Gate to Tilbury, was opened on April 13, 1854. The line was leased to the contractors who built it, Messrs. Peto, Brassey and Betts, who worked it until 1875, when the working was taken over by the directors. Mr. Arthur L. Stride was then appointed resident engineer and general manager, and remained with the company until it was taken over by the Midland Railway in 1912. The L.T. and S. Railway, though built to carry Londoners to Tilbury, whence they could be ferried across to the pleasure gardens at Rosherville, near Gravesend, eventually owed its prosperity to the rapid growth of Southend, coupled, as Mr. Welch points out, with the "extreme lowness of fares, an excellent reputation for punctuality, and a far-sighted management, which provided new services as soon as they were needed." The company had a small fleet of steamers, and its locomotives, all but two of which were tank engines, included the first Baltic (4-6-4) tank engines used in Great Britain. These were introduced in 1912 by Mr. R. H. Whitelegg, whose father, Mr. T. Whitelegg, was in charge of the locomotive department from 1879 to 1910.

Concrete Block Making Machines.

By A. SOBOLEV, B.Sc.(Eng.), A.M.I.Mech.E., A.M.I.Struct.E. H.M. Stationery Office, York House, Kingsway, London, W.C.2. [Price 1s. net.]

IN 1947, the author of this report carried out an investigation on behalf of the Chief Scientific Adviser's Division of the Ministry of Works (since transferred to the Department of Scientific and Industrial Research) of the plant and processes used in the manufacture of concrete blocks, and of the methods and organisation of block-making works. The results are now issued as Special Report No. 17 in the series of National Building Studies, and provide a technical and economic review of considerable interest. The survey covered the plants of 28 firms out of the total of 108 operating at the time, their outputs ranging from 150 to over 7,000 per day. Most of the firms, it was found, had only "a limited knowledge of the properties of the materials and machines they used," and much of the plant was rather primitive and not very efficient; but some firms who saw the possibilities of large-scale production and wished to adopt better methods "had no chance of doing so simply because no suitable machinery and plant was available." Inventors and would-be makers who may be tempted by this quotation to adventure their time and money in attempts to correct this state of affairs would be well advised, however, to study carefully Mr. Sobolev's informative report before doing so.