

BRISTOL 173 TWIN-ENGINE HELICOPTER.

ON Thursday, January 3, the first British twin-engine transport helicopter, the Bristol 173, designed and constructed by the Bristol Aeroplane Company, Limited, Filton House, Bristol, carried out its maiden flight successfully. A brief outline of the principal features of the machine was given on page 321 of our 171st volume (1951). It may be recalled that, on account of its ability to fly satisfactorily with one engine out of action, the aircraft is regarded by the Interdepartmental Helicopter Committee, whose report was published on March 9, as the first helicopter which will be acceptable for commercial operation between city centres, and that it is hoped to initiate such services by 1954. British European Airways believe that ultimately all internal services

concentrated loads occur, the tandem layout has made it possible to keep the structure weight low. To provide stability in yaw and pitch, a fixed dihedral tailplane, based on the results of stability tests in the wind tunnel on a 1/10 scale model, has been fitted. The general arrangement of the production machine which, it will be observed, has a different type of undercarriage, is shown in Figs. 2, 3 and 4. The fuselage is divided into four main compartments—the crew compartment, with dual controls, accommodation for two pilots and access doors each side; the front engine compartment; the cabin, with seating for ten passengers in individual seats each side of a central gangway, and a triple seat at the back starboard corner of the cabin opposite the entrance door; and the rear engine compartment. Soundproof bulkheads are provided between the engine compartments and the cabin and crew compartment.

top of the fuselage; if one engine should fail, the synchronising shaft transmits the drive from the working engine to the affected rotor, a free-wheel and clutch being provided in each transmission to isolate the dead engine. To provide adequate cabin clearance for the blade tips, the rear rotor is mounted well above the fuselage on a "pylon" structure. The shafts of the front engine and front rotor are both tilted forward 5 deg. from the vertical, whereas the rear rotor shaft has a forward tilt of 7 deg. and the rear engine shaft has a backward tilt of 15 deg. This arrangement, by bringing the rear engine forward, shortens the fuselage and thus saves weight.

Considering first the power transmission to the front rotor, a combined single-plate Alvis clutch and cooling fan is mounted on top of the engine. The clutch is operated by a pneumatic system developed by the Bristol Aeroplane Company.



FIG. 1. BRISTOL 173 HELICOPTER.

Fig. 2.

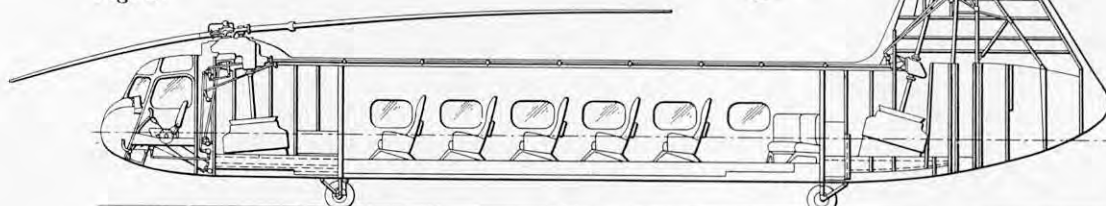


Fig. 3.

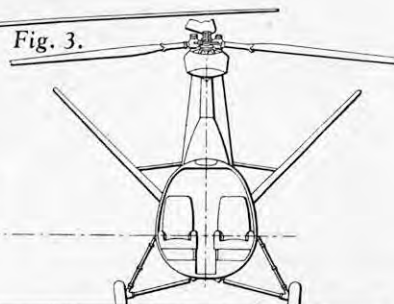
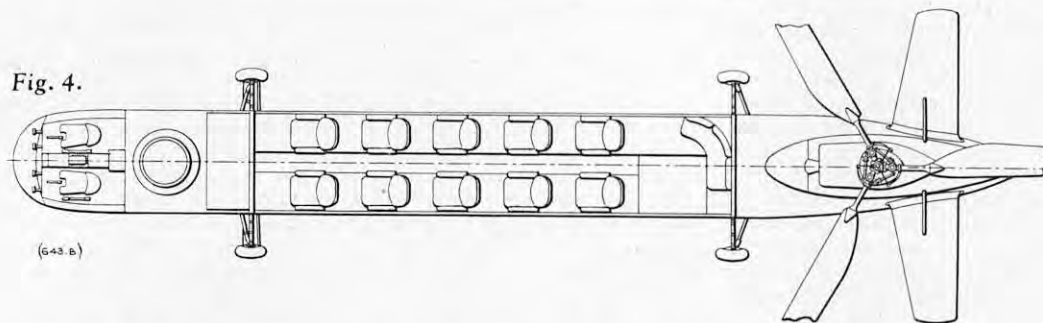


Fig. 4.



in the United Kingdom will be by helicopter. The Bristol 173 is intended primarily for carrying 10 to 13 passengers and their baggage over short ranges, but can also be converted quickly to a freighter with a cargo space of 605 cub. ft., capable of carrying 2,500 lb.

A photograph of the prototype Bristol 173 is reproduced in Fig. 1. The tandem layout, with the passenger cabin extending over the central part of the fuselage between the two engine compartments, has been selected in preference to a single- or triple-rotor layout so that the well-tried Leonides engines and rotor assemblies already developed for the single-engine Bristol Sycamore helicopter can be used; and so that the handling of the machine will be virtually unaffected by fairly large changes in the centre-of-gravity position. In conjunction with the four-wheel undercarriage, the two units of which

are located under the engine bays where the heaviest

Radial air-cooled Alvis Leonides 550-h.p. engines, type LE25 HMV, are fitted; each engine is mounted, with its cooling fan on top, on a fireproof steel floor in the engine bay and is surrounded by a steel cowling. Forward-facing air intakes to the engine bays are provided in the rotor-gearbox fairings, cooling air is sucked down by the engine fans and is discharged through an outlet in the bottom of the engine compartment, through which the exhaust gases also escape. Each engine has its own oil and fuel supply. Cooling air for the oil cooler is furnished by the engine fan through a duct in the cowling. The two contra-rotating rotors, each 48 ft. 6.7 in. in diameter, are mounted at 40 ft. 6 in. centres and are, therefore, intermeshing. Each rotor is normally driven by its own engine through a short shaft and reduction gearing. The rotors are, however, synchronised, to avoid blade collision, by a long shaft running in a duct along the

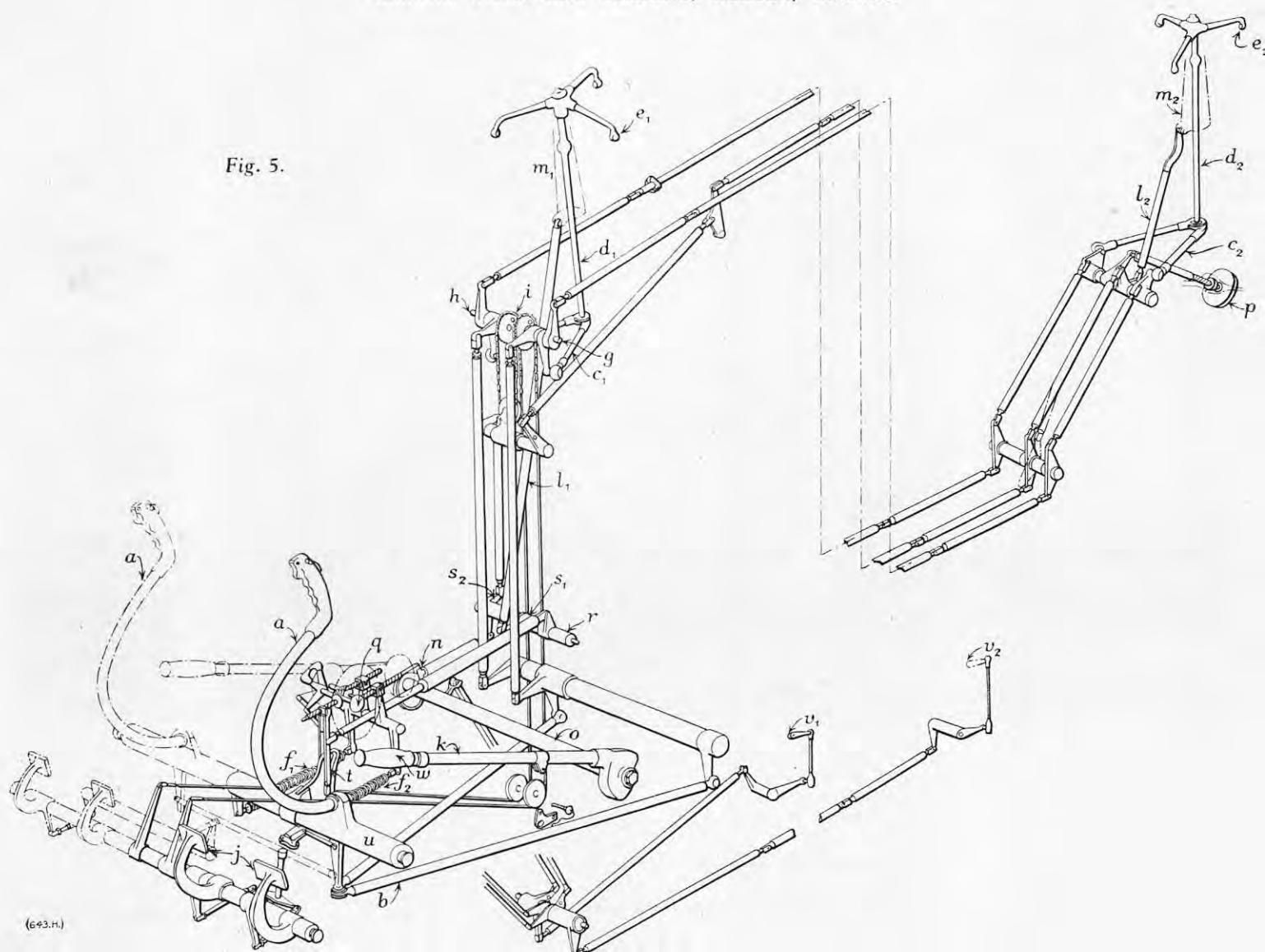
The engaging mechanism consists of a pneumatic tube, of flat elliptical cross-section, which fits between the clutch plates; to disengage the rotor from the engine, the pilot inflates the tube by a foot-operated pump, which causes the clutch pressure-plate springs to be depressed. To engage the clutch, the pilot opens a valve allowing air to escape through a metering jet, which regulates the speed of engagement so that the drive is taken up gradually and sudden loads on the rotor blades are avoided. The clutch is spring-loaded so that when the torque exceeds a given value, the clutch will slip. From the clutch, the drive is transmitted through a flexible Layrub coupling to a short transmission shaft, and thence through another Layrub coupling to the free-wheel in the front-rotor gearbox. Fig. 6, Plate III, illustrates the front-rotor hub and gearbox.

The driven member of the free-wheel, which is

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Fig. 5.



of the spring-loaded ratchet type, is coupled to the driving pinion of the front-rotor gearbox, which engages with an internal gear, giving a reduction ratio of 2.56 to 1. The internal gearwheel carries a pinion in mesh with the main rotor gear, and provides a further speed reduction of 4.7 to 1. At the cruising engine revolutions of 2,700 r.p.m., therefore, the rotor turns at a speed of 225 r.p.m. At this comparatively high speed, the rotor possesses a high kinetic energy which provides a useful margin of hovering time—estimated to be about 4 seconds—after destroying the sinking speed of the machine in the event of landing auto-rotatively with both engines out of action. The main rotor gear and the hubs of both the front and rear rotors are mounted on conical steel axles attached to the fuselage structure, which transmit the whole weight of the aircraft to the rotors.

Turning to the rear-rotor transmission, the rear engine clutch and transmission shaft are similar to those of the front unit, but the upper end of the engine transmission shaft is connected, through a free-wheel similar to that in the front unit, and thence through an intermediate gearbox, shown in Fig. 7, Plate III, to the rear-rotor transmission shaft, at each end of which is a Layrub coupling. The upper end of the rear-rotor transmission shaft is connected to a bevel pinion in the rear-rotor gearbox, shown in Fig. 8, Plate III, which engages with a bevel gear, giving a reduction ratio of 2.56 to 1. The bevel gear carries the rear-rotor pinion which drives the rear main rotor gear.

As may be seen from the diagram, Fig. 9, Plate III, the synchronising shaft between the two rotors connects the front and intermediate gearbox through bevel gears fitted at each end, the front bevel gear being coupled to the driving pinion of the

front gearbox, and the rear bevel gear being carried on the main shaft of the intermediate gearbox. A rotor transmission brake is provided on the synchronising shaft just behind the front gearbox; the brake is of the disc type and is engaged by two Ferodo pads on either side of the disc when the pilot operates the brake lever. The synchronising shaft consists of two lengths of 2-in. diameter steel tube, coupled together by a sliding serrated joint to allow for longitudinal strains in the shaft; the joint is provided with rubber grease seals. The outer ends of the tubes are connected through Layrub couplings to the bevel-gear shafts. Twelve ball bearings, six to each half-shaft, carry the synchronising shaft; to allow a certain degree of self-alignment, each inner ball race is mounted on a flat rubber sleeve, rubber-bonded to the synchronising shaft. The outer track is carried on a rubber ring in a bracket.

Each gearbox is provided with a gear-type pump, feeding oil to the gears, which are of nickel-chromium case-hardening steel to specification S.82. Most of the gear shafts are carried in tapered roller bearings. The gearbox casings, which do not have to carry heavy loads, are finned aluminium-alloy castings. Auxiliary drives are provided on the front and intermediate gearboxes: on the rear cover of the front gearbox there is a tachometer-generator drive, and a spare drive for a vacuum pump, not at present in use. The windscreen-wiper drive is taken from the front end of the front gearbox. Two electrical generators are driven by bevel gears from the intermediate gearbox, and, by an ingenious arrangement of venturi tubes, the vacuum for operating the gyroscope flight instruments is provided by the generator cooling fans.

Except that the front rotor rotates in the opposite

direction, the rotor blades and hubs are, as already mentioned, identical with those employed on the Bristol 171 Sycamore single-rotor helicopter, a description of which was given on page 297 of our 166th volume (1948). It may be recalled briefly that the rotor consists of three blades, of wooden construction and symmetrical aerofoil section, articulated in the flapping and dragging planes. It is intended ultimately, however, to adopt metal rotor blades in both single and twin-rotor machines. Fig. 11, opposite, illustrates the end of a blade, and the rotor hub assembly is clearly shown in Fig. 6. The blade roots are attached, by two pins through steel root fittings, to blade sleeves, on the inboard ends of which the pitch-changing levers are mounted. The blade sleeves are journaled on blade-sleeve axles integral with the drag-hinge links. Centrifugal loads on the blade are transmitted directly to the drag-hinge link through torsionally-flexible tie-rods, passing down the centre of the blade-sleeve axle, and clamped to the fork-end fitting on the outer end of the blade sleeve; pitch changes are accommodated by twist in the tie-rod. Movements of the blades in the drag plane are limited by drag struts between the blades, incorporating rubber buffers in addition to drag-hinge friction dampers. Control of the blade angles is carried out through a control spider, the three arms of which are connected through ball joints to the blade levers. The spider is carried on a roller bearing on a shaft (the cyclic-pitch shaft) mounted on a ball joint in a sleeve (the collective-pitch sleeve) which can slide in the hollow steel conical axle which carries the rotor assembly.

The flying-control arrangements are rather more complex than those on the single-rotor helicopter. For controlling ascent, hovering and descent, the

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(For Description, see Page 33.)

Fig. 6. FRONT ROTOR-HUB AND GEARBOX.

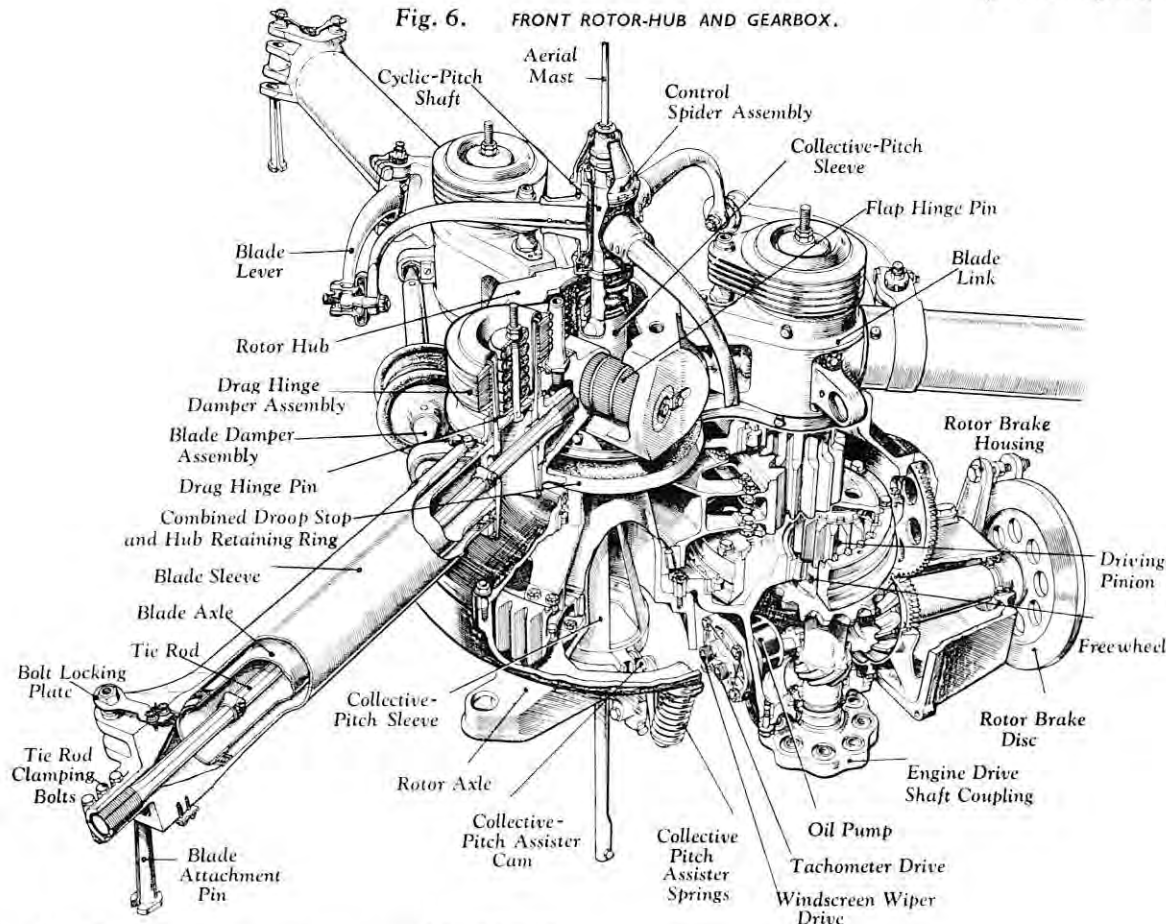


Fig. 7. INTERMEDIATE GEARBOX.

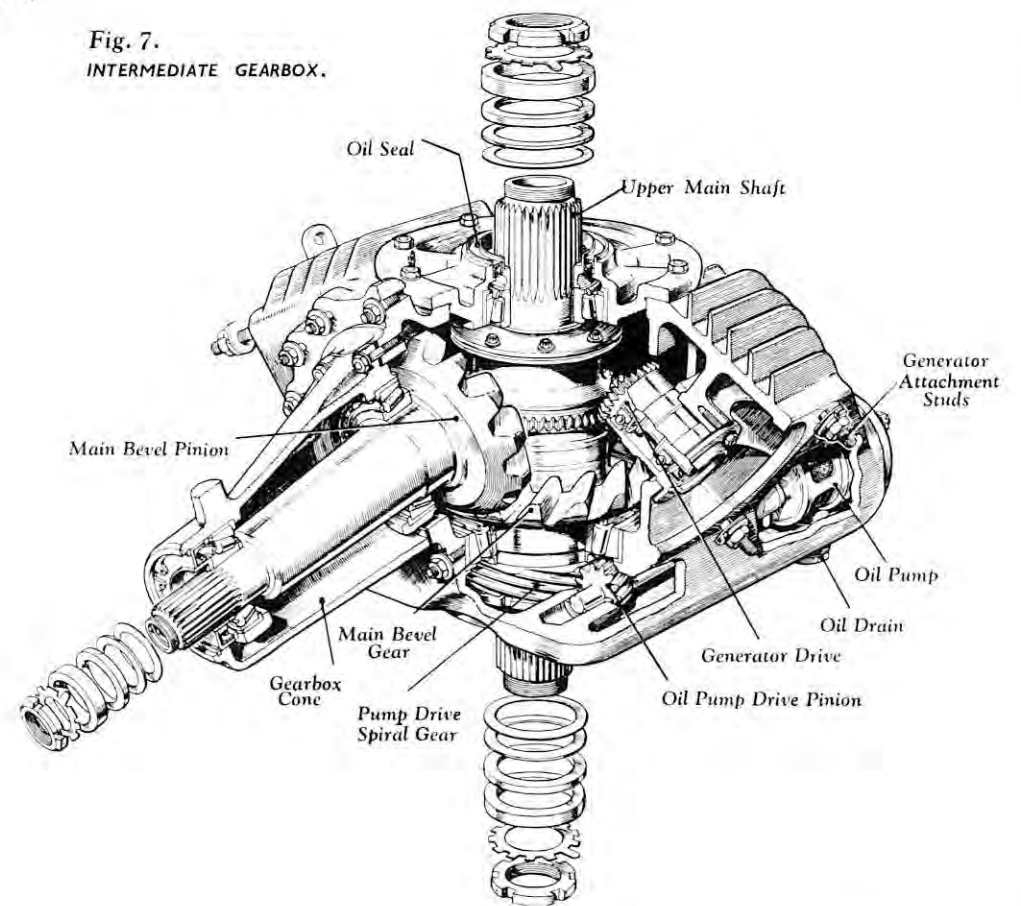


Fig. 8. REAR GEARBOX

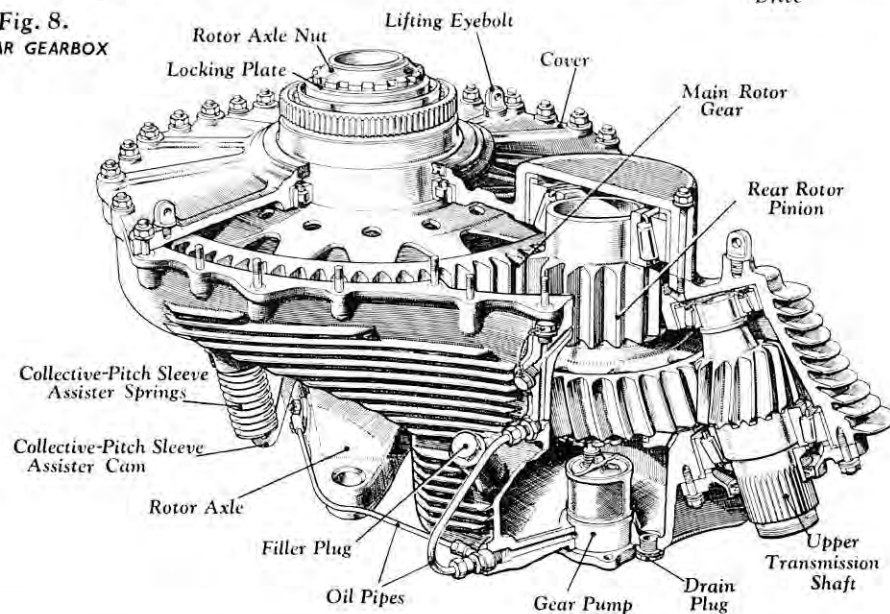
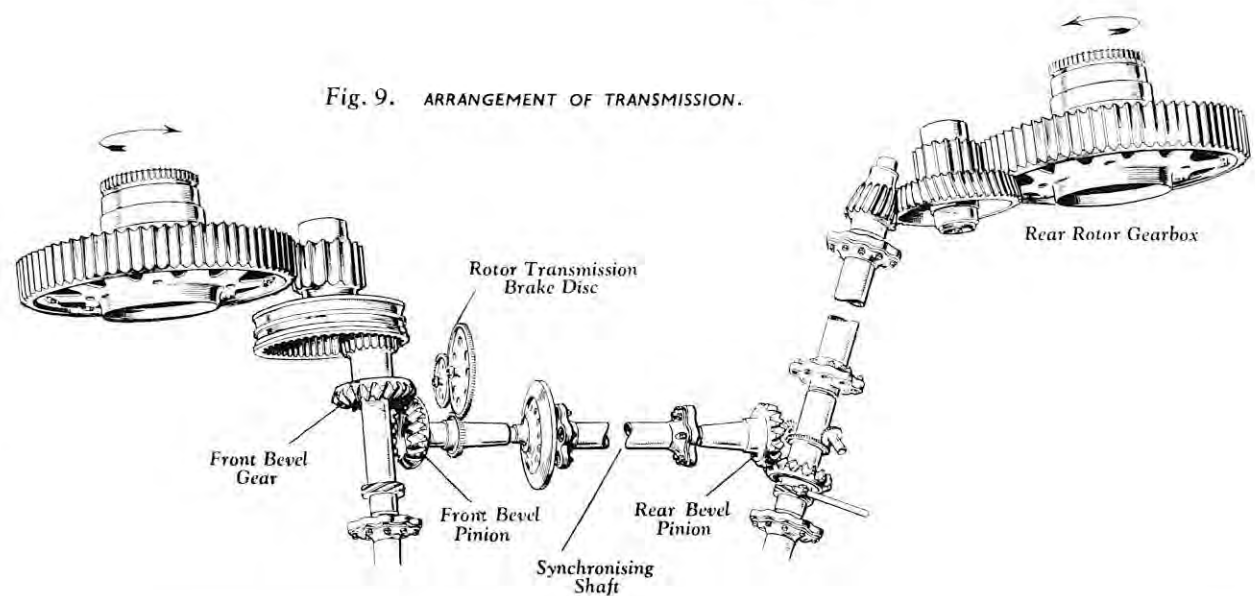
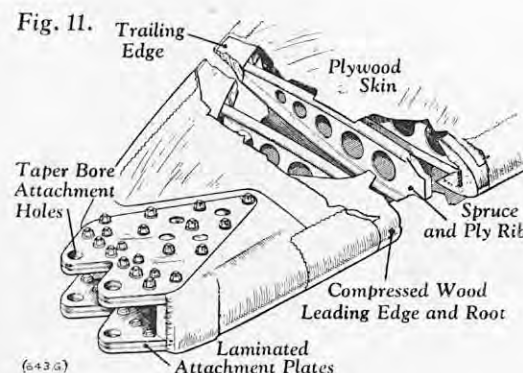
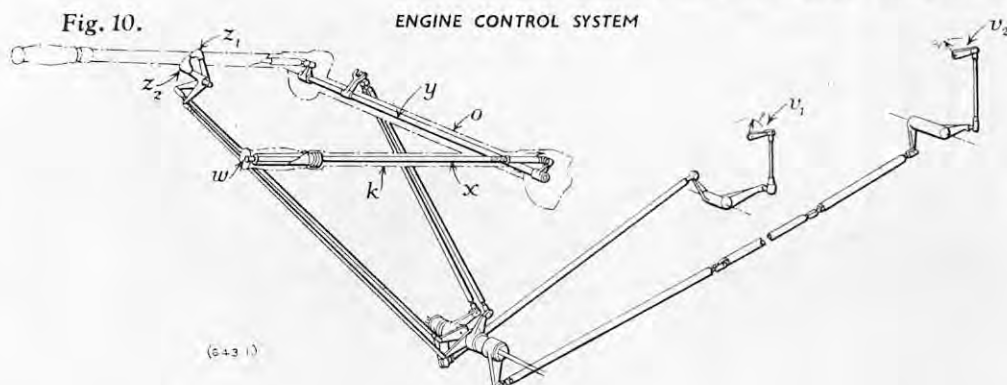


Fig. 9. ARRANGEMENT OF TRANSMISSION.



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pitch of all the blades of both rotors can be varied simultaneously by operating the collective-pitch lever, which also operates the engine throttle lever to maintain the revolutions as the blade angles are varied. For fore-and-aft and lateral control, both rotors can be controlled simultaneously in cyclic pitch (i.e., the pitch angle of each blade can be varied sinusoidally as it rotates, so that in effect the lift axis of the rotor is tilted in the required direction), by means of the cyclic-pitch control column; and turning moment can be applied by controlling the cyclic pitch of each rotor differentially, through rudder pedals. In addition, it is possible to trim the attitude of the aircraft fore-and-aft by operating the collective pitch of each rotor differentially. How these actions are carried out may be followed by reference to the control-system diagram reproduced in Fig. 5, opposite.

Considering firstly the cyclic-pitch controls, the base of the control column *a* is attached to an articulating mechanism *b* which operates, through levers and push-pull rods, similar mechanisms *c*₁, *c*₂, attached to the cyclic-pitch shafts *d*₁, *d*₂, of the front and rear rotor-control spiders, so that fore-and-aft and lateral movements of the control column are reproduced in the same sense at the two spiders *e*₁, *e*₂, providing a range of pitch change of ± 4 deg. laterally and ± 5 deg. fore and aft, the latter movement being limited by limit-rings in the rotor hub. Two spring-bias units, *f*₁, *f*₂, operated by hand-wheels, allow the pilot to trim out the fore-and-aft and lateral loads in the cyclic-pitch control column.

For control in yaw, the cyclic-pitch lever assemblies at the front rotor are eccentrically mounted on two shafts *g*, *h*, integral with two sprockets *i*. When the "rudder" pedals *j* are operated, the sprockets are rotated, through a system of levers, cables and chains, in opposite directions, thus displacing the front and rear articulating mechanisms *c*₁, *c*₂ laterally and in opposite senses, and imparting a further pitch change of ± 2 deg. on the cyclic-pitch control range.

The collective-pitch lever *k* is connected, through a system of shafts, levers, and connecting rods to the push-pull rods *l*₁, *l*₂, which operate the front and rear collective-pitch sleeves *m*₁, *m*₂, in which the rotor-control spiders are mounted. Operation of the collective-pitch lever will thus raise or lower both control-spider assemblies simultaneously, giving a range of incidence change of 10 deg. An irreversible mechanism *n* is incorporated in the cross-shaft *o*, which, it is considered, will satisfactorily suppress any vibration transmitted by the front rotor system. To guard against the possibility of resonance in the long control run back to the rear rotor, an inertia damper *p* has been provided to absorb vibration from the rear rotor, adjacent to the source. As originally designed, the collective pitch mechanism provides a 1:1 ratio of pitch change between the front and rear rotors, but provision has been made for altering the leverage of the rear rotor-control run in case flight tests show a change of fore-and-aft trim when the pitch is suddenly changed.

The use of tandem rotors makes it possible to trim the fore-and-aft attitude of the helicopter by changing the collective pitch of the front and rear rotors differentially, thus increasing the lift of one

rotor with respect to the other. The fore-and-aft trim-control wheel *q* is linked, through bevel gearing, a screw mechanism, levers, and a connecting rod, to an eccentrically-mounted cross-shaft *r*. This shaft carries levers *s*₁, *s*₂, which are so arranged that, when the shaft is rotated, the linkage to the rear rotor is displaced vertically in the opposite sense to that of the front rotor; the total pitch range adjustment provided by the longitudinal trim is $\pm \frac{1}{2}$ deg. of collective pitch in each system. The use of differential collective pitch, by altering the attitude of the aircraft, also constitutes a most effective means for accelerating or decelerating the helicopter in forward flight and it has, therefore, been interlinked with the fore-and-aft movement of the cyclic-pitch control column, by means of a cam *t* attached to the torque tube *u* of the cyclic pitch control. Fore-and-aft movement of the cyclic-pitch control column will, therefore, operate the collective pitch of the two rotors differentially as well as altering their cyclic pitch simultaneously. The cam is so designed that the "mixing" of differential pitch with cyclic-pitch control is at a maximum at the extreme fore-and-aft positions and zero at the midpoint.

The engine throttle levers *v*₁, *v*₂ are automatically actuated from the collective-pitch cross-shaft *o* by movements of the collective-pitch lever, as may be seen from Fig. 10. An over-riding control for direct operation of both throttles is provided by a twist-grip *w* at the end of the collective-pitch lever *k*, which actuates a threaded rod *x* passing down the centre of the collective-pitch lever and operates the throttle linkages through the internal cross-shaft *y*. There are also two separate throttle controls, *z*₁, *z*₂, for ground-testing, when it is essential to operate each engine independently. The ground-running levers work only when the collective-pitch lever is locked in the minimum-pitch position; they are automatically reset to their correct flight setting as soon as the pitch lever is operated.

The fuselage is a conventional light-alloy stressed-skin structure; it should be mentioned, however, that Redux metal-to-metal bonding has been adopted for attaching the stiffeners to the frames, for the prefabricated centre walkway which runs through the cabin, for the forward part of the tailplane skin (the rear part is fabric-covered) and for all detachable panels which consist of a smooth outer skin bonded to an inner corrugated frame. A double frame, with stiffened sheeting on the forward face and on the lower part of the rear face, forms the soundproof bulkhead between the cabin and the forward engine bay; the fork fittings for the forward undercarriage oleo legs and rear radius rods are attached to this frame, the forward radius rods of the undercarriage being attached to an intermediate frame in the forward engine bay. Doors are provided in the forward engine-bay bulkhead and the forward cabin bulkhead so that one of the crew can enter the cabin during flight.

Two keels extending below floor level from the forward cabin bulkhead to the forward engine-bay bulkhead carry the engine-mounting attachments, the third mounting point being on the forward engine-bay bulkhead. The front-rotor support structure consists of substantial light-alloy forgings carried between two heavy frames, which carry the

load keels. Between an intermediate transverse bearer in the forward engine bay and the forward cabin bulkhead there is a floor which supports a 70-gallon flexible fuel tank.

The rear cabin bulkhead is similar in construction to the forward bulkhead but has no doorway; the rear undercarriage attachment points are similarly arranged. The fuel tank, also of 70-gallon capacity, is immediately behind the rear cabin bulkhead and is bounded at the rear by a half bulkhead. As in the forward engine bay, two longitudinal keels between the rear cabin bulkhead and the rear engine-bay bulkhead carry the engine loads, but the side supports of the engine are actually attached to a built-up box structure supported on these keels. The rear rotor axle is supported at three points to a bolted tubular "pylon" structure attached at five points to the fuselage, to two points on each of two double frames at the rear of the engine bay and, farther aft, to a diaphragm. Torsional loads from the rotor are transferred to the fuselage through the fin fairing which is built integrally with the pylon structure. The tailplane, which has a single main spar and a light leading-edge spar, is bolted to the rear double frame in the engine bay; the tailplane bracing struts are attached to the same frame as the tailplane spar.

Between the front and rear main frames are two continuous longitudinal keels forming the bearers for the side floors, on which the seats are carried, and which are raised above the central gangway to bring the seats on a level with the cabin windows. The side floors are light-alloy sheeted grid structures; the freighter version would, however, have a timber floor extending across the width of the fuselage. On the starboard side, the frames below floor level are pierced to take a tubular duct which encloses a flexible fuel hose. At the top of the fuselage, the frames are cut out to house a duct in which are the rotor-synchronising shaft, the flying-control runs and the main electrical services. Each of the four undercarriage units consists of an oleo leg and two radius rods. The rear wheels are non-castering, but the front wheels are semi-castering and are linked with a track rod incorporating a spring coupling which forms a self-centring mechanism. They are fitted with anti-"shimmy" dampers. Manually-operated brakes are provided on the rear wheels.

Each engine is normally fed with fuel from the 70-gallon flexible-bag tank in the same compartment; a booster pump is provided in each tank, and a shut-off cock enables each tank to be isolated from its engine. It is, however, possible to feed both engines from one fuel tank by opening a cross-feed cock, normally kept closed, which connects the two tanks through a cross-feed fuel line carried below the cabin floor. Indicator lights are provided to warn the pilot when the fuel content in each tank has fallen to 10 gallons. In addition to the fuel cocks which are controlled by the pilot, there are also tank-isolating cocks, normally wired open, to allow for servicing the fuel pipe lines. Each engine also has its own oil supply, from a welded aluminium tank with an oil capacity of 5½ gallons. An isolating cock is provided in the main oil-feed line to the engine to shut off the oil supply in the event of fire. Oil returning to the tank from the engine passes through, or by-passes, an oil cooler.

A 24-volt electrical system supplies power for the aircraft lighting, the radio installation, the engine starter motor and booster coils, the engine and fuel indicating instruments, and the engine fire-extinguisher circuits. Two Rotax 2001 generators with a capacity of 1 kW each are, as already noted, driven from the main shaft of the intermediate gearbox. Since a helicopter can fly under conditions in which no ram air would be available for cooling the generators, it has been necessary to provide cooling fans; these fans have been arranged to operate the gyroscopic flight instruments, and, on later aircraft, to supply air for the cabin heating and ventilating system, in conjunction with a heat exchanger. Each generator shaft is extended rearwards to carry a centrifugal fan, which draws in air from outside the aircraft through a double venturi, giving suction at the throat of the inner venturi which is connected to the vacuum-operated gyroscopic instruments. Normally, vacuum from both generators supplies the flying instruments, but a changeover valve is provided at each venturi entry to ensure that suction is not upset if one generator should be out of action. After passing the inner venturi, the air proceeds through the outer venturi and thence through the fan and generator.

In order to provide a comprehensive background of test data for determining the safe life of the components and assemblies that are subjected to heavy fluctuating and reversed stresses, i.e., the rotor assemblies, the transmission, and the control runs, the Bristol Aeroplane Company are setting up a number of test rigs, in which it is proposed to reproduce the load distributions actually occurring in the most severe flight conditions, and to test the components over a greater number of load cycles than they would ever encounter in practice.

The rotor test tower, which was erected during 1948, was described in *ENGINEERING*, on page 584 of our 167th volume (1949); it is shown in Fig. 12. It was designed to accommodate a rotor with a maximum diameter of 70 ft. at a height of 50 ft. above the ground, and could withstand a maximum lateral force of 100,000 lb. and a maximum lift of 15,000 lb. It is supported by cables which allow the lateral stiffness to be adjusted. The rotor is driven by a motor developing 700 h.p. over a speed range from 180 to 680 motor r.p.m.; the motor can, however, develop 1,000 h.p. if required. The test tower provides for measuring the lift and speed of the rotor, the power input, the horizontal out-of-balance forces at the hub, the blade pitching moments and the collective-pitch setting.

Since our description of the tower, the equipment has been considerably developed and modified; among the modifications may be mentioned the fitting of a camera at the top of the hub to record the flapping and twisting motions of the blade for flutter investigations. To eliminate gyroscopic effects, the camera is mounted with its lens axis vertical, and is provided with a prism for viewing the blade. The tower has recently been provided with means for reproducing the flight distribution of loading on the rotor blades. Flight tests have been carried out on a Bristol 171 rotor, and strain-gauge readings have been recorded for about 20 strain-gauge stations on the blade, and the distribution of thrust has thereby been ascertained. Owing to the effect of the forward speed of the helicopter through the air, whereas the advancing blade is subjected to a fairly uniform thrust distribution which gives a hogging bending moment, on the retreating blade the thrust is concentrated towards the tip, and produces a sagging bending moment. It is possible to reproduce the latter effect by placing an obstruction at a suitable distance below the blade tip which causes a maximum upward displacement of the blade 90 deg. in advance of the obstruction; thus, flight stresses can be simulated in the rotor which is undergoing life-testing.

Fig. 12 shows the rotor test tower and the adjustable obstruction platform below the outboard end of the blade span; the platform has an area of 20 ft. by 10 ft. It can be raised to within 1 ft. of the rotor disc, when the latter is at its cruising coning angle, by a hydraulic jack. The 5-h.p. motor and pump which actuate the jack are mounted at the top of the obstruction framework; the raising of the platform can be controlled either manually,

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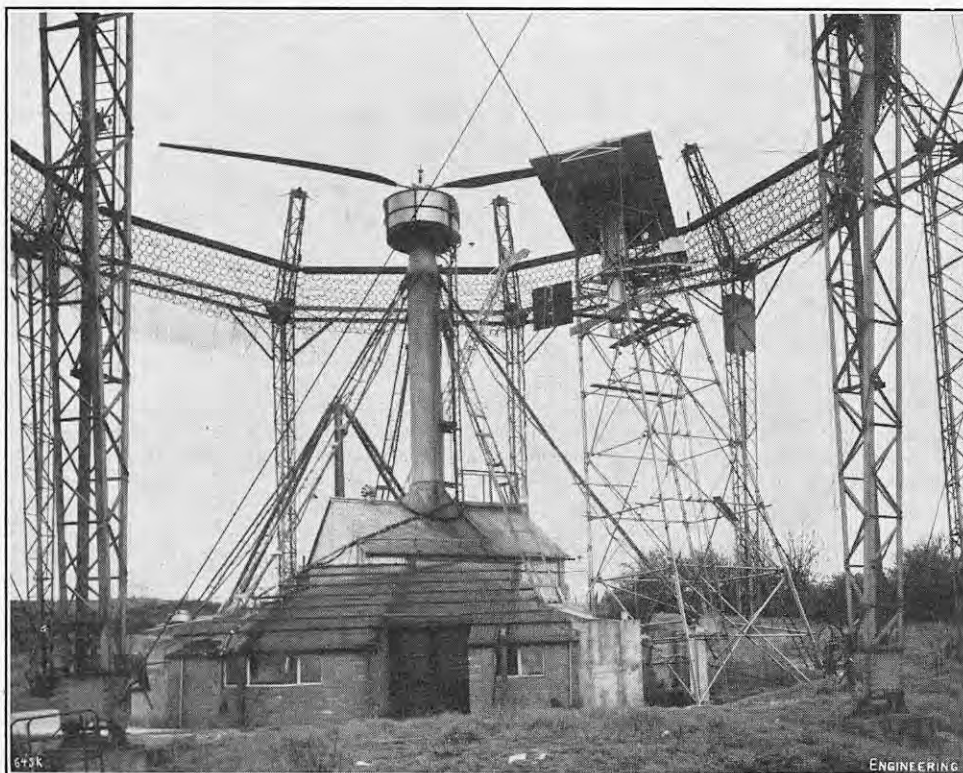


FIG. 12. ROTOR TEST TOWER AND "OBSTRUCTION" PLATFORM.



FIG. 13. AIRCRAFT HOVERING OVER FILTON RUNWAY ON MAIDEN FLIGHT.

or automatically by a cam-operated switch, the height of the cut-out can being adjustable by an observer who is stationed in a crow's nest, in the plane of the rotor disc, on one of the safety-netting supports. The crow's nest is fitted with a cine camera and with emergency controls for the tower motor and the obstruction platform. It will be realised that the range of vertical adjustment of the platform is such that it can rise above the level of the rotor hub; in addition to the emergency controls already referred to, therefore, automatic safety switches are provided to ensure that the platform does not foul the rotor. The 24-volt electrical circuit controlling the pump-motor relays contains a bomb-release unit which, when energised, releases a weight and thereby shifts the manual control lever to an emergency setting, causing the pump motor to be switched on to lower the obstruction platform rapidly, in approximately 2 seconds, from its highest position. Normally, lowering of the platform is carried out slowly under gravity. The bomb-release unit can be energised in three ways: by either of the operators (one is stationed in the control room and one in the crow's nest) actuating a bomb-release switch; whenever the main tower

motor is stopped; and by trip wires which are broken by the rotor if it approaches too closely to the obstruction platform.

For determining the safe life of the three rotor gearboxes, a closed-circuit rig has been built; it is used also for testing Sycamore gearboxes. In this apparatus, the output shaft of the test gearbox is connected to its input shaft through an adjustable serrated coupling and a two-stage gearbox of equal reduction ratio, so that the reduction of speed from the input of the test gearbox to the output is equal to the step-up in speed from the output to the input; thus, a motor of only 60 h.p. is sufficient to drive the rig. By twisting the two halves of the serrated coupling relative to each other to a predetermined torque, it is possible to apply any desired load to the gear teeth. It is intended to carry out strain-gauge measurements on the gearbox input shaft in flight, and then to reproduce the flight-stress distribution in the test rig. For this purpose, it will be necessary to provide torque fluctuations in the rig; it is possible that this will be done by incorporating a flywheel at the bottom of the driving shaft, and supplying suitable impulses to resonate the shaft at engine speed.

For carrying out whirling tests and correcting lack of balance in the tubular rotor-synchronising shaft, another special rig has been set up. It accommodates the full 40-ft. length of shaft, and is used also as a welding jig for attaching the end fittings. Each of the ball bearings supporting the synchronising shaft in the aircraft is set up in carefully-aligned housings carried on the structural steel framework of the rig; the out-of-balance force on the housing is measured by a strain-gauged link on one side of the bearing housing, which is initially loaded by a pre-tensioning spring on the other side. At each housing, anti-phase beams are provided to damp out vibrations in the rig. Intermediate bearing blocks between the ball-bearing housings prevent the shaft from reaching dangerous amplitudes in the event of whirling.

The strain-gauge readings are recorded on a cathode-ray oscillograph near the control panel. The phase of the vibration is determined by an electrical instrument which measures the angular displacement. In carrying out a test on a synchronising shaft it is first run up slowly to a maximum speed of 4,800 r.p.m., i.e., 20 per cent. overspeed, to check that whirling does not develop. The shaft is then run at 4,000 r.p.m., and the out-of-balance forces are measured. The shaft is then balanced by clipping small balancing collars on to it adjacent to the bearings; the collars are finally trimmed on the shaft so as to give the required balance.

Some of the principal dimensions and data for the Bristol 173 may be of interest. As already recorded, the diameter of each rotor is 48 ft. 6.7 in., and the distance between their centres is 40 ft. 7.61 in. With the blades folded, the overall length of the machine is 78 ft. 2 in., the width 17 ft., and the height 15 ft.; the undercarriage track is 9 ft. 6 in. wide. The overall length of the fuselage is 55 ft., the passenger cabin being 26 ft. 2 in. long by 5 ft. 3 in. wide, by 5 ft. 8½ in. high over the gangway. The normal all-up weight is 10,600 lb., giving a rotor loading of 2.85 lb. per square foot and a take-off power loading of 9.64 lb. per horsepower.

The weight "break-down" of the aircraft is as follows: structure (fuselage, undercarriage and tailplane), 1,944 lb.; rotor assemblies and transmission, including synchronising shaft, 2,273 lb.; power unit, including fuel and oil systems, 2,308 lb.; fixed electrical and radio services, fire extinguisher systems and instruments, 305 lb.; fixed cabin equipment, 594 lb.; removable operational equipment and cabin furnishings, 400 lb.; giving a basic aircraft weight of 7,824 lb., and a disposable load (exclusive of crew and oil) of 2,346 lb. at the normal all-up weight of 10,600 lb. It should be mentioned that the machine is designed to operate at overloads up to 13,500 lb.; it is estimated that the aircraft will still be able to hover at that weight within the "ground-cushion"—usually considered to extend to a height of about one rotor diameter.

The performance of the Bristol 173 has yet to be proved; the designers estimate, however, that at the normal all-up weight of 10,600 lb., the cruising speed at sea-level will be 105 m.p.h., at the maximum weak-mixture power, 300 brake horsepower per engine. At the most economical cruising speed, 100 m.p.h., the maximum still-air range, without allowances, is 430 miles. The hovering ceiling is 6,950 ft. at maximum power; the service ceiling 19,600 ft.

Although the Bristol 173 has been designed as a civil-transport aircraft, it also offers excellent possibilities in the military field as a troop transport or freight carrier in forward areas, an ambulance, for air-sea rescue work, for air observation and photography, and in the capacity of a crane. By a simple re-arrangement of the folded-rotor layout, it can be stowed compactly in the hangar of an aircraft carrier.

BASRAH PETROLEUM COMPANY.—The first oil produced from the Southern Iraq concession area of the Basrah Petroleum Company was loaded on December 19, 1951, at Fao, the oil terminal specially constructed at the mouth of the Shatt El Arab River, 70 miles from the oilfields. Exports this year are expected to be 2.2 million tons, all obtained from the Zubair field, and by 1955 the annual production, it is estimated, will be 8 million tons.

THE ENGINEERING OUTLOOK.

II.—THE MANPOWER SITUATION.

WHEN Sir Walter Monckton became Minister of Labour in November, he was under no delusion about the difficulties of his new office, for, as he explained, the present labour force cannot meet all the demands which will be made on it. In the statement of policy contained in the King's Speech, the Government expressed their concern over "the serious shortage of labour, particularly skilled labour, which has handicapped production in a number of essential industries" and they promised to "review, in consultation with representatives of those concerned, the possibilities of making available more labour for these industries and of ensuring the best use of the existing labour force." The total deficiency amounts to half a million, most of whom will be required in the engineering industry. The Government have not so far brought up the question of direction of labour, and will obviously try to avoid it if possible. Of the many indirect methods of matching jobs and workers, potentially the most potent is credit control, and already the Government have instituted measures to make it effective. Whether these will be adequate or whether, indeed, there are any measures open to the Government which could possibly be effective against the natural immobility of labour is not easily seen at this stage. The purpose of this article is to draw attention to some of the relevant factors in coming to a conclusion.

Between September, 1950, and September, 1951, the first year of re-armament, there has been little or no change in the total working population (see Table I, herewith, taken from the *Monthly Digest*

TABLE I.—Great Britain: Distribution of Total Manpower (Thousands).

	June, 1948.	September, 1950.	September, 1951.
Total working population	23,146	23,454	23,482
Males	16,057	16,126	16,031
Females	7,089	7,328	7,451
H.M. Forces	846	708	840
Males	807	685	817
Females	39	23	23
Persons on release leave	92	6	8
Registered unemployed	282	292	235
Total in civilian employment	21,926	22,448	22,399
Males	14,945	15,234	15,064
Females	6,981	7,214	7,335
Agriculture, forestry and fishing	1,268	1,261	1,185
Mining and quarrying	869	834	848
Manufacturing industries	8,114	8,500	8,746
Building and contracting	1,497	1,495	1,452
Gas, electricity and water	296	327	365
Transport and communications	1,814	1,807	1,793
Distributive trades	2,639	2,852	2,654
Professional, financial and miscellaneous services	3,925	3,937	3,946
Public administration:—			
National Government Service	688	649	640
Local Government Service	766	786	770

of Statistics). Increased demands of the Services, in fact, reduced the number in civil employment from 22.45 millions in September, 1950, to 22.40 millions in September, 1951. There was, however, an increase of 246,000 in manufacturing industries, and it is a healthy sign that there was a reduction of 198,000 in the distributive trades. The increase in the numbers employed in manufacturing industries is to be accounted for largely by the metals and engineering industry, whose labour force increased by 181,000; most of this, presumably, by defence production, although this is by no means clear from the available statistics. From Table II, herewith, which is taken from the *Ministry of Labour Gazette*, it will be seen that a large part of the increase is accounted for by electrical engineering, which increased its strength from 530,000 to 584,000. Much of this increase is accounted for by wireless instruments, telegraph and telephone equipment and electrical machinery, for which there are large orders under the re-armament programme, but, since these industries also increased their exports, re-armament may not have been the major factor in the expansion.

The increase in the number employed in the manufacture of boilers and boiler-house plant could hardly have been due to re-armament demand, but merely indicates that the industry was at last in a position to remedy the bottleneck which shortage of this type of plant was causing in power-station construction. In spite of the difficulties of obtaining labour, the machine-tool industry, in which much of the output is certainly for defence, succeeded in increasing its labour by 10 per cent.

TABLE II.—Great Britain: Employment in the Metal Manufacturing and Engineering Industry. (Estimated: Thousands.)

	June, 1948.	September, 1950.	September, 1951.
Metal Manufacture	496.0	502.3	536.5
Blast furnaces	20.0	20.5	20.3
Iron and steel melting, rolling, etc.	194.7	197.7	213.4
Iron foundries	106.4	107.3	118.6
Tinplate manufacture	17.0	17.5	17.4
Steel sheet manufacture	18.5	19.1	19.2
Iron and steel tubes (incl. melting and rolling in integrated works)	29.3	41.5	43.5
Non-ferrous metals, smelting, rolling, etc.	100.1	98.7	104.1
Engineering, Shipbuilding and Electrical Goods	1,820.2	1,834.3	1,912.5
Shipbuilding and ship repairing	225.9	195.4	203.1
Marine engineering	78.0	72.9	74.8
Agricultural machinery (excl. tractors)	40.4	39.7	42.8
Boilers and boiler house plant	17.5	19.1	26.0
Machine tools	76.7	74.5	81.6
Stationary engines	23.3	25.5	27.2
Textile machinery and accessories	67.2	68.3	68.9
Ordnance and small arms	41.2	41.4	45.7
Constructional engineering	71.1	71.9	74.4
Other non-electrical engineering	664.8	695.8	683.7
Electrical machinery	164.9	164.8	178.8
Electric wires and cables	62.2	58.6	64.2
Telegraph and telephone apparatus	44.4	44.3	49.5
Wireless apparatus (excl. valves) and gramophones	67.2	82.5	98.8
Wireless valves and electric lamps	36.6	35.8	42.7
Batteries and accumulators	19.3	20.6	20.7
Other electrical goods	119.5	123.2	129.6
Vehicles	878.9	922.1	976.8
Manufacture of motor vehicles and cycles	285.4	312.9	306.9
Motor repairers and garages	205.8	207.4	231.1
Manufacture and repair of aircraft	141.6	149.1	165.2
Manufacture of parts and accessories for motor vehicles and aircraft	72.6	81.8	106.1
Railway locomotive shops	59.1	55.4	59.5
Other locomotive manufacture	25.5	25.6	22.2
Manufacture and repair of railway carriages and wagons and trams	76.6	79.4	77.1
Carts, perambulators, etc.	12.3	10.5	8.7
Metal Goods not elsewhere specified	491.4	492.1	503.1
Tools and cutlery	53.2	52.4	55.1
Bolts, nuts, screws, rivets, nails, etc.	40.6	40.8	38.1
Iron and steel forgings, not elsewhere specified	33.3	33.7	36.2
Wire and wire manufactures	37.3	37.8	36.7
Hollow-ware	50.5	51.0	55.7
Brass manufactures	37.9	34.0	40.5
Metal industries, not elsewhere specified	238.6	242.4	240.8
Precision Instruments, Jewellery, etc.	124.3	133.6	137.1
Scientific, surgical and photographic instruments, etc.	72.0	79.1	85.0
Manufacture and repair of watches and clocks	14.7	17.2	16.3
Jewellery, plate and refining of precious metals	29.5	28.9	27.6
Musical instruments	8.1	8.4	8.2

Miscellaneous non-electrical engineering, which accounts for rather more than one-third of the number employed in the engineering, shipbuilding and electrical goods group, lost 12,000; possibly due to competition for labour from the defence programme, but more probably to such normal civilian influences as a falling demand for their products. In the vehicle group, a gain of 55,000 is accounted for largely by the aircraft industry, in which the labour force increased by 16,000, and by the manufacture of aircraft accessories. The statistics include employment in the manufacture of

motor-vehicle accessories, which has probably fallen off almost 5 per cent., in step with the fall in the output of motor vehicles. It is likely, therefore, that the increase in employment in the manufacture of aircraft has been greater than the figures suggest.

Armament industries succeeded, therefore, in attracting only a limited number in 1951. A very high rate of recruitment could not be expected in the first year of the programme—expenditure under which is running well behind the planned level of 1,250 millions. Even so, the number of suitable personnel recruited by such vital industries as machine tools and aircraft was disappointingly low. At the beginning of November, Air Chief Marshal Sir Guy Garrod estimated that the aircraft industry required 150,000 more workers in the next 18 months if the air re-armament programme was to be carried out. According to the Ministry of Labour statistics, the number engaged in the manufacture and repair of aircraft increased by only 16,100, to 165,200, in the year to September, 1951. This, of course, takes no account of the number engaged in the manufacture of components, presumably included in Sir Guy's estimate. Nevertheless, it is clear that the rate of recruitment is very inadequate. The rate of increase, moreover, is by no means uniform throughout the country. Some companies are said to be losing hands, while aircraft manufacturers in the London area are finding little difficulty in getting the necessary personnel. The dispersion of the aircraft industry throughout the country, however, has been accentuated by the necessity for subcontracting on a large scale. As a result, the inability of the manufacturers in some districts to obtain the necessary labour may seriously dislocate the whole programme. In the aircraft industry the problem of finding skilled workpeople is not so acute as, for example, in the machine-tool industry, for production depends on jigs to a larger extent. Nevertheless, skilled personnel are required to fill key positions and they are not easily found. The shortage of skilled workers is a serious problem.

Among the major difficulties attendant on the recruitment of both skilled and unskilled workers are the shortage of housing and the insecurity of the new employment offered. It is now clear that the Conservative Party has found its programme of 300,000 houses a year impracticable in 1952, at least, if only because of the prior demand of re-armament upon finance and resources. Even at a rate of 300,000 houses a year, re-armament according to present intentions would be over before sufficient houses could be built to make any impression on the mobility of labour. Moreover, there does not appear to be any means of lessening the insecurity of employment offered in the armament industries; very strong incentives indeed are needed to attract workers into the aircraft industry, for example, which has had a bad history of paying off surplus labour and which, indeed, was doing so as late as the beginning of 1950. Positive monetary incentives cannot be given without putting up the cost of the defence programme, and, if they were, might only excite demands for higher wages from men of similar skills in other industries. The only alternative policy, short of compulsory direction, is that of making labour redundant in low-priority industries.

The powers assumed by the Labour Government under the former Control of Engagements Order represent about the limit of direction acceptable to a free society and these only succeeded in bringing into useful employment a few hundred persons. The Government have given an assurance that nothing will be done about a new Control of Engagement Order without a joint arrangement with industry. They are reported to be working on the subject and to be discussing it with the National Joint Advisory Council, but no statement is to be made until Parliament resumes on January 29.

Redundancy in low-priority industries can be brought about by financial measures designed to reduce the demand for their products, by denying them the necessary credit for carrying on production, or by withholding supplies of raw materials. This last method has already had some effect in restricting production of some types of household hardware and electrical appliances, embodying scarce materials. Control of this sort is clumsy and

costly, and not worth undertaking unless materials are very scarce. Moreover, it affects only the small sector of industry manufacturing durable consumer goods for sale in this country. Discriminatory measures in granting or withholding credit must also fail to be universally effective. In any case, the directions given by the Government to the banks and to the Capital Issues Committee on this subject are designed only to restrict fresh capital outlay and to prevent speculation in stocks, property and commodities. The new financial policy of the Chancellor of the Exchequer in bringing about a redistribution of labour will be effective only if it restricts the demand for consumer goods. Instructions to the banks and finance houses to limit finance for hire purchase may have less effect than might be imagined. A request by the Bank

TABLE III.—United Kingdom: Index of Rates of Wages in Industry.

Date (End of Month).	Men.	Women.	Juveniles.	All Workers.
1947:				
June ..	100	100	100	100
December ..	103	103	106	103
1948:				
June ..	105	107	108	106
December ..	107	109	110	107
1949:				
June ..	108	111	112	109
December ..	109	112	113	109
1950:				
June ..	109	113	114	110
December ..	113	116	118	114
1951:				
January ..	115	118	119	115
February ..	115	118	120	116
March ..	116	119	121	117
April ..	117	120	122	118
May ..	117	121	123	118
June ..	118	122	124	119
July ..	119	124	126	120
August ..	119	124	126	120
September ..	120	125	127	121
October ..	120	126	128	122

TABLE IV.—Great Britain: Average Earnings, April, 1950, and April, 1951.

	Average Weekly Earnings.	
	1950.	1951.
Mining and quarrying (excluding coal) ..	s. d. 137 2	s. d. 150 9
Treatment of non-metalliferous mining products other than coal ..	129 1	142 1
Chemicals and allied trades ..	129 2	141 8
Metal manufactures ..	155 4	167 5
Engineering, shipbuilding and electrical goods ..	133 3	145 5
Vehicles ..	146 8	155 3
Metal goods, not elsewhere specified ..	124 6	134 2
Precision instruments and jewellery, etc. ..	122 6	132 1
Textiles ..	103 11	114 10
Leather, leather goods and fur ..	111 2	120 5
Clothing ..	91 4	99 5
Food, drink and tobacco ..	108 2	115 7
Manufactures of wood and cork ..	122 7	138 9
Paper and printing ..	125 10	131 5
Other manufacturing industries ..	119 8	130 0
Building and contracting ..	133 0	152 7
Gas, electricity and water ..	131 10	146 0
Transport and communications (excluding railways and London Transport) ..	132 9	145 6
National and Local Government Service ..	110 11	118 8
Average of above ..	124 1	136 2

of England was made to the leading financial institutions as long ago as 1946 not to extend hire purchase, and to restrict it as far as possible to industrial goods. The large growth in hire purchase since that time is to be accounted for largely by sources other than the banks and the large financial houses, and will be curbed only by special legislation to amend the Hire Purchase Act of 1938. Action of this kind has not been ruled out by the Government. The main points of the new policy, however, are the funding of 1,000 millions of the floating debt, the increase in the rate of interest, and withdrawal of the facilities for the automatic discounting of bills to any value required. The new policy is by no means a return to a rigorous "sound" money policy, but at least it puts an end to the continual automatic creation of credit, bank deposits and fresh spending power in the hands of the public. Withdrawal of subsidies and increases in taxes can then reduce the amount of money which the public has available for spending on non-essentials. Whether or not luxury industries will then be forced to discharge employees will still depend, however, largely on the course of wages.

Never has the need for a wages policy been greater. From January to November, 1951, the weekly wage bill in industry increased by 5.9 millions, compared with 1.1 millions in the corresponding period of 1950. The increase in engineering wages amounted to 1.3 millions, compared with 18,500. The rapid advance in the index of wage-rates in industry from 110 in June, 1950, to 122 in October, 1951, may be seen in Table III, herewith. Table IV compares the average earnings in various industries in 1950 and 1951. The claim of the Confederation of Shipbuilding and Engineering Unions for an increase in wages of 11. a week has not been met in full, but the grant to its members of 11s. a week and a second week's holiday with pay will cost the industry 100 millions a year. The granting of an 8 per cent. increase in wages by the Railway Staff National Tribunal involves 14.2 millions per annum and has already resulted in an increase in railway freights. The recent grant to the miners—13s. 6d. a week for underground workers and 11s. 6d. a week for surface workers—will cost 26 millions a year and is equivalent to an increase of 2s. 6d. a ton in the price of coal. The increase in prices announced on December 28 are much larger—7s. 8d. a ton in the London area—since they take into account the new Miners' Pension Fund and the increase in freight rates. The large increase in wage demands in 1951 coincided with the ending of the acceptance of the "wage-freeze" principle by the Trades Union Congress, but the unions are clearly not fully responsible for the rises. The cost-of-living index has risen even faster and farther than the index of wages—from 114 in June, 1950, to 129 in July, 1951—and the fact that the Government took no action to restrict credit and arrest the inflation implies that they were relying on higher prices to absorb the excess spending power.

To leave the settlement of wages under these conditions to unrestricted collective bargaining was to invite demands for wage increases. Detailed compulsory wage-fixing is, of course, out of the question; perhaps the most that is feasible is for the Government to lay down the circumstances in which they would find an increase in wages acceptable—for example, an ascending scale parallel to that of the cost of living. Hitherto, in formulating their economic plans, the Government have made estimates of Government expenditure, investment outlay, etc., but while wages are excluded from the reckoning much of this detailed budgeting is invalidated. The Government should publish for general guidance an estimate of the total wage bill which could be met, having regard to all the other scheduled items in their plan; they may use this as a basis in advising what wage increases would be acceptable. An overall plan of this sort, well publicised, might be sound public relations policy. Public opinion moulded in this way should be a strong enough support and, indeed, is the only safeguard under free collective bargaining against irresponsible sectional demands. Under these conditions, unions would hesitate to face the Arbitration Tribunal if they knew that their case was contrary to the public interest; and the Arbitration Tribunal, instead of being guided by expediency, as so often in the past, would have a principle to apply in coming to any particular decision. Acceptance of a policy outlined above would, of course, have to be matched by restrictions on distributed profits acceptable to the unions, but this presents no difficulties, since dividend limitation, broken in very few instances although enforced only by the weight of public opinion, has been effective for some time.

The repeal of Industrial Disputes Order No. 1305 by Order No. 1376 of August 14, 1951, is to be welcomed, even though it abolishes the restraints on free collective bargaining and marks a return to the pre-war system. It is, in fact, a reaffirmation of British faith in collective bargaining at a time when its abuse could do much harm to the community. The original Order, however, as Mr. Alfred Robens pointed out, had been unenforceable, for "in the last analysis one cannot stop people striking if they are determined to do so" and "experience has shown that the enforcement of sanctions against persons taking part in strikes and

lock-outs gives rise to extreme difficulties." Besides setting up an Industrial Disputes Tribunal in place of the National Arbitration Tribunal, the new Order includes some provisions for strengthening the official machinery of negotiations. The Minister of Labour can now refer to the Industrial Disputes Tribunal applications from employers' organisations and trade unions only when negotiations between them have failed. Trade-unionists may thus feel more disposed to use their unions as the means of obtaining the most satisfactory settlement of a dispute.

While intended to reduce unofficial strikes, the new regulation may, however, increase them, for unofficial bodies and disaffected sections who can no longer obtain official recognition of their claims may be all the readier to resort to strikes. One other aspect of the new Order which gives some cause for concern is the exclusion of matters concerning the "closed shop," and disputes arising from the dismissal of individuals, from the scope of the Tribunal. This makes it all the more important for the unions to have behind them the full support of their members. Without it, not merely the present regulations but the whole system of collective bargaining will be unworkable. Confidence in the unions, however, has tended to fall lately; total membership fell from 9.3 millions in 1948 to 9.2 millions in 1950 (the most recent year for which figures are available). To bolster up their weakening position, they have resorted to "closed shop" tactics, and to eliminating and absorbing, where

gramme, but to the far-reaching changes in the engineering industry which make it more rewarding to do unskilled work at the conveyor belt or standing by a special-purpose machine under quantity production than to do highly skilled work in a small engineering shop. Moreover, though conditions in Britain are much less favourable to this development than those in the United States, a considerable increase in bulk production techniques must still take place if productivity is to be increased. As the premium upon skill disappears, few can be persuaded to undertake long and arduous apprenticeships, and yet, even in factories where every possible operation is mechanised, a high degree of skill is still required at some key points. Sir Godfrey Ince, Permanent Secretary of the Ministry of Labour and National Service, has suggested that the solution may be to reduce the period of apprenticeship training; it may even be possible, he claims, to train young men in two crafts in the time now taken for one.

Strong support is given to this view in the report of the Anglo-American Council on Productivity on "Training of Operatives," published in October, wherein it was pointed out that apprenticeship in the United States may be as short as two years and averages $3\frac{1}{2}$ to 4 years, but that the length in any particular case can vary with the aptitude and diligence of the student. Shorter apprenticeship in the United States is possible, to some extent, because the age of entry is higher; men can become apprentices up to the age of 35 and will not normally

accounts for much of the success—and many of the failures—of the American industrial system. It extends to the very roots of child education, where, according to the Team, the American high schools set out to give their pupils a social and occupational competency for present-day life—and are succeeding. Such culture as is imparted "has its roots in contemporary life." Whether, however, this is such a blessing as claimed is, at least, doubtful. American children certainly acquire "an easy confidence of manner and expression," but their level of academic attainment is not high. The American attitude of "fitness for purpose" extends even to human beings; just as it is a waste to make anything better than is warranted by the purpose, it is, so the Americans consider, a mistake in vocational training to teach more than is required for any job. Pupils "are not educated to be deeply knowledgeable, but trained to be effective in a particular occupation."

Education of this sort may go far to increasing material wealth, but is still questionable in its effects. There are higher aims in the field of human endeavour than material wealth, among them the achievement of an integrated personality which this sort of training comes dangerously near to making impossible. The Productivity Team praise the fuller realisation in the United States of the importance to industry of sound vocational training in the schools. Few could take exception to this, though it is not, perhaps, as great an advantage as the Team suppose; but it does not seem quite so commendable that principals and staffs of schools should adopt towards industry "almost the approach of salesmen." There are, however, many advantages in their system of education of which the Americans are justly proud; for example, higher education is enjoyed by a much greater proportion of the population than in the United Kingdom. About 45 per cent. of pupils from elementary schools go on to high school, and of them a third go on to college. The system, moreover, has the advantage that nothing in it is static. No practices are unalterably established; there is a constant process of evolution.

The report on the training of operatives was followed in November by one on the "Training of Supervisors," which also indicates some ways in which Britain can benefit by American example. Here again is the same attitude expressed in the principle that supervisor training should not be "sprayed on with a hose," but that every programme should be designed and applied to meet a specific need. The American methods, nevertheless, hold much that would be of value in Britain, where far too little thought is given to supervisor training. In most of the larger companies in the United States, a substantial amount of money is spent on the selection and training of supervisors, but, since this is never accounted for separately, no strict financial evaluation of the benefits accruing is available. It is, however, obviously considerable. Before a man becomes a supervisor, he has generally been given intensive pre-formanship training, which may last up to two years, and after appointment he receives continuous training in leadership as well as in the technical aspects of his job by lectures and discussion groups at regular intervals. This system makes possible considerable decentralisation of authority, right down to the first-line supervisors, who are often responsible for their own budgets and are generally encouraged to be "managers of their own business." They are supplied with up-to-date statistics and are kept informed of current trends, to which they energetically react in their own interests. Very great emphasis is given to training in "human relations," upon the improvement of which, rather than upon technology, may depend future advances in productivity. Treatment of this subject varies greatly throughout industry and many of the methods employed are far from satisfactory. The important thing, however, is recognition of the importance of the problem; better understanding will follow in due course.

There is little cause for satisfaction in Britain over the high local figures of labour turnover; available evidence suggests that much of the movement is due to bad management. It is worth noting, however, that American figures are no better, and in many industries are worse, than the British.

TABLE V.—GREAT BRITAIN: PLACINGS BY EMPLOYMENT EXCHANGES* 1949/1950/1951.

Industries.	Men, 18 and Over.		Boys Under 18.		Women, 18 and Over.		Girls Under 18.		Total.	
	1949-50.	1950-51.	1949-50.	1950-51.	1949-50.	1950-51.	1949-50.	1950-51.	1949-50.	1950-51.
Metal manufactures ...	46,743	27,812	5,761	5,213	5,859	3,812	1,397	1,346	59,760	38,183
Engineering, shipbuilding and electrical goods ...	183,378	127,850	24,578	23,476	55,308	42,378	9,764	10,285	273,028	203,989
Shipbuilding and ship-repairing ...	—	38,171	—	2,579	—	995	—	163	—	41,908
Engineering ...	—	74,899	—	17,676	—	21,815	—	6,012	—	120,402
Electrical goods ...	—	14,780	—	3,221	—	19,568	—	4,110	—	41,679
Vehicles ...	66,974	45,593	12,623	13,630	13,744	10,807	2,938	3,097	96,279	73,127
Metal goods, not elsewhere specified ...	40,490	24,730	7,244	6,571	26,262	17,000	5,176	4,472	79,172	52,773
Precision instruments ...	6,874	4,575	2,204	1,936	6,149	3,950	1,450	1,346	16,677	11,807
Total metal and engineering industries ...	344,459	230,560	52,410	50,826	107,322	77,947	20,725	20,546	524,916	379,879
Total, all industries ...	1,409,679	1,062,397	180,069	173,050	640,661	516,901	177,939	172,447	2,408,348	1,924,795

* 40 weeks period from December 22, 1949, to September 27, 1950.
40 weeks period from December 21, 1950, to September 26, 1951.

possible, smaller unions. Between 1948 and 1950, the number of unions declined from 726 to 704. Altogether, 320 have disappeared since 1938, though the total membership has increased by 3.2 millions or 50 per cent.

Whether even a satisfactory wages policy would secure sufficient workers for the re-armament programme is doubtful. Mr. Roy Harrod, writing in the *Financial Times* on December 12, maintains that the resources which can be set free by cutting consumer demand are small compared with total requirements. He proposes to find the personnel and the capacity for the re-armament programme by cutting down the volume of exports. This could be done without endangering the external balance by charging higher prices for British exports, and the most obvious way of doing this is by revaluing the pound sterling. Mr. Harrod's argument depends upon the assumption that the existing level of exports could be maintained at higher prices; but, surely, devaluation was undertaken simply because the necessary volume of exports could not be maintained at the level of prices ruling at that time. If, however, Mr. Harrod is right in his claim that little is to be achieved by cutting down home consumption, and is over-optimistic about the possibility of reducing exports while charging more for them, it is an inescapable conclusion that, without aid from the United States, re-armament on the projected scale is impracticable. It is sincerely to be hoped that Mr. Harrod is wrong in the first, but right in the second, particular.

Manpower has to be of the right type as well as sufficient in quantity. The difficulty which the machine-tool industry is experiencing in finding craftsmen is due, not to the re-armament pro-

be indentured under 18; in one factory, the productivity team found an apprentice aged 62. Ministry of Labour training centres in the United Kingdom have much evidence of the speed at which adults can pick up a new trade, and, indeed, in Sir Godfrey Ince's words, there is "no shadow of doubt that, by intensive training methods, a very high degree of skill can be acquired in a very short time." It has been planned, with the agreement of industry, to revive these training centres to meet the present emergency, but progress so far has been disappointing. The present British apprenticeship system takes much too long and while, no doubt, it was satisfactory when the school-leaving age was lower and apprenticeship coincided with adolescence, it is out of touch with modern conditions. Higher wages must, of course, accompany later apprenticeships, and under United States law the minimum wage for apprentices is 50 per cent. of that of journeymen. Federal apprenticeship standards, as recommended by the Federal Bureau of Apprenticeships, compare very favourably with the British and, in some ways, the system guarantees the apprentice more all-round training. He may, for example, be indentured to his local joint apprenticeship committee (which includes representatives from employers' and workers' federations and sometimes from the Federal Bureau) and not to an employer. If his experience in any factory is too restricted, he can then be easily transferred to another. The report points out that, in Britain, similar ideas have been considered by some industries, and recommends their wider adoption. It is worth noting that the regularised indentured apprenticeship in the United States did not begin until about 1920. This factor of recent development, indeed,

THE ABBEY WORKS OF THE STEEL COMPANY OF WALES.

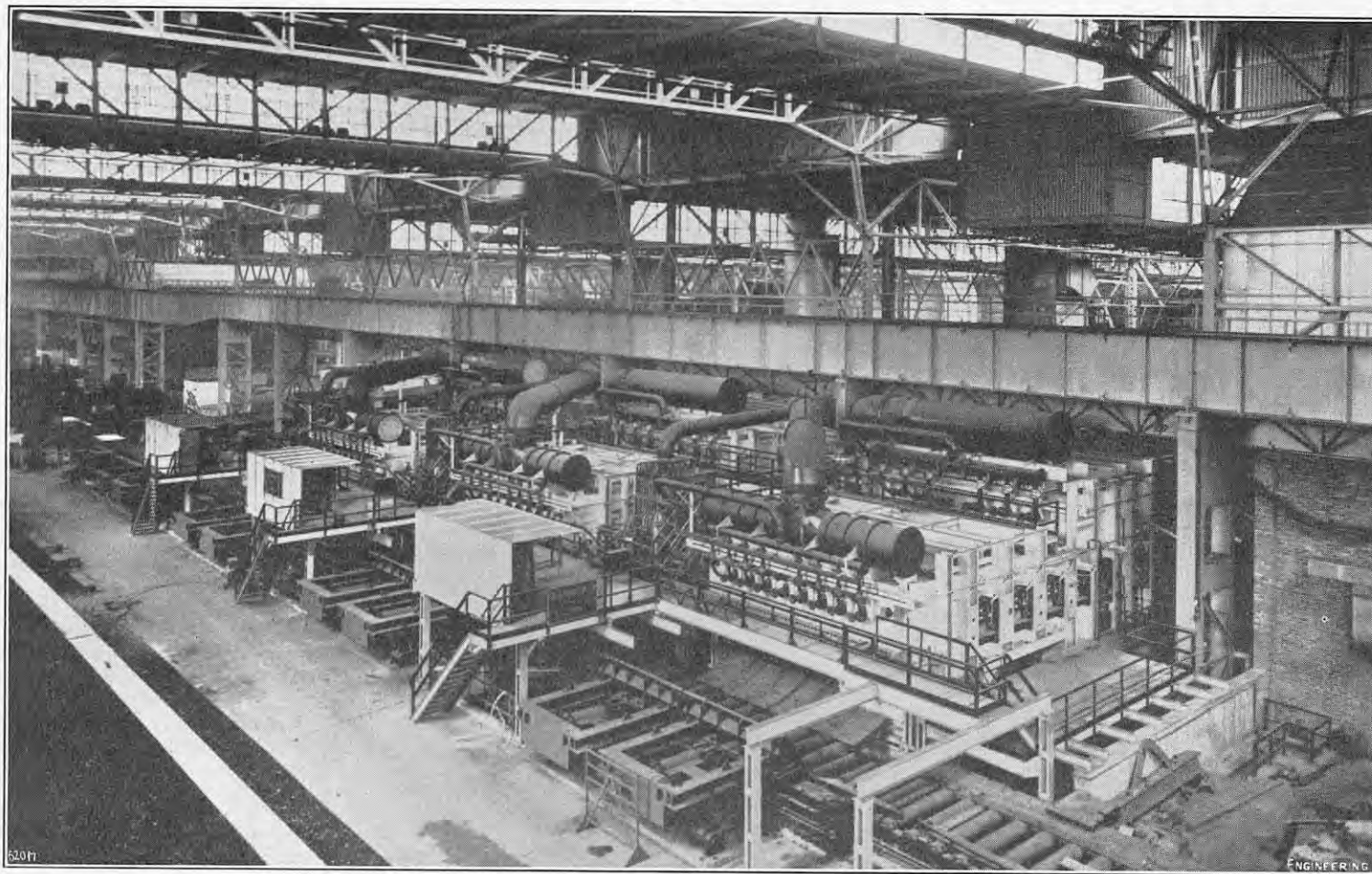


FIG. 12. SLAB-HEATING FURNACES.

A British Institute of Management survey, covering 250,000 persons, shows that, of the number of men leaving their employment in the six months to December, 1950, 21.8 per cent. had been there less than one month, 20.3 per cent. between one and three months, 21.5 per cent. between four and 12 months, and only 12.8 per cent. had held their jobs for more than five years. This represents a considerable waste, not only in the cost of engaging labour, but also in production costs, such as the time taken to train new workers, the extra scrap and tool breakages incurred, production delays, and overtime paid to others, when a job is vacant, to maintain output. The percentage turnover in the engineering and electrical goods industries in 1950 (the latest full year for which figures are available) was 34, in metal manufacture 28.8, in vehicles 29.9, and in miscellaneous metal manufactures 44.9 per cent. These rates, which are remarkable, compare favourably with those in other industries; textiles, for example, had a turnover of 36.5 per cent.; food, drink and tobacco, 47.7 per cent.; and chemicals, 30.0 per cent. Fortunately, there seems to have been considerable improvement in the rate of turnover in 1951. In Table V, on page 39, it will be seen that the number of placings by the Employment Exchanges in the 40 weeks to December, 1951, was considerably lower in all the engineering industries than in the corresponding period of 1950—and yet there was an increase in the numbers employed in these industries. Total placings in all industries, moreover, fell from 2.4 millions in the earlier period to 1.9 millions in the later.

Research into human relations in industry is by no means neglected in Britain. The British Institute of Management and the National Institute of Industrial Psychology have been very active in this field; indeed, the latter organisation have recently published, with the sponsorship of the Human Factors Panel of the Committee on Industrial Productivity, a detailed study of supervision in British industry entitled *The Foreman*. Sound research has always been a strong point in Britain; it is in applying the results that the

weakness sometimes lies and there is a falling below American standards. In this instance, it is of vital importance that the shop floor should make fullest use of the best available knowledge, not only for the present emergency, but for the whole industrial future of Britain. Only if the best possible use is made of the available manpower will a decreasing and ageing working population be able to maintain themselves in the manner of life to which they have been accustomed.

INSTITUTION OF MECHANICAL ENGINEERS PAPERS.—Meetings in London for the second half of the current session of the Institution of Mechanical Engineers have recently been announced. They are as follows: "The Marine Gas Turbine from the Viewpoint of an Aeronautical Engineer," by A. Holmes Fletcher (January 25); "Powered Flying Controls: Some Design Considerations," by F. J. Bradbury and S. M. Parker (February 1); "Noise in Private Cars," by J. R. Bristow (February 12); "The Allocation of Machines to Operators," by T. F. O'Connor (February 15); three papers on "Knock" in automobile engines and octane numbers in relation to road performance, by J. D. Davis, D. Downs, R. W. Wheeler, M. J. Eatwell and J. G. Withers (February 22); "Gear-Tooth Stresses and Rating Formulae," by H. E. Merritt (February 29); "Use of Heavy Fuels for Medium-Sized Marine and Stationary Diesel Engines," by J. R. P. Smith (March 7); "Shock Absorbers," by J. W. Kinchin and C. R. Stock (March 11); "Basic Engineering Standards and their Place in Design," by Captain C. G. Adams, R.N. (retd.) (March 14); "Centrifugal Pumps in Steam Power Stations," by R. Pennington (March 21); presentation of annual report and accounts (March 28); "Some Considerations Regarding a Factory Maintenance Engineering Department," by Max Bentham (April 4); "Long-Distance Diesel Buses on the European Continent," by J. A. Steenman (April 8); the James Clayton Lecture, "Some Aspects of the Mechanics of the Cavitation Process," by Professor R. T. Knapp (April 18); "Explosions in Enclosed Crankcases of Steam and Internal-Combustion Engines," by John Lamb (April 25); and "The Control and Recovery of Dust and Fume in Industry," by Robert Ashman (May 2). The annual lecture to the Graduates' Section, London, at 3 p.m. on January 26, will be on "Mechanical Installations in Buildings," by Mr. P. T. Fletcher.

THE ABBEY WORKS OF THE STEEL COMPANY OF WALES.

(Continued from page 4.)

THE slab-heating furnaces at the Abbey steel-works, of which three are at present installed, were constructed by Messrs. Stein and Atkinson, Limited, Wilton-road, London, S.W.1, and are illustrated in Fig. 12. They are of the triple-fired zone type, with end charging and discharging, and are capable of heating 105 tons of slabs per hour from cold to rolling temperature. Each furnace is 88 ft. long and 20 ft. wide between the inside walls. The slabs, which vary in width up to 5 ft. and in thickness from 5 in. to 8½ in., can be charged in a single row of 18-ft. slabs or in a double row of slabs up to 8 ft. 6 in. long. They are pushed from the furnace table by electric pushers and slide by gravity down the discharge slope on to a live-roller table which takes them to the mill. As far as the soaking hearth, they are supported on water-cooled skid pipes, which are, in turn, carried on vertical water-cooled pipes over the lower combustion chamber of the main heating zone. The portions of the skids and supports which are directly exposed to the flame, are covered with refractory material to conserve fuel. The soaking hearth is of solid refractory in which steel blooms are embedded. The upper layer of this hearth, over which the slabs are pushed, is of plastic material. The electrically-operated doors at both ends are each half the width of the furnace, so that only one side need be opened when charging and discharging half-length slabs.

Firing is effected either by heavy fuel oil or coke-oven gas through combination burners, manufactured by Messrs. Urquhart (1926), Limited, London. Either fuel can be used at will in any of the three zones. The combustion air is pre-heated in Stein recuperators and is delivered to the burners by fans with an output of 25,000 cub. ft. of air per minute. These fans were manufactured by Messrs. Davidson and Company, Limited, Belfast, and are driven by G.E.C. motors. Control

ABBEY WORKS; STEEL COMPANY OF WALES.

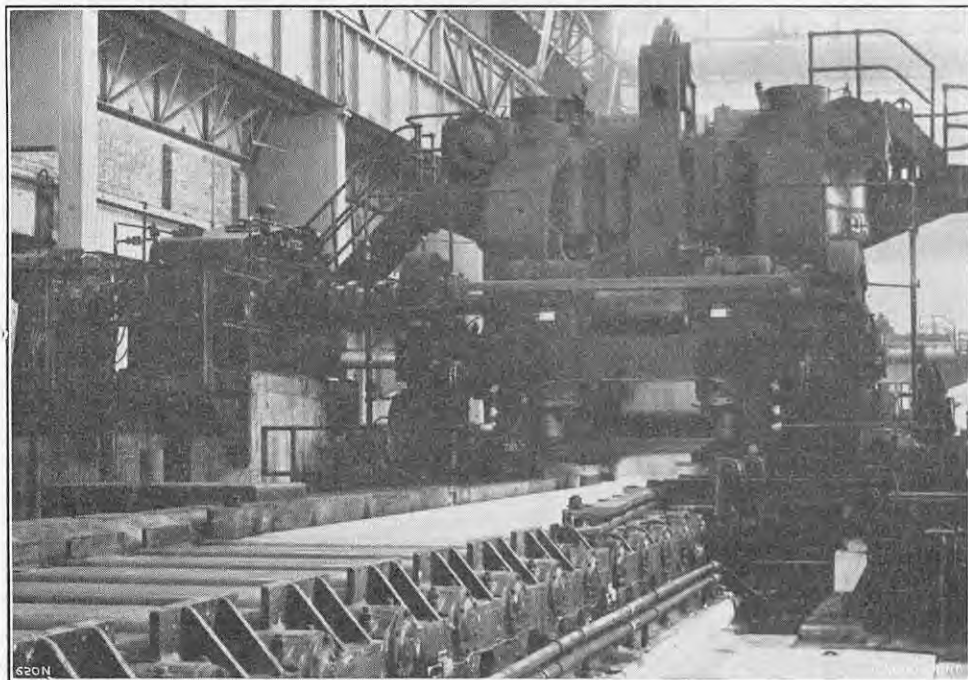


FIG. 13. 80-IN. CONTINUOUS STRIP MILL.

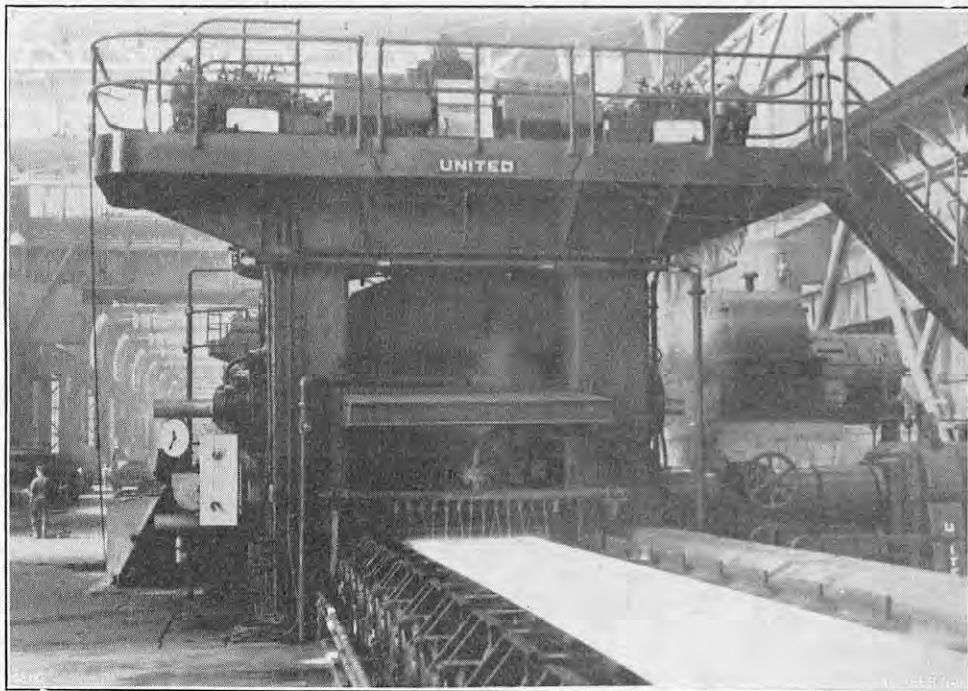


FIG. 14. CONTINUOUS STRIP MILL IN OPERATION.

is automatically effected from panels in front of the furnaces, which carry all the necessary indicating and recording instruments. Oil is delivered from bulk storage tanks into two 10,000-gallon service tanks, from which it is drawn by steam-driven Weir pumps. Thermostatically-controlled heaters are provided to raise the temperature to 120 deg. F.

On emerging from the re-heating furnaces, the slab is carried on rollers to the hot strip mill, shown in operation in Figs. 13 and 14, and in 16, on page 42. This mill, which is the principal feature of the Abbey works, has a throughput of 300 tons per hour, and is designed to roll plates 72 in. wide and up to $\frac{3}{4}$ in. thick, as well as strip down to 0.048 in. thick, at speeds from 900 ft. to 1,800 ft. per minute. It was constructed by the United Engineering and Foundry Company, Pittsburg, and consists of a primary scale breaker through which the slabs are passed to detach the oxide scale that has accumulated in the slabbing mill or during re-heating. This breaker is a two-high mill with 36 in. by 72 in. rolls which are carried in Morgoil bearings. The slab is next fed by turntables and a pusher into a

broadside mill, the work rolls of which are 42 in. in diameter, while the back-up rolls are 54 in. in diameter and the barrels 130 in. long. The function of this unit is to turn the half-length slabs, the maximum length and width of which are 8 ft. 6 in. and 60 in., respectively, through an angle of 90 deg. and to roll them sideways, producing a slab 74 in. wide by 8 ft. 6 in. long. This slab is then turned back through 90 deg. for further rolling. Next comes a slab squeezer, in which the symmetry of the piece is adjusted before it enters the three roughing mills. The first two stands of this mill have 80-in. barrels with work and back-up rolls 36 in. and 54 in. in diameter, respectively. The work rolls of the third stand are 27 in. in diameter. All three mills have Morgoil bearings on the back-up rolls and Timken four-row bearings on the work rolls; each stand incorporates an edging mill. Between the last roughing mill and the first finishing mill is a delay table, 185 ft. long, on which the work is held until its temperature has fallen to the correct value for the next operation.

The first finishing stand is preceded by a rotary

crop shear, in which the front end of the strip is cropped, and by a pinch-roll scale breaker which cracks the scale formed on the material during rolling. Each of the six finishing stands is equipped with 80-in. barrels, the work rolls and finishing rolls being 27 in. and 54 in. in diameter, respectively. Morgoil and Timken bearings are used as on the roughing mill, the former being supplied with lubricant from two separate systems, each of which comprises an electrically-driven pump, cooler, thermometer and alarms. Two similarly-equipped systems are used to supply oil to the edger and shear drives and to the screwdowns and pinions of the mill. Motor-operated centralised pressure systems are also provided for supplying points requiring grease lubrication.

The slab shear balance is supplied from hydraulic equipment consisting of a pump and accumulator, while two other sets of similar equipment are provided for the hydraulic roll balances on the scale breaker, broadside mill and roughing mill and for those on the finishing mill, respectively. In addition, three other hydraulic systems supply power to the slab lift, slab turner and down coiler. A high-pressure descaling and scrubbing plant is also provided.

The electrical equipment employed for operating this part of the plant is very complete and may be treated in detail. The scale breaker is driven by a 12,500-h.p. 3.3-kV slip-ring induction motor, which was constructed by Metropolitan-Vickers Electrical Company, Limited, Trafford Park, Manchester, 17. Its synchronous speed is 375 r.p.m., but an automatic slip regulator in the rotor circuit enables a speed drop up to 20 per cent. at twice full load to be obtained. This enables the 20,000 h.p.-seconds of energy stored in the flywheel to be utilised, and the motor and line are thus relieved of the peak demands of the mill. The motor, which has a pull-out torque of $2\frac{1}{2}$ times the full-load torque, is mounted on a bedplate which is fitted with pads along which the stator can be moved to enable the windings to be examined. It is cooled on the closed system, the air being circulated by a centrifugal fan at the cooler outlet. The motor is controlled by a liquid starter and automatic slip regulator, and can be stopped and reversed in emergency by push-buttons.

The broadside mill is driven by a 3,500-h.p. 11-kV slip-ring motor with a synchronous speed of 500 r.p.m., which is designed for a 20 per cent. speed drop at 100 per cent. overload; and has a flywheel with a stored energy of 70,000 h.p.-seconds. This motor was also constructed by the Metropolitan-Vickers Company and is generally similar to that on the scale breaker. As its speed is higher, no external circulating fan is required. It is also controlled in the same way as the scale-breaker motor. The edge squeezer is driven by a G.E.C. 500/1,000-h.p. direct-current motor, which runs at speeds from 375 to 750 r.p.m., and is arranged for cascade exciter control. Like the other auxiliaries mentioned below it is supplied with power from an 850-h.p. four-machine motor-generator.

Each of the roughing mills is driven by a 4,500-h.p. 11-kV three-phase synchronous motor, which was constructed by the Metropolitan-Vickers Company; one of them is illustrated in Fig. 15, on page 42. A view in the motor room in this part of the mill is given in Fig. 19, Plate IV, the control board being visible along the left-hand side. The motors are of the salient-pole type with solid cast-steel rotors and solid poles, to which shoes for retaining the field coils are bolted. Their pull-out torque is $3\frac{1}{2}$ times the full-load torque. The motors are excited from a direct-coupled exciter on which there is an additional field winding, so that the excitation can be increased as the load on the main motor rises. The additional field is energised from a series transformer in the stator circuit of the main motor, the secondary of which is connected through a rectifier to the winding. Starting and inching are effected by series reactors.

The delay tables which, as mentioned above, are placed between the last of the roughing stands and the crop shear, are driven by 75-h.p. G.E.C. motors, which run at 525 r.p.m. The crop shear is driven by a 300-h.p. motor constructed by the same firm and running at 460 r.p.m.; this, like that on the slab squeezer, is arranged for cascade exciter control.

A main and pilot exciter are arranged so that a considerable change in the output of the former can be obtained as a result of a very small change in the field of the latter.

The first two stands of the finishing mill are each driven through gearing by a 4,500-h.p., 800-volt direct-current motor running at speeds of 125 to 282 r.p.m.; the third, fourth and fifth stands are driven directly by 5,000-h.p. 800-volt motors running at speeds of 78 to 156, 105 to 210 and 125 to 250 r.p.m., respectively; and the last stand by a 4,000-h.p. 800-volt motor operating at 132 to 296 r.p.m. All these motors were constructed by the British Thomson-Houston Company, Limited, Rugby, and a view of the motor room, which lies adjacent to the mill proper, is given in Fig. 20, Plate IV. Each motor has its individual exciter and the six exciters are, in turn, supplied by a control exciter, the voltage of which is adjusted electronically. They are cooled on the closed-circuit system, any leakage from which is made up by air drawn through a Precipitron filter.

The direct-current power for operating these six motors is derived from the 11-kV three-phase mains through ten transformers and 30 permanently-sealed steel-tank B.T.H. rectifiers, each of which is rated at 700 kW, thus giving a total capacity of 21 MW. These rectifiers are illustrated in Fig. 21, Plate IV. The ten transformers are arranged in five groups of two, the primary of one of which is wound in star and of the other in delta. Phase shifting auto-transformers, giving phase shifts of -12 deg., -6 deg., $+6$ deg. and $+12$ deg., are arranged on the line side of four of the transformer groups, and current-limiting series reactors are connected in the circuit of all five groups. This arrangement of transformers and auto-transformers produces the equivalent of 60-phase rectification at the 'bus-bars, thus practically eliminating any interference with communication circuits.

Starting, stopping, speed control and running in the reverse direction at low speed, are effected from a desk in the control pulpit of the mill. The voltage of the rectifiers is regulated from zero to 800 volts by motor-driven phase-shifters, which are connected in the grid circuits. The voltage can also be maintained constant, irrespective of changes in the load or supply voltage, by an electronic regulator operating on the rectifier grids. The closing of the main oil circuit-breakers in the transformer circuits, and the starting of the exciters and fan motors are effected from a desk in the motor room, a view of which is given in Fig. 22, Plate IV. Instruments show the current in the main circuits, while annunciators indicate over-temperature of the motor bearings and ventilating air, as well as of other emergency conditions.

Owing to the large power involved, special attention has been paid to the protective arrangements. The circuit-breakers through which the transformer groups are supplied are arranged to open instantaneously at a fairly high setting and are also fitted with overload trips of the definite minimum inverse time delay type. Between each group of three rectifiers and the 'bus-bars is a high-speed circuit-breaker which is designed to trip instantaneously on a reverse current. These circuit-breakers, in conjunction with arc-suppression control of the rectifiers through the grids, provide protection in case the rectifiers should back-fire. They are arranged to re-close automatically after an interval, so that a back-fire on one rectifier only switches out one of the ten rectifier groups for a short period without interfering with the operation of the mill. A further high-speed circuit-breaker is connected in the circuit of each mill motor and is arranged to trip on forward over-current or reverse current.

Between each pair of finishing stands is a loop lifter, which is driven by a G.E.C. mill-type motor, controlled from the operator's pulpit. All these motors are supplied from a separate $7\frac{1}{2}$ -kW 100-volt generator, and the five generators, as well as a 10-kW constant-voltage exciter, are coupled together and driven by a 40-h.p., 415-volt squirrel-cage motor. The motors driving the auxiliaries on both the roughing and finishing strip mills are controlled by switchgear constructed by Messrs. Allen West and Company, Limited, Brighton, which is similar to that installed on the slabbing mill and described above.

ABBEY WORKS; STEEL COMPANY OF WALES.

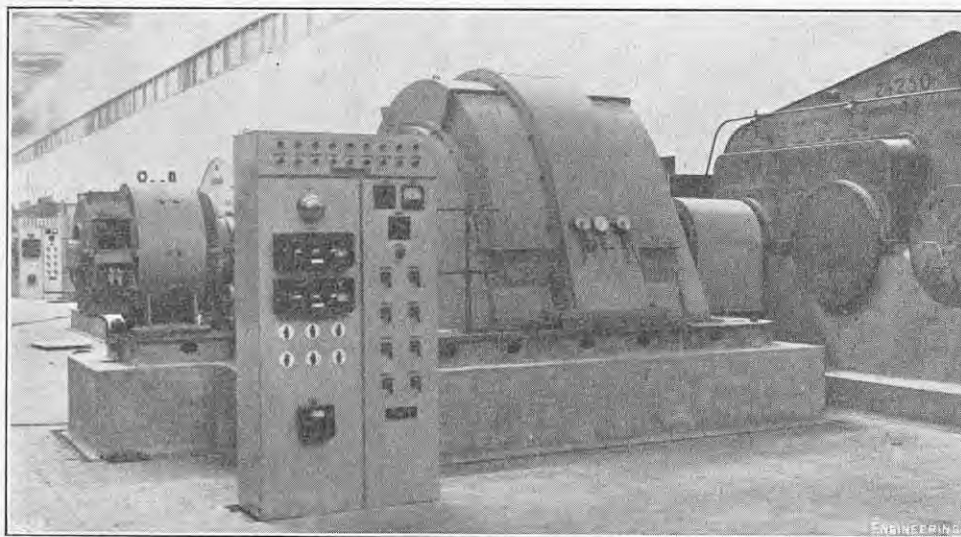


FIG. 15. 4,500-H.P. 11-KV MOTOR FOR ROUGHING STAND.

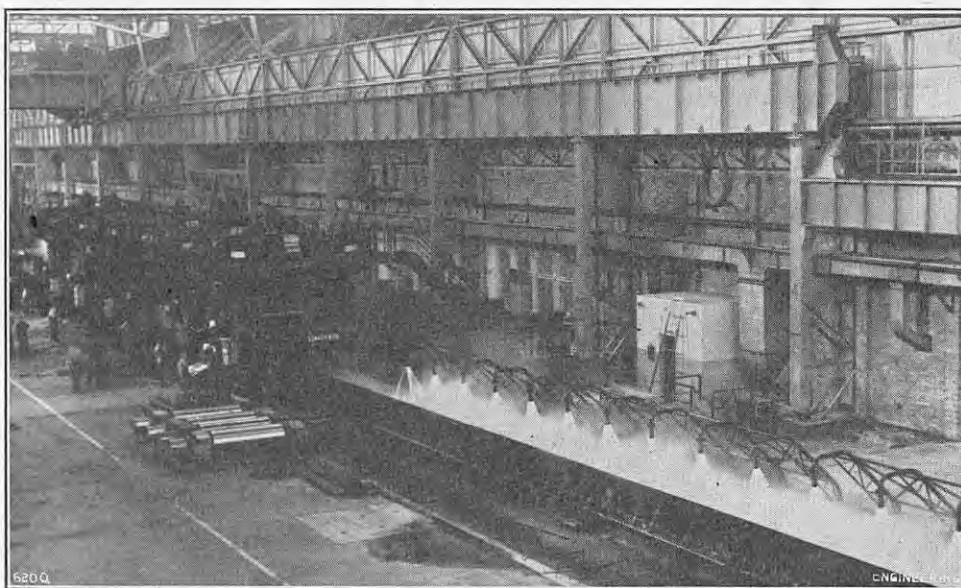


FIG. 16. FINISHING STANDS AND RUN-OUT TABLE.

About 85 per cent. of the output of the hot mill consists of strip in coils, $7\frac{1}{2}$ per cent. of flying sheared sheets and $7\frac{1}{2}$ per cent. of plates. When strip is being rolled, it travels down the first run-out table to one of two coilers, being guided through pinch rollers driven by two 75-h.p. mill-type motors. Illustrations of this part of the plant are given in Figs. 16, 17 and 18. The mandrels of the coilers are driven by 300-h.p. totally-enclosed force-ventilated motors with cascade exciter control; and the strip is tightly wrapped on to them at starting by wrapper rolls. These wrapper rolls are then withdrawn until the coil is nearly completed, when they are once again brought into operation to iron down the tail. Finally, the coil, which has a maximum weight of $13\frac{1}{2}$ tons, is pushed off the coiler by pneumatic rams on to a tilting carriage, which up-ends it on to a conveyor for dispatch to the stocking area.

Power for driving the flying shears, run-out tables and coilers in this section of the mill is obtained from two motor-generators, each comprising a 1,500-h.p. 3.3-kV synchronous motor, which is directly coupled to its exciter and to four generators. The main control boards for the motor-generators and motors are installed in the motor room illustrated in Fig. 19, Plate IV.

Coils from the stocking area are either dispatched by rail to the Trostre works of the company or go to the cold-reduction plant at Abbey for further processing. We propose to describe both these plants in subsequent issues of ENGINEERING.

(To be continued.)

SOLVENT-EMULSION DEGREASERS FOR METALS.

MESSRS. SUNBEAM ANTI-CORROSIVES LIMITED, Electrolyte Works, 9a, Ladbroke-grove, London, W.11, have sent us particulars of three of their degreasing agents, all of the solvent emulsion type, for the removal of grease and dirt from metal parts. These, they state, have proved efficient and economical alternatives to the vapour degreasing agents. The first, Stripalene No. 41, is a brown transparent liquid into which the parts to be cleaned are immersed for a period ranging from 5 to 20 minutes. The liquid is used at room temperatures. The dissolved grease and dirt are then rinsed off with a spray of water or in agitated water. The liquid has been developed for the cleaning of iron, steel, copper, aluminium, zinc and magnesium, or their alloys, prior to plating or other finishing operation. The second degreasing agent, Stripalene No. 4S, is a pale yellow mobile liquid which forms an emulsion with tap water and is intended for use in spray washing machines. The liquid contains no acid or alkali, and is stated to be based mainly on synthetic sulphonated products. When metal parts are cleaned with this substance, a very thin film of the cleaner remains on the surface, which, it is claimed, acts as a temporary rust preventive. Stripalene No. 4S can be used cold, but the best results are obtained at temperatures of between 120 deg. and 160 deg. F. This cleaner is stated to be particularly useful for the removal of cutting lubricant and swarf from metal parts during machining and inspection operations. The preparation may be applied manually with the aid of a cloth or mop, but it is emphasised that the best results are obtained when it is used in the form of a forced spray, the pressure being as high as possible. The last of the three metal cleaners, Stripalene

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(For Description, see Page 40.)



FIG. 19. CONTINUOUS-MILL MOTOR ROOM

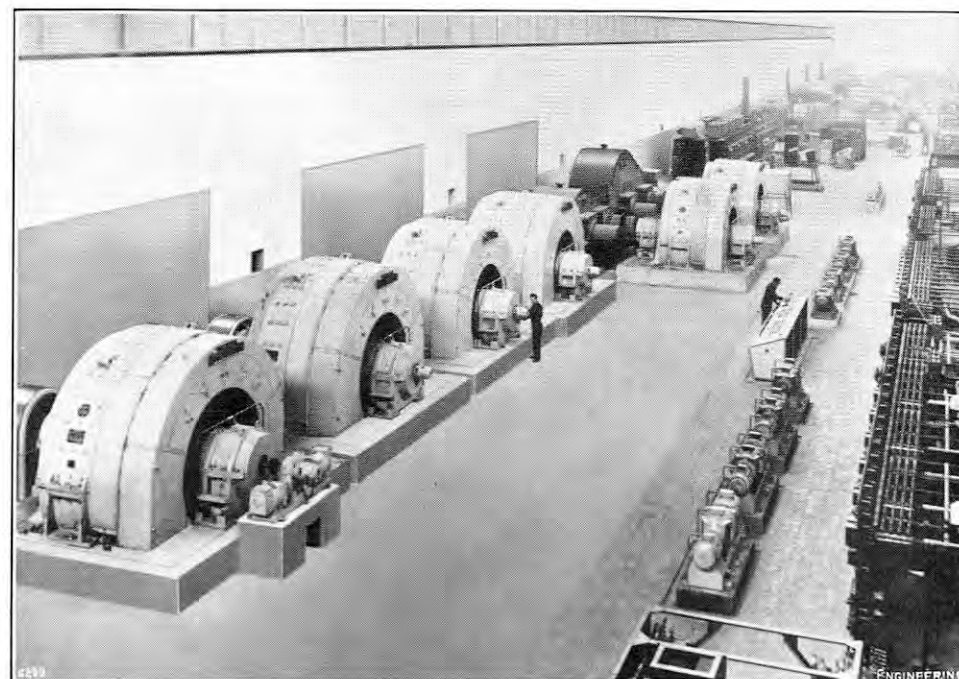


FIG. 20. DIRECT-CURRENT MOTORS FOR FINISHING STANDS.



FIG. 21. RECTIFIERS FOR FINISHING STANDS.

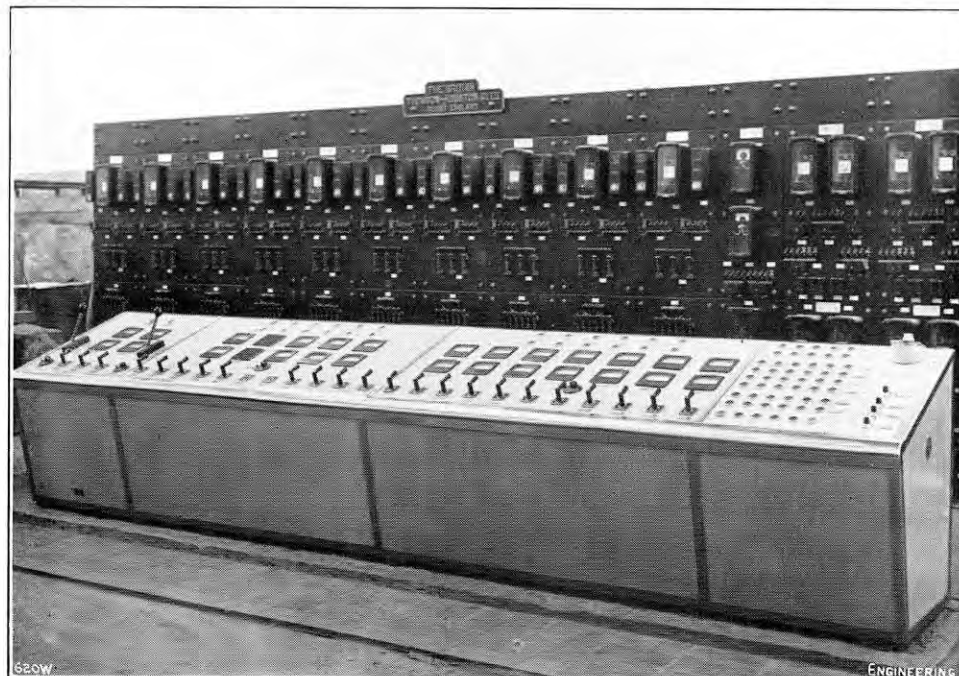


FIG. 22. CONTROL DESK.

THE ABBEY WORKS OF THE STEEL COMPANY OF WALES.

(For Description, see Opposite Page.)

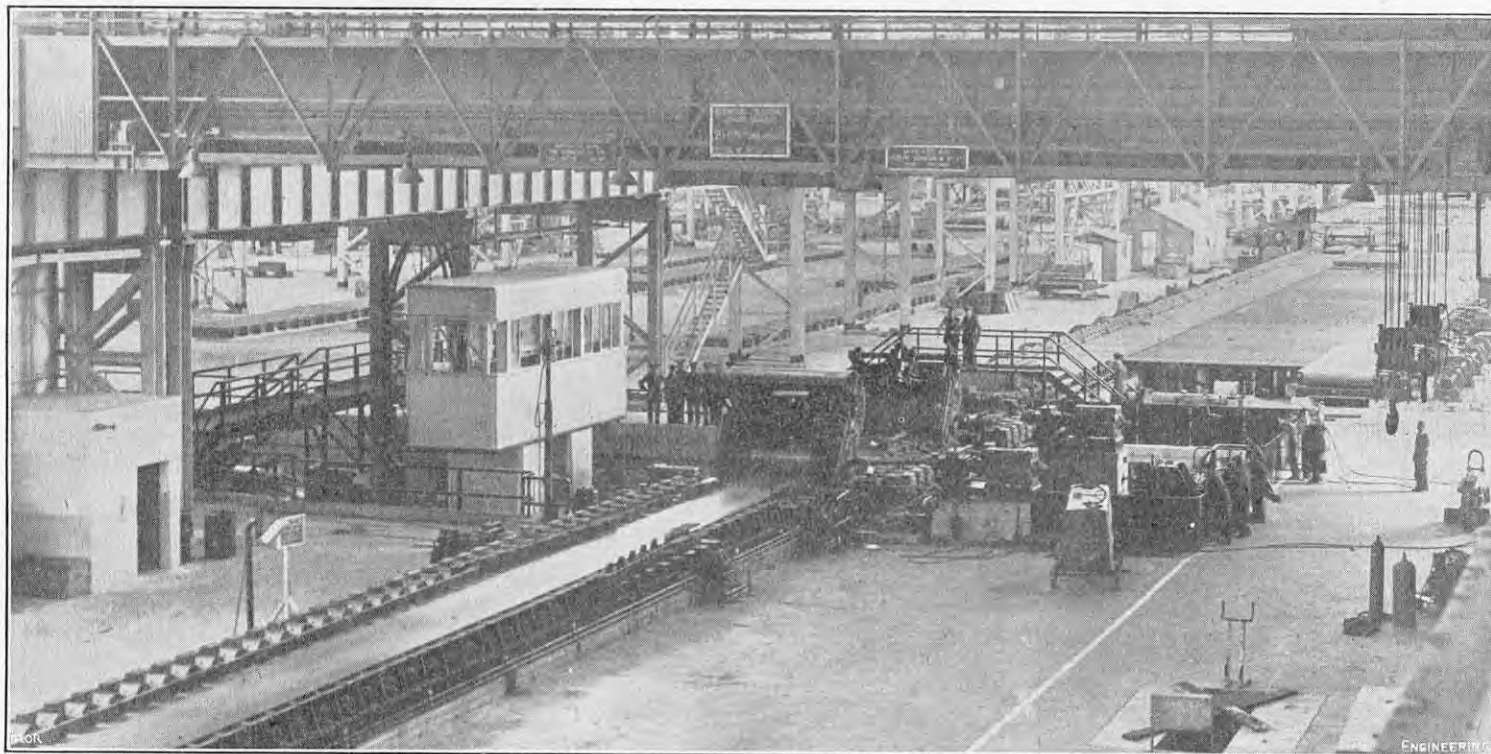


FIG. 17. RUN-OUT TABLE AND COILERS.

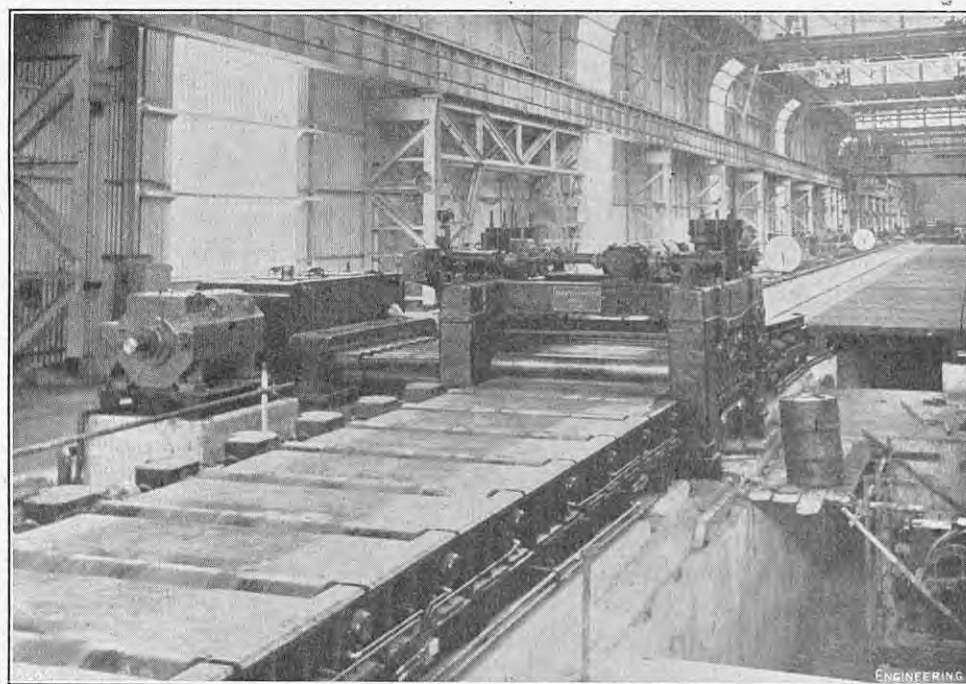


FIG. 18. HOT-PLATE FINISHING LINE.

No. 756, is a dark brown liquid of medium viscosity. This, we are informed, has been specially developed for the efficient removal of all types of synthetic enamels and paints, oil, dirt, and grease contaminations and protectives from the surface of aluminium, tin, zinc, magnesium, and other ferrous and non-ferrous metals and alloys. Anodised aluminium and phosphate coatings on metals, it is stated, are not affected by the solution, which is used at a temperature of from 150 deg. to 170 deg. F. Articles to be cleaned are completely immersed in the solution contained in a mild-steel tank and when all the oil, dirt and grease have been removed and any underlying paint or enamel has blistered from the surface, the part is lifted out of the stripping solution and drained. All the loose particles of coating are then removed by immersion in a tank of agitated clean hot water and the parts are ready for the finishing operation. The solution has a de-fatting and blistering action on the skin and operatives should wear protective clothing, gloves, and boots.

CONTRACTS.

SCOTT & SONS, Bowling, near Glasgow, have received an order from the Tees Towing Co., Ltd., for a tug which will be employed exclusively on river work. Her propelling machinery, a 750-h.p. Diesel engine, will be supplied by CROSSLEY BROS. LTD., Manchester.

During December the British Electricity Authority placed contracts for equipment for power stations, transforming stations and transmission lines amounting, in the aggregate, to 37,297,120l. The principal contracts include 132-kV 2,500-MVA switchgear for Brunswick Wharf power station, with the BRITISH THOMSON-HOUSTON Co., LTD.; two 300,000-lb. per hour boilers for Hackney power station, with SIMON-CARVES LTD.; two 12,500-kW turbo-alternators, condensing and feed-heating plant for Cowes power station, with the BRUSH ELECTRICAL ENGINEERING Co., LTD.; six 300,000 lb. per hour boilers for Portishead "B" power station, with MITCHELL ENGINEERING LTD., and one 60,000-kW turbo-generator for this station, with METROPOLITAN-

VICKERS ELECTRICAL Co., LTD.; two 300,000 lb. per hour boilers for Goldington power station, with CLARKE, CHAPMAN & Co., LTD.; three 100,000-kW turbo-generators for Castle Donington power station, with METROPOLITAN VICKERS ELECTRICAL Co., LTD.; two 60,000-kW turbo-alternators, condensing and feed-heating plant for Drakelow power station, with the ENGLISH ELECTRIC Co., LTD.; two 515,000 lb. per hour boilers for this station, with INTERNATIONAL COMBUSTION LTD., and high-pressure steam and feed piping, also for this station, with AITON & Co., LTD.; two 150,000 lb. per hour boilers for Northampton power station, with SIMON-CARVES LTD.; three 515,000 lb. per hour boilers for Meaford "B" power station, with BABCOCK & WILCOX LTD., and condensing and feed-heating plant for this station with the BRITISH THOMSON-HOUSTON Co., LTD., and HICK, HARGREAVES & Co., LTD.; one 515,000 lb. per hour boiler for Stourport "B" power station, with INTERNATIONAL COMBUSTION LTD., and auxiliary power-control and alarm cables for this station, with JOHNSON AND PHILLIPS LTD.; twelve 360,000 lb. per hour boilers for Uskmouth power station with BABCOCK AND WILCOX LTD., and auxiliary switchgear, transformers and accessories for this station, with the GENERAL ELECTRIC Co., LTD.; two cooling towers and circulating water conduits for Connaught Quay power station, with the YORKSHIRE HENNEBIQUE CONTRACTING Co., LTD.; condensing and feed-heating plant for Ince power station, with HICK, HARGREAVES & Co., LTD.; two 30,000-kW turbo-generators and condensing and feed-heating plants for Doncaster power station with the BRUSH ELECTRICAL ENGINEERING Co., LTD.; one 40,000-kW turbo-alternator and condensing feed-heating and evaporating plant for Blackburn power station, with the ENGLISH ELECTRIC Co., LTD.; one 550,000 lb. per hour boiler for Keadby power station, with the STIRLING BOILER Co., LTD.; three 60,000-kW turbo-alternators for Wakefield power station, with the ENGLISH ELECTRIC Co., LTD., and condensing plant and auxiliaries for this station, with WORTHINGTON-SIMPSON LTD.; one 360,000 lb. per hour boiler for the North Tees power station, with BABCOCK AND WILCOX LTD.; one 60,000-kW turbo-alternator, condensing, feed-heating and central evaporating plant for Carrington power station, with the METROPOLITAN VICKERS ELECTRICAL Co., LTD., and 3,300-volt and 415-volt switchgear for this station with the ENGLISH ELECTRIC Co., LTD.; two 360,000 lb. per hour boilers for Chadderton power station and one 300,000 lb. per hour boiler for Fleetwood power station, with SIMON-CARVES LTD.; one 60,000-kW turbo-alternator for Portobello power station, with RICHARDSONS, WESTGARTH & Co., LTD., and one 540,000 lb. per hour boiler for this station with INTERNATIONAL COMBUSTION LTD.; one 550,000 lb. per hour boiler for Stella South station, with CLARKE, CHAPMAN & Co., LTD.; and four 300,000 lb. per hour boilers for Roosecote, with YARROW & Co., LTD.

INDUSTRIAL POWER STATION AT SINDRI, INDIA.

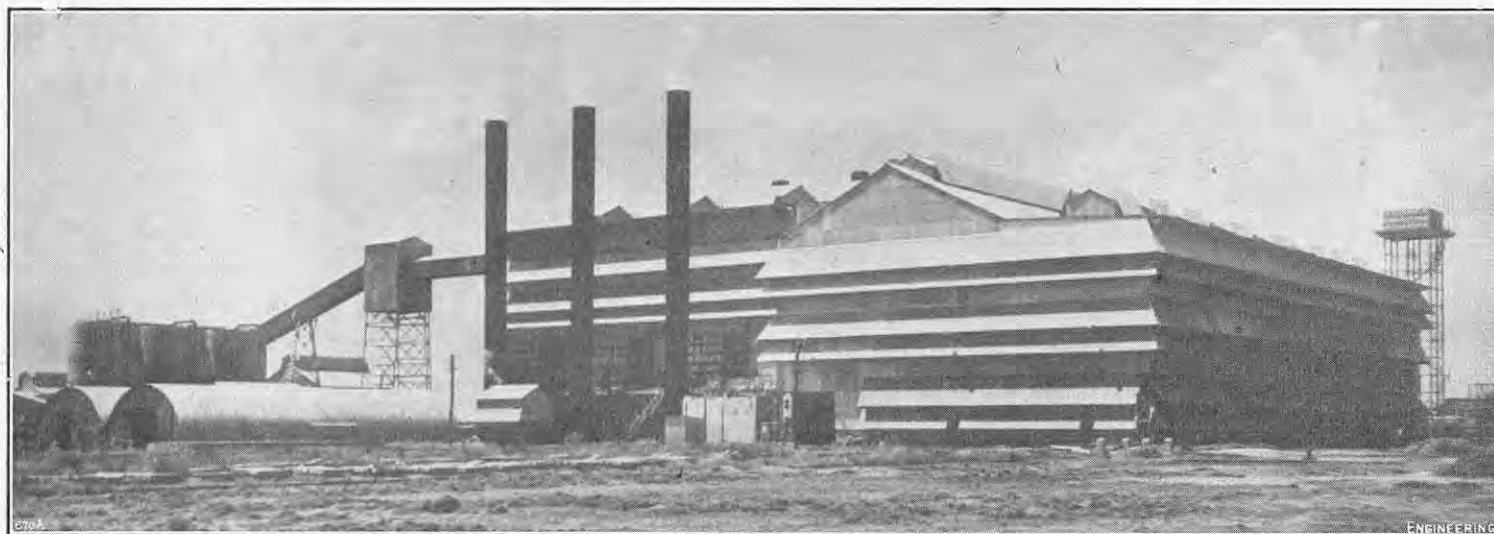


FIG. 1. SINDRI POWER STATION.

ELECTRICITY SUPPLY IN FERTILISER PRODUCTION.

THE disastrous famine which occurred in Bengal in 1943 was aggravated by the fact that the Japanese were in virtual control of the adjacent seas and were also occupying a number of large rice-growing areas in Asia. As a result, there was a death roll of some four million and attention was forcibly drawn to the circumstance that India's efforts to feed herself were not keeping pace with her growing population and rapid industrialisation. To increase food production it was also evident that greater dependence would have to be placed on artificial fertilisers and that, as the manufacturing capacity of the sulphate of ammonia plants at that time did not exceed 40,000 tons per annum, immediate steps must be taken to raise the output to as much as 350,000 tons. A technical mission from the United Kingdom, headed by Mr. G. S. Gowing, of Imperial Chemical Industries, Limited, and consisting of Mr. J. G. Rigg, of the same organisation, and Mr. T. H. Riley, of the Power-Gas Corporation, Limited, was therefore invited to consider how this increase could be brought about. As a result, a sulphate of ammonia factory has been established at Sindri on the banks of the Domadar River, in which full use is being made of electric power in the various production processes.

This factory, for which the Chemical Construction Corporation, of New York, acted as engineers and the main British contractors were the Power-Gas Corporation, Limited, Stockton-on-Tees, is the largest of its kind in India. It is designed to produce 1,000 tons of ammonium sulphate a day using coke obtained from the Bihar coalfields and gypsum from the Punjab. The coke is employed to generate water gas from which, in turn, ammonia is produced, the latter being converted into ammonium sulphate by the anhydrite process. Chemical by-products are also being manufactured in considerable quantities and the layout of the factory is such that the present output can be doubled without difficulty. Alternatively, the factory could be extended to produce nitric acid or nitro-chalk.

Sindri lies on the edge of the Bihar coalfield and, as fertiliser manufacture requires considerable quantities of power, it was decided to erect a generating station, a general view of which is given in Fig. 1, to supply the needs both of the works and the adjacent public network. There is also a demand for considerable quantities of process steam. The main steam-raising plant consists of six tri-drum boilers which were constructed by Messrs. Babcock and Wilcox, Limited, Farringdon-street, London, E.C.4. Each of these boilers, which are shown in course of erection in Fig. 2, has an output of 175,000 lb. of steam per hour at a pressure of 650 lb. per square inch and a temperature of 835 deg. F. They are 47 ft. between the centres of the front and rear stanchions and 64 ft. high from the ash basement to the upper drums. They are equipped with water-cooled furnaces, the walls of which consist of bare tubes backed with refractory tiles. The fuel—a local low-volatile coal containing about 18.5 per cent. ash—has hitherto been considered unsuitable for steam raising, but this difficulty is being overcome by the use of Babcock-Detroit Rotograte spreader stokers with forward-running grates, which can be seen in the view of the firing aisle reproduced in Fig. 3 opposite. In this type of stoker, the coal is fed from

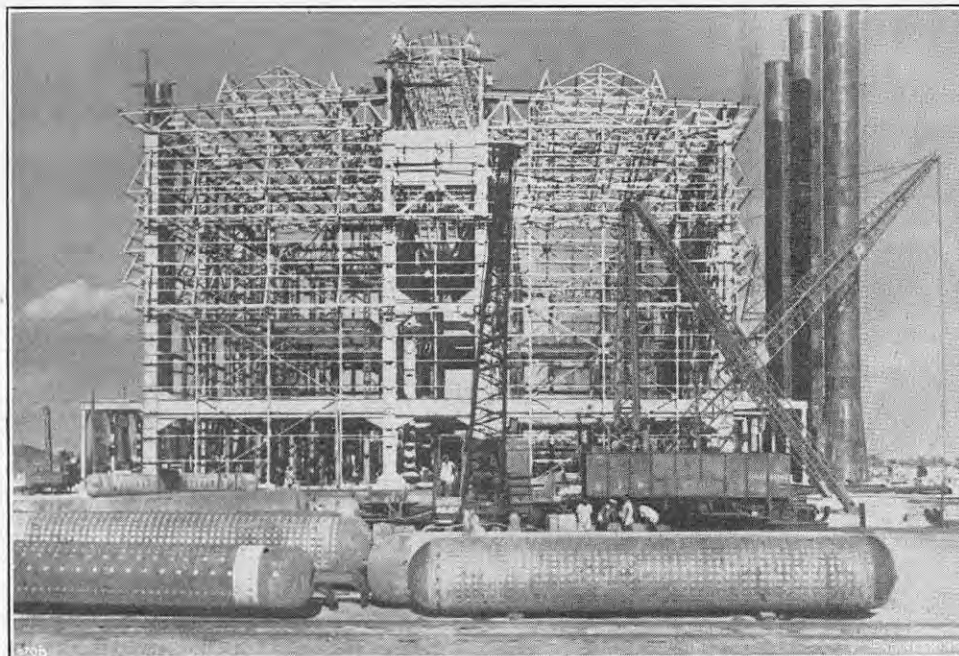


FIG. 2. 175,000-LB. BOILERS BEING ERECTED.

a hopper to a revolving rotor, which throws it towards the back of the furnace, where combustion takes place partly in suspension and partly on the moving grate. Since the kinetic energy of the coal is directly proportional to its weight, the large pieces travel farther than the small, thus ensuring uniform distribution. The forward running grate also makes it certain that the heavier particles remain longer in the furnace, thus facilitating complete combustion. It is claimed that this type of stoker, with a comparatively uniform fire, responds rapidly to changes of load and enables a wide range of fuel to be dealt with.

Two-stage superheating is employed, using bare-tube superheaters with an inter-stage attemperator. Grit is collected in hoppers near the economisers and air heaters and is returned to the furnace for re-firing. All the boilers are equipped with automatic combustion control and operate in conjunction with flash-welded steel tube economisers, to which feed water is admitted at a temperature of 320 deg. F. Air heaters of the three-pass cross-flow tubular type have also been provided and each boiler is fitted with hand-operated retractable single-nozzle, multi-jet and mass-jet soot blowers. Forced, induced and secondary draught fans are installed, those on four of the units being electrically operated, while those on the other two can, if necessary, be steam-driven. Owing to the use of pass-out turbines the amount of water required for make-up is unduly high. Permutit softening equipment, with a capacity of 500,000 lb. per hour, has therefore been installed, together with supplementary phosphate-sulphite treatment plant.

The generating plant in the station consists of four 15-MW condensing turbines and two 12.5-MW non-

condensing turbines, which exhaust at a pressure of 25 lb. per square inch. All these machines were constructed by Messrs. C. A. Parsons and Company, Limited, Newcastle-on-Tyne. In addition, there is a 400-kW Diesel set, which provides power for the auxiliaries when required. Cooling water for the condensing sets will, for the time being, be obtained from towers, since the flow of the river on which the station is situated is irregular owing to the porosity of the bed and the demand for new water in the factory is as high as 10 cusecs. To overcome this difficulty it is proposed either to construct a reservoir in a valley upstream of the station or to utilise the Denoda Valley scheme, some 90 miles above Sindri. At present, supplies of water are brought to the site from upstream where the river bed is rock.

Electricity is generated at 11 kV and is transmitted at this voltage from the power station to the factory, where it is stepped down to 3.3 kV in six 7-MVA and five 3-MVA transformers and to 400 volts in 27 1.25-MVA units. These transformers were all constructed by the English Electric Company, Limited, Queen's House, Kingsway, London, W.C.2, and are of that firm's core-type construction. They are oil-immersed and designed to meet the high temperature conditions on the site. In the case of the 7-MVA and 3-MVA units cooling is effected by radiators, which are attached to the fabricated sheet steel tanks. The 1.25-MVA units are cooled by tubes. To allow for variations in the high-voltage supply, $\pm 2\frac{1}{2}$ per cent. tapplings are provided and are controlled by off-circuit switches. On the 11-kV side, the terminals consist of shrouded-type bushings, while on the low-tension side cable boxes are used. Conservators are fitted to main-

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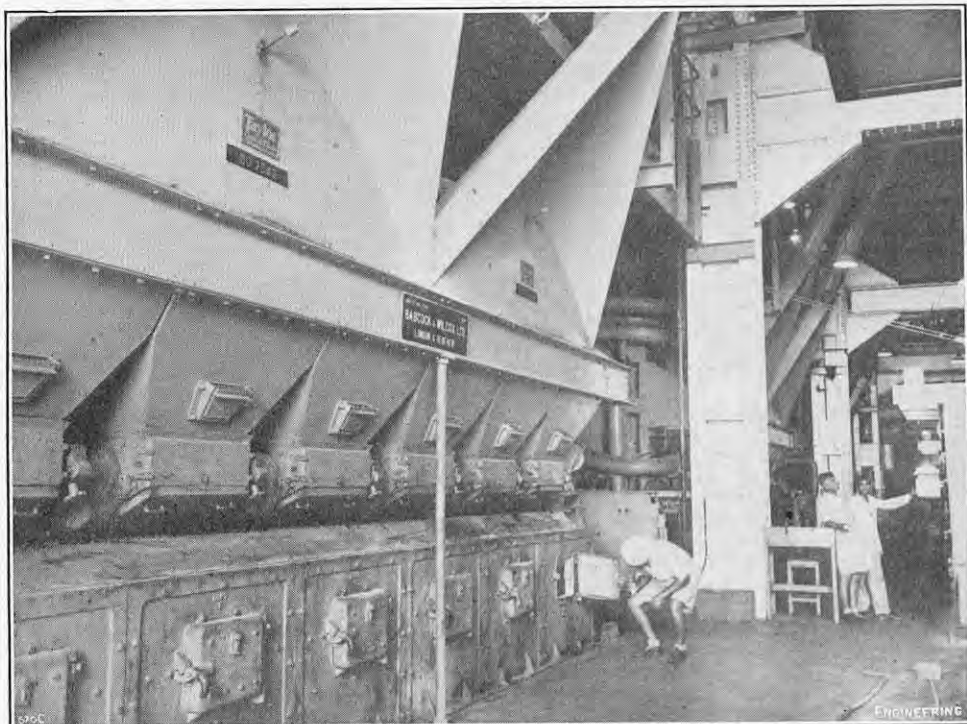


FIG. 3. FIRING AISLE IN BOILER HOUSE.

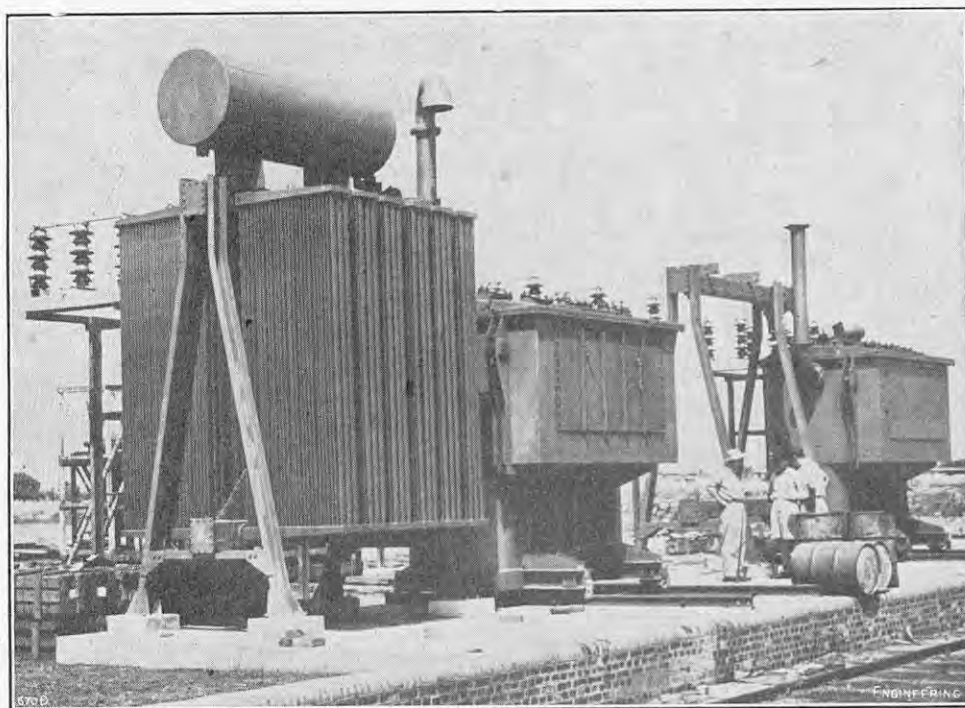


FIG. 4. 10-MVA 11/132-KV TRANSFORMER.

tain a head of oil in the main tank and a double float Buchholz device is incorporated to safeguard the transformer against incipient or major faults. The transformers are installed in 15 substations in each of which there is one spare unit of each rating.

The generators, high-tension feeders and transformers are controlled from a 25-panel metalclad switchboard, which was also constructed by the English Electric Company and is illustrated in Fig. 5, on page 48. This consists of totally-enclosed horizontal draw-out units with a rupturing capacity of 1,000 MVA, which are arranged for double 'bus-bar service. 'Bus-bar selection is effected on load and the switches are operated by solenoids. The switchboard is divided into three sections, the first of which comprises 10 panels for controlling three generators, five feeders, one reactor and one 'bus-bar coupler. The second, of eight panels, controls two generators, four feeders, one reactor and one 'bus-bar coupler, and the third, of seven panels, one generator, four feeders, one reactor and one 'bus-bar coupler. Each section of the main switchboard is therefore interconnected through a reactor, which is arranged so as to limit the short-

circuit rating when all the generators are operating in parallel. These reactors are accommodated in chambers immediately below the 11-kV switchgear, and the connections thereto are made through air-insulated conductors assembled in totally-enclosed sheet-steel chambers upon which remote manually-operated isolating switches are mounted. In addition to controlling the factory circuits, this switchboard is connected to the 10-MVA, 11/132-kV transformer, illustrated in Fig. 4, through which power is supplied to the public network. All the switchgear is controlled from a separately mounted control and relay switchboard, which is illustrated in Fig. 6, on page 48.

The 11-kV side of the works transformers can be isolated by outdoor switches of the vertical-break type, which are operated from ground level. Each of these isolating switches is interlocked with its associated circuit-breaker, so as to ensure correct sequence of operation. The connections between the transformer and isolating switches consist of rigid copper conductors, the cross-section of which is sufficient to withstand short-circuit conditions.

The power station auxiliaries are controlled from a

17-panel switchboard, which incorporates totally-enclosed air-insulated horizontally-isolated air-break switches. This switchboard, which is designed for an operating voltage of 3.3 kV, is in two sections, which are interconnected through a circuit-breaker. Operation is by solenoids and interlocks are provided to prevent the 'bus section breaker being closed at the same time as the transformer breaker. The 400-volt circuits in the power and substations are also controlled by air-break switchgear with isolators on both the cable and 'bus-bar sides of the circuit-breakers.

The power load in the factory consists of 510 English Electric motors, with individual outputs ranging from 275 h.p. to less than $\frac{1}{2}$ h.p. Motors of 200 h.p. and upwards are supplied with three-phase current at 3.3 kV and those of lower output at 400 volts. The majority of the motors are of the squirrel-cage induction high-torque type and are arranged for direct starting. They are nearly all totally enclosed and are cooled by external fans. The windings are insulated with glass tape and are double impregnated. The motors driving the lifts, cranes and sulphate driers are, however, of the slip-ring induction type.

All the cables in the power house and factory were manufactured by British Insulated Callender's Cables Limited, Norfolk-street, London, W.C.2. The 11-kV cables used for the connections between the alternators and the main switchgear and between the switchgear and the substations; the 3.3-kV cables supplying power to the large motors and the 600-volt cables for the smaller motors and for lighting are all paper insulated, while wire-armoured rubber-insulated multi-core cables have been used for the control circuits.

CONTRA-ROTATING FANS FOR SHIP VENTILATION.

HITHERTO the use of axial-flow fans on ships has been confined to types with static pressures up to about $1\frac{1}{2}$ in. water gauge, owing to the sound level reached at high tip speeds. Higher pressures can, however, be developed at moderate tip speeds by employing multi-stage designs, but the solution is expensive and does not lend itself to quantity production from standardised components. This disadvantage, it is claimed, has now been overcome in the Aerofoil contra-rotating two-stage fans which have been constructed by Messrs. Woods of Colchester, Limited, for installation by Messrs. Vickers-Armstrongs in the motorship *Atreus* of the Blue Funnel Line. These fans consist of two opposite-handed impellers, which are driven in opposite directions by two independent motors. They develop $2\frac{1}{2}$ times the pressure of a single-stage unit of equal size and speed without a proportionate increase in the sound level. Alternatively, such a fan will provide a given volume and pressure at about two-thirds of the tip speed of a single-stage fan and is then appreciably quieter. Moreover, as in a contra-rotating Aerofoil fan the rotating air delivered from one impeller is discharged into the other, the blades of which are designed so that the exhaust from it is axial, the energy absorbed from the air by a single-stage impeller is saved. As, too, the air both enters and leaves in an axial direction, two or more contra-rotating units can be connected in series. Two contra-rotating fans will develop twice the pressure of one and the units may be connected so as to provide pressures up to about 20 in. water gauge.

The *Atreus* is equipped with four 38-in. contra-rotating Aerofoil fans for ventilating the machinery spaces, each of which moves 13,500 cub. ft. of air per minute against a static pressure of 1 in. water gauge and absorbs about 3.5 brake horse-power at 680 r.p.m. This duty could have been carried out at a lower first cost by using 38-in. single-stage fans running at 1,000 r.p.m., but the shipowners preferred to employ the slow speed double-duty type, owing to the reduced sound level, the high efficiency, the simple regulation and the added security against failure. The fans are termed double-duty, since with a direct-current supply either full or two-thirds output can be obtained by connecting the motors in series or parallel respectively. With an alternating current supply the same result may be obtained by switching off one of the impellers. In both cases the power consumption at the lower volume is reduced to less than half the maximum.

It may be added that the components of these fans, which are constructed by Messrs. Woods with impeller diameters from 6 in. to 48 in., are manufactured to close limits. The impellers, hubs and motor frames are die cast and all the castings are checked by X-ray examination. The fan casings are made to extremely small tolerances in a special shop and the motors, which are produced in the same factory, are built specifically for this type of duty. The use of an adjustable impeller enables precise requirements in air delivery, pressure, sound level and dimensions to be met economically from standardised and interchangeable parts.

NOTES FROM THE INDUSTRIAL CENTRES.

SCOTLAND.

THE LATE SIR THOMAS BELL, K.B.E.—As we go to press, news has been received of the death of Sir Thomas Bell, K.B.E., formerly managing director of the Clydebank shipyard of Messrs. John Brown & Co., Ltd.. Sir Thomas, who was 86 years of age, had been associated with the Clydebank yard for nearly 50 years when he retired in 1935, having entered the service of Messrs. J. and G. Thomson, Ltd., in 1886, some 13 years before the business was acquired by John Brown & Co. He received the K.B.E. in 1917 for his services to shipbuilding, during the first World War, towards the close of which he acted, for some 18 months, as Deputy Controller of Dockyards and Shipbuilding at the Admiralty. We hope to publish a more detailed memoir of Sir Thomas Bell in next week's issue.

RENFREW AND PRESTWICK AIRPORTS.—The Hon. J. S. MacLay, C.M.G., M.P., Minister of Civil Aviation, inspected Renfrew Airport on January 3, and later met members of the Scottish Advisory Council for Civil Aviation and the Scottish Aerodromes Board at two meetings in Glasgow. The Minister reiterated the need for further development of Prestwick, the international importance of which he emphasised, and he put forward for discussion proposals for immediate action at Prestwick. The Minister, however, wished to obtain the considered views of both the Scottish Aerodromes Board and the Scottish Civil Aviation Advisory Council before taking a final decision, and he announced that he would be prepared to return and discuss these matters with them before the end of the month. The question of facilities at Renfrew was also discussed.

STEEL PRODUCTION BY THE COLVILLE GROUP.—Ingot production by the Colville group of companies declined by 223,766 tons in 1951 as compared with the preceding year, a drop of 12 per cent. The output totalled 1,663,404 tons against 1,887,170 tons in 1950. An official statement attributes the decrease to the shortage of scrap, stocks of which became exhausted in the second half of the year. Pig-iron production by the group increased by nearly 60,000 tons, or about 12 per cent. The Clyde Iron Works, Tolleross, had an output of 546,335 tons for 1951, compared with 488,303 tons in 1950.

GLENCHIL MINE, CLACKMANNAN.—Work has commenced on the construction of Glenchil Mine, south of Alva, Clackmannanshire, permission having been given by the Secretary of State for Scotland at the close of December. This is believed to be the biggest surface drift project yet attempted in this country. The eventual output is estimated to reach 3,000 tons a day, and the life of the mine will be about 50 years. Production is expected to begin in about three years.

EXTENSION AT LARNE HARBOUR.—Three sections of the Mulberry harbours, used in the Normandy invasion, are shortly to be towed from Stranraer to Northern Ireland, where they will be used for an extension to Larne harbour. They will provide extra berthing of nearly 900 ft.

CLEVELAND AND THE NORTHERN COUNTIES.

STEEL TONNAGE ALLOCATIONS.—Buyers of iron and steel are considerably disappointed with the extent of the tonnage allocations issued for delivery over periods beyond the end of this month. Producers and merchants have embarrassingly large arrears of commitments, under contracts, for supply by January 31, and the position threatens to necessitate a cancellation of orders unless substantial renewals of tonnage distribution permits are made obtainable.

NORTHERN PRODUCTIVITY EXHIBITION, NEWCASTLE.—Proposals to hold a Northern Productivity Exhibition in Newcastle-upon-Tyne, at some time during the present year, have been discussed by the Northern Regional Board for Industry. At the invitation of Sir Mark Hodgson, chairman of the Board, a council comprising representatives of professional and trade associations, chambers of commerce, the Federation of British Industries, the universities and technical colleges, trade unions, nationalised industries and Government departments has been formed. The object of the exhibition is to show, by demonstration and practical application, how increased productivity can be achieved, for example, by joint consultations, incentive schemes, pension arrangements, motion study, factory layout, production control, colour in industry, etc.

TRADE ON THE RIVER WEAR.—Figures issued by the River Wear Commissioners show that, during the first 11 months of 1951, exports included 7,429 tons of machin-

ery in new ships, compared with 10,578 tons in 1950, and 11,348 tons in 1938. Imports included 166,116 tons of iron ore (51,125 tons in 1938); 3,866 tons of chrome ore (nil in 1938); but only 9,662 tons of iron and steel scrap, as against 45,140 tons in 1950. In 1938, it may be noted, the scrap imports were only 6,901 tons.

PROJECTED FOUNDRY EXTENSION AT SOUTH SHIELDS.—C. W. Taylor & Co., Ltd., Templetown Ironfoundry, South Shields, are understood to be negotiating with South Shields Corporation for the purchase of over 7,000 square yards of land for foundry extensions.

STEEL FOR SHIPBUILDING.—The Northern Regional Controller for the Ministry of Supply, Mr. F. C. Wake, has issued a statement dealing with reports that steel supplies for shipyards were to be cut by as much as half under the steel rationing scheme. Mr. Wake stated that mistaken impressions had been caused by the notification of steel allocations to steel-using firms. It was entirely wrong to suppose, he said, that supplies would be reduced from February 4, and that the allocations represented a cut of 40 to 50 per cent. for industry as a whole. The average weekly deliveries of steel to industry would continue throughout the year at the present levels, but there would be some change in the amounts allocated to various users. It is understood that firms on non-essential work have been told that their steel supplies will be reduced unless they obtain work under the defence programme. This is likely to cause temporary unemployment. Most Tyne shipyards are waiting to see what their actual allocation of steel will be before commenting on the matter. The Furness Shipbuilding Co., Ltd., at Haverton Hill-on-Tees, have described their steel allocation for the period February to June as "far below requirements," and state that they feel great anxiety in consequence.

LANCASHIRE AND SOUTH YORKSHIRE.

STEEL RATIONING.—The necessity for some rationing of steel is fully realised in Sheffield, where there is no sign of an improvement in steel production. The initial notifications, however, have been disquieting. Engineering firms state that they cannot manage on the allocations of about 50 per cent. of what they asked for. A serious situation will also arise in the tool trades unless a revision of allocations is made. Some firms are to receive only 40 per cent. and others 50 per cent. of their requirements. They visualise short-time working and the disappointment of many customers including those overseas. Export business in hand tools from Sheffield has been increased to a value of 11,000,000l. a year and tool-makers are very concerned with the prospect of having to surrender some of this business, achieved at considerable cost. The hard part of the scheme is that those who have acceded to requests to expand outputs will be the biggest sufferers.

THE SALVAGE DRIVE.—Collection of salvage has become an important feature of works organisation. For example, at the works of Samuel Fox & Co., Ltd., Stocksbridge, near Sheffield, Mr. J. Wheelan, has been responsible for the collection during the last financial year of 74 wagon loads of iron and steel scrap, as well as 35 tons of clean waste paper. In addition, waste oil has been sent to the refineries.

THE LATE MR. R. S. DONALD.—We note with regret the death of Mr. R. S. Donald as the result of a motor-car accident in Saudi Arabia on December 28. Mr. Donald, a director of North Lonsdale Tar Macadam Ltd., a wholly-owned subsidiary company of Thos. W. Ward Ltd., Albion Works, Sheffield, played a leading part on behalf of his firm in negotiations with the Government of Saudi Arabia concerning a new road which is being built from Jeddah to Medina. As general manager of this civil-engineering undertaking, Mr. Donald had been in Saudi Arabia for the past 18 months.

THE LATE MR. R. F. D. BRUCE.—We note also with regret the death, on January 2, after a prolonged illness, of Mr. Robert Fernie Dunlop Bruce. Mr. Bruce, who was the elder son of the late Major R. N. D. Bruce, of the Duke of Wellington's Regiment, had been for many years manager of the magnetic-chuck section of the sales organisation of James Neill & Co. (Sheffield), Ltd., Composite Steel Works, Napier-street, Sheffield, 11. Mr. Bruce was a member of the Council of the Machine Tool Trades Association and also of the Allied Trades section of the Association and was well known in tool trades circles throughout this country.

THE MIDLANDS.

BIRMINGHAM DEVELOPMENT PLAN.—Further details of the development plan for the city of Birmingham, placed before the City Council, have now been published. It is based on the assumption that the city's boundaries will remain unchanged, and proposes the construction

of multi-storey buildings for industrial, commercial and residential purposes. Some extensive civil engineering work will be involved in the city centre, where subways are planned and footpaths are to be widened. A series of ring roads and radial connections, with tunnels and flyovers at intersections, is planned to ease traffic congestion. Car parking, for long a problem in Birmingham, is being dealt with by the provision of several new car parks, including a multi-storey one capable of holding 7,400 vehicles; others will be underground, or beneath ring-road viaducts. Provision has been made in the plan for work which will be undertaken by public authorities. New Street and Snow Hill railway stations will be rebuilt, and there will probably be a new railway hotel near the city centre. New gasworks at Washwood Heath and a new electric generating station at Nechells are projected.

THE STEEL POSITION.—The approach of steel rationing has caused considerable concern in many sections of Midland industry. What the exact position will be is uncertain, but it is clear that there will be no more steel available in terms of total tonnage, and that, if an increased quantity is to be diverted to defence work, it will have to be found by reducing the allocations for other purposes. The allocations notified to some firms show drastic reductions. The largest single trade affected is that of cycle manufacture, which has already lodged a protest against the steel allocation notified to it. Birmingham and district produce over 60 per cent. of the bicycles made in this country, employing about 15,000 persons directly, and many more indirectly. Birmingham has been producing between 40,000 and 45,000 bicycles a week, and representatives of the trade have pointed out that about three-quarters of this output is exported.

TRADE UNION INQUIRY INTO RAW MATERIALS POSITION.—The Transport and General Workers' Union are making an independent effort to discover the extent of the raw material shortages in the Midlands. Questionnaires are to be sent to shop stewards and factory managements in the Birmingham, Wolverhampton, Coventry and Stafford areas. The union secretary, Mr. J. Leask, is also vice-chairman of the Midland Regional Board for Industry, and the information obtained will be placed before that body.

LEA HALL COLLIERY.—The new colliery which is to be opened near Rugeley, Staffordshire, has been given the name Lea Hall. Preparatory work on sinking the shaft is in progress, and provision is being made for an output of from 6,000 to 8,000 tons of coal a day. There is a proposal that the British Electricity Authority should build a power station near to the new colliery, the coal being taken directly from the pithead to the power station by conveyor. Coal reserves of over 500 million tons have been proved in the West Midlands area.

HELICOPTER LANDING SITE FOR THE BLACK COUNTRY.—The town council of Bilston, Staffordshire, propose to include in their planning proposals provision for a helicopter landing ground. A site of three acres on the council's Loxdale industrial estate has been earmarked for the purpose. At present the only helicopter landing ground in operation in the area is that at Hay Mills, Birmingham, which has to be approached by roads which carry a very heavy traffic.

BEWDLEY GASWORKS.—The gasworks at Bewdley, Worcestershire, are to be closed. They are more than a century old, and supplied only a small number of consumers. In future, the load will be carried by the works at Kidderminster, four miles away, and a main has been laid recently for this purpose.

SOUTH-WEST ENGLAND AND SOUTH WALES.

ROAD WORKS IN CARDIFF.—Cardiff's Public Works Committee have cut their estimates for road and street works in the coming financial year by 69,000l. As a result, the total call upon the rates will amount to about 549,800l., which sum is still nearly 123,000l. above that for the current year.

LABOUR POSITION AT HIRWAUN TRAINING ESTATE.—Three Welsh M.P.s, Mr. D. Emlyn Thomas (Aberdare), Mr. D. J. Williams (Neath), and Mr. Tudor Watkins (Brecon and Radnor) have attended joint talks with Government officials at the Hirwaun Trading Estate, on the redundancy of more than 1,000 employees at three radio factories on the estate. They were told that, at the factory of Murphy Radio, Ltd., where 250 employees were dismissed recently, the position had changed and the prospects were now much brighter. At the factory of Fergusson Radio Corporation, Ltd., it was stated that the main cause of the redundancy of 160 employees was shortage of materials; but Sobell Industries, Ltd., where between 600 and 700 had been declared redundant, have not secured any Government contracts.

NOTICES OF MEETINGS.

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

INSTITUTION OF ELECTRICAL ENGINEERS.—Western Centre: Monday, January 14, 6 p.m., Offices of South Western Electricity Board, Colston-avenue, Bristol. "The Protection of Electrical Power Systems," by Mr. H. Leyburn and Mr. C. H. W. Lackey. **North-Eastern Centre:** Monday, January 14, 6.15 p.m., Neville Hall, Westgate-road, Newcastle-upon-Tyne. "Economic Plant Sizes and Boiler-Set Groupings on the British Grid," by Mr. B. Donkin and Mr. P. H. Margen. **Mersey and North Wales Centre:** Monday, January 14, 6.30 p.m., Town Hall, Chester. "Electricity in Newspaper Printing," by Mr. A. T. Robertson. **London Students' Section:** Monday, January 14, 7 p.m., Savoy-place, Victoria-embankment, W.C.2. Film Evening. **Radio Section:** Wednesday, January 16, 5.30 p.m., Savoy-place, Victoria-embankment, W.C.2. "Comparison of Ionospheric Radio Transmission Forecasts," by Mr. A. F. Wilkins and Mr. C. M. Minnis. **Southern Centre:** Wednesday, January 16, 6.30 p.m., Dorset Technical College, Weymouth. "Servo Mechanisms," by Professor A. Tustin. **Utilization Section:** Thursday, January 17, 5.30 p.m., Savoy-place, Victoria-embankment, W.C.2. "Domestic Electrical Installations; Some Safety Aspects," by Mr. H. W. Swann.

INSTITUTE OF FUEL.—North-Eastern Section: Monday, January 14, 6.30 p.m., King's College, Newcastle-upon-Tyne. "Modern Boiler Plant," by Mr. A. S. Dodds. **Institute:** Tuesday, January 15, 5.30 p.m., Institution of Mechanical Engineers, Storey's-gate, St. James's Park, S.W.1. "Llandarcy and Fuel Efficiency," by Mr. R. B. Southall. **Midlands Section:** Tuesday, January 15, 6 p.m., James Watt Memorial Institute, Birmingham. "Recent Developments in Coal Carbonisation," by Dr. W. Idris Jones. **North-Western Section:** Wednesday, January 16, 6.30 p.m., Engineers' Club, Manchester. "Boilers," by Mr. H. E. Partridge. **Yorkshire Section:** Wednesday, January 16, 6.30 p.m., The University, Leeds. Film Evening. **Scottish Section:** Friday, January 18, 7 p.m., Royal Technical College, Glasgow. "Fan Design and Equipment," by Mr. D. S. Macfarlane.

INSTITUTION OF PRODUCTION ENGINEERS.—Sheffield Section: Monday, January 14, 6.30 p.m., Royal Victoria Station Hotel, Sheffield. "Hot Press Forging," by Mr. H. E. Hows. **Yorkshire Section:** Monday, January 14, 7 p.m., Hotel Metropole, Leeds. "Modern Development in Heat-Treatment Practice," by Mr. K. J. B. Wolfe. **Western Section:** Wednesday, January 16, 7.15 p.m., Grand Hotel, Bristol. 1. "Productivity and the Machine Tool," by Mr. N. Stubbs. **Edinburgh Section:** Wednesday, January 16, 7.30 p.m., North British Station Hotel, Edinburgh. "Human Relations in Industry," by Mr. W. P. Kirkwood. **Glasgow Section:** Thursday, January 17, 7.30 p.m., 39, Elmbank-crescent, Glasgow. "British Watch and Clock Production," by Mr. R. Lenoir. **West Wales Section:** Friday, January 18, 7.30 p.m., Central Library, Alexandra-road, Swansea. "Industrial Maintenance of Machines," by Mr. R. M. Buckle. **Eastern Counties Section:** Friday, January 18, 7.30 p.m., Public Library, Northgate-street, Ipswich. "Production Engineering as a Career," by Mr. T. B. Worth.

INSTITUTE OF PACKAGING.—Northern Area: Monday, January 14, 6.30 p.m., Grand Hotel, Manchester. "Printing Applied to Packaging," by Dr. F. W. Clulow.

ASSOCIATION OF SUPERVISING ELECTRICAL ENGINEERS.—Central London Branch: Monday, January 14, 7 p.m., St. Ermin's Hotel, Caxton-street, S.W.1. "Aluminium Sheathed Cables," by Mr. P. M. Hollingsworth.

INCORPORATED PLANT ENGINEERS.—Glasgow Branch: Monday, January 14, 7 p.m., Engineering Centre, 351, Sauchiehall-street, Glasgow. Discussion on "Can Work-Study and Incentive-Bonus Schemes be Successfully Applied to Maintenance Work?" **Dundee Branch:** Monday, January 14, 7.30 p.m., Mathers Hotel, Dundee. "Heat Transfer," by Mr. R. A. Brecknell. **Liverpool and North Wales Branch:** Thursday, January 17, 7.15 p.m., Radiant House, Bold-street, Liverpool. Discussion on "Armourplate and Toughened Glass."

JUNIOR INSTITUTION OF ENGINEERS.—North-Western Section: 16, St. Mary's Parsonage, Manchester. Monday, January 14, 7.30 p.m., Presidential Address on "Enterprise in Engineering," by Air Commodore F. R. Banks. Saturday, January 19, 2.30 p.m., "Chemicals from Petroleum," by Mr. W. Simpson. **Institution:** Friday, January 18, 6.30 p.m., 39, Victoria-street, S.W.1. "Concrete Quality Control," by Mr. S. J. Crispin.

CHEMICAL ENGINEERING GROUP.—Tuesday, January 15, 5.30 p.m., Geological Society's Apartments, Burlington House, Piccadilly, W.1. "The Patent Act of 1949," by Mr. Norman Brown.

INSTITUTION OF CIVIL ENGINEERS.—Maritime Engineering Division: Tuesday, January 15, 5.30 p.m., Great George-street, S.W.1. "Oil-Loading and Cargo-Handling Facilities at Mina al-Ahmadi, Persian Gulf." Part I, "Planning and Design," by Mr. C. W. N. McGowan. Part II, "Construction," by Mr. R. C. Harvey and Mr. J. W. Lowdon.

INSTITUTION OF HEATING AND VENTILATING ENGINEERS.—South-Western Branch: Tuesday, January 15, 6.30 p.m., G.E.C. Building, Cathays Park, Cardiff. "Steam Accumulators," by Mr. W. Goldstern. **Yorkshire Branch:** Wednesday, January 16, 7.30 p.m., Hotel Metropole, Leeds. Annual Meeting. **Liverpool Branch:** Thursday, January 17, 6.30 p.m., Radiant House, Bold-street, Liverpool. "Costing for the Heating Engineer," by Mr. L. Forni.

INSTITUTE OF METALS.—South Wales Local Section: Tuesday, January 15, 6.30 p.m., University College, Swansea. "Metallurgy and Transport," by Mr. T. H. Turner.

INSTITUTION OF WORKS MANAGERS.—Leicester Branch: Tuesday, January 15, 7 p.m., Loughborough College, Loughborough. "Production Control," by Mr. E. H. Goodchild. **Northampton Branch:** Thursday, January 17, 7.30 p.m., Franklins Gardens Hotel, Northampton. "Management Research, Work Study and Job Evaluation," by Professor T. U. Matthew.

INSTITUTE OF BRITISH FOUNDRYMEN.—Slough Section: Tuesday, January 15, 7.30 p.m., Messrs. High Duty Alloys, Ltd., Slough. "Modern Melting Practices," by Mr. F. Evans.

BRITISH INSTITUTION OF RADIO ENGINEERS.—South Midlands Section: Tuesday, January 15, 7.15 p.m., Public Library, Rugby. "Television Signals," by Mr. G. L. Stephens.

INSTITUTE OF ROAD TRANSPORT ENGINEERS.—North-West Centre: Tuesday, January 15, 7.30 p.m., Victoria Hotel, Wigan. "Vacuum and Air Brakes," by Mr. S. H. Edge. **Midlands Centre:** Tuesday, January 15, 7.30 p.m., Crown Inn, Broad-street, Birmingham. "Dieselisation," by Mr. S. Johnson. **Institute:** Thursday, January 17, 6.30 p.m., Royal Society of Arts, John Adam-street, W.C.2. "Tyre Construction," by Mr. W. R. Good.

ROYAL UNITED SERVICE INSTITUTION.—Wednesday, January 16, 3 p.m., Whitehall, S.W.1. "The Merchant Navy," by Mr. R. G. Grout.

ROYAL STATISTICAL SOCIETY.—Research Section: Wednesday, January 16, 5.15 p.m., London School of Hygiene and Tropical Medicine, Keppel-street, W.C.1. "Design and Analysis of Block Experiments," by Mr. K. D. Tocher.

INSTITUTION OF LOCOMOTIVE ENGINEERS.—Wednesday, January 16, 5.30 p.m., Institution of Mechanical Engineers, Storey's-gate, St. James's Park, S.W.1. "New Steel Electric Railway Stock for the Indian Government Railways," by Mr. S. E. Lord, Mr. J. F. Thring and Mr. H. H. C. Barton.

LIVERPOOL ENGINEERING SOCIETY.—Wednesday, January 16, 6 p.m., 24, Dale-street, Liverpool. "Bouellat Radiant Water-Tube Boiler," by Mr. F. W. Bauer.

INSTITUTION OF STRUCTURAL ENGINEERS.—Northern Counties Branch: Wednesday, January 16, 6.30 p.m., Neville Hall, Westgate-road, Newcastle-upon-Tyne. "Reconstruction of Houdon-on-Tyne Gas Works," by Mr. W. R. Garrett. **Yorkshire Branch:** Wednesday, January 16, 6.30 p.m., Great Northern Hotel, Leeds. "Structural Engineering at Abbey Works," by Mr. A. V. Hooker.

INSTITUTE OF INDUSTRIAL ADMINISTRATION.—London Centre: Wednesday, January 16, 7 p.m., 8, Hill-street, W.1. "Management in Practice": No. 5, "Saving the Business from Wreck," by Mr. R. Hopkins.

DIESEL ENGINE USERS ASSOCIATION.—Thursday, January 17, 2.30 p.m., Caxton Hall, S.W.1. "Recent Experiments in the Lubrication of Oil Engines," by Mr. L. J. Izard.

INSTITUTION OF MINING AND METALLURGY.—Thursday, January 17, 5 p.m., Geological Society's Apartments, Burlington House, Piccadilly, W.1. "Mineralisation at Castle-an-Dinas Wolfram Mine," by Mr. D. Kear; and "Production of Pure Cerium Metal by Electrolytic and Thermal Reduction Processes," by Mr. P. M. J. Gray.

INSTITUTION OF MECHANICAL ENGINEERS.—Midland Branch: Thursday, January 17, 6 p.m., James Watt Memorial Institute, Birmingham. "The 'Lost-Wax' Process of Precision Casting," by Mr. J. S. Turnbull. **Institution:** Friday, January 18, 5.30 p.m., Storey's-gate, St. James's Park, S.W.1. Thomas Lowe Gray Lecture on "Ship Research," by Dr. S. Livingston Smith. **AUTOMOBILE DIVISION.—Luton Centre:** Monday, January 14, 7.30 p.m., Town Hall, Luton. "Trailers and Semi-Trailers," by Mr. A. Marenbon. **North-Eastern Centre:** Wednesday, January 16, 7.30 p.m., The University, Leeds. "Very Large Road-Haulage Vehicles," by Mr. C. E. Burton.

PERSONAL.

SIR CUTHBERT BARWICK CLEGG, J.P., and MR. GEORGE HARDMAN have been elected directors of Textile Machinery Makers, Ltd., Oldham.

MR. ATHOLL BLAIR, C.B.E., M.I.Mech.E., and MR. HARRY SHOOSMITH, A.C.G.I., M.I.C.E., M.I.Mech.E., Wh.Sc., have had conferred upon them the Fellowship of the City and Guilds of London Institute (F.C.G.I.).

MR. J. HOWDEN HUME, managing director of James Howden & Co., Ltd., Glasgow, has been elected President of the Scottish Engineering Employers' Association.

MR. J. SIDNEY HAMPTON, director of Davy and United Roll Foundry Ltd., Billingham, Co. Durham, has been appointed to the additional post of general manager.

MR. A. B. WARING has succeeded SIR PETER BENNETT as chairman of JOSEPH LUCAS LTD., the name of which is to be changed to JOSEPH LUCAS (INDUSTRIES) LTD.

MR. ALONZO LIMB has been appointed sole managing director of C. C. Wakefield & Co., Ltd. Previously he had shared the responsibility of this post with Mr. W. H. SENNECK, who has now retired after 45 years of service. Mr. Senneck is retaining his seat on the board. Mr. W. F. LIST and Mr. L. M. BROADWAY have been appointed assistant managing directors.

MR. C. W. MARSHALL, B.Sc. (Eng.), M.I.E.E., deputy chief engineer (research), British Electricity Authority, has been appointed controller of the Authority's South West Scotland generation division, in succession to the late Mr. E. J. EDGAR.

MR. F. BLACKITH, technical manager, Mr. C. A. CLARKE, engineer, and Mr. B. W. ANGEL, works manager, have been appointed directors of Wellworthy Piston Rings Ltd., Lymington, Hampshire.

MR. HAROLD CARRINGTON WOOD, M.I.Mech.E., has retired after an association of more than 42 years with the Wellman Smith Owen Engineering Corporation Ltd., and their predecessors.

MR. J. K. INGRAM and Mr. W. J. CHADDER, M.I.Chem.E., M.Inst. Gas E., have been elected directors of the Woodall-Duckham Vertical Retort and Oven Construction Co. (1920) Ltd., 63-67, Brompton-road, London, S.W.3.

MR. D. S. WOODLEY, A.M.I.Mech.E., M.I.H.V.E., deputy chairman of Keith Blackman Ltd., Mill Mead-road, Tottenham, London, N.7, has been appointed joint managing director with the present chairman and managing director, Mr. M. BURNINGHAM. Mr. S. E. NELSON, B.A. (Cantab.), has succeeded Mr. Woodley as chief engineer.

MR. B. C. GOTELEE has been appointed joint managing director of the Expert Tool and Case Hardening Co. Ltd., with Mr. IVOR LLOYD. MR. HAROLD CHERRY has been elected to the board.

MR. E. H. ATKIN, formerly chief engineer of the Aircraft Division of Avro Canada, has been given the newly-created position of technical director. Mr. J. C. FLOYD, formerly works manager, becomes chief engineer and Mr. D. E. WISEMAN, formerly production planning manager, becomes works manager. Mr. F. T. SMYE has been made general manager.

MR. H. T. PARKER, general manager, marketing division, the Plessey Co., Ltd., Ilford, Essex, is leaving the full-time employment of the company, but will continue to operate as publicity adviser to the board.

MR. A. M. KEMPSON, joint managing director, Imperial Chemical Industries Ltd. (Metals Division) has retired after 44 years of service. His successor is Dr. M. COOK, hitherto research director. Two new directors, Mr. ST. J. ELSTUB and Mr. G. A. D. SMITH, have joined the board.

MR. A. E. L. COLLINS, B.Sc. (Eng.) (Lond.), M.I.Mech.E., at present road-transport superintendent to the Government of Hyderabad, Deccan, India, is to be representative of the Society of Motor Manufacturers and Traders in India, Pakistan and Ceylon, in place of Mr. E. T. MUNDAY, who is being transferred as representative of the Society in Australia.

MR. P. R. SUTT, formerly director of production, Tecalemit Ltd., is now director and general manager.

MR. E. W. MARVILL, M.B.E., has been promoted to the position of general works superintendent, and Mr. H. B. HARRIS, B.E.M., to that of production manager, of F. Perkins Ltd., Queen-street, Peterborough.

MR. A. A. MIDDLETON, B.Sc., A.M.I.C.E., has become a partner in the firm of Sir M. MacDonald and Partners, 72, Victoria-street, London, S.W.1.

The editorial and publishing offices of the "A.C.V. GAZETTE," are now at 50, Page-street, London, S.W.1 (Telephone: VICTORIA 4777.)

It has been decided to wind up S. PORTER & CO. LTD., chemical plumbers, voluntarily and to merge this firm into the organisation of NORDAC LTD., Cowley Mill-road, Uxbridge, Middlesex, as a separate department.

The offices and library of the ASSOCIATION OF ENGINEERS, INDIA, have been removed to 24, Netaji Subhas-road, Calcutta, 1.

INDUSTRIAL POWER STATION AT SINDRI, INDIA.

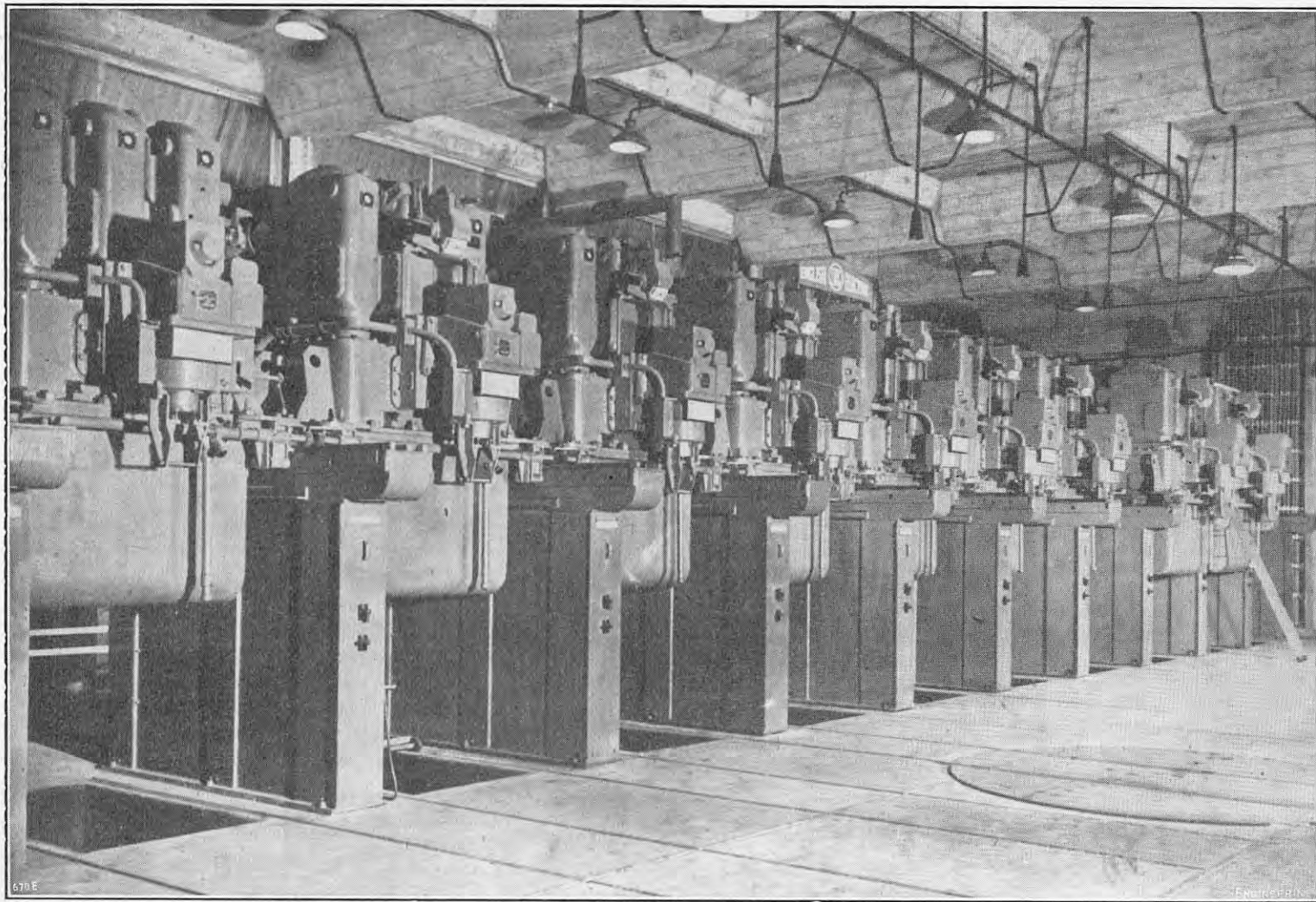
(For Description, see Page 44.)

FIG. 5. 1,000-MVA 11-KV SWITCHGEAR.

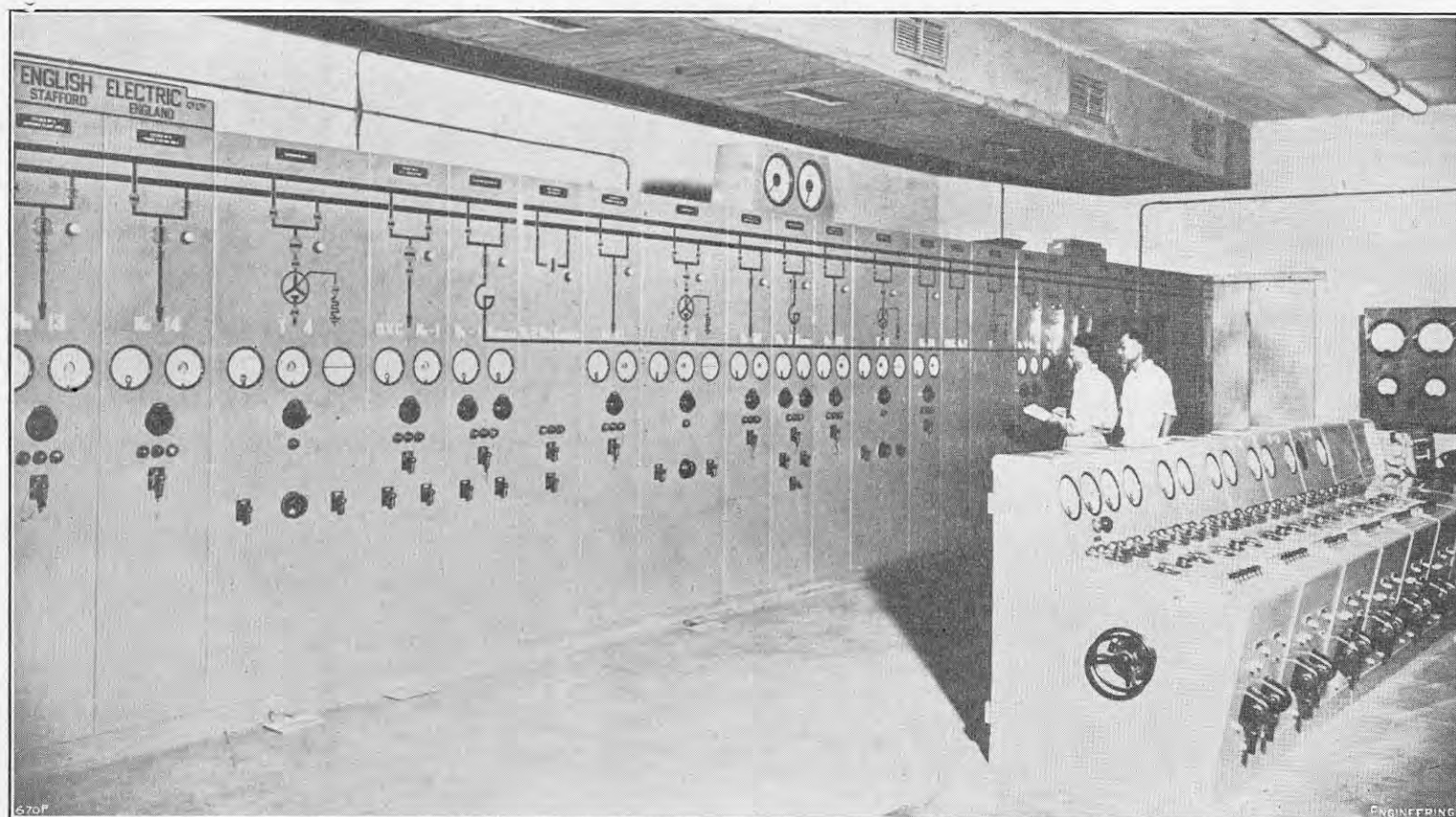


FIG. 6. CONTROL ROOM AT SINDRI POWER STATION.

ENGINEERING

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

Registered at the General Post Office as a Newspaper.

We desire to call the attention of our readers to the fact that the above is the address of our Registered Office, and that no connection exists between this Journal and any other publication bearing a similar title.

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

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of Canada £5 10 0
For Canada £5 5 0

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ADVERTISEMENT RATES.

Terms for displayed advertisements on the green art paper wrapper, on the inside black and white pages and in the buff art paper two-colour supplement, as well as for insets, can be obtained on application to the Manager. The pages are 12 in. deep and 9 in. wide, divisible into four columns 2½ in. wide. Serial advertisements will be inserted with all practicable regularity, but absolute regularity cannot be guaranteed.

The charge for advertisements classified under the headings of "Appointments Open," "Situations Wanted," "Tenders," etc., is 10s. for the first four lines or under, and 2s. 6d. per line up to one inch. The line averages six words and when an advertisement measures an inch or more, the charge is 30s. per inch. If use is made of a box number the extra charge is 1s. per insertion, with the exception of advertisements appearing under "Situations Wanted." Series discounts for all classified advertisements can be obtained at the following rates:—5 per cent. for six; 12½ per cent. for thirteen; 25 per cent. for twenty-six; and 33½ per cent. for fifty-two insertions.

TIME FOR RECEIPT OF ADVERTISEMENTS.

Classified advertisements intended for insertion in the current week's issue must be received not later than first post Wednesday.

"Copy" instructions and alterations to standing advertisements for display announcements must be received at least 10 days previous to the date of publication, otherwise it may be impossible to submit proofs for approval.

The Proprietors will not hold themselves responsible for advertisers' blocks left in their possession for more than two years.

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The Index to Vol. 171 of ENGINEERING (January-June, 1951) is now ready and will be sent to any reader, without charge and postage paid, on application being made to the Publisher. In order to reduce the consumption of paper, copies of the Index are being distributed only in response to such applications.

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ENGINEERING

FRIDAY, JANUARY 11, 1952.

VOL. 173.

No. 4485.

CHEMICAL ENGINEERING RESEARCH.

In a sense, some aspects of most industries may be described as examples of chemical engineering; the treatment of boiler feed water and the burning of fuel in a boiler firebox are both chemical operations. It would not be possible to draw a firm line between chemical and non-chemical engineering and when, in a report on chemical engineering research, "Utilisation of energy (heat, light and power)" is found in a list of "the chemical engineering research subjects of immediate interest" it might appear that large sections of mechanical and electrical engineering are merely branches of chemical engineering. If this is so, then it would naturally be expected that a central chemical engineering research body, on the lines of the Mechanical Engineering Research Organization, would be in existence. So far is this from being the case, however, that the Council of the Institution of Chemical Engineers approached the Advisory Council of the Department of Scientific and Industrial Research expressing anxiety about "the inadequacy of chemical engineering research in Great Britain."

As a result of this approach, the Advisory Council appointed a committee, in April, 1949, "to review the needs for research in chemical engineering and the extent to which they can be met by existing facilities." The report* of the committee has just been published. The committee were not asked to suggest means by which "the gaps in the supply of chemical engineering research data" could be filled but it is stated in the report that "observations on this important matter" have been addressed to the Advisory Council. From the above remark and from a reading of the report it

may be surmised that the formation of a chemical engineering research organisation to form an out-station of the Department of Scientific and Industrial Research has been suggested. The existing out-stations, such as those dealing with fuel, building and roads, were set up as it was considered that the subjects with which they were respectively concerned were so broad, and covered such a variety of interests, that they could not fairly be expected to be dealt with in their many ramifications by industrial firms.

Chemical engineering is a wider subject than fuel or building and certainly appears a suitable subject for research by a State organisation. It concerns the food industries, plastics, cement manufacture, soap, some aspects of power production, oil refining, fertilisers, paints and the whole field of heavy and light chemicals. Chemical engineering must not be confused with chemistry for which research facilities are highly developed. There is a Government Chemical Research Laboratory, and industrial chemical firms carry out research on an extensive scale. It would not be easy to formulate a precise definition of chemical engineering, but the definition, expressed in the form of the distinction between chemical technology and chemical engineering, which is given in the report, may be accepted as satisfactory. Chemical technology is said to be concerned with "the process of manufacture of particular products," and chemical engineering with "the study of plant and operations which are generally and widely applicable to all industries."

The committee sent out a questionnaire to university departments, Government departments, research associations, nationalised industries, and industrial firms engaged in chemical-engineering research asking what chemical-engineering research subjects were of immediate interest to them. A list of subjects was given and comment on the relative importance of these was asked for. A second list covered subjects suggested as suitable for immediate investigation. Some of the items in these lists seem so broad, or indefinite, that it is difficult to see what a chemical-engineering research station would do about them, were such a station set up. The item, "Utilisation of energy (heat, light and power)" has already been quoted. Another is "Utilisation of waste products." This is not an example of a general fundamental problem of the type with which a chemical-engineering research station might be expected to deal. The best way to utilise waste material will depend on the nature of the waste material. The matter can only be effectively dealt with by an organisation handling the particular materials concerned, although a central research station might be consulted about specific problems.

Other of the items cover matters on which much work has already been done, or is being done, and comes within the sphere of existing organisations. Examples of these are "Research on the development of industrial instruments generally" and "Effluent treatment." The latter is a surprising item to find in the lists. Effluent treatment is one of the main activities of the Water Pollution Research Laboratory and if a chemical-engineering research station is set up it will be able to find plenty to do without attempting to annex part of the fields of other organisations.

Some of the matters mentioned above would naturally arise in connection with research on specific chemical-engineering problems, but are not peculiar to "chemical engineering" in the sense in which that term will normally be understood. There is no reason to suppose that the committee did not realise this, and, in addition to the lists of "chemical engineering subjects" given in the questionnaire, a list of "Special Chemical Engineering Subjects" is given in another part of the report. This covers fundamental chemical-engineering operations, or

* Report of the Committee on Chemical Engineering Research. H.M. Stationery Office. [Price 1s. 6d. net.]

problems, such as sublimation, leaching, scrubbing, selective absorption and many others. It is the business of the chemical engineer to study the mechanism of such operations and to deal with "the design of plant necessary for carrying them out efficiently on a large scale." In connection with this basic duty of the chemical engineer, the report states that "the simple truth of the matter is that practically all industrial installations, many of which work at relatively high efficiency, have been developed empirically." It would be the business of a chemical engineering research station to establish scientific data on the basis of which such industrial plant could be designed.

It is remarked in the report that "striking examples can be cited of manufacturing operations which, although having their origin in this country, have been left to other countries to develop or to modernise, with the result that they are now operated here under foreign licences or in plant either purchased from abroad or constructed to foreign designs." This, or something very like it, has been said very often; there is, or was, some truth in it, but the matter has frequently been exaggerated. Presumably, the implication of the remark, as made in the report, is that if industrial firms could be furnished with data enabling them to design and construct full-scale plant for the commercial utilisation of laboratory discoveries and developments, then such dependence on foreign enterprise would no longer be in evidence. In many developments in chemical engineering, as in some other branches of work, a pilot plant represents a necessary stage between the laboratory and the factory, and the committee is of opinion that the carrying forward of discoveries "to the pilot stage, thereby opening up the way for their industrial utilisation . . . could best be performed at a central laboratory."

One statement in the report, which is closely and logically connected with the above remarks, is that "the greatest need is for physical data in a form which can easily be translated into terms which are immediately applicable to the installation to be built." It is added that "one of the tragedies of the present time undoubtedly is that so much of the information which exists, possibly in obscure and unrelated form, is unknown to potential users." This appears to be an example of the over-statement from which the report is not free. A "tragedy," apart from the use of the word in drama and literature, is "a dreadful calamity or disaster" and it really cannot be supposed that the chemical-engineering firms of this country are so ignorant of the current technical advances in their own spheres of work as to constitute a calamity. Most firms of any status now operate information departments of their own.

This, however, is not to say that useful assistance might not be given to such departments, and to individual scientific workers, by considerable extension of general information services. The Fuel Research Station, the Building Research Station, the Road Research Laboratory, and some others all now publish abstract journals and it would be of value if the postulated chemical-engineering research station could do the same thing. This particular form of activity is not specifically suggested in the report, but the recommendation that a "central technical bureau of information" should be set up and should occupy itself with the "central indexing of information" and "the preparation of collected references" appears to amount to much the same thing. The further statement that "important papers should be critically reviewed," is not likely to meet with universal acceptance. A chemical-engineering research station could do much valuable work, but it is not desirable that it should attempt to assume the role of a final court of appeal for the promulgation of *ex cathedra* judgments.

ECONOMY IN RAILWAY CIVIL ENGINEERING.

THE severe restrictions on expenditure under which railway civil engineers have laboured since the war—indeed, since the beginning of the war—have encouraged, as no handicap has before, a search for economy in construction, maintenance and renewals; hence the discussion on "Economy in Railway Civil Engineering," held at the Institution of Civil Engineers on November 13. The national policy of reducing capital expenditure, though it may be dictated by short-term financial considerations, is difficult to justify if the long-term interests of the country are considered. A balance of trade with overseas countries may be restored, but only temporarily, since continuing prosperity depends on up-to-date plant and machinery. A greater proportion of Britain's wealth should be going into making better roads, railway systems, factories, machine tools and the like, so that the resultant services and products are competitive. These remarks apply with special force to British Railways, since they are saddled with a system which has not been rebuilt and modified to meet changing conditions and needs. Schemes such as the rebuilding of Euston station have either had to be postponed or only partially authorised.

The four "Notes" which served to open the discussion at the Institution of Civil Engineers showed that, in spite of present limitations, railway civil engineers are determined to bequeath to their successors tracks, bridges and other structures which will not require the high maintenance costs that are unavoidable with old structures to-day. Mr. J. Taylor Thompson, M.C., who spoke on "Economy through Organisation," said that railway track has been improved in design and that, whereas daily attention was essential years ago, the introduction of flat-bottom track with its stronger and stiffer section and the absence of keys, as well as the adoption of improved fastenings, has made it possible for the track to go for long periods without repair. The method of maintaining the tracks, Mr. Thompson suggested, should be reviewed in the light of this change and the fact that, with the mechanisation of permanent-way work, the issue of power plant to small length gangs is generally uneconomic. Though daily attention would still be required for emergencies, the repairing of the track, he thought, could be regarded as work to be dealt with as it became necessary; this principle is already followed for the maintenance of structures. The length gangs responsible for fixed lengths of line would be replaced by patrol-men for day-to-day safety and by mechanised gangs carrying out specified repair work, as required, over an extended area. Instead of manpower being provided on a standard basis of assumed requirements for a given length of time, it would be provided only as and when required for specified work.

The annual labour costs of maintenance and renewal of the permanent way and structures amount to about 28,000,000*l.*, and it was, in effect, this figure which the discussion was intended to help to reduce. Mr. P. S. A. Berridge, M.B.E., dealt solely with bridges in his note on "Economy through Design." An annual expenditure of 2,750,000*l.*, he said, was incurred in the examination, repair and renewal of bridges, tunnels, and culverts on British Railways. Many of the structures built in good sound masonry had stood the test of time and could be expected to last *ad infinitum*, but for accountancy purposes the average life of steel and reinforced-concrete bridges in Great Britain had, in the past, been taken as only 55 years. He therefore dwelt on improvements in design which are intended to increase the life of girder bridges and, at the same time, reduce expenditure on examination, repair and maintenance. Comparing the costs of different forms of construction

for a double-line square under-line span of 40 ft., he found that, assuming 100 for a bridge with ballasted tracks, riveted girders with transverse rolled-steel beams and reinforced concrete cast *in situ*, an open-deck span of riveted girders with cross girders and stringers cost only 80 units. Mr. Berridge asked whether, in view of the need for economy, the Ministry of Transport regulations should not be amended to allow this, the cheapest form of construction, to be adopted in Great Britain. The next cheapest design (82 units) consisted of welded girders with a prestressed precast concrete unit deck and ballasted tracks. The comparison was not quite valid, however, as it was unlikely that such a span would be erected by rolling it into position—the method of erection on which the comparative costs were based.

Some of the points in bridge design to which the author drew attention, in their bearing on maintenance costs, were the avoidance of designs which required extensive scaffolding for routine painting; the use, wherever conditions permitted, of deck-type spans, which involved less steelwork, were cheaper to fabricate and erect, and easier to paint; the provision, in the case of medium-length multiple-track spans, of a separate structure under each track, so as to avoid deformation of the transverse decking when one track deflected under load while the adjacent unloaded tracks remained level; and the avoidance of rigid connections between a continuous deck and the tops of the main girders, unless the deck shared in carrying the main bending stresses and the connections were designed for the shear stresses imposed upon them by reason of their position above the neutral axis. Past neglect of the latter consideration, in the connections between the decking and the main girders of through-type plate-girder spans, has given the maintenance engineer a costly legacy, but the modern designs described by Mr. Berridge avoided this weakness.

Mr. Taylor Thompson indicated the potentially greatest cause of inefficiency in railway civil engineering when he remarked that a great risk of waste lay in the danger of "finding work for the men rather than men for the work, and this tends to arise from a fixed labour force being allotted to a fixed area." The "cabinet system" which he described—so-called because the documents used are kept in a specially-designed cabinet—is being used as a means of overcoming this difficulty and of economising in both labour and material. Mr. G. C. Stevens, who spoke on "Economy through Labour Productivity and Incentive Schemes," described a method of works control which ensures that the causes of falling productivity are known immediately they occur and enable management to take remedial action. As he remarked, this is in striking contrast to the old methods whereby the efficiency of a works was measured by figures produced by an accountant, often several weeks after the usual monthly period had elapsed. Experience had shown that the more difficult the subject was to study and bring into the field of incentive working the greater is the financial saving to be realised.

Mr. A. K. Terris, B.Sc. (Eng.), presented a "Note" on "Economy by Supervision." The problem of finding the correct balance between senior administrative or management staff and basic or site supervision, and the correct relationship of the total to the number of men employed is more involved in railway work than it is in a factory where a tightly-knit organisation prevails. As the four "Notes" showed, however, the search for a solution to all these problems is leading to an efficiency in railway civil engineering that was not even visualised 50 years ago. It may be that conditions of full employment and restricted capital expenditure will be, in spite of the frustration engendered, the means of bringing about much-needed reforms.

NOTES.

ALLOCATION OF STEEL SUPPLIES.

THE mounting claims of the defence programme and of the export drive, it is pointed out in a statement issued by H.M. Government, have made it imperative, in the face of a national steel shortage, this year, of 1½ million tons, to allocate supplies of steel on a system based upon the priorities of national needs. The shortage is shown to be the result of three circumstances. The first is the reduced level of home steel production, due to falls in imports of scrap and of iron ores. The second is the increased demand from the arms factories as production is gradually stepped up, and the third is the necessity, owing to the grave trade deficit, of increasing exports of plant, machinery and steel goods of all kinds. As these growing needs for steel must be met, the home market will have to suffer; moreover, as the minimum needs of basic industries, such as coal, transport and power production must be protected, the sacrifice will have to be borne by other home steel-consuming industries. The allocation, it is emphasised, is to be carried out with great care; a central committee, after close examination, will allot quantities among the broad classes of national need, and individual departments will sub-divide the quantities thus allotted to them among the concerns within their purview. It is further pointed out, in the statement, that a strenuous effort is being made by the Government to find means of raising supplies, by increasing imports of ore and also of semi-finished and finished steel. The problem is looked upon as being of the greatest urgency but the Government is hopeful that means will be found to lessen its severity and to limit the period during which allocations at the present level need to continue. It is conceded that as soon as more steel is available, allocations will be increased, with, however, the same regard to national priorities.

THE INSTITUTION OF MECHANICAL ENGINEERS.

At a meeting of the Institution of Mechanical Engineers on Friday, January 4, with the President, Mr. A. C. Hartley, in the chair, a paper on "Considerations on Bogie Design, with Particular Reference to Electric Railways," by Mr. W. S. Graff-Baker, B.Sc. (Eng.), M.I.Mech.E., was presented by Mr. A. W. Manser, owing to the unavoidable absence of the author. The review of the subject which the paper gave was related mainly to the experience on London Transport, where rapid acceleration, severe braking, frequent stops, and electric traction present the designer with a special problem. Surveying the conditions under which a bogie operated, the author said that wheels with coned tyres followed a sinusoidal course when travelling along a straight track. Practical difficulties prohibited the use of cylindrical tyres, so a cone of only 1 in 100 had been adopted. Running was improved, although the treads had to be returned more frequently. Wheels not rigidly attached to axles in pairs might overcome the problem of lateral oscillation, but the effective use of the maximum braking power necessitated the conventional rigid mounting of wheels on axles. Regenerative or rheostatic braking was attractive, but as every axle on a train had to be braked, it would be necessary to have a motor on every axle; that, however, was seldom economic. It was found desirable, in practice, that the combined spring system of the bogie should be aperiodic to avoid setting up resonant movements. Apart from the use, in the United States, of helical springs combined with shock absorbers, it had been common practice to provide two sets of springs on a bogie—helical springs and laminated springs—which had considerable damping effect. The Swiss had made some use of torsion-bar springing, and on London Transport a set of bogies was running experimentally in which the bolster springs, spring plank, and hangers were replaced by a pair of rubber springs in shear, disposed at appropriate angles between an extended bolster and the outside of the bogie frame. To avoid excessive rolling, the bolster springs and the side bearing springs should be as far as possible from the longitudinal axis of the bogie. To reduce

wear and the number of wearing surfaces in a bogie, manganese steel was used, as well as rubber washers at the ends of radius bars and bushes of the Silentbloc type in links. The use of a large number of tyres, as in France, seemed to be unfavourable unless a supplementary fare could be charged. However, a wider running rail now under consideration might change the economics considerably. The bogie frame should be made as stiff as was reasonably possible so as to avoid fatigue due to the "winding up" of the frame on curves.

PHYSICAL SOCIETY'S EXHIBITION.

Plans are now well advanced for the 36th annual exhibition of scientific instruments and apparatus arranged by the Physical Society, which will be held in London from Thursday, April 3, to Tuesday, April 8, 1952, with the exception of Sunday, April 6. As in 1951, the exhibits will be housed in both the main building of the Royal College of Science, Imperial Institute-road, and the Huxley Building, Exhibition-road, South Kensington, the latter building being opposite the Science Museum. Admission tickets will be valid for both buildings. The exhibition invariably arouses wide interest among scientific circles and is expected to be more than usually attractive this year owing to the considerable scientific effort at present being expended on the development of instruments and other equipment for the services and for the needs of the productivity and export drives. A wide range of new equipment for use in pure and applied research in Britain has also been developed, much of which is expected to be on view. In accordance with custom, lectures will be given by well-known scientists during the exhibition, on this occasion on Friday, April 4, and Monday, April 7; further details, however, have not yet been announced. The prize-winning entries of the Society's competition in craftsmanship and draughtsmanship will also be on view. A handbook of the exhibition, containing descriptions of the exhibits, and priced at 7s. 3d., post free, will be available early in March, on application to the Physical Society, 1, Lowther-gardens, Prince Consort-road, London, S.W.7.

EARLY REFINING OF PIG IRON.

Although the production of iron is now so widespread, and so much has been written about each and all of the processes involved, not a great deal is known about the earliest developments in the art. One of the leading authorities on the subject is Dr. H. R. Schubert, M.A., who delivered a paper upon it to the Newcomen Society at their meeting on Wednesday, January 9, held at the Iron and Steel Institute, London, S.W.1. Entitled "Early Refining of Pig Iron in England," the paper dealt with the transition from the direct process of iron-making from the ore, in bloomeries, to the indirect process of blast-furnaces and fineries. In Germany, Austria, Italy, Sweden and, later, in France, refining was carried out in one hearth only; but in Belgium, Luxembourg, in France before the Nineteenth Century, and in England, two hearths were used, one being termed the "finery" and the other the "chafery." This second method, which was introduced into England from France, was developed originally in Belgium and, for that reason, was known as the Walloon process. There was some evidence, Dr. Schubert stated, that a blast-furnace combined with a finery might have been working at Marches-les-Dames, near Namur, as early as 1340, and there was a finery in Central France in 1402, but it was not until the close of the Fifteenth Century that it was introduced into England. The earliest evidence of ironfounders in England was in 1490, when iron was being produced at Buxted, in Sussex. As a result of researches in Italian, German and French records of the Sixteenth Century, and the Seventeenth Century English writings of John Ray, Henry Powle and Dr. Robert Plot, Dr. Schubert was able to describe in some detail the construction of the hearths, the terms used to describe the various component parts and the tools, and the successive stages of the process, which remained in use, with few essential changes, until the end of the Eighteenth Century, when Henry Cort's process of puddling and rolling was introduced in South Wales.

OBITUARY.

MR. G. A. JUHLIN.

WE regret to record the death of Mr. G. A. Juhlin, a former chief electrical engineer of Metropolitan-Vickers Electrical Company, Limited, which occurred at Goostrey, Cheshire, on December 31, at the age of 71. He was well known for the developments he initiated in the design of large electrical generators. These included the construction of the first 110-MVA alternator installed in this country while many of the modern machines running to-day in power stations throughout the world are examples of his skill.

Gustaf Adolf Juhlin was born in Stockholm on November 13, 1880, and was educated at the Municipal School and Technical College in that city, obtaining a diploma in mechanical engineering from the latter institution. He served as improver and draughtsman with two Swedish engineering firms before coming to this country in 1902, when he joined the firm of Dick, Kerr and Company, of Preston. After being engaged on the design of direct-current machines, he was appointed chief designer of alternating-current equipment in 1907. In 1915, he joined the staff of the British Westinghouse Electric and Manufacturing Company (now the Metropolitan-Vickers Electrical Company) at Trafford Park, Manchester, and two years later became chief engineer of the plant department, in which capacity he was responsible for the design of all the firm's large electrical machines. He was appointed chief electrical engineer of the company in 1941 in succession to Mr. J. S. Peck, who retired in that year, and later joined the board as director of electrical engineering. He retired in 1947. During his long connection with the design of generators and motors he played a leading part in the development of 33-kV windings for alternator stators, in the introduction of compressed mica as an insulating material, in the use of rotary converters for direct-current electric traction, and in the application of electric drives to rolling mills. He also assisted in the introduction, in 1928, of the cross-jet explosion pot for high-voltage circuit-breakers.

Mr. Juhlin was elected a member of the Institution of Mechanical Engineers in 1943. He joined the Institution of Electrical Engineers as a member in 1916 and served as chairman of the North-West Centre in 1923-24. He contributed a number of papers to the proceedings of the latter Institution and was awarded the Hopkinson, Ayrton and Silvanus Thompson premiums.

NEW MERCHANT-SHIP TONNAGE.—During the year which ended on December 31, 1951, plans for 750 ships amounting to over 4,000,000 tons gross were approved by Lloyd's Register of Shipping for construction to the Society's classification. This is the highest figure to be recorded in any peace-time year and has been exceeded only once before, namely, in 1918, when the total was 4,750,000 tons gross. Of this figure, 408 ships, totalling 2,236,000 tons, are to be built in the United Kingdom, and 342 ships, amounting to 1,792,000 tons, abroad. More than half of the total tonnage is accounted for by new tankers, which include a number exceeding 600 ft. in length, vessels in the latter class totalling nearly 500,000 tons gross.

REPORTS RELATING TO ATOMIC ENERGY.—The Ministry of Supply announce that arrangements have been made whereby certain reports in the "unclassified" category, that is, those which do not contain secret information or restricted matter, on subjects connected with atomic energy, will be on sale to the public through the Stationery Office. This extends an existing arrangement whereby reports from the British atomic-energy project which become "declassified," that is, removed from any previous category of classification, are made available for sale. Declassification proceeds according to rules laid down and subscribed to jointly by Great Britain, the United States and Canada. The titles of reports on sale will be listed by the Stationery Office in the *Daily List of Government Publications*, and additional quarterly lists will be issued by the Ministry of Supply. A first list, containing 51 reports, has already been circulated. The price of the unclassified reports will be approximately 2d. per page. Orders for reports should be addressed to H.M. Stationery Office (Sales Division), Cornwall House, Stamford-street, London, S.E.1.

MECHANICAL HARMONIC ANALYSER.

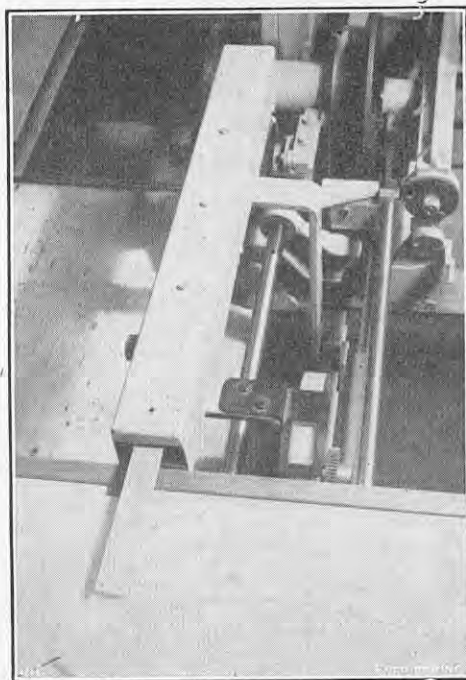


FIG. 6. INTEGRATOR UNIT.

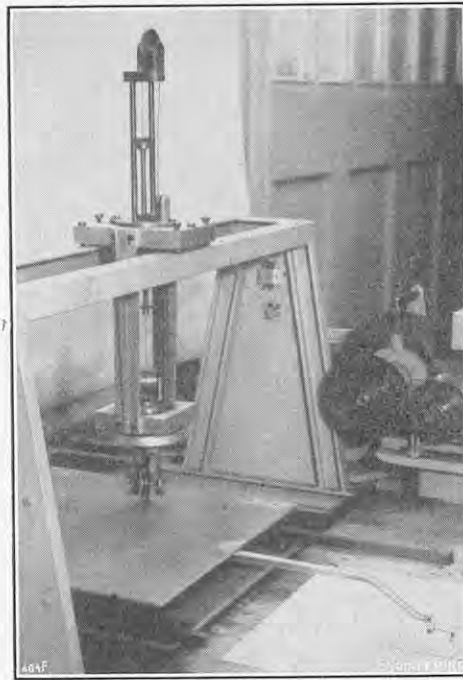


FIG. 7. RESOLVING SYSTEM.

axis by a flexible wire coupled to the manually-operated cursor which is used to follow the curve, so that the rotary motion of the wheel is proportional to the change in the ordinate of the curve.

To determine the n th harmonic of the input curve, the friction wheel is set along the $\theta = 0$ line, as indicated in Fig. 1, when the cursor is at the origin of the curve. Then the variable-speed gear is adjusted until the friction wheel makes n revolutions about its vertical axis when the curve is moved through one period. Consider the motion of the resolver plate when the curve has been moved an amount θ , and is then moved a further amount $\delta\theta$. The corresponding change in the ordinate of the curve is δh ; hence, the friction wheel, which is inclined at an angle $n\theta$ to its original direction, will drive the resolver plate an amount $\kappa \delta h$, say, in the direction $n\theta$. When this increment is made infinitesimally small, the plate motion will be κdh in the direction $n\theta$ and its displacements in the directions O X, O Y will be

$$dx = \kappa \frac{dh}{d\theta} \sin n\theta d\theta$$

$$dy = \kappa \frac{dh}{d\theta} \cos n\theta d\theta.$$

It follows that if the curve is tracked continuously throughout one period, the final co-ordinates of the locus traced by the resolver plate will be

$$OX = \kappa \int_0^{2\pi} \frac{dh}{d\theta} \sin n\theta d\theta \quad (4)$$

and

$$OY = \kappa \int_0^{2\pi} \frac{dh}{d\theta} \cos n\theta d\theta \quad (5)$$

as shown in Fig. 3, opposite, for the case of the fundamental wave form of Fig. 4.

Since

$$\frac{dh}{d\theta} = \frac{d}{d\theta} f(\theta) = -a_1 \sin \theta - 2a_2 \sin 2\theta \dots - na_n \sin n\theta + b_1 \cos \theta + 2b_2 \cos 2\theta \dots + nb_n \cos n\theta \quad (6)$$

it follows, from equations (2) to (6), that

$$a_n = -\frac{OX}{\kappa \pi n}$$

$$b_n = \frac{OY}{\kappa \pi n}$$

Thus, the closing vector of the locus traced by the resolver plate has rectangular components that are proportional to the Fourier coefficients a_n and b_n . Alternatively, the vector itself represents the amplitude and phase of the n th harmonic in the derivative of the input curve.

The derivative of one sinusoidal quantity is another,

n times larger and 90 deg. in advance of the first.

Thus, for example, $\frac{d}{d\theta} (\sin n\theta) = n \cos n\theta = n \sin (n\theta + \frac{1}{2}\pi)$. Hence, if we change the nomenclature of the reference axes, now calling the O X axis which gave the sine term of the derivative curve, the cosine axis, and correspondingly calling O Y the sine axis, the projections of the closing vector on these axes will be proportional to the components present in the input curve, the vectors for harmonic terms having to be divided simply by their own harmonic order. To exemplify this, consider the case of a triangular wave that commences with an initial ordinate $h = \frac{1}{3}h_{\max}$, as shown in Fig. 4, opposite. The fundamental terms in the wave are $0.7 \sin \theta$ and $0.405 \cos \theta$, and it should be noted that the cosine term is the smaller of the two. On analysing this curve, the locus shown in Fig. 5 was obtained for the fundamental component. The projections on the O X and O Y axes correspond to the components present in the derivative curve, and now the sine term is the smaller of the two. However, if we use the final sine-cosine nomenclature for the axes, the components have values corresponding to the Fourier series of the input curve. The locus obtained when testing for the second harmonic, which is actually absent from this input curve, is also shown in Fig. 5 and it will be seen that it returns to the origin. The true fundamental component is $0.81 h \sin (\theta + 30 \text{ deg.})$ and the estimate obtained by the harmonic analyser was $0.813 h \sin (\theta + 28.50 \text{ deg.})$.

The proportions of the analyser were largely determined by the input table and the frame carrying the ball and roller integrator unit, which were part of a projected analyser which was to have used a Scotch yoke linkage for generating the sine and cosine terms. However, when the need for a harmonic analyser became urgent, the original plans were discarded and the present simpler system was evolved. The operation of the analyser depends on two linkages, one of which rotates the friction wheel in the vertical plane and the second of which rotates the friction wheel about its horizontal axis. The former motion is derived from the input table carriage, which runs on steel balls in V grooves machined in the two longitudinal members of the supporting frame. Parallel motion of the table is ensured by a similar V groove in one of the longitudinal members of the carriage; the other longitudinal member is machined flat and rests on the steel balls in the second frame member. The table can be moved manually by the large handwheel on the left of the front panel, in Fig. 2, and this is normally used when setting the analyser for a particular harmonic.

A variable-speed electric-motor drive, which is engaged by a clutch, is provided for traversing the table when a curve is actually being followed. Were this not provided, an operator would have to turn a handwheel with each hand simultaneously, a process which most people find difficult. Both drives are friction drives on to a wire attached to the table carriage and held taut by weights attached at each end. A rack and pinion drive, attached to the underside of the table, transmits the table motion to the disc of the variable-speed gear through a gear of ratio $\sqrt{2}:1$, reversal of which allows a 2 to 1 variation in harmonic range. The gear ratio is set with the aid of a calibrated scale coupled to a screwed rod which is used to position the ball between the disc and the roller of the integrator unit, illustrated in Fig. 6, on this page. The output of the gear is transmitted to the resolver head by a drive consisting of piano wire, which is kept taut by a pair of spring-loaded jockey pulleys, and turns the friction wheel about its vertical axis.

The second motion of the friction wheel is also maintained by a wire drive. A wire is attached to a sleeve which is moved axially by rotation of the large handwheel on the right in Fig. 2. It is then guided by a series of pulleys until it passes over the pulley at the apex of the apparatus and terminates in a swivel located between the top pair of vertical rods. It is necessary to introduce a swivel at this stage before continuing the drive to the friction wheel, otherwise, when investigating the n th harmonic, the wire would be twisted n times. The drive, continued from the other side of the swivel, is then taken round a drum machined on one side of the friction wheel and is attached finally to a spring-loaded drum, mounted on the rotatable part of the resolver head, which maintains the whole drive taut. The cursor arm is attached to this drive so that the rotation of the friction wheel is proportional to the movement of the cursor.

The resolving system, illustrated in Fig. 7, herewith, consists of a duralumin top plate which runs on a pair of rails mounted on an intermediate carriage, which is itself supported on a second pair of rails at right angles to the first. Parallel motion in each axis is obtained by having V-tired wheels which run in a slot machined in one rail of each pair. This arrangement allows free movement of the resolver plate in the horizontal plane but does not allow the plate to rotate. In order to allow for small irregularities in the surface of the resolver plate the resolver head is spring-loaded and has about 0.01 in. freedom of movement; an amount which, even if it were all needed, is negligible in comparison with the normal displacements of the plate. The setting of the friction wheel is facilitated by a scale engraved on the skirted disc, visible in Fig. 7, just above the wheel itself; and by disengaging the drive from the table to the wheel by rocking the roller away from the ball of the gear unit, the friction wheel can be set to the $\theta = 0$ line and the cursor set on the origin of the curve independently of one another.

This analyser can determine harmonics up to the 20th in curves of 27-in. period and 4-in. peak-to-peak amplitude. It can, of course, be used to analyse curves of shorter period, but there is then a proportional loss of harmonic range. These dimensions were fixed by records that had been obtained, prior to the construction of the analyser, during an investigation of the response of a human operator following a target. The analysis of this data required harmonic analyses of two related records, one above the other, on chart paper. The input table, therefore was made wide enough to accommodate both records, and the limitation on width imposed by the restriction of the cursor movement to 4 in. was overcome by mounting the cursor on an extensible arm.

(To be continued.)

ERRATUM.—On page 17, *ante*, there appeared a reference to "H.M.S. Valiant" instead of "H.M.S. Vanguard"; a slip of the pen which escaped correction and for which we apologise. As it happens, the statement that there is "only one H.M.S. Valiant" is still true, but the present bearer of what was formerly a battleship's name, we understand, is a harbour tug.

BRITISH ELECTRIC GENERATING PLANT CONSTRUCTION.

THE progress made in the installation of electric generating plant in this country during 1951 was described by the Chairman of the British Electricity Authority (Lord Citrine) at a Press conference on Thursday, January 3. He said that, in spite of many difficulties, mainly due to inadequate priorities for the supply of materials, the new plant brought into service had provided an additional capacity of 1,113 MW. This constituted a record, being 148 MW, or 15.3 per cent., more than in the previous year and 410 MW, or 59 per cent., more than in 1949. It was also the first time that more than 1,000 MW had been brought into use in one year.

The additional plant had been installed in 25 stations, (as shown in the accompanying table). Ten of these, indicated in italics, are new, and brief details of them were given in *ENGINEERING* from March onwards in our 171st and 172nd volumes (1951). As will be seen, the plant comprises 28 turbo-alternators with an aggregate installed capacity of 1,235 MW and 46 boilers with an aggregate evaporative capacity of 13,080,000 lb. per hour. A feature of the new stations is the increased employment of the "unit" system (in

Asked about supplies of power from abroad Lord Citrine said that demand exceeded supply both in Norway and Switzerland. Moreover, it was not at present practicable to transmit power by submarine cable over the distances involved, although the possibility of using high-tension direct-current for this purpose was being considered. Discussions were taking place with Electricité de France to discover whether means of mutual assistance could be devised, but the peak periods in the two countries coincided; and there was severe rationing in parts of France. In reply to a question whether the shortage of generating capacity could be alleviated by the Authority encouraging the installation of Diesel plant in factories, he pointed out that the relevant restrictions on the use of such plant had been removed until 1959, although a survey of the position would be made in 1954. He did not add, as he might have done, that such plant also requires steel; and it is the shortage of this material which is a principal obstacle to the solution of present difficulties.

On the subject of finance Lord Citrine said that, any reduction in costs which should result from the higher efficiency of modern power plant might be offset by the higher costs of materials, equipment and labour; and these had already risen considerably.

TABLE I.—PLANT COMMISSIONED IN BRITISH POWER STATIONS DURING 1951.

Power Station.*	Divisions.	Turbo-Generators.		Boilers.		Main High-Pressure Pipework.
		Installed Capacity in MW.	Maker.†	Capacity in Lb. per Hr.	Maker.‡	Maker.§
Agecroft	N.W.	—	—	2 × 315,000	Int. Comb.	S. & L.
Battersea "B"	London	1 × 60	Met.-Vick.	—	—	Ait.
Blackwall Point	London	2 × 30	E. E.	2 × 365,000	B. & W.	B. & W.
Bracehead	S.W. Scotland	2 × 50	Parsons	3 × 300,000	B. & W.	B. & W.
Bromborough	Mersey	2 × 50	E. E.	4 × 300,000	B. & W.	S. & L.
Clarence Dock	Mersey	1 × 51.5	Met.-Vick.	—	—	S. & L.
Cliff Quay	East.	—	—	2 × 365,000	B. & W.	Ait.
Clyde's Mill	S.W. Scotland	1 × 30	E. E.	2 × 180,000	Var.	S. & L.
Croydon "B"	S.E.	2 × 52.5	Met.-Vick.	3 × 320,000	Sim. Car.	Ait.
Fulham	London	1 × 60	E. E.	—	—	Ait.
Keadby	H.Q.	—	—	1 × 550,000	Stirl.	Parsons
Llynfi	S. Wales	2 × 30	E. E.	1 × 300,000	Stirl.	S. & L.
Nechells "B"	Mid.	2 × 52	Parsons	3 × 230,000	Int. Comb.	S. & L.
Neepsend	York.	—	—	2 × 190,000	Mitchell	Ait.
North Tees "C"	N.E.	1 × 60	Parsons	2 × 360,000	B. & W.	B. & W.
Peterborough	East.	2 × 20	E. E.	3 × 160,000	B. & W.	B. & W.
Plymouth "B"	S.W.	1 × 31.5	Met.-Vick.	1 × 320,000	Var.	B. & W.
Poole	South.	1 × 50	Met.-Vick.	3 × 300,000	Int. Comb.	Ait.
Portobello	S.E. Scotland	1 × 60	Rich. West.	—	—	Ait.
Rye House	East.	1 × 32	Rich. West.	1 × 350,000	B. & W.	S. & L.
Skelton Grange	York.	2 × 60	Parsons	3 × 360,000	Int. Comb.	Ait.
Staythorpe	E. Mid.	—	—	2 × 240,000	B. & W.	Ait.
Thornhill	York.	—	—	3 × 180,000	Mitchell	S. & L.
Walsall	Mid.	—	—	1 × 180,000	B. & W.	Ait.
Westwood (Wigan)	N.W.	2 × 30	B.T.H.	2 × 300,000	B. & W.	S. & L.

* The power stations the names of which are printed in italics are new stations in which plant was commissioned for the first time in 1951. The others are existing stations to which extensions were made.

† Met.-Vick. is Metropolitan-Vickers Electrical Company, Limited, Manchester, 17; E.E. is English Electric Company, Limited, Kingsway, London, W.C.2.; Parsons is Messrs. C. A. Parsons and Company, Limited, Newcastle-on-Tyne; Rich. West. is Messrs. Richardson Westgarth and Company, Limited, Hartlepool; and B.T.H. is the British Thomson-Houston Company, Limited, Rugby.

‡ Int. Comb. is International Combustion, Limited, Woburn-place, London, W.C.1; B. & W. is Babcock and Wilcox Limited, Farringdon-street, London, E.C.4; Var. is Yarrow and Company, Limited, Glasgow; Sim. Car. is Simon-Carves, Limited, Stockport; Stirl. is Stirling Boiler Company, Limited, Farringdon-street, London, E.C.4; and Mitchell is Mitchell Engineering, Limited, Bedford-square, London, W.C.1.

§ Ait. is Aiton and Company, Limited, Derby; and S. & L. is Stewarts and Lloyds, Limited, 41, Oswald-street, Glasgow, C.1.

which one boiler supplies one generator) and at the new station at Castle Donnington, near Derby (now in course of construction) this system will be further extended by the installation of six 830,000-lb. boilers each of which will supply a 100-MW set.

The Authority have planned for considerably higher rates of commissioning during future years, namely, 1,150 to 1,400 MW in 1952; 1,300 to 1,500 MW in 1953; 1,400 to 1,600 MW in 1954; 1,500 to 1,700 MW in 1955; and 1,600 to 1,800 MW from 1956 onwards. It is pointed out, however, that realisation of these rates depends almost entirely on the necessary priority being obtained for the supply of labour and materials as well as, of course, the release of essential capital resources. Actually, the addition of 1,550 MW has been authorised during 1952, but if this rate of construction can be exceeded the increase would be permitted. Unless, in fact, an annual increase of 1,880 MW can be attained from 1956 onwards the demand will continue to outrun the supply.

In reply to questions, which ranged over a large variety of subjects, Lord Citrine attributed the reduction in the number of times load had been shed this winter to the load spreading, which had led to a reduction of 500 MW in the demand; to the comparatively mild weather; and to the intensive programme of overhauls, which had been carried out during the summer and had made an additional 1,000 MW of plant available. An attempt was being made, he said, to increase the period between overhauls, but if cold weather occurred there was still no guarantee that load shedding would not be necessary. These results were a tribute to the careful planning and energy displayed by the technical staffs of the Authority.

A particular problem was presented by the continual rise in coal costs and, although the Authority was anxious to avoid changes in prices to consumers, he could hold out no hope that tariffs would not be increased.

Work was in progress on the construction of one semi-outdoor station, but it was proposed to investigate the effects of the British climate on its operation before deciding whether the use of this form of construction should be extended. The possibility of employing forms of cladding lighter than brickwork was also being investigated. Finally, he considered that the policy of exporting boilers was mistaken.

LECTURES ON CORROSION.—A course of evening lectures on "The Corrosion of Metals" will be delivered by Mr. S. C. Britton, M.A., of the Tin Research Institute, at the Northampton Polytechnic, St. John-street, London, E.C.1, on Tuesday evenings at 7 p.m., commencing on January 15. The first lecture deals with general principles and with oxide films on metals, electrochemical action, corrosion products, and effects of stress. The second and third lectures, on January 22 and 29, will be concerned with the forms of corrosion as they affect the various metals, such as oxidation and scaling, atmospheric corrosion and immersion in liquids. The fourth lecture, on February 5, will deal with protection by coatings; the fifth, on February 12, with protection by means other than coatings, and the last lecture, on February 19, with corrosion testing. The fee for the course is 20s., but a student already enrolled in a Polytechnic course may also attend this course for an additional fee of 15s.

ENTERPRISE IN ENGINEERING.*

By AIR COMMODORE F. R. BANKS, C.B., O.B.E.,
M.I.Mech.E.

FOR about 200 years we, of this country, have been "on top of the world" as an industrial and engineering nation; but, in more recent years, the awakening of other peoples in other lands to the possibilities of controlling their own industrial and engineering destinies has resulted in greater competition in the engineering field than ever before. The two World Wars have been mainly responsible for this change and nationalistic outlook; and, if conditions have altered so drastically as the result of war, one generation is hardly in the position to criticise another for the present state of affairs. It is the responsibility and privilege of those who live to-day to improve conditions for those who are to follow, and the engineer can probably contribute more than anyone else to the industrial well-being and to the future prosperity of this country.

When some measure of industrial discipline is restored and when grown men cease to act like spoilt children if things are not exactly to their liking, and when they refuse to follow irresponsible agitators, then this country will have some chance of re-shaping itself as the major Power for good in the world. We are, in fact, a major Power and still have considerable world influence; but this has been the result of energy built up and stored in the flywheel during the centuries. We must not let the flywheel run down. Hard work is too often regarded as a drudgery rather than something worth while. This is largely due to post-war unrest and also because, in the last two or three decades, there have been more, and more various, facilities for relaxation, which have themselves now become matters of serious pursuit. Perhaps the real reason for the disproportionately large interest now taken by the mass of the people in entertainment is the high rate of direct taxation, which does not encourage them to make any extra effort in their work; but the enthusiasm and ambitions of the professional man, the engineer, if he is worth his salt, will rise above such things and he will keep them in their proper perspective.

To-day, an engineering degree from one of the universities is considered essential; but a university degree is only the start. It is, in fact, very similar to the granting of "wings" to a pilot. It qualifies the man, and only qualifies him, to obtain experience in his profession; and it is a passport to enter an organisation in order to gain that experience. Having entered a firm, whatever its class of engineering, the young engineer will naturally tend to gravitate towards the particular activity in which he is interested. My advice is, try to get on the shop floor first in order to obtain experience of the particular product made by the firm and learn how machine tools and other equipment are used. Then go to the experimental department, to understand thoroughly the operation of the finished product—following through to the service department to see the troubles which occur after the product has been in the hands of the user. After two or three years in all the departments mentioned, the young engineer will be in a better position to know in which branch he wishes to specialise; and, if the firm in question has a proper scheme for training engineers, they will be able to place him in the section or department most useful to him, and to them.

There is, of course, the case of the man with inherent engineering ability, but who is unable to pass examinations. I do not think this type of individual is sufficiently considered or catered for to-day, particularly in view of the fact that there is always a shortage of good men; but the greater technical knowledge of to-day, compared with that of 40 years ago, is such that a much higher standard of education is necessary in order to meet modern requirements.

I think, therefore, that it should be the responsibility of industry, the universities and technical colleges, to get together and try to hammer out an engineering curriculum which has as its basis a good mixture of practical engineering and technical or theoretical instruction; so that the man who is unable to pass the academic requirements for a B.Sc. can take a more simple and practical test and obtain a certificate which will qualify him to enter a firm, to start his engineering career. With equal opportunity, if he grasps it, and continued technical (theoretical) training, there is no reason why he should not do as well as his more academic brother.

Assuming the young engineer to have obtained a relatively responsible position in a firm by the time he has reached 25 years of age, the question often arises as to whether he should continue with that firm or seek further experience in another firm doing similar work. I would say that this entirely depends upon the standing of the first firm in its particular class of engineering and how he gets on in the firm, or how he is treated.

* Presidential address to the Junior Institution of Engineers, delivered in London on Friday, December 14, 1951. Abridged.

But, in any case, once he has achieved a position of responsibility, he should stay in that position for about five years. Then he might make a change if he so desires. He should, however, seek to establish himself finally in a firm by the time he is 35 years of age. In other words, two changes in ten years should not be regarded as excessive.

To the heads of engineering firms, I would say: give the more promising of your personnel every opportunity to take charge of sections and departments, so that they may learn the art of administration and leadership. There is a general lack of good administrators; and, in the past, insufficient attention has been paid to the advancement of engineering and other staff to administrative positions, which will help to fit them for still higher posts as officers of the company.

I am now going to say something of the aviation engine, as representative of the particular class of engineering in which I have had nearly 30 years' experience. The high-duty aviation engine differs in many respects from other types of prime mover. First, it must be of the smallest bulk and weight possible for the power it produces. Second, since there is little or no finality in aviation, there must always be the urge for progressive engine improvement in order to meet the demands for better aircraft performance. Third, the development of the aviation engine is very costly and has now to be supported nationally through the medium of Government contracts.

Although the first flights by the Wright brothers, in 1903, were the start of powered flight, the real aviation era commenced in France, in 1909, where a number of ingenious engines were designed and built. In those days, the whole conception of an aviation engine came almost entirely from the brain of the individual engineer. And success, in the form of orders, rewarded the man who better combined the right degree of inventiveness with good detail and mechanical design, and whose "sixth" sense permitted him to guess correctly the engine shape and power attractive to the aircraft designer.

The value of good engineering development began to be appreciated during the middle of the first World War. Previously, an engine of promising design was often condemned and quickly discarded because of sheer lack of experience and technique to cure continued or frequent mechanical failures. Even after this first appreciation of the necessity for developing an engine out of its troubles, some ten or 15 years were to pass before it became a fully developed art or technique. There are still firms who are not yet alive to the importance of intensive development.

It is a truism to say "there is nothing new under the sun," and such developments as fuel injection, the propeller reduction gear and the metal propeller were all first thought of and tried in 1909. For instance, the Antoinette engine built in that year was a 90-deg. V-type eight-cylinder liquid-cooled (or, rather, steam-cooled) engine. It had direct fuel injection into the inlet ports, in place of a carburettor. Its radiator or condenser was in the form of a series of tubes arranged along the fuselage sides of the Antoinette monoplane. This engine was fitted with a metal propeller, the blades of which could be adjusted, on the ground, to give optimum pitch setting. The Antoinette engine eventually went out of use because of failure to cure the troubles associated with the injection system and, also, I believe, the ignition.

Another ingenious engine of that time was the Gnome, the cylinders of which rotated around a fixed crankshaft. The Gnome, with other rotary engines which followed, was also used in the early fighters of the first World War and, for many years afterwards, in training aircraft. At about the same time came the Anzani and the Salmons, both static radial engines, the latter having liquid cooling. Also among the engines built in the same period was the Renault, a 90-deg. V-type eight-cylinder air-cooled engine. The Renault had fan cooling, the air being directed by ducts from the fan to each bank of four cylinders. It was probably the first aviation engine to have a propeller reduction gear, since the propeller was driven directly from the camshaft and, therefore, ran at half the crankshaft speed.

Steam or evaporative cooling was tried many years after the Antoinette engine, between the two World Wars, but was discarded on the grounds of impracticability. In the case of fighters, when indulging in aerobatics, it was found that the steam went where the water should have been and vice versa. To-day, the piston-type aviation engine is either air-cooled or pressure liquid-cooled. In the latter case, the liquid is usually a blend of about 70 per cent. water and 30 per cent. ethylene glycol. The pressure system and the glycol content permit higher temperatures to be attained without boiling or loss of coolant—avoiding the use of an oversize radiator, which was previously necessary for operation in tropical conditions and for the relatively short periods of high-power running during the take-off and climb of the aircraft. This

development, which resulted in a much smaller radiator, has brought about an important reduction in "drag" or resistance. The use of glycol also depresses the freezing point of the coolant.

The aviation gas turbine, particularly the turbo-jet, has the disadvantage of a relatively high specific fuel consumption. While a considerable improvement, of some 20 per cent., has been achieved during the ten years of this engine's existence, still greater improvement must come if it is to be fully competitive in all fields of aviation. This is in sight and will come in the not too distant future.

The jet-propulsion gas turbine, or turbo-jet, consumes an enormous amount of air, some of which is burned with the fuel and all goes through the engine. An engine such as the Sapphire, which gives 7,200 lb. thrust, consumes about 190 tons, or over five and a half million cubic feet, of air per hour. It will be appreciated, therefore, that a difference of 1 per cent. or 2 per cent. in the efficiency of processing this large quantity of air—in taking it into the compressor, raising its pressure, burning some of it with fuel and then expanding it, through the turbine and nozzle—can have a profound effect upon power and fuel economy, or overall efficiency.

It might interest you to hear about the engine development for the Schneider Trophy Contests of 20 years or more ago. While this is past history, the contests of 1929 and 1931 were very important to the cause of aviation and had considerable influence, later, upon the fighter aircraft and its engine. The story of the preparation of the engines for these contests, which is also an excellent example of what has to be done to produce a successful aviation engine, particularly concerns the Rolls-Royce R-type racing engine fitted in the victorious Vickers-Supermarine seaplane. What I am about to describe is also one of the best illustrations I can give of the influence of good leadership, good team work and the most effective use of money at a high rate of expenditure.

It was in 1927 that the British Government decided, for the first time, officially to support a team of R.A.F. pilots and aircraft for the Schneider Trophy Contest. This team, in the same year, was successful in winning the Trophy from Italy, at Venice. The contest was won at an average speed of 281 m.p.h. by a Supermarine S5 seaplane fitted with a high-compression (10:1) unsupercharged and geared Napier Lion engine, giving about 880 brake horse-power.

In 1929, with Italy as the challenging country, the Air Ministry realised that the Lion engine had reached the limit of its development in unsupercharged form, and they instructed Napier to develop it as a supercharged engine. Even so, it was appreciated that the power might still be less than that required for the forthcoming contest. Therefore, the Ministry asked Rolls-Royce to develop an engine of considerably greater power.

The basic engine, chosen by Rolls as the most suitable for developing in racing form, was their Buzzard or H type. This was a 60-deg. V-type 12-cylinder liquid-cooled engine of 6-in. bore and 6.6-in. stroke, having a cylinder capacity of 36.7 litres. The H-engine, in its normal military form, gave something over 800 brake horse-power. By some detail redesign of connecting rods and reduction gear, etc., and an entirely new and larger supercharger to provide more air at high boost, and by increasing the engine speed, this first racing or R-engine developed more than 1,800 brake horse-power at 2,900 r.p.m. The supercharger design was interesting in that it had a double-sided rotor, to keep the overall engine bulk or envelope within that required by Supermarine for their machine. Even the engine camshaft covers on the cylinder blocks were shaped to conform to, and form part of, the engine cowling. The combination of the Supermarine S6A seaplane and the R-engine won the 1929 Contest at an average speed of 328 m.p.h. The same machine then raised the world air speed record to 357 m.p.h., immediately after the event.

Early in 1931, with the Italians again expected as challengers, there was considerable indecision regarding our participation in this event, which had now assumed considerable national and international importance. The Government of that day at first decided, on the grounds of national economy, not to support an official British team, but were shamed into reversing their decision by the patriotic Lady Houston, who guaranteed, and gave, 100,000l. towards expenses.

All this uncertainty, however, cut time very short for the preparation of machines and engines; and, literally, there were only little more than six months available before the date of the contest. Therefore, Rolls-Royce Limited were committed to the improvement of the 1929 engine, to reach the target power of 2,300 brake horse-power. Parallel with this work, it was necessary to give the High Speed Flight of the R.A.F. a sufficient number of engines and aircraft with which to keep in training and practice. The machines used for this purpose were the old S5's, and the S6A's of 1929.

A more or less arbitrary figure of six hours' flying time was decided upon for the maximum life of the practice engines; after which Rolls-Royce would send, to the Team's base at Calshot, a reconditioned engine and take back the time-expired engine to their Derby works for overhaul. This organisation worked like a clock. There was a Rolls team of engineers at Calshot, in permanent attendance, to look after the installation of the engines, their running and removal. The running time, of six hours, was taken to include all engine running on the ground (in the aircraft) and practice flights, which included bursts of full power. It was estimated to be the equivalent of one hour at full throttle on the test bed.

Since rail transport, for delivering and returning engines, would have been too slow and tedious, Rolls-Royce fitted an old Phantom I car chassis with a cradle to take an R-engine. This used to do the journey between the Derby Works and Calshot in phenomenal time. It was a most inspiring time for all concerned, largely because of the energy and drive of the team leader and then head of the Rolls-Royce Experimental Department, Hives, now Lord Hives, the present chairman and joint managing director of Rolls-Royce Limited.

There was considerable, if well-concealed, nervous tension when it came to putting the new engine through its official acceptance test. The Air Ministry requirements for this were the successful completion of a run of one hour's duration at full throttle at the pre-ordained sea-level power. This, it was considered, would amply cover the contest conditions, plus something over "to make quite sure." With only about five weeks remaining before the contest, the first modified R engine of increased power was submitted to the acceptance test. It broke a crankshaft after about 34 minutes running. The engine was whipped off the bed and was in its component parts in about an hour. The history of the crankshaft was checked, and it was found that it had already done some hours of experimental running. Therefore, another engine was built, having an entirely new crankshaft. The engine was put up for the hour's run, and, this time, after running perfectly for 58 minutes, the shaft broke again. It was on the eve of August Bank Holiday, with the contest only about a full month away.

Since there was obviously no time to change its design radically or that of the crankcase and bearing housings accommodating it, it was decided to strengthen the shaft merely by leaving more material in the hollow pins and journals; but all the steelworks in Sheffield had then shut down for the Bank Holiday. This, however, did not deter Rolls-Royce Limited. The manager of their experimental machine shop went to Sheffield and got the crankshaft forging people to work over the holiday and produce one forging ready for machining at Derby on the Bank Holiday Monday—to be followed by further forgings within the week.

As a result of this effort, the engine was put through a successful acceptance test run in about one week from the date of the final crankshaft failure. A maximum power of 2,350 brake horse-power was obtained at 3,200 r.p.m., for an engine "dry" weight of 1,630 lb. or 0.7 lb. per brake horse-power. This power was equivalent to more than 1 brake horse-power per cubic inch of piston displacement.

Since the Italian challengers did not materialise, due to their unreadiness, the Supermarine S6B machine, fitted with this engine, won the Trophy outright at an average speed of 340 m.p.h.

The Supermarine seaplane also had many interesting technical features. It had surface cooling for the engine, where, instead of the conventional radiator, the coolant circulated between the double skin of the light-alloy wing covering. The hollow tail fin became the lubricating oil tank and cooler combined, the oil being led to and from the engine by surface tubes arranged along the fuselage sides of the machine.

Since there were no variable-pitch or constant-speed propellers in those days, the pitch of the metal propeller then fitted was set for maximum performance of the engine in the air. Therefore, the propeller was stalled and inefficient at the take-off condition. Viewed from the side, it looked like a paddle-wheel, since it had a pitch of, approximately, 19 ft. 6 in. for a diameter of about 9 ft.

When starting the take-off procedure the pilot had to face out-of-wind, because the propeller torque could not, at low forward speed, be held or counteracted by the rudder. This out-of-wind allowance was so judged that the subsequent swing brought the aircraft into wind—sufficient speed had then been gained for the rudder to become effective. To help to alleviate this effect, one float was made larger than the other, and it also held more fuel.

The postscript to this final Schneider Trophy Contest is worth mentioning. After the event, it was naturally wished to wind up the proceedings by an attempt on the world air-speed record; but in the opinion of Hives and others, this had little attraction unless the speed were raised to 400 m.p.h. or over.

It had to be at least 400 m.p.h.; 399.9 m.p.h. would not be interesting. Therefore, it was necessary to step up the power of the engine to about 2,600 brake horse-power; and the only quick way to do this was by the use of a special fuel.

In the meantime, a further difficulty presented itself. The Air Ministry wished to remove the High Speed Flight from Calshot without delay and reinstate the latter as a flying-boat base, which meant an immediate attack on the record with the existing contest engines and fuel. This would inevitably have resulted in a speed below 400 m.p.h.

While the arguments and pleadings for more time were going on, Rolls were quietly and quickly preparing an engine for the record. On account of the short time available, there could be little mechanical modification; but stronger connecting rods were fitted, to deal with increased engine speed and loading. The engine was built and fuel tests commenced. By using a high proportion of methanol (synthetic methyl alcohol) in the fuel, it was possible to raise the power considerably—at the expense of fuel consumption. The alcohol acted as a liquid charge cooler and reduced the temperature rise through the supercharger, allowing a greater charge weight to enter the engine cylinders. In the first tests, the supercharger gear ratio was raised to permit higher boost; and this, together with the fuel, gave a maximum power of over 2,800 brake horse-power. But such a large power increase proved excessive for the engine, and some of the cylinder holding-down bolts fractured. Therefore, the original blower gear ratio was restored and the power reduced to 2,600 brake horse-power, or about 250 brake horse-power more than that of the contest engine but sufficient for the record attempt.

During the tests, we found that the engine appeared to be starved of fuel, despite the increased jet size to accommodate the high alcohol content. It was eventually discovered that the total flow rate through the jets was larger than the amount of fuel the pump could deliver, so the ratio of the fuel-pump driving gears had to be increased. This happened one evening, when the Rolls machine-shop staff had already gone home. A messenger was sent to find the senior gear-cutting specialist, who had gone out for the evening. He was eventually located, and came back to the works to labour all night, cutting new gear blanks. In about 24 hours, the engine was running at the required power. A few days later, it had completed a bench test, to simulate six runs up and down the official three-kilometre speed course, and was ready for delivery to Calshot. The engine was rushed down to Calshot and installed and, within a week, the air-speed record had been raised to 407 m.p.h.

The lesson to be learned from this story is that nothing worth while can be achieved in life without effort and some risk; and outstanding success requires enthusiasm in addition to experience and ability. That Schneider Trophy experience was responsible for Rolls-Royce's continued effort and success; and it gave to this country its best fighter engine, and one of the best bomber engines, of the war—the Merlin.

MINERS' CAP LAMPS FOR LOCOMOTIVE SHED STAFF.—After experimenting with the use of miners' cap lamps by staff engaged in examining locomotives and boilers at running sheds, British Railways have decided to extend their use. The lamps leave the men with both hands free to do their work, and enable them to direct the light where it is most needed. A battery is carried on a belt worn by the man, and a switch enables a beam of light or a diffused light to be used as required.

ALMANACS AND CALENDARS.—We have received daily tear-off calendars from Richard Sutcliffe, Ltd., Universal Works, Horbury, Wakefield, and the Universal Ball Bearing Repair and Manufacturing Co., 111-115, Hamersmith-grove, London, W.6; and a monthly tear-off wall calendar from the Ateliers de Constructions Electriques de Charleroi, Charleroi, Belgium. The last-mentioned contains reproductions in colour of twelve paintings depicting various aspects of bygone Belgian manners and customs. The North British Locomotive Co., Ltd., Glasgow, have sent us a tear-off wall calendar having four months to each sheet; and John Laing and Son, Ltd., Bunn's-lane, London, N.W.7, have sent us a tear-off wall calendar of six sheets, each reproducing in colours paintings illustrating work performed on contracts recently undertaken by the company. A coloured wall map of the world, in two sections, has reached us from the Bristol Aeroplane Co., Ltd., Filton House, Bristol. This map has attached to it a tear-off calendar, each sheet of which displays the current month in heavy type, and the preceding and following months in smaller type. We have also received a monthly tear-off wall calendar from John I. Thornycroft & Co., Ltd., Thornycroft House, Smith-square, London, S.W.1, and a monthly tear-off desk calendar from Ford's Advertising, Ltd., 151, Whiteladies-road, Bristol, 8.

LABOUR NOTES.

THERE was a sharp decline in the number of industrial disputes in progress in the United Kingdom during November, 1951, but an increase in the number of persons involved in them. According to statistics published in the *Ministry of Labour Gazette* for December last, there were 137 strikes in progress during November, with 35,900 persons involved in them and 91,000 working days lost; the comparative figures for October being 212 strikes in progress, with 30,000 workpeople involved and 113,000 days' work lost. During November, 1950, there were only 112 strikes in being, in which 20,300 persons took part and a total of 69,000 days were lost. Of the total of 91,000 days lost during November last, 77,000 were lost by 33,200 workpeople who were involved in stoppages which began in that month. Some 28,400 of these persons were directly involved, while the remaining 4,800 were only indirectly concerned. Most of the latter were employed at establishments where strikes occurred and lost their work as a result, but were not themselves parties to the disputes. The number of days lost during November also included about 14,000 days lost by 2,700 workpeople owing to stoppages which had continued from the previous month.

Of the 137 disputes in progress during November last, 20 were in being when the month began and 117 were commenced during the month. Included in the latter figure were nine stoppages, directly involving 4,500 employees, which arose out of demands for advances in wages, and 42 other stoppages, directly involving 3,800 employees, which were caused by other disagreements on wage questions. Difficulties respecting working hours were the cause of four strikes, in which some 2,400 operatives were concerned. No fewer than 17 strikes, directly involving 5,700 workpeople, arose on questions respecting the employment of particular classes of workpeople or of certain individuals; while another 44 disputes, directly involving 11,900 workpeople, occurred owing to other grievances respecting working arrangements. One stoppage of work, which deprived about 100 people of their employment, took place in support of workpeople involved in another dispute altogether.

The number of industrial disputes which commenced during the eleven months from January to November, 1951, totalled 1,633, and in these, and the disputes already in being when the year began, some 369,600 persons were involved and 1,650,000 working days were lost. The comparative figures for the corresponding period in 1950 were 1,266 disputes commenced, with a total of 294,800 workpeople involved in all stoppages in progress during those months and about 1,361,000 working days lost. During the first eleven months of last year, there were 81 strikes in the engineering industry and, in these, 24,300 operatives were involved and 132,000 days lost, while, in the shipbuilding and ship-repairing industry, there were 101 strikes, but the number of operatives involved was only 14,500 and the loss of working days amounted to the comparatively small total of 73,000. The vehicle-building trade was responsible for 64 stoppages, in which 54,700 employees were involved and some 249,000 days were lost. Among firms engaged in the treatment of non-ferrous mining products, there were 16 stoppages with 1,100 employees involved and about 2,000 days lost. In the coal-mining industry, there were 1,000 strikes during the eleven months. Over 128,000 miners were involved in them and more than 337,000 working days were lost.

Difficulties confronting the National Coal Board at the present time were referred to by Sir Hubert Houldsworth, the Board's chairman, at a Press conference on Tuesday last, during which he reviewed the work accomplished by the Board in the course of its five years' existence and spoke of the industry's outlook for 1952. Three outstanding problems were the need to effect substantial increases in the quantity of coal to be exported overseas during the next twelve months, the loss which the Board will incur as a result of the importation of coal during the present winter, and the opposition of certain sections of mining employees to the industry's supplementary pension scheme, which came into operation on January 1, last. So far, no official forecast has been made of British coal exports for 1952, but they are expected to exceed those obtained during 1951, possibly to a small extent only, provided that production can be maintained and that home consumption is not materially increased. A spell of cold weather during the remaining winter months, with a run on coal stocks for domestic consumption, would make a material difference. It is suggested in some quarters that the Government will advocate a target of 20 million tons for export and bunkers during 1952. This would fall far short of the 46 million tons exported during 1938, but would be a considerable

advance on the total of 11,653,000 tons reached during 1951, of which 7,925,000 tons were exports and 3,728,000 tons were bunkers.

Statistics for the coal industry for the whole of 1951 have now been issued by the Ministry of Fuel and Power. The arrival of coal from overseas during the year amounted to 1,220,700 tons, compared with a total of 8,200 tons imported during the twelve months of 1950. The Board is likely to be faced with a loss of about 4,000,000 lb. as a result of its imports of coal during the present winter. Between now and the end of April, 600,000 tons of coal will be imported, about 500,000 tons from the United States and the remainder from India. There will be a loss, including freight charges, of from 6l. to 7l. a ton on the American coal, this being the difference between the average pithead price of British coal—2l. 16s. a ton—and the amount paid by the Board for the foreign coal.

Miners in several parts of the country, who have not yet expressed their willingness to join the new pension scheme for the industry, have complained strongly against the deductions for pension contributions which were made by the Board from their first pay packets in January. In some instances, the men have demanded the re-payment of the contributions, which amount to 1s. 6d. for underground miners and 1s. 3d. for men engaged on surface work. An official of the National Union of Mineworkers in the North-Eastern Division is reported to have said that union representatives were told that if the men did not wish to participate in the pension scheme they must sign a form contracting out, when their contributions would be returned. The principal objectors to the payments appear to be the younger miners, mostly under 30 years of age, who are asking that they should be allowed to commence their contributions when they reach that age.

The increasing difficulty of finding employment for elderly ex-Service men is referred to in the annual report of the national executive council of the British Legion for 1950-51, which was issued on Friday last. The report states that, although unemployment among men aged 40 and under is almost non-existent, the absence of work for older men was beginning to cause some concern. The difficulty of obtaining employment was particularly noticeable in the case of men over the age of 55 and ex-regular officers. During the twelve months covered by the report, the Legion had succeeded in placing 8,210 men and women in suitable work. The council expresses its regret at the lack of success which has attended its efforts to obtain substantial increases in the basic pension rate for disabled ex-Service men and women, and in pensions for war widows.

Short time had to be introduced by the Rover Company, Limited, at their works at Solihull, Birmingham, during the past week, owing to the lack of sufficient supplies of steel. Most of the firm's employees worked only a three-day week. An announcement issued by the Rover Company stated that the present steel-supply difficulty was temporary and that it was expected that full-time employment would be resumed as from next Monday.

A team of fuel experts, under the leadership of Mr. W. L. Boon, Powell Duffryn Technical Services Limited, is due to leave Britain for New York on January 31, to study methods employed in the United States for the conservation of fuel supplies. The team is being sponsored by the Anglo-American Council on Productivity and is expected to stay in the United States for about two months, during which period it will visit a number of industrial centres, in order to pursue its investigations into the causes and remedies of fuel wastage. Representatives of the engineering, cotton, woollen, heating and ventilating, brewing, chemical and paper industries, the British Coal Utilisation Research Association, the Institute of Cost and Works Accountants, and the Trades Union Congress are included in the team.

The Industrial Disputes Tribunal met in London on Monday last to consider the dispute concerning lightermen employed in the Port of London, which had been recently referred to the Tribunal for arbitration. Evidence for both the employers and the union is understood to have been presented to the Tribunal but the hearing was held in private. The decision is expected to be published in the course of the next few days and will be binding on the two parties concerned, the Association of Master Lightermen, and the Watermen, Lightermen, Tugmen and Bargemen's Union. It may be recalled that difficulties which arose with the employers over the union's claims for increased pay led to go-slow action on the men's part and to their refusal to work overtime. As a result of this, there was considerable dislocation of the work of the port during several weeks preceding Christmas.

SHORTCOMINGS OF STRUCTURAL ANALYSIS.

Fig. 1. BENDING AND TORSIONAL STRESSES IN STEEL BEAM.

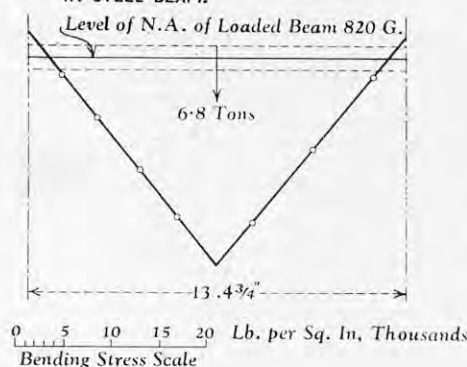
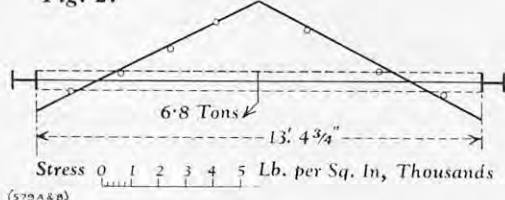


Fig. 2.



SHORTCOMINGS OF STRUCTURAL ANALYSIS.*

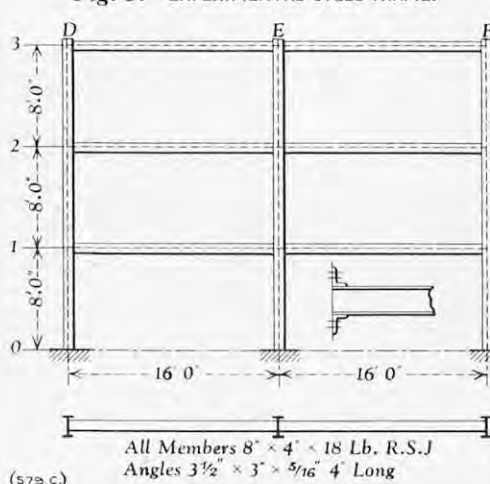
By PROFESSOR J. F. BAKER, O.B.E., M.A., Sc.D.

A MEMORIAL lecture, to be complete and satisfactory, must deal with a subject not only of value in itself, but linked in some way with the distinguished man who is to be remembered. It is my misfortune that, though I served the first part of my apprenticeship in a shipyard, I soon deserted the sea-going ship for the airship. However, what I lack in experience in the field to which Andrew Laing made such memorable contributions I make up in enthusiasm and admiration. Though this lecture will not deal with Laing's own work, I like to think that, as he was not merely a theorist but a great creator and practical man, the subject would have appealed to him.

A great deal of nonsense has been written in the past 75 years about the gap between theory and practice. The engineer whose business it is to create, to make something, is essentially a practical man, but this does not mean that he is not interested in the scientific aspect of his subject or in theory. In the early, less complicated, days the engineer was his own research worker; there was then no conflict between theory and practice, because it was the so-called practical man who was urgently deriving and checking theories which would enable him to press on with greater works more quickly than simple empirical methods would allow. In general, the engineer is not afraid of mathematical analysis, and the practical man often surprises his academic colleagues by the touching faith he has in the results of elaborate calculations based on doubtful assumptions. In such cases, there is not any strife between theory and practice; rather the practical man has been hoodwinked or is hoodwinking himself by the unjustified application of theory. It is this state of affairs in the realm of structural analysis and design which I wish to discuss.

During the past 20 years, greater advances have been made in the elastic stress analysis of structures than in any other branch of applied mechanics. Before that time it was possible, and then only with great labour, to deal with a structure of not more than about twelve degrees of redundancy, so that the primary and secondary stresses in most practical structures could not be determined. Now there are virtually no insoluble theoretical problems, and engineers are quite prepared to undertake elaborate calculations of the stresses in their structures as a check on design. The question to be considered is how far this application of advanced theory is justifiable. It must be understood that the methods used in proportioning the members of the structure in the original design are not under discussion. They are, in many cases, for redundant structures, so crude as to defy justification; but it is extremely difficult to substitute, for any but the least complicated forms of structure, rational methods which are yet simple enough to be practicable. The designer, by the use of these crude methods, or by intuition, has designed his structure; he may

Fig. 3. EXPERIMENTAL STEEL FRAME.



then, where the undertaking is important enough, carry out a stress analysis and will be prepared on the evidence of the results obtained to modify the structure.

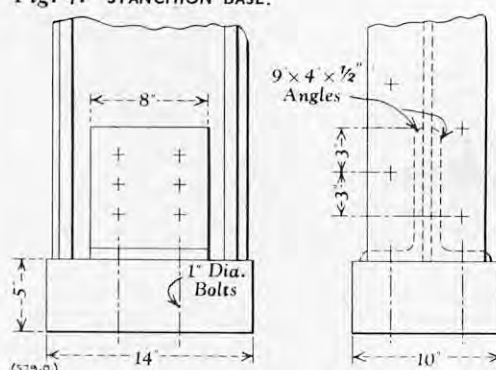
If, in these 20 years, advances had been made in mathematical analysis alone, it would not be easy to examine the question that has been posed. Fortunately, experimental methods have also advanced, so some data are available of the strains in actual full-scale structures from which observed stresses can be deduced to compare with those calculated. These experimental data cannot be obtained reliably from tests of small-scale model structures, since such models are likely to be idealised owing to the difficulty of reproducing on the small scale all practical details. Small-scale structures can often be tested usefully to provide a mechanical analysis of stresses more economically even than modern mathematical methods allow, but it must be remembered that one cannot get out in the answer more than one put in when stating the problem. If, as is inevitable, simplifications have been made in constructing the model, then the results are affected just as they are by the usual simplifying assumptions which make a mathematical analysis possible. In comparing calculated and observed stresses, it is the effect of these simplifying assumptions that are in question and so model results cannot be used.

The simple elastic theory can be depended upon to give values, sufficiently accurate for design purposes, of the stresses due to any load system in members of a structure in which the characteristics of the connections are known, the members are without imperfections and perfectly straight, or, if initially curved, where the magnitude of the curvature is known. Elastic analysis can give, therefore, for an existing structure in which departures from straightness and the characteristics of connections can be measured, an accurate estimate of what are often called the primary and secondary stresses. Measuring the departure from straightness and the characteristics of the connections, etc., is virtually impracticable because of its cost, and has only rarely been done. It is, in any case, a useless suggestion to make to the designer, because he cannot afford to build his structure, make the measurements, carry out his refined analysis and then modify his structure if the results are unsatisfactory.

One thing that always delights me is the accurate results obtained by making use of Bernoulli's simple assumption that, in a beam, a plane cross-section at right angles to the plane of bending before strain remains plane after strain. Fig. 1, herewith, shows the bending stresses deduced with the use of this assumption from the observed longitudinal strains in the flanges of a 10 in. by 4 1/2 in. joist, subjected to a central concentrated point load. It will be seen, from the way the observed points lie so close to the straight lines representing the calculated stresses, how reliable the assumption is. However, all was not quite as well as it appears in this beam, because, though the load was placed as carefully as possible over the centre-line, there must have been some eccentricity, because longitudinal stresses due to torsion were detected as shown in Fig. 2. These torsional stresses, which were just 10 per cent. of the bending stresses, would not have appeared in any normal analysis.

This is something of a digression. The stresses in a structure can only be determined accurately at sections not in the immediate neighbourhood of joints or applied loads because, in the stress analysis of structures, we always rely on St. Venant's principle, which states that forces applied at one part of an elastic structure will induce stresses which, except in a region close to that part, will depend almost entirely upon their resultant action and very little upon their

Fig. 4. STANCHION BASE.



distribution; or more crudely, that at the points of application of loads, at supports and at joints, there are concentrations of stress and irregularities of stress distribution sensitive to small differences in the conditions at these points, but that, at distances equal to about the depth of the member, the effects of the small differences disappear and the stress distribution depends only on the resultant action, the bending moment, shear force, etc. We rely on St. Venant's principle and usually ignore what happens close to the joint or load, because it is far too laborious and difficult to do anything else; but this must not blind us to the fact that the local or tertiary stresses at these places are apt to be high, and that at them also the primary and secondary stresses often have their greatest values. Forgetting, for the moment, these tertiary or local stresses, it can be said again that the power of analysing primary and secondary stresses is of little use to the engineer faced with designing a structure by a permissible-stress method, because, before it is designed, the characteristics of the connections and the imperfections of the members will not be known.

This statement needs support. It can be obtained from an examination of the elastic stresses developed in a real structure. My first example is the straight-forward case of a two-bay three-storey steel frame made up of the same 8 in. by 4 in. by 18 lb. I-section throughout (Fig. 3), the feet of the three stanchions being firmly fixed in a concrete slab and the beams being connected to the webs of the stanchions by means of the familiar stool and top cleat connections made up of 3 1/2 in. by 3 in. by 5/16 in. angle, 4 in. long, bolted to the members with 1/2 in. black bolts. This structure was subjected to a concentrated vertical load of 2 tons, applied to the centre of each beam in turn, and strain measurements were made at sections some distance from the connections to avoid local stress concentrations, so that the maximum longitudinal fibre stresses due to the bending of the stanchions in the plane of the frame could be deduced from the observations. The structure was, of course, built to be symmetrical about the stanchion E. It was to be expected, therefore, that the stresses in that stanchion would be the same whether beams DE or EF were loaded. This was not found to be the case.

The stresses at the ends of the stanchion lengths are shown in Table I, on page 58. The most striking differences occur at sections E₂E₁ and E₂E₃ where, when the load was on beam D₂E₂, the stresses were 5,130 lb. and 5,220 lb. per square inch, whereas, when the load was on beam E₂F₂, they were 3,300 lb. and 3,550 lb. per square inch. An investigator's first suspicions in such circumstances are directed at his strain readings; no strain measurement made on a full-scale structure should be accepted uncorroborated. Any strain gauge or extensometer will give readings under any conditions and they must be suspect until they are found to satisfy, within a certain acceptable limit of accuracy, all the checks of equilibrium which can be applied to the structure. One cannot urge too strongly, in these days of that attractive and apparently simple instrument, the electric-resistance strain gauge, the need for caution in accepting the evidence of strain readings. While it is justifiable, perhaps, under most carefully controlled conditions in the laboratory, to accept on its face value the measurement of strain at a single position, the difficulties met with in testing full-scale structures under service conditions are such that gauges which are self-compensating for temperature should be used wherever possible; groups of a sufficient number of gauges should be arranged at each section of a member where stresses are to be measured so that there is a check on the accuracy of the measurements; and, even then, the results should not be taken too seriously unless sufficient sections have been chosen round each joint to check the equilibrium of that joint and in each member to check the equilibrium of the member.

* The 20th Andrew Laing Memorial Lecture, delivered before the North-East Coast Institution of Engineers and Shipbuilders in Newcastle-upon-Tyne on Friday, November 9, 1951. Abridged.

The observed stresses quoted in Table I satisfied all the checks of equilibrium to within 100 lb. per square inch, and so were deemed to be accurate to that limit. It was suspected that the discrepancies were due to slight differences in the behaviour of the beam-to-stanchion connections arising from practical imperfections. This was verified by the laborious process of measuring the actual characteristics of the connections and carrying out an elaborate analysis allowing for them, the results of which agreed closely with the observed stresses.

No special precautions had been taken in erecting this apparently symmetrical frame, so it was decided to re-erect it as before, using the same connections but having the bolts all tightened by the same erector, using a 10-in. spanner. The results, shown in Table II, herewith, are even more alarming. While there is now fair agreement in the greatest stresses due to loads on beams D_2E_2 and E_2F_2 , those produced by loading beams D_1E_1 and E_1F_1 , which were satisfactory in the first test, fail to agree. While, in the first test, the greatest percentage difference was 55.5 per cent., it has now risen to 138 per cent. To see what improvement could be obtained under most carefully controlled conditions, the frame was re-erected with entirely new bolts and cleats, and a special spanner was made which would tighten the $\frac{1}{2}$ -in. bolts with a torque of 600 lb.-in. to within 5 per cent. Even with these quite impracticable refinements, differences of the order of 25 per cent. were observed in the greatest bending stresses.

Similar discrepancies have been observed when testing actual building structures. A particularly straightforward case was found when investigating the behaviour of the Cumberland Hotel, London. A single-bay frame there appeared to be symmetrical in every way. When symmetrical loads were applied to the beam, however, the bending stresses in the two stanchions were not the same, the discrepancies at different floor levels varying from 4 to 30 per cent. Here again they arose almost certainly from differences in the apparently identical beam-to-stanchion connections.

An example of the other kind of shortcoming in elastic analysis, the high and uncalculated stress near a support, was also found in testing this particular frame in the Cumberland Hotel. As shown in Fig. 4, on page 57, the squared end of each stanchion was held down to a 14-in. by 10-in. steel slab, 5 in. thick, by four 1-in. bolts. The stanchion was a 12-in. by 8-in. B.S.B., with 8-in. by $\frac{5}{8}$ -in. flange plates. Four strain gauges were attached, one at each corner of the stanchion, at such a distance, 12 $\frac{3}{4}$ in. above the top surface of the slab, that there was reasonable expectation that St. Venant's principle would be obeyed. A load was applied to a beam in the structure, subjecting the stanchion to an axial load and some bending about its major or XX axis, and strain measurements were made. The observed stresses deduced from these measurements are shown in column 2, Table III (a). It will be seen that the stress at one corner, K_1 , of the stanchion was 17 times as great as at any other corner. This was, to say the least, unexpected. It was usual, in these tests, to split the observed stresses into their component parts due to axial load, and bending about both axes, on the assumption that plane sections remain plane. This was done here, and the values are shown in cols. 3, 4 and 5 with, in col. 6, a stress which could be the longitudinal stress due to torsion, but, since there could have been no appreciable torsion in this particular stanchion, would, therefore, be a measure of the accuracy of the strain-gauge readings. This "distribution error," as it is called, is unusually high at 426 lb. per square inch. At no other of the six sections where strains were measured in this test did it rise above 66 lb. per square inch.

This is a clear indication that one of the strain-gauge readings was in serious error, or that plane sections were not remaining plane. This last condition could, of course, be brought about by a stress concentration such as would be induced were the stanchion standing on only one corner. An examination of the stanchion base showed that the holding-down bolts had not been screwed home as far as they might have been. The test was therefore repeated after the bolts had been tightened, and after an entirely new set of strain gauges had been attached at the section K to eliminate, as far as possible, the possibility of a faulty gauge. The results are shown in Table III (b). It will be seen that the pattern of the distribution is the same as before, though admittedly the greatest stress has been reduced from 1,700 lb. to 1,478 lb. per square inch. Since new gauges had been used, there is very little doubt that the original stress, many times as great as calculation would have revealed, was due to a stress concentration at the support. This conclusion is borne out by a later test, made after the reinforced-concrete floors of the building had been poured, but the stanchions were still bare. The observed stresses due to an additional load applied to the structure are shown in Table III (c). It will be seen that the distribution is

quite normal and the "distribution error" is only 86 lb. per square inch. What had happened, of course, was that the great weight of the concrete floors in this seven-storey structure had been enough to produce plastic flow in the base of the stanchion, so that it bedded down completely. Though the stresses shown in Table III (c), due to the additional load, were small and orthodox, the fact remains that the yield stress must have already been developed at the foot of the stanchion.

Many of the discrepancies in the stresses in the framed structures to which reference has just been made can be blamed on the vagaries of fairly flexible riveted or bolted beam-to-stanchion connections. An obvious way of avoiding them, it might be thought, would be to use rigid connections. Owing to the difficulty of making stiff riveted joints, rigid connections to-day are almost synonymous with welded connections. Even with these, a perfectly rigid joint is not easily obtained, as will be shown later, but where we are considering a construction which will make the stresses under working conditions close to those given by design calculations, welding adds a different but very considerable complication. This is because, by the very nature of the process, residual stresses and reaction stresses are introduced. Many investigators, not least among them H. E. Lance Martin, who published his results in your *Transactions* as long ago as 1937,* have determined the magnitudes of the strains

welding, which seems to me the rational method of fabricating structures. It must be remembered that residual stresses are also developed in the production of rolled-steel joists by cold straightening or bending, punching, machining and similar processes, so they are likely to be found in all steel structures. Though more prominence has been given to their presence in welded fabrication, there is probably little to choose in this respect between riveted or bolted and welded structures.

Let us consider now another form of structure, the ship, which will doubtless be of greater interest to many of you. Since the ship is nothing more than a beam, it is not surprising to find that the longitudinal stresses observed agree reasonably well with those calculated by the conventional beam theory. This can be seen from Fig. 5, opposite, which gives, compared with the calculated, the longitudinal stresses due to a hogging bending moment observed in the still-water trials on the m.v. Newcomb, conducted some years ago for the Admiralty Ship Welding Committee. This diagram does not show the greatest stress at each point in the cross-section, but merely the heart-of-plate stresses deduced from the skin strains measured; even these show fairly marked discrepancies in the longitudinal bulkhead. To these heart-of-plate stresses must be added the local bending stresses which, in the Newcomb, amounted to as much as 13 tons per square inch on the starboard longitudinal bulkhead, i.e., an additional stress much greater than the heart-

TABLE I.—OBSERVED BENDING STRESSES (LB. PER SQ. IN.) IN CENTRE STANCHION OF FIRST TWO-BAY FRAME FITTED WITH TYPE "A" CONNECTIONS; CONCENTRATED LOAD OF 2 TONS AT CENTRE OF EACH BEAM IN TURN.

Section.	Beam D_1E_1 Loaded.	Beam E_1F_1 Loaded.	Beam D_2E_2 Loaded.	Beam E_2F_2 Loaded.	Beam D_3E_3 Loaded.	Beam E_3F_3 Loaded.
E_0E_1	+ 2,250	— 2,730	— 300	+ 400	— 50	— 60
E_1E_0	— 4,150	+ 4,700	+ 550	— 550	— 60	+ 150
E_1E_2	+ 3,930	— 4,450	+ 2,500	— 2,175	— 275	+ 240
E_2E_1	— 2,150	+ 2,300	— 5,130	+ 3,300	+ 800	— 650
E_2E_3	— 530	+ 600	+ 5,220	— 3,550	+ 3,280	— 3,300
E_3E_2	+ 150	— 250	— 2,180	+ 2,200	— 6,360	+ 6,120

TABLE II.—Observed Bending Stresses (lb. per sq. in.) in Centre Stanchion of Second Two-Bay Frame Fitted with Type "A" Connections; Concentrated Load of 2 tons at Centre of Each Beam in Turn.

Section.	Beam D_1E_1 Loaded.	Beam E_1F_1 Loaded.	Beam D_2E_2 Loaded.	Beam E_2F_2 Loaded.
E_0E_1	+ 2,400	— 2,300	—	—
E_1E_0	— 2,510	+ 4,660	—	—
E_1E_2	+ 2,000	— 4,760	+ 2,350	— 1,490
E_2E_1	— 1,700	+ 2,200	— 3,200	+ 3,040
E_2E_3	—	—	+ 2,340	— 2,980
E_3E_2	—	—	— 1,380	+ 1,410

TABLE III.—Observed Stresses (lb. per sq. in.) at Section Above Stanchion Base.

Position of Gauges.	Observed Stress.	Probable Distribution.			Distribution Error.
		Axial Stress.	Bending Stress (about XX).	Bending Stress (about YY).	
(a) 12 $\frac{3}{4}$ in. above top surface of slab	K_1 — 1,700 K_2 + 100 K_3 + 93 K_4 0	— 377	— 424	— 474	426
(b) 12 $\frac{3}{4}$ in. above top surface of slab	K_1 — 1,478 K_2 — 419 K_3 + 228 K_4 — 45	— 428	— 520	— 333	197
(c) 12 $\frac{3}{4}$ in. above top surface of slab	K_1 — 46 K_2 — 141 K_3 — 183 K_4 — 429	— 200	+ 106	— 38	86

due to welding, and it is now generally recognised that the sum of reaction stresses and residual stresses will normally reach the yield point stress of the parent material in the vicinity of the weld, even if the rigidity of restraint is not very severe. It is justifiable to assume, therefore, that the yield stress has been reached in the welded joints of all structures before any external load system has been applied. In saying this, it is not my intention to bring any discredit on

of-plate stress. On top of all these, there were, of course, stress concentrations round hatch openings and elsewhere, the concentration factor, i.e., the ratio of observed to beam theory stress, varying from about 1.6 to 1.3. These ratios are relatively small. In other ships there are records of stress concentrations due to structural discontinuities of the order of 2.5 to 3.0. Nominal stresses exceeding 5 tons per square inch are to be expected at sea under certain conditions of loading, so it is clear that high additional stresses may be present. Even in the ship, therefore, the simple elastic theory gives only a fair estimate of the heart-of-plate stresses due to changes in load, and gives no real indication of the total stresses due to change in load. It must also be remembered that, before any loads are applied, the ship structure, like most others, will have reached the yield stress of the material at many critical points, due to the presence of residual and reaction stresses. Measurements of residual stresses in a welded tanker during construction, recently reported to the Chesapeake Section of the Society of Naval Architects and Marine Engineers, New York, showed the existence of stresses of the order of 8 tons per square inch at points far removed from any weld.

These few isolated examples do not provide conclusive evidence of the uselessness of elastic analysis as an aid to the designer, but they are typical of the great mass of data which is available and which has convinced me that, so sensitive is the redundant structure in the elastic range to small imperfections and variations inevitable in practice, that the designer is wasting his time when he embarks on an elaborate elastic analysis. This is on the assumption that the designer's aim, as is usually the case, is to produce a structure in which a permissible stress, less than the yield stress of the material, is not exceeded. Many designers will say that they are not interested in elaborate analysis, that if they are designing building structures, for instance, they merely use the method of stress calculation implied and work to the stresses given in British Standard Specification No. 449, though they know that these do not represent at all accurately the real stress distribution in the structure. This is a satisfactory retort as far as it goes. Working to B.S.S. 449 certainly produces safe building structures, but it does not cover all forms and it does not permit any advance in our art. To improve the design of orthodox forms of structure and to develop new forms, the engineer has been driven to elaborate elastic analysis because he had nothing else to guide him. My conclusion is that the elastic behaviour of practical structures is too complex and variable to enable the designer to make any real advance by this means.

This conclusion would be depressing if the engineer

* "The Determination of the Residual Strains and Stresses in Arc-Welded Plates," vol. 53.

SHORTCOMINGS OF STRUCTURAL ANALYSIS.

Fig. 5. OBSERVED AND CALCULATED STRESSES IN M.V. "NEWCOMBIA".

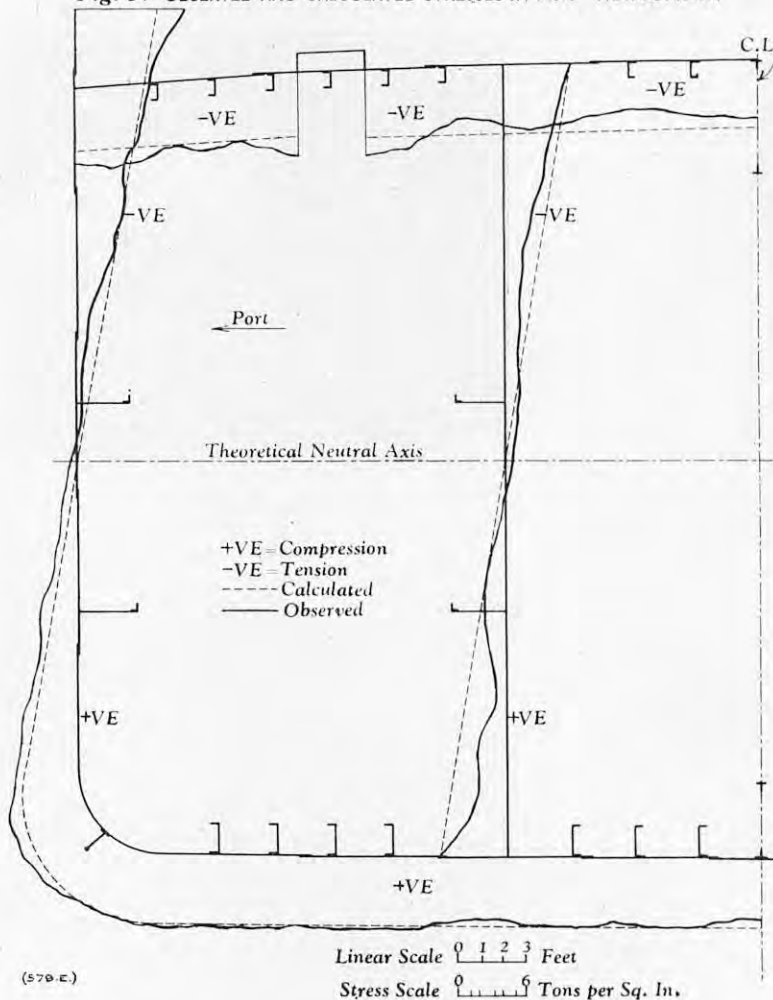


Fig. 6. BENDING AND DEFLECTION OF BEAMS.

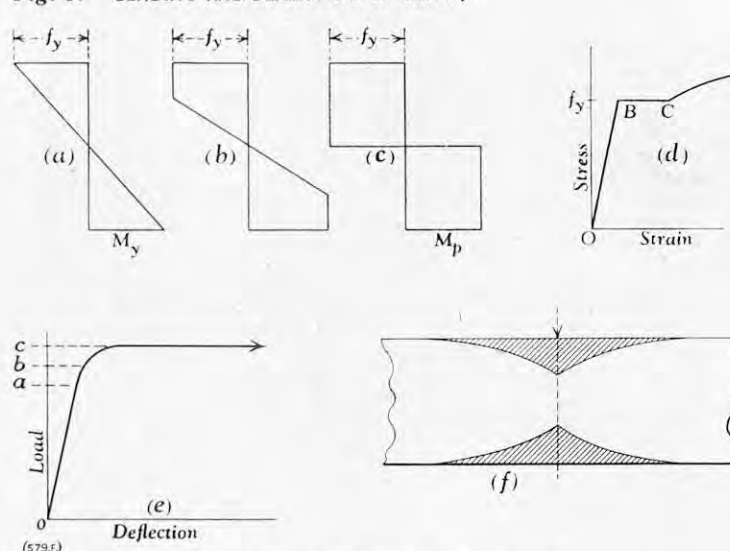
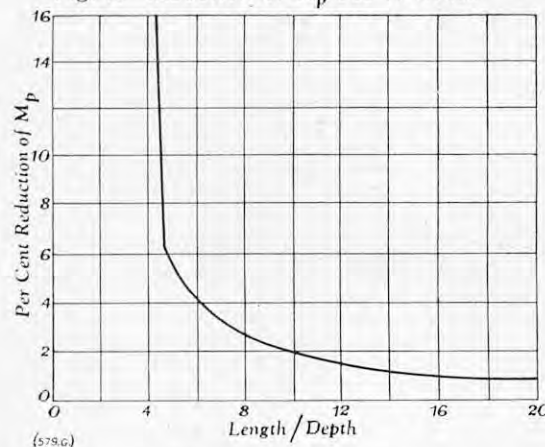
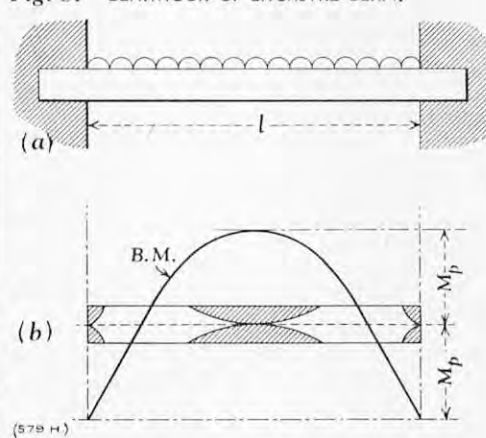
Fig. 7. REDUCTION OF M_p DUE TO SHEAR.

Fig. 8. BEHAVIOUR OF ENCASTRE BEAM.



The stress distribution in Fig. 6 (c) corresponds to theoretically infinite curvature and, therefore, when the full plastic moment has been reached at any section of a simply supported beam, the deflections become indefinitely large, as shown in Fig. 6 (e), and collapse is said to occur, though, if the load were reduced a little, it could be supported quite safely.

It may be clearer if we consider here what happens to a simply supported beam carrying a central concentrated load. As the load is increased to a value a , Fig. 6 (e), the load-deflection curve is linear. The yield stress is developed at the centre of the beam under this load a . As further load b is added yield penetrates up and down into the section, as in Fig. 6 (b), and also along the beam, forming the plastic zones seen in Fig. 6 (f), which is a side view of the central portion of the beam. The beam can support additional load until these plastic zones meet, the bending stress diagram at the centre of the beam then being as in Fig. 6 (c), when a plastic hinge forms at the centre of the beam. It is like a rusty hinge, since the full plastic moment is maintained while the deflections and rotations grow large and this is, of course, the essential part of the phenomenon. We know that this picture of what happens under a concentrated load is over-

simplified, since the effect of shear, among other things, has been neglected; but it has not been so simplified as to be misleading, and the useful conception of the plastic hinge is justified. It may be of interest to point out that the effect of shear in reducing the value of the full plastic moment, shown in Fig. 7 for an 8 in. by 4 in. joist subjected to a central concentrated load, is small except for very short beams. Thus, for a beam 5 ft. long, the reduction is only just over 2 per cent.

If the ends of the beam are *encastré*, collapse cannot occur until the beam has become a mechanism by the formation of three plastic hinges, that is, until the fully plastic moment has been reached at three sections. Consider a fixed-ended beam subjected to a uniformly distributed load, Fig. 8 (a); in the elastic range the bending moments at the ends will be twice that at the centre, so that yielding will begin at the ends of the beam. As the load is increased, zones of yielded material will develop at the ends of the beam until full plasticity has been reached at the end sections. As the load is further increased, the end bending moments will remain constant at the full plastic value M_p , and, at a certain stage, yield will occur at the centre. At the same time, relative rotations will take place between the ends of the beam and the rigid supports. Collapse will finally occur when the central section also becomes fully plastic, and the bending-moment diagram and the approximate extent of the zones will be as shown in Fig. 8 (b). It is easy to deduce from this last figure that, whatever the cross-section of this uniform beam, the load causing collapse is one-third as much as that which produced the first yield at the ends of the beam. Elastic-design methods, therefore, do not take advantage of the full additional strength obtained from end fixity. It follows that, if there are two beams in a structure, one simply supported and one *encastré*, both designed by the usual working-stress method for the same design load, then the latter will be capable of carrying one-third more load before collapse than the former. For static loads, when strength is the design criterion, this is indefensible. If the load factor, that is to say the ratio of the load causing collapse to the design load, enjoyed by the simply supported beam is adequate, why should it not be used for the *encastré* beam with a resultant economy of material?

(To be continued.)

had no other means than elastic analysis of determining the strength of his structure. Fortunately, while it is impossible to determine accurately the load which a structure can carry without exceeding somewhere a permissible stress, it is possible, in the case of structures made of a ductile material, such as mild steel, to determine with surprising accuracy the real strength of a structure, that is, the load at which it will fail or develop embarrassingly large deflections. This is possible by admitting and taking full account of the plastic behaviour of the material. To enable the engineer to make his calculations, a simple plastic theory of bending has been developed. I had the privilege of presenting to you ten years ago a paper on this subject (*Transactions*, vol. 57).

The theory is nothing more than an extension of the simple elastic theory, according to which the longitudinal stress distribution across any section of a beam, acted upon by a pure bending moment, takes the form shown in Fig. 6 (a). This theory holds for all bending moments less than the yield moment M_y under which the yield stress of the material is reached in the extreme fibres. The beam is capable of sustaining a bending moment greater than M_y , but, to deduce the corresponding stress distribution, it is necessary to consider the nature of the stress-strain relationship of the material beyond the yield point. This depends on the composition and history of the steel, but, for structural mild steel in general, the curve shown in Fig. 6 (d) is a sufficiently close approximation. After yield at B, there is a range BC of pure plastic deformation with no increase of stress, until strain-hardening occurs at C at a strain of from 8 to 20 times the strain at yield. The pure plastic range BC is usually sufficient to enable considerable deformations to take place before strain hardening has any significant effect. It is therefore reasonable to assume that, after the yield stress has been reached in any fibre of a beam under increasing bending moment, the stress in the fibre will remain constant. After this process has been carried some depth into the beam, the stress distribution will therefore be as shown in Fig. 6 (b), which corresponds to a moment of resistance somewhat greater than the yield moment M_y . The maximum moment of resistance is obtained when the whole section has been strained beyond the yield point (Fig. 6 (c)), its value then being referred to as the full plastic moment, M_p .

VERTICAL-SPINDLE DEEP-WELL PUMP.

RUSTON AND HORNSBY, LIMITED, LINCOLN.

Fig. 1.

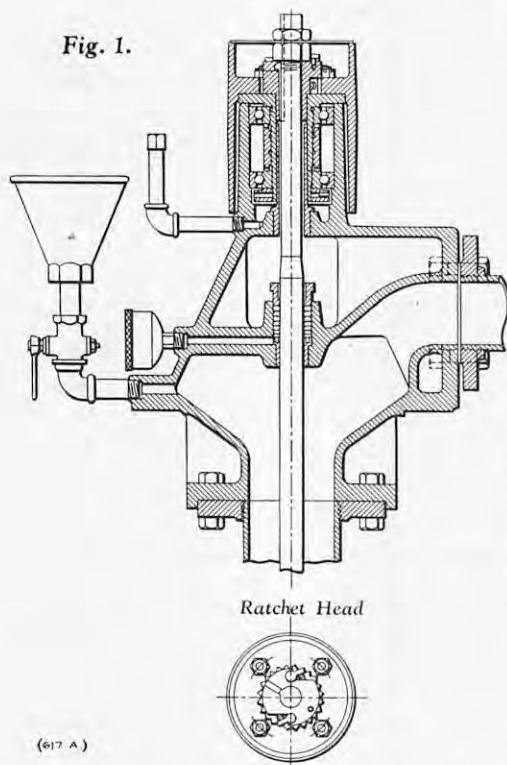


Fig. 2.

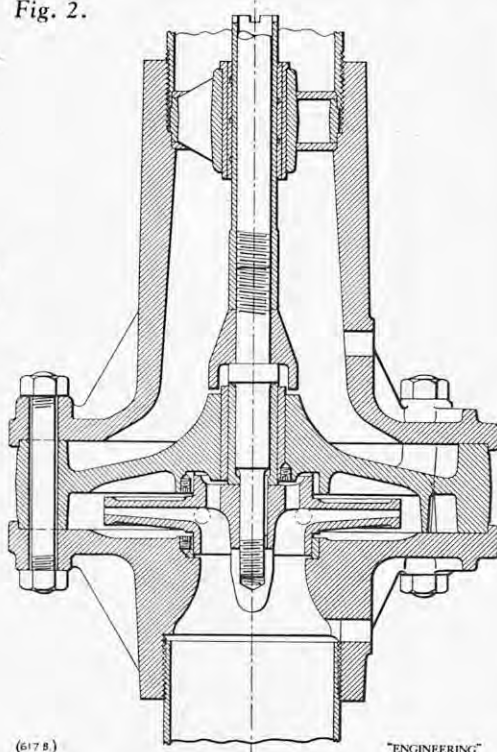


Fig. 3.

VERTICAL-SPINDLE DEEP-WELL PUMPS.

IN many agricultural districts, there is a growing demand for engine-driven deep-well pumps for irrigation purposes. To meet this need, Messrs. Ruston and Hornsby, Limited, Lincoln, have introduced their CU type of deep-well pump, a vertical-spindle engine-driven unit designed to operate at depths down to 120 ft. from well head to water level. To render the pump suitable for operation by unskilled labour, the design has been made as simple as practicable; and to reduce manufacturing costs and, at the same time, increase production, only one size of pump is being made. It is illustrated in Figs. 1 to 3, herewith.

There are four main units, namely, the delivery head, which incorporates the pulley drive and supports the complete assembly; a delivery rising column, together with the vertical driving shaft; the pump, which is suspended from the delivery rising column; and the suction pipe, terminating in either a bell mouth and strainer or a foot valve and strainer. A sectional elevation of the delivery head is reproduced in Fig. 1. As, in addition to the delivery branch, it has also to support the hanging weight of the stationary and revolving parts, while being sufficiently rigid to withstand the belt pull, the body, which is an iron casting, is exceptionally robust. It includes an extension for the driving head, which is fitted with two ball races. The top ball bearing is of the journal type for carrying the belt loading, and the bottom bearing, of the thrust type, carries all the hanging weight. They are kept apart by a distance piece or sleeve, in the base of which is machined a helical groove to convey lubricant from the oil reservoir to the top bearing. The pulley encloses the driving head and its ball bearings. Its inner bore is serrated and the sleeve which transmits the drive from the pulley to the delivery shaft is fitted with spring-loaded pawls to ensure that the drive is unidirectional, thus avoiding any risk of loosening the screwed joints in the vertical driving shaft. The drive is transmitted from the sleeve to the shaft through a 9-in. gib-head key and the weight of the driving shaft, pump impeller, etc., is transferred to the sleeve by an adjusting nut threaded on to the end of the shaft. This is locked in the required position by means of a tab-washer, and the cover over the top of the pulley is held in position by a lock nut. A stuffing box is situated below the bearing housing and is provided with a grease-lubricated bush.

The delivery rising column terminates with a short flanged portion which is bolted to the underside of the delivery head. The riser itself is made from heavy-section pipe to British Standard Specification No. 534. The bore is 4 in. and the pipe is supplied in standard lengths of 10 ft., each section being machined at its ends to receive a bearing spider to steady the driving shaft. The steel shaft, like the riser, is supplied in standard lengths of 10 ft. which are joined together by

sockets, the ends of the separate sections being threaded. To ensure that adjacent lengths of shaft abut correctly, the ends are machined square and holes are drilled for a short distance down both ends of each shaft to provide a space into which the trapped air can be compressed. The coupling sleeves are machined from stainless steel and the complete shaft is located centrally within the riser by a series of Cutless rubber bearings fitted in bronze spiders, which, as previously indicated, fit between the sections of the riser. Rotation of the pump is anti-clockwise when viewed from above; therefore, the joints for the riser have right-hand threads and those for the driving shaft, left-hand threads, so that the tendency is for all joints to be tightened when the pump is at work.

The pump is of the single-stage impeller type, with a diffuser to direct the peripheral discharge from the impeller into the rising main. The body of the pump is in three parts which, with the impeller, are machined from iron castings. Renewable bronze rings are fitted into the pump body at the eye of the impeller and round the balance piston on the upper side of it. Lengths of 4-in. steel pipe form the suction pipe, the entry of which is located as close as practicable to the bottom of the well. Pumps arranged 60 ft. or less below ground level operate satisfactorily with a combined bell-mouth and strainer, but for 70 ft. or over it is desirable to provide a foot-valve and strainer. Provided that the bearings are thoroughly wetted before starting, the water rises at a sufficiently high rate in a 60-ft. system to submerge them before damage occurs. At depths greater than 60 ft., however, the bearings may dry out before being submerged and the makers therefore recommend that the whole of the rising column should be filled with water before starting. For this purpose, a funnel is fitted on the delivery head and connected to the riser by suitable piping and a shut-off cock, as shown in Fig. 1. As the use of a foot-valve on a column of water up to 120 ft. high may cause shock on closing if an ordinary valve is used, the foot-valve used with these pumps incorporates a dash-pot type of baffle to minimise this risk. Iron castings are used for the bell-mouth, valve body and valve plate, but the valve and its seat are made from bronze with a rubber insert. The strainer is fabricated from steel and is galvanised as a protection against corrosion.

The unit is easy to install in the well, the only extra equipment needed being a set of shear legs and lifting tackle capable of carrying a load of 30 cwt. and a pair of clamps. Tests have shown that it takes from 20 to 30 minutes to add one section, and pumps of this type have been erected and lowered on to prepared foundations in one day. The pumps are usually driven by an oil engine through a 90-deg. belt drive, as shown in Fig. 3, but other prime movers may be used. They have been designated the 3CU well pumps, with a suffix according to the depth at which they work; a 3CU120 pump, for instance, is capable of

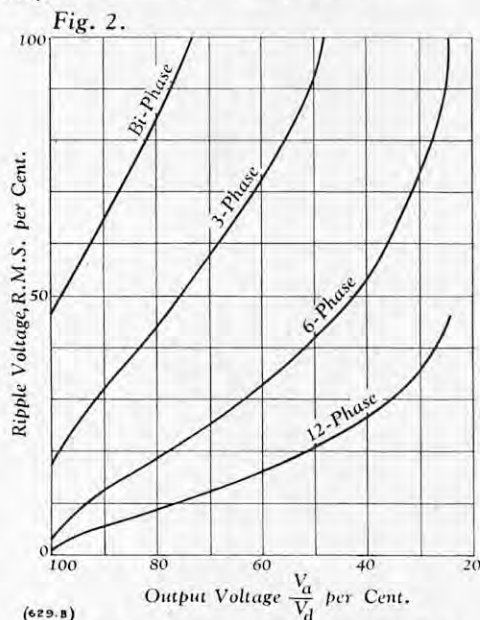
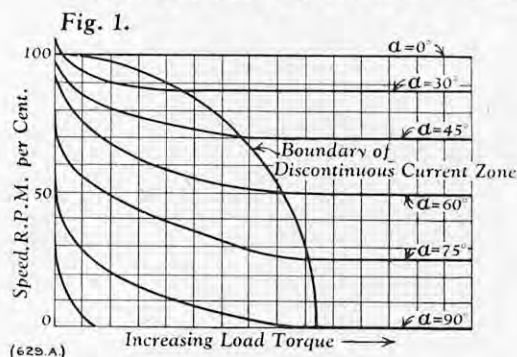
working at depths down to 120 ft. Performance varies according to the duty and speed of operation, but if the water level, for example, is 58 ft. below the ground, and the speed 3,100 r.p.m., then the 3CU50 pump will deliver 194 gallons per minute, the 3CU80, 176 gallons per minute and the 3CU120 pump, 167 gallons per minute. The corresponding outputs at 2,800 r.p.m. are 164 gallons, 149 gallons and 135 gallons per minute, respectively.

During prolonged trials, it was established that the power loss usually attributed to mechanical losses in the bearings, and generally allowed for as a fixed brake horse-power at a given speed, is not strictly correct, as additional power has to be provided to cater for skin friction set up by the shaft whirling in the flow of water. This loss has been taken into account in assessing the sizes of engine for various duties. For the cases quoted above, that is, with the water level 55 ft. below the ground and a pump speed of 3,100 r.p.m., the horse-powers required to drive the 3CU50, 3CU80 and 3CU120 pumps are 16.6 h.p., 17.4 h.p. and 18.3 h.p., respectively. Although it is not expected that these pumps will be widely used for purposes other than irrigation, they are equally suitable for elevating water to storage tanks and similar duties. Simplicity has been the governing factor in the design, so that unskilled labour can be used both on erection and operation. They can deal with a considerable amount of sand and silt in suspension and, should wear occur in any of the moving parts, it is a simple matter to effect replacement; but they are not suitable for well sinking, being basically fresh-water units.

ELECTRICITY SUPPLY IN SCOTLAND.—The Secretary of State for Scotland (the Rt. Hon. J. Stuart, M.P.) has confirmed a scheme prepared by the North of Scotland Hydro-Electric Board for the erection of overhead transmission lines between new transforming stations at Strathleven, Dunbartonshire, and Kepeulloch, Stirlingshire. It will thus be possible to give a supply to the British Electricity Authority from the lines between Loch Sloy and Windyhill to meet the growing demands in the Dumbarton area and to augment supplies in Stirlingshire and other parts of Dunbartonshire.

DISTRIBUTION OF PETROL IN WEST AFRICA.—To improve petrol distribution in the French Northern Cameroons and the interior of Southern Nigeria, the Shell and Socony Vacuum oil companies have commenced work on a scheme which, when completed, will enable bulk supplies to be delivered instead of using drums. Trains of 200-ton capacity oil barges will be used in much the same manner as on the Mississippi, and the scheme calls for the construction of four new bulk-storage depots, one of which, namely that at Garoua in the Northern Cameroons, has been completed. The barges will be propelled by a twin-screw Diesel tug and three regular trips to Garoua will be made each year. The route will be from Apapa, near Lagos, along the coastal waterways to the River Niger and then up the River Benue to Garoua. Both the barges and the tug have been designed to cope with the conditions encountered on the Niger and Benue rivers; the Benue, for example, is only navigable by vessels having an unusually shallow draft and even then for only 2½ months each year. Operation of the barge train will be entrusted to the United Africa Co., Ltd., and the Diesel tug, which is being constructed on the Clyde, is due to sail out under its own power early this year.

RECTIFIER-MOTOR VARIABLE-SPEED DRIVES.



RECTIFIER-MOTOR VARIABLE-SPEED DRIVES.*

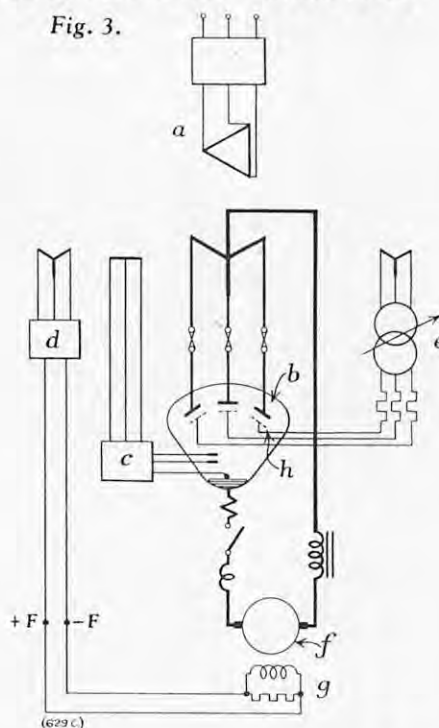
By P. BINGLEY.

THE special case of a mercury-arc rectifier feeding a load comprising resistance, inductance and back electromotive force has been analysed mathematically, but the absence of simpler treatment has retarded the development of rectifier-motor drives, except in the United States and in Sweden. The method is, however, of growing importance and the paper therefore deals with the construction of rectifiers and shunt-wound motors as a means of providing variable-speed drives for industrial machinery.

If the reasonably flat speed/torque curves required in the majority of applications are to be obtained, speed-control methods are limited to variation of the field current and of the applied armature voltage. When shunt-field control is used, speed ranges of about 3 to 1 are normal, but can be increased to about 6 to 1 by using special designs. Very wide speed ranges are also possible if armature voltage control is employed, with the proviso that, owing to reduced cooling at low speeds, the load torque which can be applied continuously is reduced, unless forced ventilation is provided.

With correct design, it is possible to obtain nearly flat voltage/current characteristics with free-firing and grid-controlled rectifiers between full load and light load, the slope of the curves corresponding to a regulation of about 6 per cent. lower. This figure can be improved if special consideration is given to the effect of short-circuits upon the equipment. Where the rectifier-transformer connection involves an inter-phase reactor, the rating of the latter is usually based on a normal triple-frequency electromotive force, equal to one quarter the phase-neutral voltage, the coil on each link carrying half the full-load current. With zero firing-delay, normal operation holds good until the load current falls to a transitional value, when the output voltage will rise sharply by some 15 per cent. If, however, the firing delay is not zero, the average value of the triple-frequency electromotive force across the ends of the reactor, and thus the transitional load value, will be increased. The result is that with a 30-deg. delay the rating of the reactor must be twice the normal value and under the worst conditions must be about 3.5 times that value. Nevertheless,

Fig. 3.



the usual transformer connection with a delta primary and a double-star secondary is the most advantageous owing to the less severe anode duty. Peak current values are halved and those of the root-mean-square current are about 30 per cent. less.

When the armature voltage is controlled by a rectifier in the primary circuit of the transformer of a free-firing rectifier the speed/torque curves only differ from those mentioned above in that the variation of the speed with the load will be slightly greater owing to the inherent regulation of the added equipment. The speed/torque characteristics of motors fed from grid-controlled rectifiers will also be the same for the higher torques, but for any particular speed setting there will be a critical value below which the speed of the motor will rise rapidly as the torque is further reduced. Fig. 1 shows a typical family of speed/torque curves for a rectifier-motor equipment operating without an inductor in the direct-current circuit, and with firing-delay angles α between 0 and 90 deg. This comparatively sudden change in performance occurs because the output current of the rectifier has changed from a continuous to a discontinuous state and the motor armature is being fed by a series of current pulses. Any inductance in the load circuit will, therefore, affect the voltage regulation of the equipment, as though it were present in the anode circuits.

Most analyses of rectifier operation assume an infinite inductance in the load circuit and that there will be no current ripple. These assumptions are not, however, valid for loads containing a finite inductance and a back electromotive force. The limiting condition for current continuity occurs when the peak value of the ripple current is equal to the average value of the load current. This condition is fulfilled when the difference between the extinction and firing angles (both measured from the commencement of the cycle) is equal to 2π divided by the number of phases per group in the rectifier system. The speed regulation of the motor will then be normal. In circuits with resistance only, the root-mean-square ripple voltages with different firing delay angles for various rectifier connections are shown in Fig. 2, where V_a is the mean output voltage of the rectifier with a firing delay angle α and V_d the mean output voltage with no firing delay, there being no smoothing and the effect of overlap being neglected. In this case a very limited useful speed range will result when equipment having the usual number of phases (three or six) is employed; and current discontinuity will occur when

$$\alpha_c = \frac{\pi}{2} - \frac{\pi}{p}$$

where α_c is the critical firing delay angle and p is the number of phases per group in the rectifier system. The addition of inductance to the circuit increases this critical angle, because the energy stored in the inductance forces the anodes to continue conducting after their potential has become negative with respect to the neutral point of the transformer winding from which they are fed.

If, however, a back electromotive force is present

in the load circuit, an anode, when released, may not always be able to conduct, since the average value of that force may be higher than the instantaneous value of the anode voltage. The output of the rectifier is therefore reduced if the back electromotive force rises. In most practical cases, the resistance of the load circuit is negligible and consideration of the back electromotive force and inductance will normally show whether or not the current will be continuous for a given set of conditions. Since the range of speeds and torques is fixed by the duty of the particular drive, the general problem is to decide the critical value of inductance that is necessary to ensure continuity over the working range. The rectifier connections can be varied to assist in this decision, but for most drives above about 15 h.p., six-phase connections are used until extremely large capacities are encountered. Bi-phase operation is rarely employed on account of the large values of inductance required, even with small speed ranges.

Many small horse-power drives, in which servo circuits are employed to obtain a constant preset speed, are designed to operate with a discontinuous armature current within the working speed range. The consequent inferior speed characteristics have been mitigated by automatically adjusting the firing points of the anodes to meet the load changes. When this form of control is employed, the value of the ripple current will be large compared with the steady direct-current and the motor must be designed accordingly. Since there is no reverse-current path through the rectifier the motor will be unable to exert a braking effect if the load-torque reverses and the armature terminal voltage may therefore rise to an undesirably high value. To counteract this, it is usual to switch a dummy load across the armature or to arrange the rectifier to operate as an inverter when regeneration commences. When the equipment is required to operate at temperatures below about 10 deg. C. it is usually necessary to take precautions against surges generated as a result of "ion deficiency." The transformer can be protected by connecting surge diverters to the rectifier anodes and the bulbs by heating the cathode pool and simultaneously controlling the forced ventilation. The field resistor may be used to provide additional heat for this purpose when the motor is not running; or a small quantity of argon can be introduced into the bulb after evacuation and before sealing. It is, however, difficult to gauge the amount of argon admitted and, unless this is done correctly, the liability to back-fire may be increased. It is also uncertain how long the argon will remain unabsorbed by the anodes. Suitable designs can only be prepared if a good knowledge of the characteristics of the drive is available. In particular, larger motors than are actually required should not be installed, as the lowest value of the torque will be less than anticipated and the size of the inductor will consequently be increased. A nearly constant torque over the working speed range is the condition most favourable to rectifier-motor equipments.

The simplest way of obtaining a supply at constant voltage to the motor field is to use selenium rectifiers fed from an auxiliary transformer or a tertiary winding on the rectifier transformer. Alternatively, a supply can be obtained from two or three field anodes in the rectifier bulb. The field can also be connected in the excitation circuit of the rectifier, but this necessitates the use of a non-standard motor; and there may be starting difficulties owing to the high inductance of the field. Where auxiliary anodes are used in the larger bulbs the cathode spot is liable to travel over the area of the pool, so that the length of the arc path may be suddenly doubled or trebled and instability result. If the total load of the field and the auxiliaries requiring a constant voltage is large, an auxiliary bulb is sometimes employed or a grid-controlled unit may be used. Either wire-wound shunt-discharge resistors or non-linear absorbers are included to provide a field-discharge path, while as a protection against field failure the coil of the main direct-current contactor is energised from the field supply, or a resistor is connected in series with the field to reduce the current until the main direct-current contactor has closed. The resistor is then by-passed by an auxiliary finger on the contactor. The commonest methods of varying the field current are either to employ a conventional regulator or a regulating transformer of the sliding-contact type. Less used are grid-controlled auxiliary anodes, a separate grid-controlled bulb or transductors connected in series with the alternating-current supply to the field rectifier.

The armature voltage can be varied by using a rotary booster in the direct-current circuit or by employing a regulator in the primary circuit of the transformer. Where speed changes are rarely needed the transformer secondary can be tapped, but this leads to complications in design, especially when the number of phases used in rectification exceeds three. Grid control is the commonest method, the principal connections of which are shown in Fig. 3, herewith, a

* Paper read before the Utilisation Section of the Institution of Electrical Engineers on Thursday, December 13, 1951. Abridged.

being the rectifier transformer, *b* the main three-phase rectifier and *c* and *d* the ignition and excitation unit and the field rectifier, respectively. The phase shifter and grid-current limiters are indicated at *e*, the motor at *f* and the shunt-discharge resistor at *g*. The interposition of control grids *h* between the anodes and the cathode enables the firing instants to be delayed beyond their natural points in the cycle and thus allows the main direct-current output voltage to be varied. For sinusoidal working, phase-shift control is generally used. This is quite satisfactory for manual control, but may lead to difficulties when the regulator is motorised, owing to large differences in movement required to obtain equal increments of output voltage at different parts of the control range. When a simple induction regulator is used for phase shifting, the supply to it is liable to distortion by the rectifier, especially if the output current becomes discontinuous and the rectifier forms the major portion of the alternating-current load. This distortion results in a change of firing instant and tends to give a lower output voltage. The machine then decelerates and draws less current. The wave shape consequently resumes its original form and the motor accelerates as the firing instant is corrected. Distortion thus appears again and the cycle is repeated indefinitely. Bias-shift control is less frequently used, owing to fluctuations in the output voltage when firing delay angles are large. There is also an unsatisfactory relationship between the angular rotation of the controlling device and shaft speed. Amplitude control and grid-leak (slope) control are unsuitable and are not employed.

If impulse control is used the whole range of possible ignition potentials is employed simultaneously, the result being a constant firing-delay angle. It is also essential when several grid-controlled bulbs are to work in parallel, since if the current is to be shared equally between the bulbs all the grids associated with the same phase must be released together. The impulses may be generated mechanically, by using a synchronously-driven commutator, or statically, by using electronic or electromagnetic devices. Fig. 4 shows one way in which thyristors can be used to generate strip-fronted impulses, the bias unit being indicated at *a* and the load resistors across which impulses are developed at *b*. This arrangement has the disadvantage that the control unit and main bulbs are directly interconnected. They can, however, be separated, in which case the cathodes of the thyristors can be made common and they can, in fact, be replaced by a small grid-controlled rectifier bulb. Valve failure and heating time delays when starting up are thus eliminated, but the first cost and size of such a unit is three or four times those of the thyristor equivalents. In some circuits, the anodes of the thyristors are supplied with direct-current through an oscillating circuit. The valve can thus be made to stop conducting once it has started as the anode current consists of a series of pulses. The phase shift of the impulses is effected by using bias-shift technique. With this system the phase-shifting induction regulator is eliminated and an impulse with a constant amplitude is generated over the whole control range.

When electromagnetic equipment is used the principal alternatives are peaking transformers with Mumetal shunts and small shell-type transformers with more or less normal case construction. These generate peaks by virtue of the circuits in which they are connected. One phase of such a control system is shown in Fig. 5, in which *a* is the series inductance, *b* the peaking transformer and *c* a second inductance. The output voltage potentiometer for controlling the direct-current supply is indicated at *d* and the load at *e*. The reactor is arranged so that the current in the transformer primary has a nearly triangular wave form. The core of the transformer is saturated once per cycle and generates two impulses of short duration, one positive and one negative; the latter is suppressed by a suitable metal rectifier. The instant at which saturation occurs can be predetermined by the current flowing in the control winding. While the triangular current wave form is maintained, the impulse may be shifted in phase with respect to the supply without loss of peak height. In practice, a shift of about 120 deg. is possible using both positive and negative control currents. With correct design the impulses have a satisfactory form and maintain a suitable constant amplitude in operation. Considerable care is needed, however, to ensure that the wave-front remains sensibly vertical, an essential point if the bulbs are to be operated in parallel. With such systems very large motors may be controlled using very little power in the regulating circuit, a point which is advantageous where motor speed has to be a function of more than one variable, as signal mixing is then possible. With the transformer connections arranged so that all the anodes fire in turn, an impulse width of 5 to 10 electrical degrees is satisfactory, but where inter-phase reactors are used, the width of the impulse and, consequently the rating of the unit, must be increased.

A disadvantage of grid control is that the power factor is reduced almost in the same ratio as the output voltage; and cannot be corrected by using normal methods. To avoid the use of large firing delay angles and the associated low power factors, a combination of tap-changer and grid control can be employed, but its initial cost is high. In the multiple-anode method, each phase of the secondary winding on the rectifier transformer is connected to more than one anode and each anode has a lower voltage than its neighbour. The anodes are brought into use in turn by means of grid control. The need for tapping switches and induction regulators is thus avoided, but the utilisation factor is poor, owing to the large number of idle anodes; and the transformer connections are difficult to arrange.

As regards control, the starting, stopping and overload-protection circuits are normal. The coil of the main contactor may be energised from the auxiliary (field) rectifier, as that protection against field failure is obtained. Both the contactor and overload trip coil should be in the direct-current and not in the alternating-current circuit. The phase-shifting regulators may be driven by a split-series-field reversing

Fig. 4.

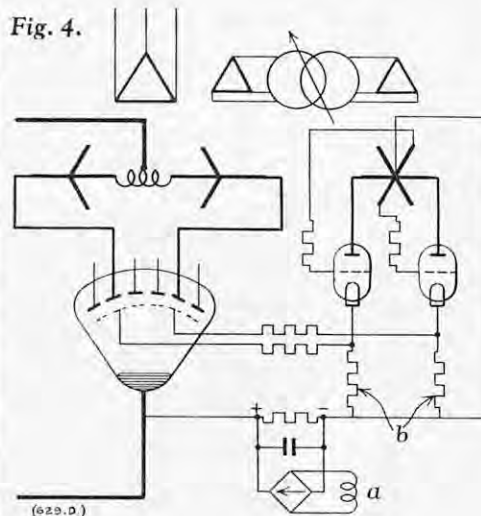
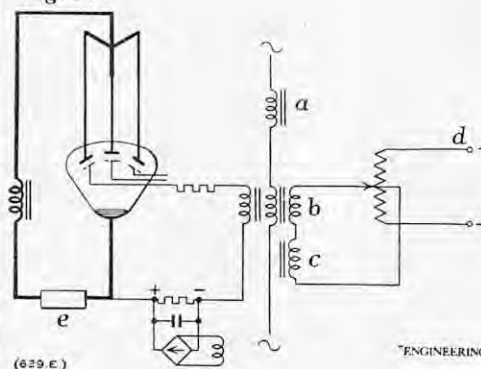


Fig. 5.



fractional horse-power motor, while current-limiting devices can be provided to enable automatic starting and acceleration to be employed. To obtain dynamic braking, a finger (which is normally closed) on the main contactor is used to connect a resistor across the armature of the smaller motors when the contactor coil is de-energised. On the larger equipments a separate contactor is used. With free-firing rectifier, inching is effected by using conventional equipment. With grid-controlled rectifiers, either the phase-shifter can be set to give the output voltage required for inching or the output voltage can be reduced to zero and then suddenly raised to the required amount by employing bias-shift methods.

The armature terminal voltage may be maintained constant by using an error-operated feed-back system. The armature voltage is then compared with a suitably stabilised reference voltage, the difference being amplified and made to operate the grid control or primary regulator mechanisms. Alternatively, a sensitive voltage relay may be employed. While these systems compensate for supply fluctuations, they do not guarantee a constant speed, since the effect of the ohmic drop in the armature and the armature reaction are not corrected. To overcome these defects to some extent, a device known as an IR compensator may be used. This consists of a current transformer connected in either the primary or secondary circuit of the rectifier transformer. The secondary circuit of this transformer is connected to a metal rectifier, the output of which provides a bias. This bias, which is

approximately proportional to the load, can be used to alter the phasing of the grid control and thereby to adjust the terminal voltage of the armature. The drawbacks to this device are that it is unaffected by supply fluctuations; it constitutes positive feed back; and, unless the speed/torque characteristics of the motor are level or drooping, it may cause instability; for the same reason it may cause trouble at starting, unless it is slow acting; and it does not necessarily provide the same degree of compensation at any speed. In spite of these drawbacks, these circuits have been widely employed.

In order to maintain the shaft speed, the same method as that described above for the armature terminal voltage is used, except that a voltage derived from a tachometer-generator coupled to the motor shaft is compared with the reference voltage. In cases where the phase shift for grid control is obtained by devices employing small control currents, various speeds may be selected at will by arranging suitably switched circuits to give the desired control currents at the correct instants. Where only small control currents are required, the output current of a rectifier can be limited to a pre-determined maximum. The control circuit used must remain quiescent until pre-set load is reached and will then operate, retard the firing angle and bring the current once again to a safe value. Such circuits may contain either thermionic valves or static electromagnetic devices, such as transducers. Where adjustments are not critical metal rectifiers may sometimes be employed in place of diode valves. When armature and field control are used together, the limiter must strengthen the field before reducing the armature voltage.

Reversing may be accomplished by using contactors or by connecting two rectifiers in reverse-parallel. Where contactors are used grid suppression may be employed and applied immediately before each contactor operation, so that the contactor opens when no current is flowing. One disadvantage of the reverse-parallel connection is the circulating current which can flow through the rectifiers without traversing the motor armature. Calculations of this current for different conditions show that six or more phases are preferable. The cross-connection will always be superior if rapid reversals are required, as on mine hoists and planing machines. It must not be forgotten, however, that sudden changes in the load are at once reflected in the alternating-current supply system, as the rectifier possesses none of the momentum of rotating machinery. Inverted operation of the rectifiers may be used to obtain a braking torque or to convert the unwanted kinetic energy in large rotating machines into useful power. Good applications are few and the first cost is high, as the grid-control equipment must be extremely reliable. Small equipments do not always work well when the duty cycle is infrequent, as the arms of the inverter bulb become lined with condensed mercury, so that it is very likely that commutation will be unsatisfactory. Nevertheless, given a suitable application, inverters of all sizes have been made and many have given satisfactory service over long periods.

In conclusion, the rectifier-motor drive is a working competitor of the Ward-Leonard drive and is capable of supplying motors, the speed of which has to be varied over wide ranges against heavy torques. It cannot, however, be expected to compete economically with the simple shunt-controlled drive, unless local circumstances warrant a separate power unit. Neither can it compete economically with the alternating-current commutator-motor drive where smaller speed ranges, say 3 to 1, or wider ranges at the expense of good regulation, are required. The development of selective control devices and their associated circuits has enabled very accurate speed control to be obtained. Reversals make application more difficult and increase the cost of the unit. The importance of designing the unit after consideration of the whole drive cannot be too highly stressed. The "packaged" drive can be successful only for small horse-power units, which are produced in comparatively small quantities and are standardised, as a number of facilities must be included, all of which are not necessarily used in any one application. Further, the small horse-power drives, using one or two thyristors only, are intended merely for use with motors designed to cope with the large ripple current values.

The fact that a mercury-arc rectifier controlled by static electromagnetic devices may only have two moving parts (the cooling fan and the operation relay) gives it a definite advantage over the Ward-Leonard set, over the alternating-current commutator motor and over electronic units which, although as static as the mercury-arc equipments, have filaments with not accurately predictable lives and which require heating before being ready for operation. The efficiency of the rectifiers in rectifier-motor equipment is very similar to that of normal rectifiers, so that the overall efficiency may be extremely good if the motor armature voltage is in the 500-volt range and is still well comparable with other types of drive if 250-volt armatures are used.

TRADE PUBLICATIONS.

Roller Levelling Machines.—The Bronx Engineering Co., Ltd., Lye, Worcestershire, have issued a new booklet on their roller levelling machines. The text is published in English, French and Spanish and the booklet contains brief details of their range of strip, sheet and plate levelling machines.

Universal Joints.—The Motor Gear & Engineering Co., Ltd., Essex Works, Chadwell Heath, Essex, have issued a new catalogue on their range of universal joints. This is a most useful publication as, in addition to containing the usual information such as sizes and capacities of the various units, it includes sections dealing with the theory and design of universal joints and their care in service.

Rolling-Mill Rolls.—A brochure published by Sir W. G. Armstrong Whitworth & Co., Ltd., Close Works, Gateshead-on-Tyne, 8, deals with the high-grade heat-treated rolls which they make up to 40 tons in weight. A general account is given of the manufacture and inspection, including searching for internal flaws by ultrasonic means, and of the various "Closeloy" steels used for the rolls.

Contractors' Plant.—We have received from the Chaseside Engineering Co., Ltd., Station Works, Hertford, a brochure dealing with their light excavator. The brochure is intended to illustrate the versatility of the machine and shows how it can be used for such diverse operations as building-site clearance, excavation, material handling, backfilling trenches and elevating building materials to scaffold height.

Mining Conveyor Systems.—Full details of their range of gate belt conveyors are contained in a comprehensive booklet issued recently by British Jeffrey-Diamond, Ltd., Wakefield, Yorkshire. Three sizes of drive head are manufactured and the booklet describes these in detail as well as giving full information on the intermediate sections, belt-storage gear, tail ends, power units and sequence-interlocking gear and belt-protection gear.

Small Ball and Roller Bearings.—Miniature Bearings, Ltd., 192, Sloane-street, London, S.W.1, now have copies of a second edition, in English, of the R.M.B. miniature-bearing catalogue No. 4, which is issued by Miniature Ball Bearings Co., Bienne, Switzerland. It gives, in addition to details of the range of small ball, roller and special bearings, the results of tests carried out on the bearings to determine the friction in them, the variation of torque due to friction, etc.

Dust Collectors.—A comprehensive brochure dealing with their Tornado T-type dust-collecting units has been received from Keith Blackman, Ltd., Mill Mead-road, Tottenham, London, N.17. These units employ a settling chamber as well as a fabric air filter and are produced in five sizes, the capacities of which range from 335 cub. ft. per minute to 1,100 cub. ft. per minute. The brochure contains specifications of the different units, dimensioned drawings, some typical applications, performance data and details of some representative installations.

Petroleum Chemicals Plant.—Reprints of three papers describing the building of their petroleum chemicals plant at Manchester are contained in a 50-page booklet received from Petrocarbon, Ltd., 170, Piccadilly, London, W.1. They deal respectively with the general engineering, the fuel heat and power and the chemical engineering aspects, the first paper having been presented before the Manchester Association of Engineers in February, 1950, the second before the Institute of Fuel in April, 1950, and the third before the North-Western branch of the Institution of Chemical Engineers in April, 1951.

Clutches and Power Take-Offs.—A service manual dealing with their range of Rockford gear-tooth drive over-centre type clutches and power take-offs has been issued by the Borg and Beck Co., Ltd., Tachbrook-road, Leamington Spa. The manual describes the construction and operation of the clutches, gives detailed maintenance instructions and includes a comprehensive spare-parts list. Details of the various clutches used by the principal manufacturers of such equipments as air compressors are also given. Copies of the manual can be obtained by operators and service organisations from Automotive Products Co., Ltd., Leamington Spa.

Central Concrete Batching and Mixing Plants.—As an interim measure, pending publication of their catalogue on circular-type batching and concrete-mixing plants, materials-handling equipment, etc., Blaw Knox, Ltd., 94, Brompton-road, London, are issuing some of its pages in the form of leaflets. So far, three such leaflets have been issued and these deal, respectively, with their 60-cubic-yard and 90-cubic-yard plants with manual control; their 140-cubic-yard and 200-cubic-yard plants with semi-automatic control; and their 400-cubic-yard and 600-cubic-yard plants with fully-automatic control. Full details of each size of plant are given, such as the size of bin, the design of the feed gates and weigh hoppers and the methods of handling the cement and aggregates, and each leaflet includes a general arrangement drawing setting out the major dimensions.

LAUNCHES AND TRIAL TRIPS.

S.S. "ROONAGH HEAD."—Single-screw cargo vessel, accommodating twelve passengers, built and engined by Harland and Wolff, Ltd., Belfast, for the Ulster Steamship Co., Ltd. (Managers: G. Heyn & Sons, Ltd.), Belfast. Main dimensions: 430 ft. (between perpendiculars) by 59 ft. 3 in. by 39 ft. 4 in. to shelter deck; gross tonnage, 6,200. Double-reduction geared turbines developing a total service power of 5,000 s.h.p. and two Babcock and Wilcox oil-burning boilers. Launch, December 17.

M.S. "PROMETHEUS."—Single-screw oil tanker, built and engined by Burmeister & Wain, Copenhagen, Denmark, for Jacob Odland S.S., Haugesund, Norway. Main dimensions: 465 ft. between perpendiculars by 62 ft. 10½ in. by 34 ft. 8 in. to main deck; deadweight capacity, 13,250 tons on a draught of 27 ft. 3¼ in.; gross tonnage, 8,675; capacity of cargo tanks, 632,400 cub. ft. Six-cylinder two-stroke single-acting directly-reversible oil engine, developing 4,600 b.h.p. at 110 r.p.m. and giving a speed of 14 knots, fully loaded. Trial trip, December 18.

M.S. "GRETA."—Single-screw oil tanker, built by the Naksof Shipyard, Ltd., Naksof, Denmark, for Leif Erichsen, Bergen, Norway. Main dimensions: 510 ft. 2½ in. overall by 65 ft. 9 in. by 36 ft. 3 in. to main deck; deadweight capacity, about 15,600 tons on a draught of 29 ft. 1½ in.; oil-tank capacity, 730,000 cub. ft. Seven-cylinder two-stroke oil engine, developing 6,850 i.h.p. and a service speed of 14 knots, constructed by Burmeister & Wain, Copenhagen, Denmark. Trial trip, December 18.

S.S. "TOFO."—Single-screw ore-carrying vessel, built and engined by William Gray & Co., Ltd., West Hartlepool, for Compania Sud-Americana de Vapores, Valparaiso, Chile. First vessel of an order for two. Main dimensions: 415 ft. between perpendiculars by 57 ft. 6 in. by 34 ft. to upper deck; deadweight capacity, about 9,500 tons on a draught of 25 ft. Triple-expansion steam engines and two forced-draught oil-fired boilers, developing 1,835 i.h.p. at 69.5 r.p.m. Trial speed, nearly 12 knots fully loaded. Trial trip, December 18.

M.S. "REGENT SPRINGBOCK."—Single-screw oil tanker, built by the Blythwood Shipbuilding Co., Ltd., Scotstoun, for the Bowring Steamship Co., Ltd., London, E.C.3. Main dimensions: 516 ft. between perpendiculars by 70 ft. 6 in. by 38 ft.; deadweight capacity, 17,600 tons on a draught of about 30 ft. Rowan-Doxford five-cylinder two-stroke opposed-piston oil engine, developing 5,600 b.h.p. at 116 r.p.m. in service, constructed by David Rowan & Co., Ltd., Glasgow. Speed on trial, about 14½ knots. Trial trip, December 19.

M.S. "CHAKRATA."—Single-screw cargo vessel, accommodating twelve passengers, built and engined by Swan, Hunter, and Wigham Richardson, Ltd., Newcastle-upon-Tyne, for the British India Steam Navigation Co., Ltd., London, E.C.3. Main dimensions: 455 ft. between perpendiculars by 62 ft. 6 in. by 40 ft. 9 in. to shelter deck; deadweight capacity, about 9,200 tons on a draught of 27 ft. 2½ in.; gross tonnage, 7,150; cargo-carrying capacity, 94,000 cub. ft. insulated and 550,000 cub. ft. (bales) uninsulated. Swan Hunter-Doxford six-cylinder opposed piston oil engine, developing 6,800 b.h.p. at 116 r.p.m. Speed, 14½ knots in service. Trial trip, December 19.

S.S. "EASTERN STAR."—Single-screw cargo vessel, with accommodation for twelve passengers, built and engined by Harland and Wolff, Ltd., Belfast, to the joint order of Common Brothers, Ltd., Newcastle-upon-Tyne, and Matheson and Co., Ltd., London, E.C.3. Main dimensions: 435 ft. between perpendiculars by 59 ft. 9 in. by 38 ft. 6 in. to shelter deck; gross tonnage, about 6,200. Parsons triple-expansion condensing steam turbines with double-reduction gearing, and two oil-fired Babcock and Wilcox boilers, to develop 7,250 s.h.p. at 110 r.p.m. in service. Trial trip, December 20.

M.S. "SUNNAAS."—Single-screw oil tanker, built by the Caledon Shipbuilding and 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, 13,870 tons on a draught of 28 ft. 9 in.; gross tonnage, 9,280. Vickers-Doxford four-cylinder opposed-piston Diesel engine, developing 4,400 b.h.p. and a speed of 13½ knots in service, constructed by Vickers-Armstrongs Ltd., Barrow-in-Furness. Trial trip, December 31.

M.S. "BRITISH MAPLE."—Single-screw oil tanker, built by Sir James Laing and Sons, Ltd., Sunderland, for the British Tanker Co., Ltd., London, E.C.2. One of a series constructed for these owners. Main dimensions: 463 ft. 5½ in. between perpendiculars by 61 ft. 9 in. by 34 ft. 1 in.; deadweight capacity, 12,160 tons on a draught of 27 ft. 7½ in. N.E.M.-Doxford four-cylinder opposed-piston oil engine, developing 3,100 b.h.p. at 105 r.p.m., constructed by the North Eastern Marine Engineering Co. (1938), Ltd., Sunderland. Service speed, 11½ knots. Trial trip, December 31.

BRITISH STANDARD SPECIFICATIONS.

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

Thermal Insulating Materials for Buildings.—A new specification, B.S. No. 1785, dealing with thermal insulating materials for buildings, has been issued. It is concerned with materials having no other function than that of thermal insulation in building structures within the temperature range of 20 deg. to 150 deg. F. The types of materials included are loose-fills (such as slag wool, glass wool, foamed slag and granulated cork), quilts, mats, rigid or semi-rigid slabs, lightweight concrete and reflective materials (such as aluminium foil and foil-faced boards). Material requirements are specified and limiting figures given for weight per cubic foot, thermal conductivity, emissivity, and water repellency. Recommended methods for determining these properties are described in appendices. [Price 2s. 6d., postage included.]

Masonry Walls Ashlared with Natural or Cast Stone.—The Council for Codes of Practice for Buildings, Construction and Engineering Services, Lambeth Bridge House, London, S.E.1, have now issued, in final form, Code No. C.P. 121.201 covering masonry walls ashlared with natural stone or with cast stone. The Code deals with the design and erection of masonry walls consisting of blocks of stone, finely square-dressed to given dimensions and laid in courses of not less than 12 in. in height, with thin joints. Recommendations are made on the selection of natural and cast stone and on materials suitable for damp-proof courses and for mortar. General notes regarding subsequent maintenance and repair work to defective stonework are included. [Price 6s., postage included.]

Metal Scaffolding.—A new edition of B.S. No. 1139 supersedes the war-emergency specification issued in 1943 and the specification now includes both steel and aluminium-alloy tubes and fittings, the range of fittings having been considerably extended. Prefabricated components of which the principal members are made of steel, such as trestles, tripods and frames, and suspended scaffolding are now included in the publication. Diagrammatic drawings, illustrating the positions in which the various types of coupling and other fittings are generally used, are given, and data are included on the material to be employed, the construction of the components and the finishes and tests necessary to ensure satisfactory performance in service. [Price 5s., postage included.]

Coloured Pitch Mastic Flooring Incorporating Lake Asphalt and Bitumen.—A new specification, B.S. No. 1783, has been prepared to cover coloured pitch mastic flooring the binder of which consists of a mixture of low-temperature pitch, lake asphalt and certain other bituminous substances. The composition of the material and the quality requirements of the various constituents are laid down. Emphasis is placed on the temperature limits and the avoidance of the use of any materials which will cause irritant or otherwise objectionable fumes at the working temperature specified. Clauses on the binder and its components are included, as well as recommendations for the application of the flooring. [Price 2s. 6d., postage included.]

Pressure Gauges.—A new specification, B.S. No. 1780, deals with the wide variety of pressure gauges that are in general use throughout industry and may be bought in large quantities under contract or as single units from engineering suppliers. The publication concerns indicating pressure gauges, vacuum gauges and combined pressure and vacuum gauges of the Bourdon-tube type from 2 in. to 12 in. in nominal size and having maximum scale readings up to 16,000 lb. or 6 tons per square inch. The specification covers direct-mounting, surface-mounting and flush-mounting test gauges with concentric scales, and industrial gauges with both concentric and eccentric scales. The testing and inspection of the gauges are described in one section, while testing apparatus and methods, the installation and use of gauges, and the effect that acceleration, due to gravity, may have on gauges manufactured and used in different parts of the world, are discussed in appendices. [Price 6s., postage included.]

Steel Windows for Industrial Buildings.—This new specification, B.S. No. 1787, has been prepared to meet a demand for standard windows for industrial buildings such as factories and warehouses. Two ranges of windows are covered, one having both horizontal and vertical glazing bars and the other having many of the vertical glazing bars omitted. Clauses relating to material, construction, interchangeability, rust-proofing, fixing and other matters are included. [Price 4s., postage included.]

ANNUALS AND REFERENCE BOOKS.

Guide to the Coalfields, 1951.

Edited by R. H. Walkerdine and C. Treharne Jones. The Colliery Guardian Company, Limited, 30 and 31, Funnell-street, London, E.C.4. [Price 18s.]

As has previously been the case, much of the space in the 1951 edition of this handy guide is devoted to descriptions of the deep mines operated by the National Coal Board or under licence from the Board. By a judicious use of abbreviations, many particulars are given in a small space, including such matters as the position of each mine, its telephone number, the class of coal brought to the surface, and the seams worked, whether electricity is used for lighting and power in the colliery, and the number of men employed below and above ground. Shorter sections are concerned with data regarding officials of the Ministry of Fuel and Power, learned societies and institutions, trade unions and other organisations connected with, or interested in, the coal industry. On 158 Ordnance Survey maps, drawn to a scale of 1 in. to one mile, each individual colliery is surrounded by a black circle and its name given above in block letters. The maps are correlated by nine key maps, one to each division of the Coal Board. It seems to us that reference to the sectional maps could be rendered easier if, as is common in many guide books, the page numbers were given on the key maps instead of the sectional map number.

British Chamber of Commerce, France: Year Book, 1951.

6, Rue Halévy, Place de l'Opéra, Paris (9e).

This new edition of the *Year Book* of the British Chamber of Commerce in France contains, as heretofore, an alphabetical list of the members and associates of the Chamber and separate lists of members and associates in Boulogne-sur-Mer, Calais and Dunkirk, Le Havre, Lille, Lyons and Rouen. In all cases full postal and telegraphic addresses, telephone numbers and brief particulars of the nature of the business carried on, are given. In addition to these main sections, shorter sections concerning trade marks, a classified-trades list of members and associates, the report of the board of directors of the Chamber for 1950, the President's address delivered at the annual general meeting on April 6, 1951, lists of officers of H.B.M. Embassy, and of officers of the Canadian, Australian, South African, and other Dominion Embassies and Legations are given.

Mechanical Engineers' Handbook.

Edited by PROFESSOR LIONEL S. MARKS. British re-issue of 5th edition. McGraw-Hill Publishing Company, Limited, Aldwych House, London, W.C.2. [Price 5l. 7s. 6d.]

This handbook, being confined, ostensibly, to mechanical engineering, and containing over 2,100 pages and an index with 12,000 entries, covers the field in considerable detail. It has been revised since the war and now includes chapters on some of the newer subjects, such as gas-turbines, atomic power, transonic and supersonic aerodynamics, rockets, heat pumps, machining of plastics, automatic process control, alloys for high temperatures, adhesives and powder metallurgy. Many other chapters have been revised. This "British re-issue of the fifth edition" has been printed in the Netherlands, and the new format has been most agreeably arranged. The first part of the handbook deals with the units, mathematics, mechanics, thermodynamics, properties of materials, etc., that are basic to mechanical engineering. There are then four sections on those counters of mechanical-engineering design, namely, machine elements, gearing, bearings, pipes and pipe fittings. Apart from the customary sections on railway engineering, marine engineering, aeronautics, etc., there are others on subjects only allied to mechanical engineering, such as building construction, electrical engineering, electron tubes and radio, and surveying, as well as two on statistical quality control and industrial management and cost accounting. The only general criticism that may be levelled is that the references given at the head of some sections are solely to the American literature; this occurs, for example, in the section on gas turbines. Advocates of universal languages should note that, even where two great industrial nations use a common language, there is sometimes—as in this example—a reluctance to treat each other's literature as common property. On the whole, however, the handbook is one of the best on mechanical engineering.

COMPENSATED TEMPERATURE REGULATOR: ERRATUM.

—At the end of the article on the compensated temperature regulator made by Messrs. Sunvic Controls, Ltd., which appeared on pages 23 and 24 in last week's issue of *ENGINEERING*, the words "To be concluded" were erroneously appended.

ELECTRONIC DELAYED-ACTION RELAY.

On page 23, *ante*, we described a compensated temperature regulator developed by Sunvic Controls, Limited, 10, Essex-street, Strand, London, W.C.2. The same firm have also produced the electronic relay, Type ED2, illustrated in Fig. 1, herewith, which shows the instrument with its cover removed. This relay has been designed for use with light-contact instruments such as accurate thermostats, contact thermometers and toluene regulators. The inherent accuracy of such instruments can be realised only with contacts having the smallest practicable gap and no differential action, and the relay has been designed to effect positive switching of a load under such conditions even when there is vibration at the contacts.

Details of the circuit are given in Fig. 2, herewith. As in the case of the instrument described previously, a thermal cycling unit is incorporated which controls a hot-wire vacuum switch. The contacts of the sensing element are connected across the grid of a triode valve and, by their opening and closing, control the grid potential. This, in turn, determines whether the valve passes a current or not. The anode load of the valve is a winding on the bimetal strip *a* of the thermal

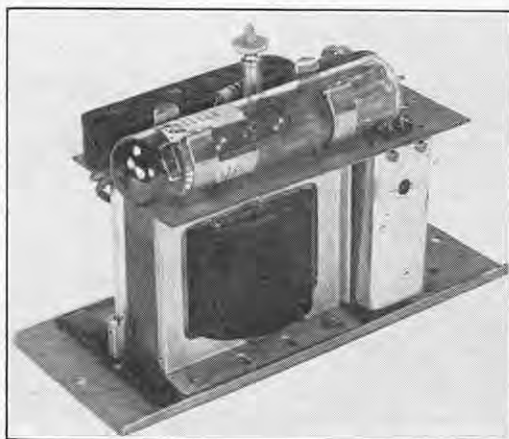
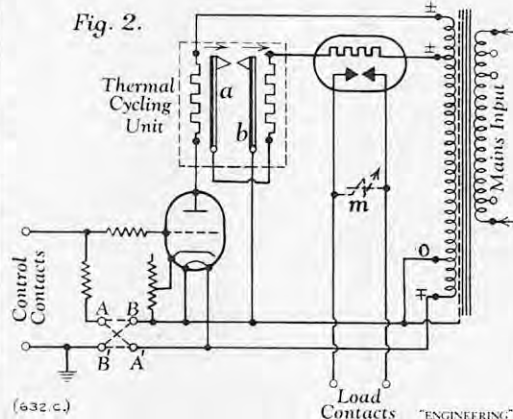


FIG. 1.



cycling unit, which also contains the bimetal strip *b*, which moves in the same direction as *a* when heated. Thus, when there is a demand for additional power, the anode current heats the bimetal strip *a* so that the contacts close. This completes the circuit of the heater on strip *b*, which also contains the hot-wire vacuum switch. The heating of strip *b* tends to re-open the contacts of the thermal cycling unit, thus reducing the delay in breaking the circuit when the demand for power is removed and the valve ceases to conduct. In this way, the unit acts as a relay with a delay of about 8 seconds. In order to ensure a positive make and break at the contacts of the thermal cycling unit, one of the bimetal strips carries an adjustable permanent magnet at its free end, which causes the contacts to come together with a snap action when they are sufficiently close.

When used with a suitable thermostat, the unit also gives a measure of proportional control. Thus, if there is vibration at the contacts of the thermostat, the current through the valve will fluctuate rapidly and have a mean value between its extremes over a limited range of temperature. The resulting variation in the rate of heating of the bimetal strip *a* gives proportional control over this temperature range. The surge suppressor, *m*, shown connected across the load contacts, in Fig. 2, is fitted only when the unit is required to control inductive loads. The unit is contained in an enamelled steel case, measuring 4½ in. by 2½ in. by 6½ in., and weighs 3½ lb. It operates on alternating current at 200-250 volts, or 100-110 volts, and

consumes 15 watts, approximately. The current at the sensing contacts is 10 microamperes, approximately, and the current which can be switched is 11 amperes at 100 to 130 volts, or 9 amperes at 200 to 250 volts. Alternative connections are indicated, in Fig. 2, for cases where the load contacts are required to be either open or closed normally. For normally closed contacts, A A' and B B' are connected. In the alternative case, A B and A' B' are connected.

BOOKS RECEIVED.

Theory of Perfectly Plastic Solids. By PROFESSORS WILLIAM PRAGER and PHILIP G. HODGE, JUN. John Wiley and Sons, Incorporated, 440, Fourth-avenue, New York 16, U.S.A. [Price 5.50 dols.]; and Chapman and Hall, Limited, 37, Essex-street, Strand, London, W.C.2. [Price 44s. net.]

Manpower Resources and Utilization. Principles of Working Force Analysis. By DR. A. J. JAFFE and CHARLES D. STEWART. John Wiley and Sons, Incorporated, 440, Fourth-avenue, New York 16, U.S.A. [Price 6.50 dols.]; and Chapman and Hall, Limited, 37, Essex-street, Strand, London, W.C.2. [Price 52s. net.]

Théorie et Pratique des Travaux à la Mer. By PROFESSOR MARCEL BLOSSET. Editions Eyrolles, 61, Boulevard Saint-Germain, Paris (5e). [Price 3950 francs.]

The Institution of Mechanical Engineers. Automobile Division. Proceedings 1948-49. Proceedings 1949-50. Offices of the Institution, Storey's Gate, St. James's Park, London, S.W.1.

Deterioration of Structures of Timber, Metal and Concrete Exposed to the Action of Sea-Water. Nineteenth Report of the Committee of the Institution of Civil Engineers, being a general summary of the experimental work carried out to date on timber. By J. BRYAN. Second edition. The Institution of Civil Engineers, Great George-street, London, S.W.1. [Price 5s., post free.]

Beitrag zur Berechnung von Bohlwerken. By DR.-ING. HERMANN BLUM. Wilhelm Ernst und Sohn, Hohenzollerndamm 169, Berlin-Wilmersdorf, Germany. [Price 8.60 D.M.]; and Lange, Maxwell and Springer, Limited, 41-45, Neal-street, London, W.C.2. [Price 15s. 1d.]

Manual of Commercial Timbers. By DR. H. E. DESCH. Volume I. Dr. H. E. Desch, 11, Haymarket, London, S.W.1. [Price 1 guinea.]

The Welding of Non-Ferrous Metals. By DR. E. G. WEST. Chapman and Hall, Limited, 37, Essex-street, Strand, London, W.C.2. [Price 55s. net.]

Materials Technology for Electron Tubes. By WALTER H. KOHL. Reinhold Publishing Corporation, 330, West 42nd-street, New York 18, U.S.A. [Price 10 dols.]; and Chapman and Hall, Limited, 37, Essex-street, Strand, London, W.C.2. [Price 80s. net.]

King's Manual of Gas Manufacture. Section 10, containing Chapter XVII. *Instrumentation.* By E. HADEN and W. D. CADWALLADER. Walter King Limited, 11, Bolt-court, Fleet-street, London, E.C.4. [Price 5s. net, postage 3d.]

Office Management. The Task of Getting Things Done. An Official Report of the Office Management Association based on the Papers and Deliberations at the National Conference held in Bournemouth during April, 1951. Office Management Association, 8, Hill-street, London, W.1. [Price 7s. 6d.]

Second Report of the Local Government Manpower Committee. H.M. Stationery Office, Kingsway, London, W.C.2. [Price 1s. 6d. net.]

Town and Country Planning. Statutory Instruments, 1951. No. 2156. The Mineral Development Charge Set-Off Regulations. 1951. H.M. Stationery Office, Kingsway, London, W.C.2. [Price 2d. net.]

Ministry of Fuel and Power. Fuel Efficiency Bulletin No. 52. Power and Fuel in the Milling Industry. H.M. Stationery Office, Kingsway, London, W.C.2. [Price 1s. 3d. net.]

Laboratory Instruments. Their Design and Application. By DR. A. ELLIOTT and J. HOME DICKSON. Chapman and Hall, Limited, 37, Essex-street, Strand, London, W.C.2. [Price 32s. net.]

Rockets, Missiles and Space Travel. By WILLY LEY. Second edition. Chapman and Hall, Limited, 37, Essex-street, Strand, London, W.C.2. [Price 30s. net.]

The Exporter's Year Book, 1952. Syren and Shipping, Limited, 26-28, Billiter-street, London, E.C.3. [Price 40s. net.]

Drawing Office Organization. Formerly B.S.1100: Part 9. Revised edition. British Institute of Management, Management House, 8, Hill-street, London, W.1. [Price 5s.]

Job Evaluation. A Practical Guide. British Institute of Management, Management House, 8, Hill-street, London, W.1. [Price 7s. 6d.]

Muddy Waters. The Army Engineers and the Nation's Rivers. By ARTHUR MAASS. Harvard University Press, Cambridge 38, Massachusetts, U.S.A. [Price 4.75 dols.]; and Oxford University Press (Geoffrey Cumberlege), Amen House, Warwick-square, London, E.C.4. [Price 31s. 6d. net.]