EXHIBITS AT THE BRITISH INDUSTRIES FAIR, BIRMINGHAM.

(*For Description, see Page* 573.)

FIG. 32. 12-FT. SPHERICAL INTEGRATING PHOTOMETER; GENERAL ELECTRIC CO., LTD.

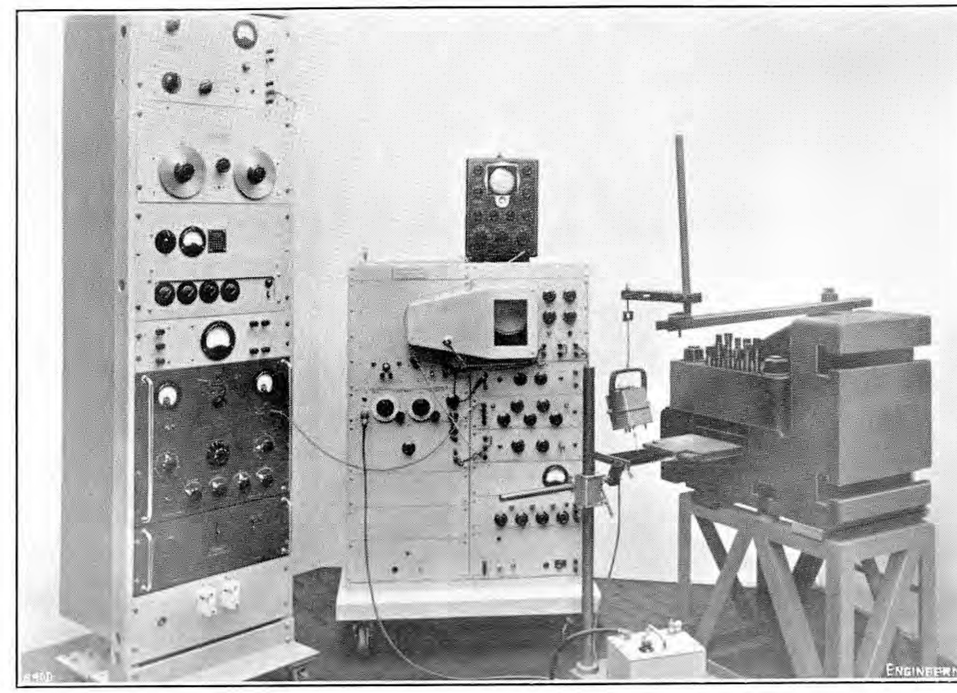

FIG. 33. APPARATUS FOR MEASURING TURBINE BLADE FREQUENCIES: GENERAL ELECTRIC CO., LTD.

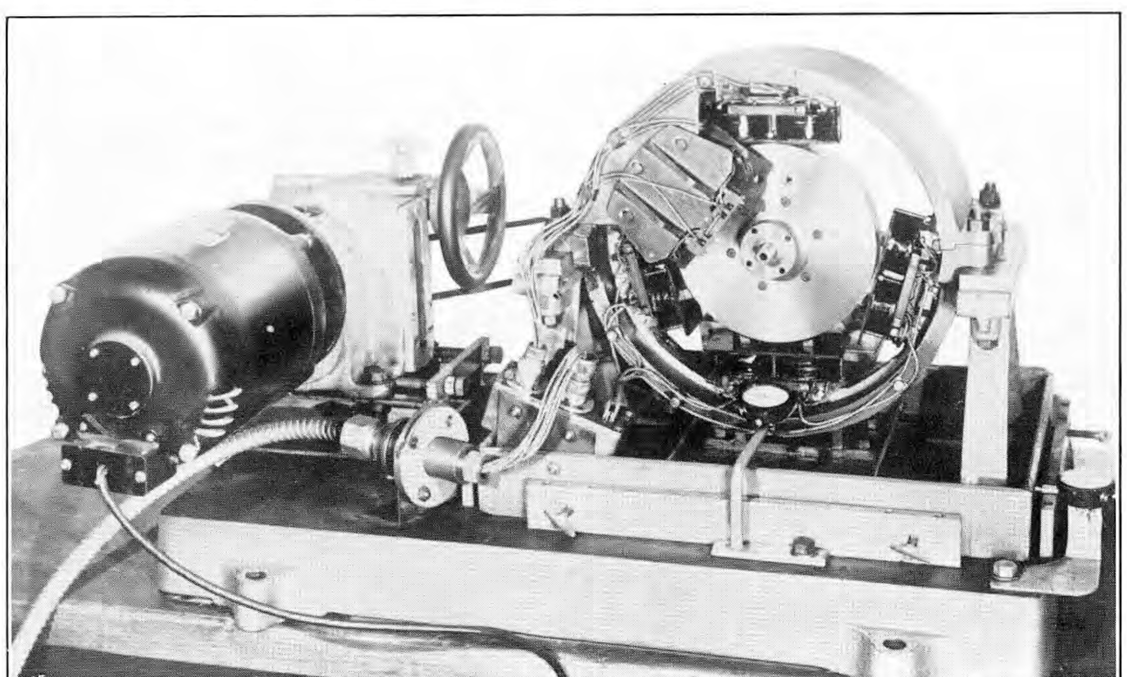

FIG. 34. TURBINE TEST EQUIPMENT; GENERAL ELECTRIC CO., LTD.

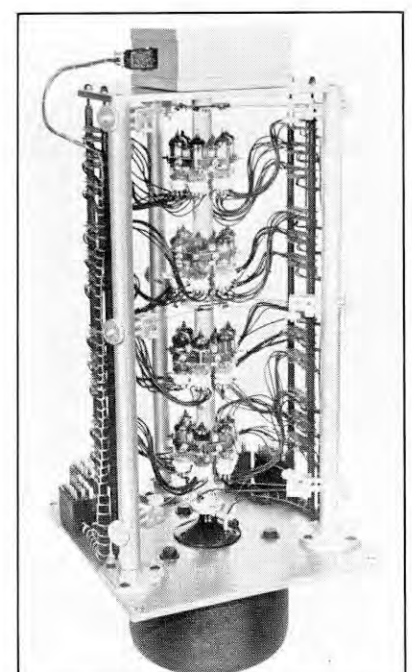

FIG. 35. THERMIONIC-VALVE TESTER; GENERAL ELECTRIC CO., LTD.

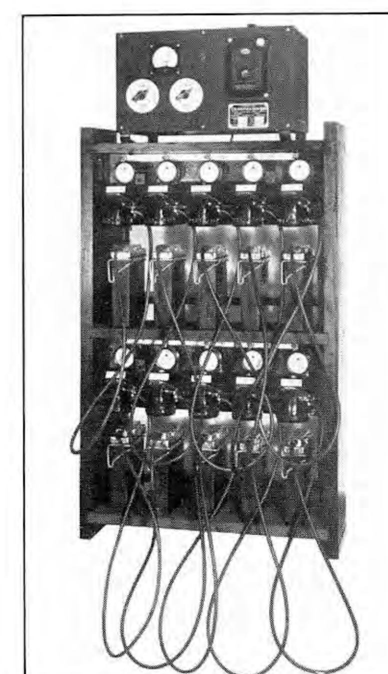

FIG. 36. CHARGING FRAME FOR MINERS' LAMPS; OLDHAM AND SON, LTD.

THE BRITISH INDUSTRIES FAIR AT BIRMINGHAM—II.

SOME further exhibits which are being shown at the Castle Bromwich, Birmingham, section of the British Industries Fair, are described below.

SPHERICAL INTEGRATING PHOTOMETERS.

The stand of the General Electric Company, Limited, Magnet House, Kingsway, London, W.C.2, has been arranged this year to illustrate the work of the organisation's research laboratories and some of the results achieved therein. For this purpose it has been divided into two parts, the first of which shows the "tools" and the second the "products" of research. Among the former mention may be made of the spherical integrating photometer, which, with its control table, is illustrated in Fig. 37, herewith. The sphere of this instrument is 1 m. in diameter and is used for measuring tungsten filament lamps up to 200 watts. It will be seen that one quarter of the sphere is hinged and forms the opening through which the lamps are loaded.

FIG. 37. ONE-METRE SPHERICAL INTEGRATING PHOTOMETER; GENERAL ELECTRIC CO., LTD.

Behind this photometer is a photograph of a 12-ft. diameter photometer, which is installed in the company's photometry laboratory and is used for measuring the light from fluorescent tubes up to 9½ ft. in length. This photometer, the arrangement of which is shown in Fig. 32, on Plate XXVII, is fabricated from rolled aluminium panels, which are supported in an angle-iron framework. In order that the operator can manipulate the light source at the centre of the sphere from a comfortable working height, the whole structure is recessed in the floor, the base being about 2½ ft. below floor level. A steel gang plank, flush with the floor, is mounted on roller bearings so that it can easily be moved through the 6 ft. diameter circular opening in the surface of the sphere. The door, which closes this circular opening and completes the sphere, weighs 3 cwt. It is suspended on chains and counterbalanced by weights. These weights run inside the tubular members on which the door running rails are supported. The raising and lowering gear is driven by an electric motor, the controls for which are interlocked, so that it cannot be started unless the gang plank is fully withdrawn. Interlocks are also provided which prevent the operator entering the sphere while high-voltage lamps are being tested.

INSTRUMENTS FOR TURBINE TESTS.

A test set for obtaining measurements on groups of turbine blades is being shown in operation on the stand. This set is illustrated in Fig. 33, on Plate XXVII. It consists of a moving-coil vibrator the armature of which is attached through a spindle to the blades under test. The coil of this vibrator is energised by a high-frequency current which is obtained from an electronic variable-frequency oscillator and amplifier. Vibration is then detected by an electronic method which depends on the changes in the capacitance between the vibrating blades and a small plate placed close to their surfaces. This change, in turn, alters the frequency of a high-frequency circuit, thus giving a frequency modulated signal which is transmitted to a discriminator. The amplified output from this discriminator is applied to the plates of a cathode-ray tube and the amplitude of the wave track on the screen then gives an indication of the amplitude of the vibration of the blades. By using a capacity pick-up and frequency modulation, high sensitivity is obtained and small vibrations at frequencies above 10,000 cycles per second can easily be detected.

Another apparatus, which has been designed for use with steam turbines, consists of three sets of detector coils. These coils are placed inside the turbine, one to measure axial displacement, one to measure vertical eccentricity and displacement and the last to measure horizontal eccentricity and displacement. Any distortion that may occur can then be read off on the instrument and a clear picture thus obtained of what is happening while the set is running. Since these conditions obviously cannot be reproduced at an exhibition the experimental equipment shown in Fig. 34, on Plate XXVII, has been constructed to illustrate the principles involved. This test gear, which is also used to develop and calibrate the instruments, consists of a disc rotating on a shaft which simulates the motion actually encountered in a turbine.

VIBRATION TESTS ON VALVES.

The vibration machine illustrated in Fig. 35, on Plate XXVII, is intended to illustrate the techniques used to improve the life and performance of thermionic valves. The valves, 24 of which can be dealt with at a time, are held in V-blocks which are cut in a vertically-mounted tubular carriage. This carriage is supported by wires and simple harmonic motion is imparted to it by the moving coil of a motor, which is mounted directly on its lower end. The motion of the carriage is both electrically and optically monitored at frequencies from 50 to 5,000 cycles per second and at a maximum acceleration of about ten times that of gravity. It may be added that particular care has been taken to ensure that standing waves are not set up on the carriage, so that all the valves are therefore subjected to the same stresses. This uniformity of treatment is particularly important when the valve quality is being statistically assessed, since where the number of defective valves during life test is small the statistical significance of the results obtained is correspondingly high. There must therefore be no doubt that any failure is caused by a defect in the valve itself and is not due to exceptionally severe test conditions having been applied to that valve alone.

CIRCUIT-BREAKERS.

The main exhibit on the stand of Messrs. Johnson and Phillips, Limited, Charlton, London, S.E.7, consists of a range of their new Trinal interchangeable circuit-breakers and oil switches. This range is made up of three units: an arc-controlled circuit-breaker, a plain-break oil circuit-breaker and an oil switch. All these units are of similar dimensions and have common fixings, so that they can be accommodated and, if necessary, interchanged, in the firm's standard metalclad cubicle and truck-type housing.

An illustration of an oil circuit-breaker of this pattern, with arc control devices and certified by the Association of Short-Circuit Testing Authorities for a capacity of 250 MVA at 6·6 kV and 11 kV, appears in Fig. 38, on page 574. The tank and top plate are of welded steel plates, the joint between the two being formed by a tongued and grooved gasket, which renders it both gas and oil tight. The top plate is designed to form a housing for the internal mechanism and to provide a suitable expansion chamber for cushioning the impulse pressures set up under short-circuit conditions. The emission of oil is restricted by a baffled vent which, however, allows the free release of gas. The bolted or plug-type terminals are carried in Bakelised paper bushings, which are cemented into stiffening tubes, the latter being welded into the top plate.

The contacts are of the single-break type. Each moving blade is hinged at one contact block and passes through the cross-jet pot to make a box formation of finger contacts at the other block. This arrangement obviates the pinch effect often associated with this type of contact, and the order in which contact is made ensures that the magnetic loop cannot force the contacts apart when the breaker is closed on a short-circuit. To ensure a uniform current path at the hinged side of the moving blade, the hinge pin is shunted by a flexible

EXHIBITS AT THE BRITISH INDUSTRIES FAIR, BIRMINGHAM.

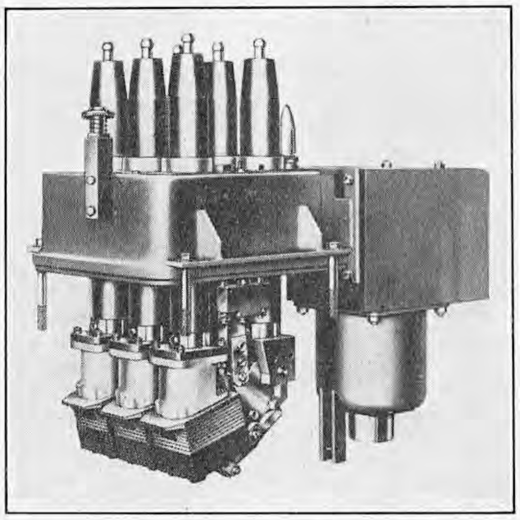

FIG. 38. 250-MVA OIL CIRCUIT-BREAKER; JOHNSON AND PHILLIPS, LTD.

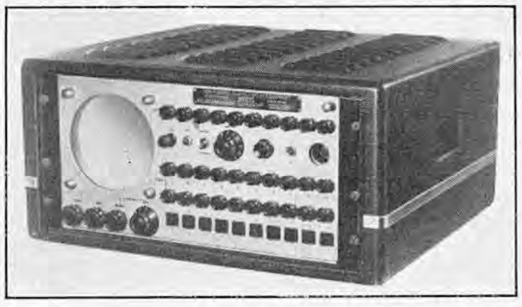

FIG. 39. 10-CHANNEL STRAIN DISPLAY EQUIPMENT; ELLIOTT BROTHERS (LONDON), LTD.

FIG. 40. TEMPERATURE CONTROLLER; ELLIOTT BROTHERS (LONDON), LTD.

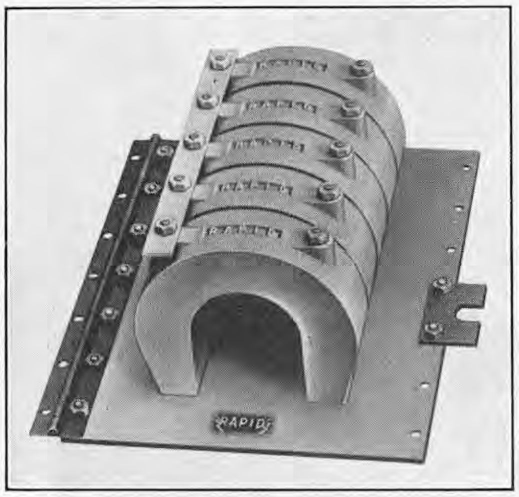

FIG. 41. HINGED MAGNETIC SEPARATOR; RAPID MAGNETIC MACHINES, LTD.

conductor and the high-pressure side contacts are so arranged that they act as additional shunts. As a result, the moving blade is held in constant contact with the hinge pin and the moving parts are given a "dead-beat" action, so that bounce is avoided.

The well-known cross-jet pattern of arc control forms part of the design of these circuit-breakers. The contact mechanism is entirely enclosed within the top plate and consists of a simple coupled bell-crank arrangement, which is very rapid in action. The toggles necessary to reduce the forces for tripping are contained in the external closing mechanism and not within the breaker. The closing mechanism can be either hand, spring or solenoid operated, the three types being interchangeable. A solenoid magnet can also be substituted for a power spring device without disturbing the main operating mechanism. All the mechanisms are of the free handle type and are arranged to incorporate most forms of trip releases.

Another exhibit on this stand of which mention may be made is a fuse-switch unit which has been designed for use in the smaller class of substation and in other situations where the employment of circuit-breakers is not justified. It is of metal-clad construction and comprises an oil switch backed up by high rupturing capacity fuses. These fuses are contained in an air-insulated compartment and are fitted with a trip for opening the switch. The unit is designed so that it can easily form a part of switchboard with compound-filled or air-insulated 'busbars and is provided with an interlocked earthing device. It is made with normal current capacities of 200 amperes at 3·3 kV and of 75 amperes and 65 amperes at 6·6 kV and 11 kV, respectively. The breaking capacity rating is 150 MVA at 3·3 kV and 250 MVA at 6·6 kV and 11 kV.

BATTERIES AND CHARGING EQUIPMENT.

The exhibits of Messrs. Oldham and Son, Limited, Denton, Manchester, include ranges of their "Heavy Duty" and Major" batteries for the starting and lighting of motor cars; of their "Demi-Armoured" batteries for commercial and passenger vehicles; and of their traction and marine batteries, which are being shown in sectioned form. An aircraft battery is also on view. The chief feature on the stand is, however, the 10-type frame and charger for miners' cap lamps, of which an illustration appears in Fig. 36, on Plate XXVII. This equipment shows the application of the firm's "self-service" system to small installations and consists of a ventilated metal cabinet which is installed above the charging frame. The incoming alternating-current mains are connected to a three-phase transformer, the primary of which is provided with six coarse and six fine tappings to give the necessary voltage regulation. These tappings are brought out to the rotary switches which can be seen on the front of the cabinet. The secondary of the transformer is connected to a bank of selenium half-wave rectifiers in which conversion to the direct current necessary for charging takes place.

The cap lamps, which are charged by means of this apparatus, consist of a moulded Bakelite body about $2\frac{1}{2}$ in. in diameter, which is fitted with an internal parabolic reflector of aluminium and an external screwed ring to carry an $\frac{1}{8}$-in. armoured glass. The head-piece is secured to the miner's helmet by a clip at the rear of the body. The cable is led in through a lock-nut so that strain on the internal connections is eliminated, while a rotary switch enables either the main or pilot bulb in the lamp to be selected. To put the lamp on charge, a key switch behind the headpiece clip is slipped over a stationary key on the charging frame, which is connected to the negative lead. The head-piece is given half a turn to bring the key into contact with a connection inside the headpiece, while, at the same time, an external stud is brought into contact with a spring on the charging frame, thus forming the positive connection. To remove the battery after charging, the head-piece is rotated half a turn in the opposite direction and withdrawn from the key. No moving parts are involved and it is claimed that the system is foolproof.

STRAIN DISPLAY EQUIPMENT.

Among the exhibits on the stand of Messrs. Elliott Brothers (London), Limited, London, S.E.13, is a ten-channel strain display equipment illustrated in Fig. 39, above. This portable self-contained unit is capable of displaying the strain at different points in a test piece on a cathode-ray tube; one ot them is in use at the Royal Aeronautical College, Cranfield, for testing the undercarriage of a bomber. Resistance strain gauges are, of course, commonly used in a Wheatstone bridge circuit which can be excited either by direct or alternating current. Both arrangements, however, have their disadvantages, which are overcome in the present apparatus by using pulses of suitable duration for energising the bridge, the output of which is then applied to an alternating-current amplifier. The ten independent strain-gauge bridges in the instrument are excited by the same number of synchronised pulse generators, which are interconnected so that the pulses follow one another in turn. A pause of one pulse interval is interposed after the tenth pulse and the cycle is then repeated. Only one bridge is receiving a signal at any instant.

The outputs from all the bridges are connected in parallel and are fed to an amplifier, which drives the Y-plates of the cathode-ray tube. Two auxiliary wave forms are generated to produce two alternative forms of display. One of these consists of ten columns disposed above or below a zero line, the length of each column indicating the amplitude of the vibrating strain and the displacement of each column from zero the mean tensile or compressive strain. In the other display, the lines show the wave forms of the strain. Vibration frequencies of 0 to 11 kilocycles per second can be displayed, and up to 3 kilocycles on all ten channels. The first of the auxiliary wave forms is a voltage rising in steps, each step being in synchronism with a pulse, and is repeated with each cycle of pulses. The second wave form is a saw tooth of variable frequency which is used as a variable time base. In the first form of display, the stepped wave is applied to the X-plates of the cathode-ray tube, so that the spot moves across the screen with ten definite rest positions. In the first position, a signal is received from the first bridge and determines the ordinate on the spot, according to the strain on the corresponding gauge. Similarly, in the second position, the signal corresponds to the strain on the second gauge, and so on.

When the strain on a gauge changes, the corresponding spot on the screen moves vertically and, under conditions of fairly rapid vibration, its successive positions are seen as a line, which represents the amplitude of the vibrations. The other form of display is obtained by adding the stepped wave to the Y-plates of the cathode-ray tube. The various channels are now displaced vertically instead of horizontally and, if the X-plates receive a time-base voltage, the ten values of strain are plotted on the screen against time and are seen as wave forms. As the signal passing through the alternating-current amplifier is not symmetrical, and the amplifier itself has a finite time constant, it is necessary to provide for the restoration of zero level. During the pause in the pulsing cycle, the input to the amplifiers is zero and its output is therefore also brought to zero by a triode clamping circuit.

The cathode-ray tube and power supplies only are mounted on the main chassis, the pulse generators, amplifier, auxiliary wave-form generators and stabilising circuits for the power supplies being carried on separate chassis. These chassis can be plugged into the main chassis, thus facilitating replacement in cases of a fault.

EXHIBITS AT THE BRITISH INDUSTRIES FAIR, BIRMINGHAM.

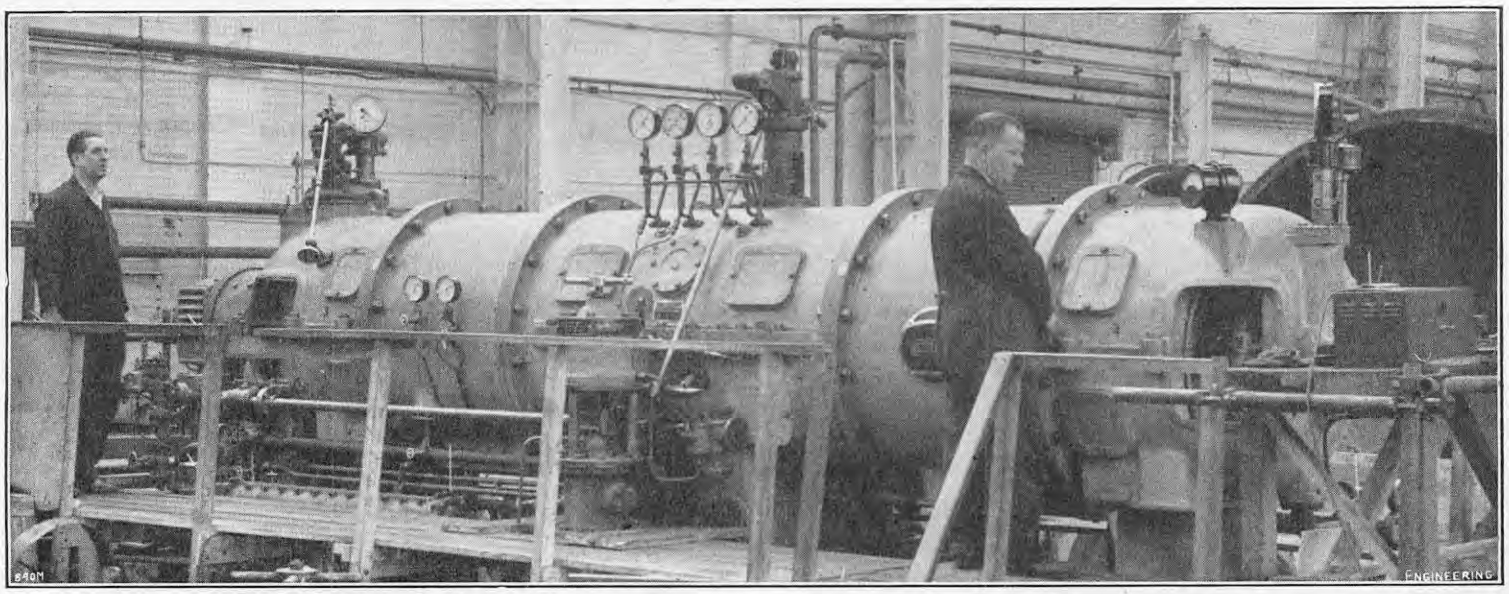

FIG. 42. 2,400-KW BRUSH-LJUNGSTROM TURBO-GENERATOR FOR KANO, NIGERIA; BRUSH ELECTRICAL ENGINEERING CO., LTD.

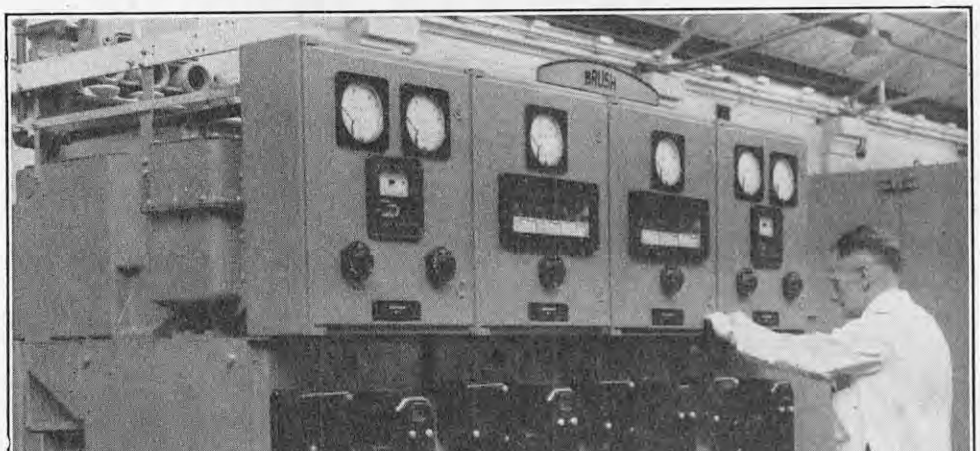

FIG. 43. 250-MVA 11-KV METALCLAD SWITCHGEAR; BRUSH ELECTRICAL ENGINEERING CO., LTD.

TEMPERATURE CONTROLLER.

Another exhibit on Messrs Elliott Brothers' stand is a controller for use with thermocouples which measure and vary the temperature of furnaces. This instrument, which is illustrated in Fig. 40, opposite, is based on the "on-off" or "high-low" system of operation, whereby the source of heat is continually fluctuating between upper and lower limits, these limits being sufficiently close to each other to ensure that the temperature variation in the controlled medium or substance is extremely small. The mechanism is operated by a small synchronous motor, which drives a double chopper bar. This bar momentarily locks the pointer, which is otherwise free to swing with the variation in reading, while its position is compared with that of a second or control setting pointer. Mercury tip switches are then operated to bring the necessary correcting influence into action, this action depending on whether the position of the first pointer is above or below the second. These switches are capable of handling up to 10 amperes at 230 volts single phase, and the frequency of operation is normally four per minute. The controlling panel on the scale is indicated by a red pointer which is pre-set by a key.

MAGNETIC SEPARATOR.

Rapid Magnetic Machines, Limited, Lombard-street, Birmingham, 12, are exhibiting a new range of permanent-magnet chutes and plate-type separators; one of the latter is shown in Fig. 41, opposite. This equipment, which incorporates Alnico or Alcomax permanent magnets, has been designed to meet the exacting requirements of the food, textile and plastic industries for the removal of tramp iron. As permanent magnets are used, no electric current is required, so that the costs of operation and maintenance are negligible. The magnetic strength is high and the separators can be used on both wet and dry processes. The separators are manufactured in a standard basic size, but individual requirements can be met by coupling two or more units together to give the correct widths or lengths. Three magnetic strengths are available and the working faces of the magnets can have either flush or stepped poles. Among the electromagnetic separators shown in operation are two for the separation of swarf, while a vibratory chute for treating fine powders that require mechanical motion to precipitate their flow are also being exhibited.

2,400-KW TURBO-GENERATOR.

The exhibits of the Brush Electrical Engineering Company, Limited, Loughborough, illustrate the firm's activities in the fields of turbo-electric generation, transformers, switchgear and motors. Included in the first class is the 2,400-kW Brush-Ljungström set shown in Fig. 42, above. This consists of a Ljungström radial-flow turbine running at 3,000 r.p.m. and designed for operation with steam at a pressure of 300 lb. per square inch and a total temperature of 700 deg. The steam consumption, taking into account the excitation and ventilation losses of the alternator, is 11·78 lb. per kilowatt-hour at full load. The alternators, to which the turbines are directly coupled and which run in opposite directions, generate three-phase current at 3·3 kV and a power factor of 0·9. The regulation at that power factor and at a constant speed with full-load excitation is 45 per cent. The alternator stators are overhung from the turbine casing and the whole unit is supported by a condenser with a cooling surface of 3,000 sq. ft. The equipment would normally be completed by a two-stage steam jet with jet inter-condenser and surface after-cooler, and an air ejector for a duty of 14·3 lb. of air per hour and a steam consumption of 225 lb. per hour. There would also be an electrically-driven extraction pump with a duty of 33,600 lb. per hour against a total head of 65 ft. and a circulating-water pump with an output of 4,100 gallons per minute against a head of 43·5 ft.

METALCLAD SWITCHGEAR.

Fig. 43 is an illustration of the 250-MVA 11-kV metalclad switchgear which is shown on the same stand. It has been specially designed for use where atmospheric conditions, such as high humidity and sudden temperature variations, are onerous, and for connection to overhead lines in areas subject to frequent lightning storms. The housing is constructed of welded steel plates and sections, with a solid floor plate. Correct three-plane alignment of

EXHIBITS AT THE BRITISH INDUSTRIES FAIR, BIRMINGHAM.

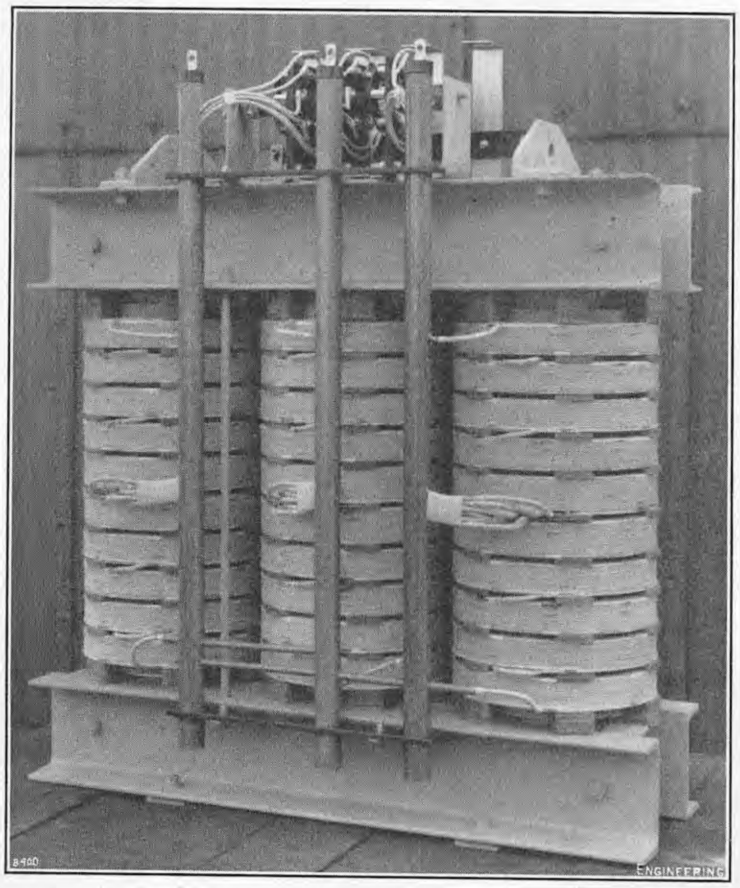

Fig. 44. 500-KVA 11,000/433-Volt Transformer; Brush Electrical Engineering Co., Ltd.

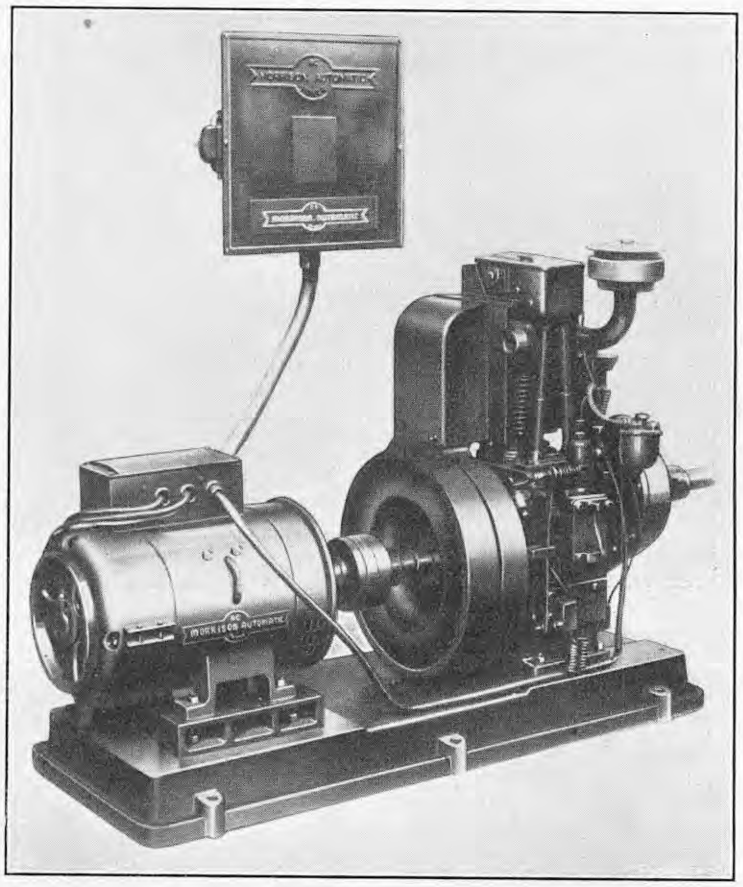

Fig. 45. $2\frac{1}{2}$-KW Diesel-Electric Generator; A. C. Morrison (Engineers), Ltd.

the truck is ensured by horizontal and vertical guides and there are double steel walls between adjacent units. All the parts are arranged for front access, and the housing supports the separate 'busbar and current transformer chambers. The truck is also of electrically-welded steel plate and sections and can be raised by a single balanced screw-jack mechanism, which is designed to ensure easy movement. The operating mechanism is mounted on the front panel of the truck so that sliding plates are eliminated. The 'bus-bar chamber, which is of aluminium alloy, is arranged for filling with Dussek Trinidite bitumen-base compound MR3. This compound is poured at the works at a temperature of about 300 deg. F. into the pre-heated moisture-free chamber through a wide top cover. There is therefore no restriction to flow, nor any risk of entrapped gases, voids or cavitation. The current transformer chamber, which is also of aluminium alloy, is filled with Penetrol.

The circuit-breakers are of the firm's standard pattern, while the isolators are solid copper plugs of circular section, which are fixed in orifice insulators and engage with floating sockets at the top of the circuit-breaker bushings when the current does not exceed 600 amperes. For higher current ratings self-aligning plugs of dumb-bell construction are used. The orifice insulators are porcelain and cement is not employed to fix them to the structure. Mal-operation is prevented by the provision of automatic interlocks, so that the main circuit cannot be made or broken except through the oil circuit-breaker, while the truck cannot be withdrawn or replaced unless the equipment is "dead." There is an interlocked clutch between the fixed operating mechanism and the moving oil circuit-breaker. Automatic gravity-operated safety shutters prevent accidental contact with the "live" high-tension conductors and these are fitted with springs to guard against interference.

Transformers.

As an example of the firm's transformers, the 500-kVA 11,000/433-volt unit illustrated in Fig. 44, above, may be mentioned. Actually the core and windings of a transformer of this type are

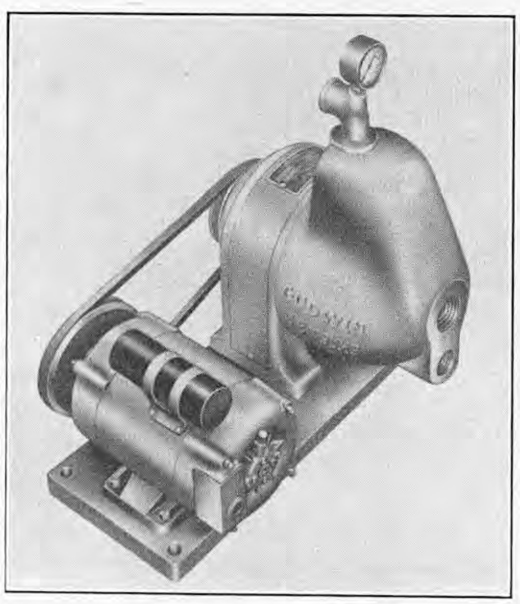

Fig. 46. Jet Pump; H. J. Godwin, Ltd.

being exhibited at Castle Bromwich to show the method of construction. The unit is fitted with an off-type roller-type tapping switch to give a regulation of $+2\frac{1}{2}$ and -5 per cent. This switch is operated from outside the tank by a handwheel which changes the tappings in the three phases simultaneously. Large ducts are fitted so that running under difficult thermal conditions is possible. The breakdown strength of the insulation is about 180 kV.

Diesel Generator Set.

Messrs. A. C. Morrison (Engineers), Limited, Rectory-place, Loughborough, are showing a selection of the generating plant they manufacture in capacities from 250 watts to 40 kVA for use on the farm, in the factory and on board ship. Typical of these is the $2\frac{1}{2}$-kW air-cooled Diesel set which is illustrated in Fig. 45; it is the smallest of the units embodying that type of prime mover. The engine is of the vertical single-cylinder four-stroke type with compression ignition, all the parts of which are totally enclosed but are readily accessible. The speed, which is 1,500 r.p.m., is controlled by a centrifugal governor. The alternator is of the self-exciting self-regulating type, and inherent regulation maintains the output voltage of either 230 volts single-phase or 230/400-volt three-phase under all conditions of load. The plant can be operated either on the fully automatic system (the engine starts directly the load is switched on and stops when it is switched off) or by remote or push-button control from distant or near points. It can also, of course, be started manually. Devices are fitted which switch off the battery should the engine fail to start and which dim the lights if the set becomes overloaded.

Jet Pump.

Messrs. H. J. Godwin, Limited, Quenington, Gloucestershire, are showing a range of reciprocating pumps and accessories for agricultural, domestic and industrial water supplies from wells; boiler feed-pumps; and petrol-storage pumps. For the first time, their jet pump, a centrifugal-pump unit working in conjunction with a hydraulic ejector, suitable for deep or shallow wells, is on view. Fig. 46 shows the belt-driven centrifugal pump and electric motor unit; a directly-coupled pump and motor unit is also available. The pump, which can also be used as an ordinary centrifugal pump without the ejector, requires a motor of from $\frac{3}{4}$ to $1\frac{1}{2}$ brake horse-power, according to the duty. The pump unit is installed at ground level, not necessarily directly over the source of supply. There are no moving parts in the well. For well duties, the ejector and its accessories are supplied separately in a "deep-well package" or a "shallow-well package," as desired; the pressure tank is also supplied in a separate package. Thus, should changing conditions demand it, it is possible to convert a shallow-well installation to deep-well operation without changing the pump unit. As a deep-well ejector pump, the jet pump has a

EXHIBITS AT THE BRITISH INDUSTRIES FAIR, BIRMINGHAM.

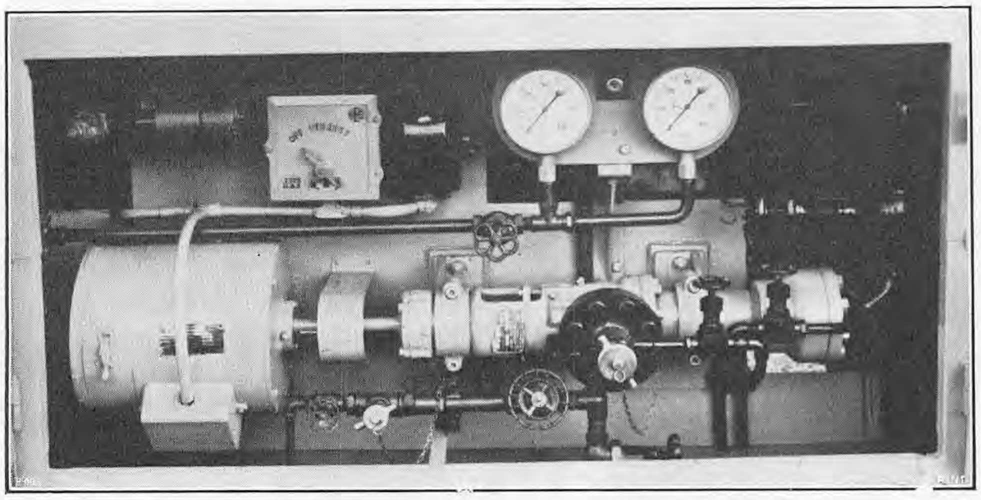

FIG. 47. PUMP FOR LIQUEFIED GASES; MONO PUMPS, LTD.

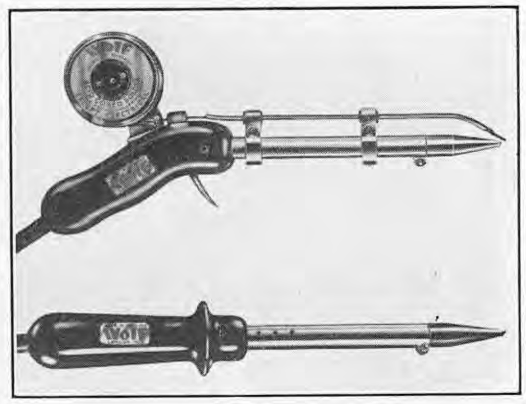

FIG. 49. SOLDERING IRONS; WOLF ELECTRIC TOOLS, LTD.

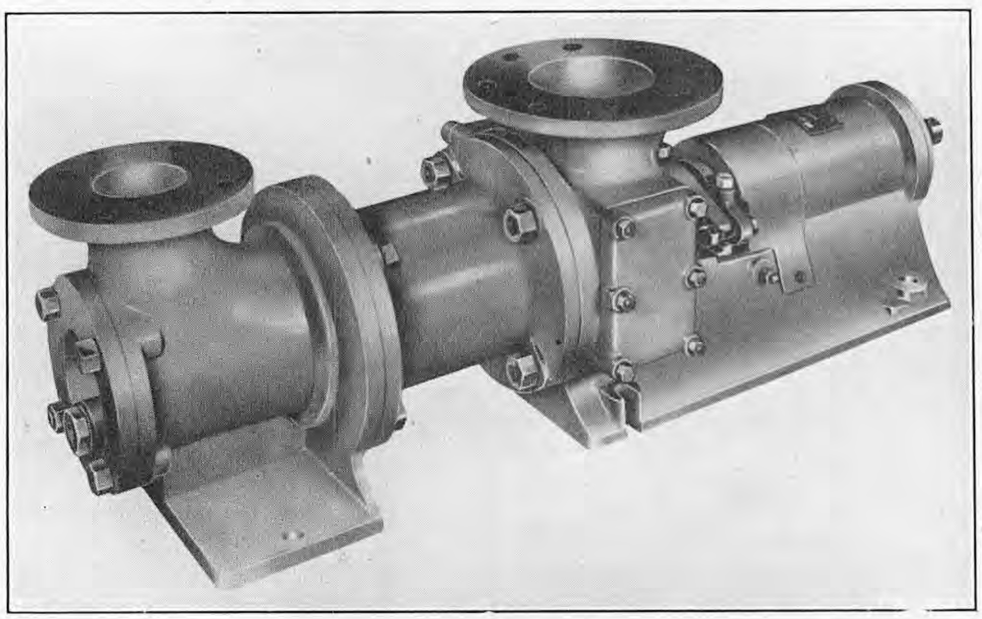

FIG. 48. PUMP FOR LIQUIDS CONTAINING FIBROUS MATERIALS; MONO PUMPS, LTD.

maximum capacity of 900 Imperial gallons per hour. The maximum lift of the pump is 120 ft, and the maximum delivery pressure is 60 lb. per square inch. The shallow-well ejector pump has a capacity of 1,350 Imperial gallons per hour and a suction lift of 20 ft.; the maximum delivery pressure is 60 lb. per square inch. Used as a centrifugal pump without an ejector, the pump capacity is 2,700 Imperial gallons per hour; the suction lift is 20 ft. and the total head is 110 ft.

For deep wells where the lift to the pump exceeds 20 ft., the ejector is submerged in the well and is connected to the pump by a two-pipe circuit. Water from the well is drawn into the pipe which is connected to the suction inlet of the pump by the vacuum developed at the ejector by the circulating water. In shallow wells with suction lifts up to 20 ft., the ejector is incorporated in the pump casing, so that a pressure higher than that obtainable from the pump alone is developed.

The centrifugal pump has a shrouded impeller, machined from a gunmetal or aluminium-bronze casting, mounted on a stainless-steel shaft. Sealing is provided by a corrosion-resistant synthetic-rubber ring of U-section which is easily replaced when necessary. In the belt-driven unit illustrated, the pump shaft runs in grease-packed ball bearings in a sealed housing. The ejectors are made of gunmetal and brass. Both types of ejector are provided with a spring-loaded rubber disc foot-valve and strainer. The deep-well ejector is also provided with a conical brass filter in the pressure pipe, to prevent the ejector nozzle from becoming blocked with foreign matter, and a gunmetal regulator valve. The pressure tank is of welded mild steel, galvanised after manufacture, and is supplied with a pressure switch, an automatic air-control valve, a wheel valve for controlling the service outlet, and other fittings necessary to provide a complete automatic water system when connected to the jet pump.

PUMPS.

Messrs. Mono Pumps, Limited, Mono House, 67, Clerkenwell-road, London, E.C.1, are showing several pumps developed recently for special applications. It may be recalled that the Mono pump, the principle of which was described fully on page 376 of our 167th volume (1947), comprises a helical metal rotor rotating in a double-helical stator which can be made of natural or synthetic rubber, or various metals. There are no valves, and the pump is self-priming. Fig. 48, above, shows the F.12 Mono pump, which is being demonstrated pumping paper stuff. It is suitable for handling most pulped material in suspension, or fluids containing fibrous materials. The delivery port is 3 in. in diameter, whereas the suction port diameter is 5 in. to give an unrestricted entry to the pump. For extremely fibrous material, a special shaft seal can be fitted, lubrication being provided by a small water feed. The pump is available in cast iron or in gunmetal, with a stainless-steel rotor. Below a speed of 720 r.p.m., the pump can operate on a suction lift of 25 ft. when handling water. At this speed, the pump has a capacity of 4,500 gallons per hour against a total head of 100 ft. of water, and a maximum capacity, against zero head, of 6,000 gallons. At speeds higher than 720 r.p.m., the suction lift is limited to 20 ft. At 960 r.p.m., the pump has a capacity of 7,100 gallons per hour against a total head of 100 ft.

Also on view is the IRG40 pump, designed for bulk handling of liquefied gases; it is shown in Fig. 47 fitted to a road tank lorry. It has been used for delivering and discharging liquid carbon dioxide transported by road tanker vehicles. When handling the liquefied gas, the pressure in the receiver must be equal to that of the discharging vessel to prevent the liquid from vaporising. The Mono pump can be reversed, so that it can be used for both discharge and delivery without a complicated system of valves. The seal between the stator and the closely-fitting rotor tends to isolate the receiving vessel when the pump is stationary. Another addition to the Mono pump range is the HM25 pump, designed to satisfy the water requirements of the average farm. It can operate on a suction lift of 20 ft. and is rated at 300 gallons per hour.

SOLDERING IRONS.

Messrs. Wolf Electric Tools, Limited, Pioneer Works, London, W.5, are showing a range of portable electric tools including drills from $\frac{1}{4}$ in. to $1\frac{1}{4}$ in. diameter, screwdrivers, grinders, polishers, sanders, hammer kits, a ball-bearing 10-in. diameter saw, engine-reconditioning equipment, and soldering irons. The latter include an "automatic" iron in which the solder, supplied on a reel mounted on the gun, is fed by trigger action. Fig. 49 shows this tool, together with one example of a range of straight-handled electric soldering irons; they can be supplied with straight or angle bits, and can be easily dismantled for replacing the heater element on the bit. They are fitted with hardwood handles provided with a heat-deflecting skirt. The power consumption is 60 watts and it takes about $3\frac{1}{2}$ minutes to melt 60/40 solder from cold.

MAGNETIC SEPARATOR.

Messrs. Electromagnets Limited, Boxmag Works, Bond-street, Birmingham, 15, are showing a range of magnetic separating and lifting equipment. One of their recent developments, illustrated in Fig. 50, on page 578, is a high-intensity electromagnetic agitated-chute separator for removing tramp iron, fine powders and similar products which require agitation to ensure a free flow. It comprises a magnetised trough fitted immediately above a stationary coil system, supported on a robust channel-section steel framework. It can be adjusted for angle. The magnetised bars of the trough are chromium-plated to facilitate the flow of material and to avoid corrosion effects. The coil system imparts a vibration to the trough, which is also mechanically agitated by a ball-bearing eccentric driven through a guarded roller chain by a totally-enclosed geared electric motor. The trough is supported on adjustable arms equipped with Silentbloc bearings. The eccentric shaft runs in dust-proof self-aligning ball bearings. At the delivery end, the magnetised trough is fitted with a magnetically-retained collapsible bridge; when the electric current is switched off, or fails, therefore, the bridge

EXHIBITS AT THE BRITISH INDUSTRIES FAIR, BIRMINGHAM.

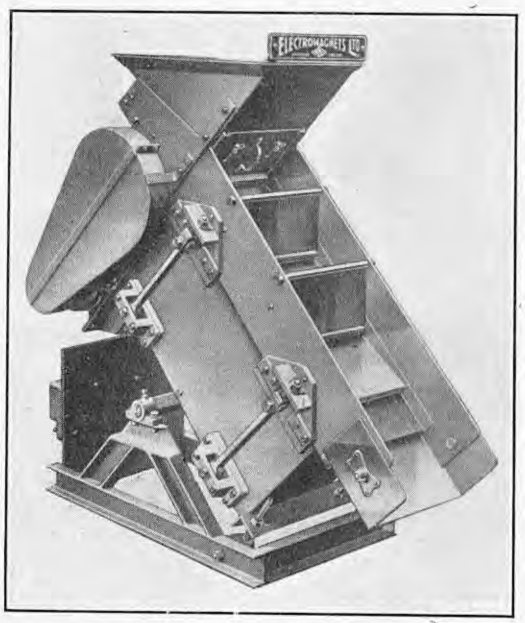

Fig. 50. Magnetic Separator; Electromagnets, Ltd.

Fig. 51.

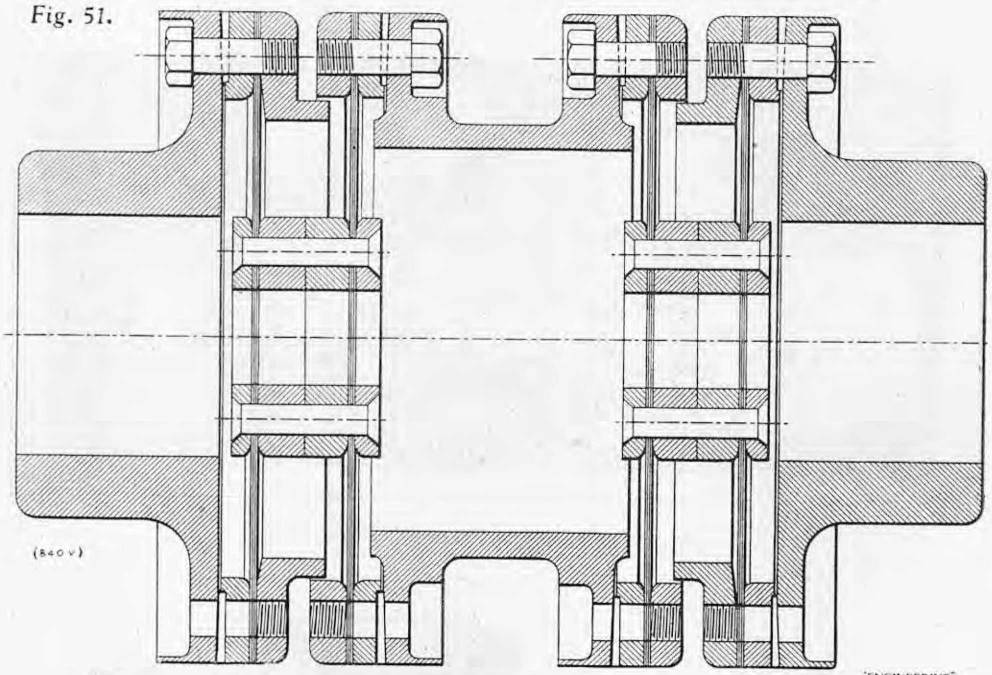

Fig. 51. Flexible Coupling for Shafts; Metaducts, Ltd.

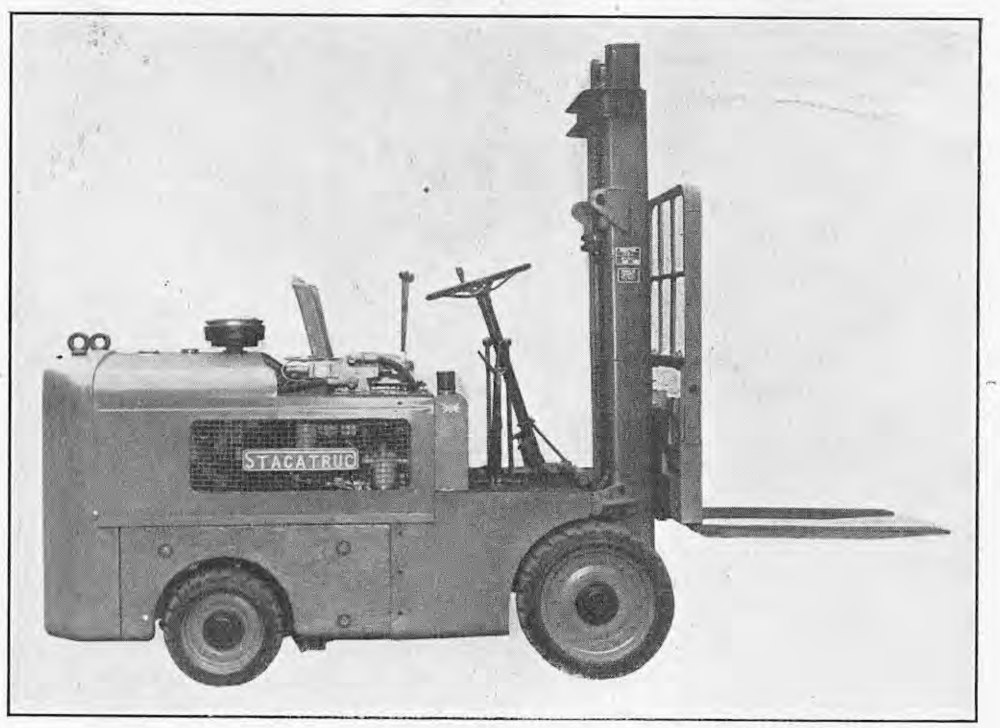

Fig. 52. Fork-Lift Truck; I.T.D., Ltd.

drops and diverts any falling tramp iron from the main delivery. The coil system is wound with high-quality electrolytic copper wire; the magnetic circuit is made from annealed dynamo steel. The magnetic intensity developed is considerably higher, it is claimed, than that of older types of magnetic agitated separators.

Also on view is a fully-enclosed Boxmag feeder head incorporated in a short-belt conveyor. The head unit itself was exhibited for the first time last year and was described on page 488 of our 171st volume (1951). This year's exhibit comprises a stationary electromagnetic head and a head guide comprising a series of small-diameter non-ferrous rollers, arranged between the poles of the magnetic head. The rollers run in self-aligning ball bearings carried in non-ferrous frames at the side of the head. A totally-enclosed fuse-box is attached to the side of the casing housing the magnetic unit. A rubber and canvas belt passes over the rollers and over a wrought-iron tail pulley mounted on a high-tensile steel shaft running in self-aligning plummer-block bearings. The tail pulley is driven by a geared motor through an enclosed roller-chain drive. Adjustment for the belt tension is provided by mounting the tail pulley and motor on a baseplate carried on a screw jack from the main frame of the machine.

Flexible Coupling for Shafts.

Metaducts, Limited, Catherine Wheel House, High-street, Brentford, Middlesex, are demonstrating, on the stand of their parent company, the Concentric Manufacturing Company, Limited, a new all-metal flexible coupling, known as the Metastream, which has recently completed its proving tests successfully. It consists of two, or more, flexible membranes of stainless steel, Monel metal or phosphor bronze, attached at their peripheries to the driving and driven members, respectively, and riveted together, through an assembly of spacer rings, at their inner boundary. The coupling thus permits angular misalignment between the driving and driven members without rotary backlash. A reasonable degree of axial movement between the driving and driven components is obtained by providing a suitable number of flexible membranes for the particular application.

Fig. 51 shows a longitudinal section through the "spacer" type of Metastream coupling. In this, a short spacer shaft is interposed between the driving and driven members and is connected to each by the flexible-membrane coupling, an arrangement which permits lateral displacement as well as angular displacement, between the driving and driven members. The Metastream coupling is not affected by climatic conditions or operating temperatures. Since the angular misalignment is accommodated by the flexure of the membranes, with no sliding or rolling contact, no lubrication is required. The coupling membranes and spacer shaft are easily dismantled without disturbing the driving and driven components.

Fork-Lift Truck.

Messrs. I.T.D. Limited (Industrial Truck Development), 95-99, Ladbroke-grove, London, W.11, an associate of Messrs. Austin Crompton Parkinson Electric Vehicles, Limited, are showing a range of fork-lift trucks with load capacities from 1,000 lb. to 5,000 lb., and lifting heights from 6 ft. to 14 ft., together with ancillary equipment which can be used with them for special handling problems; and a range of industrial platform trucks with load capacities from 2,000 to 4,000 lb., provided with either fixed or elevating platforms. Fig. 52, herewith, shows the 2 DH/9 fork-lift truck, with a capacity of 5,000 lb. and a maximum lift of 9 ft., displayed at Castle Bromwich for the first time. The 2DH/9 truck has been developed for use in areas where a fire hazard exists. It is fitted with a Perkins P4 four-cylinder Diesel engine, developing 43 brake horse-power at the maximum governed speed of 2,400 r.p.m. The air intake and exhauster silencer are designed to minimise the fire risk, and an air-operated starter motor is provided instead of the usual electric starter.

The drive is transmitted through a 14-in. diameter Borg and Beck single-plate clutch and a gearbox giving two forward and two reverse speeds. The truck has a maximum speed of 10 m.p.h. From the gearbox, the drive is transmitted through a bevel and pinion and heavy-duty differential gearing to the front-axle half-shafts, which carry pinions at their ends engaging with annular gears bolted to each road wheel. A standard Marles steering box is fitted; the steering action is transmitted to the road wheels through a drag link, bell-crank and divided track rod. The rear axle, a high-tensile steel casting, is mounted on semi-elliptic leaf springs. The road wheels run on tapered-roller bearings. The front driving wheels are provided with foot-operated Lockheed internal-expanding two-leading-shoe brakes. A parking brake is also fitted.

EXHIBITS AT THE BRITISH INDUSTRIES FAIR.

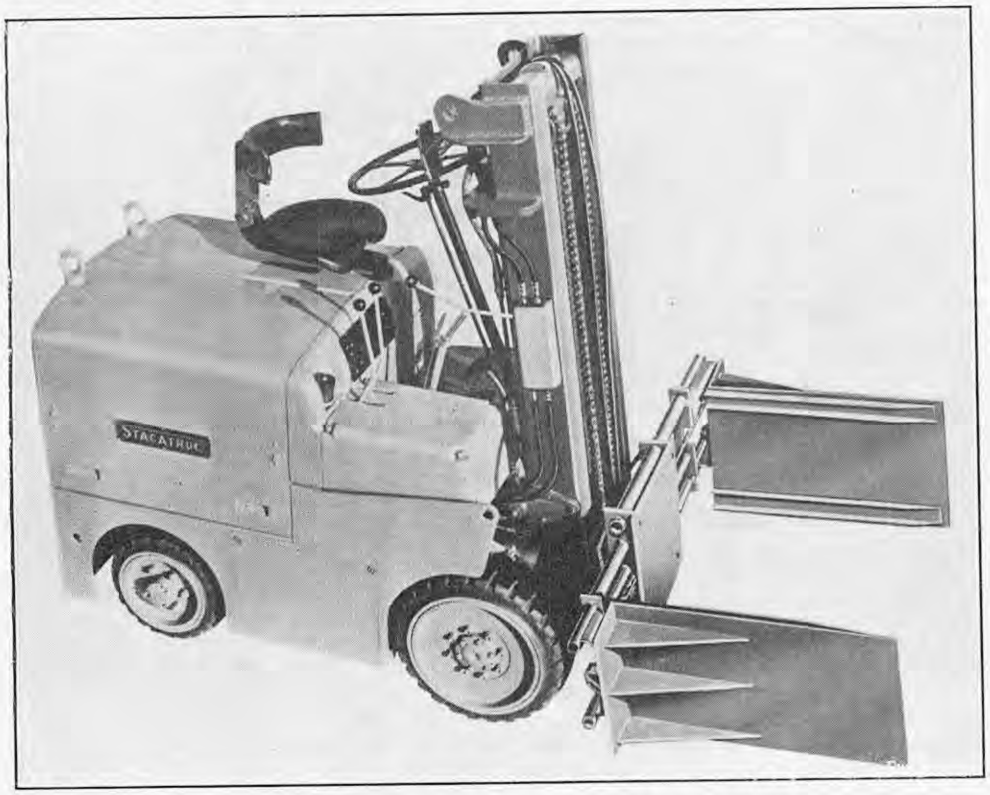

FIG. 53. LIFT TRUCK WITH GRAB; I.T.D., LTD.

The lifting and tilting motions are hydraulically operated, pressure at 1,700 lb. per square inch being supplied by an engine-driven Plessey hydraulic pump. The lifting ram and the two tilting rams are hard-chromium plated and precision ground. The tilting rams have moulded synthetic-rubber sealing boots to prevent the ingress of dirt. The hydraulic system, which is provided with non-return valves and a pressure-relief valve, is designed to give a maximum lifting speed of approximately 36 ft. per minute, and to tilt the full working load 3 deg. forward and 7 deg. backward.

The chassis is a sturdy welded-steel structure, with steel brackets supporting the steering-axle and road-spring assembly. The front-drive axle, rigidly bolted to the chassis, carries a hinge bar about which the mast-framing outer assembly pivots for the tilting action. Brackets on the mast frames engage with the tilting rams. The mast channel framing consists of an outer assembly, as already mentioned, and an inner assembly which is a sliding fit in the outer channel. The lifting carriage travels vertically on ball-bearing rollers on the inner channel; it is lifted by a cross-head attached to the lifting ram.

The cross-head carries two ball-bearing rollers over which pass two laminated chains attached to the lifting carriage. Either chain is capable of supporting the lifting carriage with maximum load. The lifting-carriage roller brackets are bolted to heavy rectangular-section steel cross-bars, in which the lifting forks, of forged alloy steel, are free to slide. The lifting forks are self-locking; they can be detached easily from the cross-bar. Access panels are provided for inspecting and servicing the engine and hydraulic units.

Also on view on the stand of I.T.D., Limited, is a battery-operated 30EH/9 truck fitted with a Rodman grab mechanism, illustrated in Fig. 53, above. This mechanism largely eliminates the necessity for using pallets, since it can handle directly such goods as barrels, packing cases, etc. The grab arms are hydraulically operated and have a range of movement from approximately 16 to 6 in. The load-carrying capacity is 1 ton. The mechanism is self-centring to ensure that the truck cannot be loaded in such a way as to upset its stability. The truck is also fitted with a free-lift mast, which enables materials to be stacked in areas where the head room is severely restricted.

(To be continued.)

LITERATURE.

Muddy Waters: The Army Engineers and the Nation's Rivers.

By ARTHUR MAASS. Harvard University Press, Cambridge, Massachusetts, U.S.A. [Price 4.75 dols.]; and Geoffrey Cumberlege, Oxford University Press, Amen House, Warwick-square, London, E.C.4. [Price 31s. 6d. net.]

THE title of this book is likely to mislead some potential readers. It might not unreasonably be assumed to be concerned with river pollution, or possibly silting. Actually, it is in no sense a technical treatise and is solely concerned with political and administrative activities. The "mud" which forms part of the title is metaphorical. The book is a sustained attack on the proceedings of the Corps of Engineers of the United States Army. As has been illustrated many times by articles in these columns, this body has been responsible for large numbers of important civil-engineering works in the United States. It appears from Dr. Maass's pages that it was set up in its present form in 1802 and was made responsible for the maintenance of navigation on rivers, and flood-control improvements and related works. It may be conjectured that a military body was entrusted with these duties in the civilian field because, at that early date, no other technical organisation was in existence. It is stated in a foreword, contributed by the late Mr. Harold L. Ickes, that the Corps is now "a small, powerful and exclusive clique of about two hundred Army officers" which controls "some fifty thousand civilian employees." Much of the river training, irrigation and water-power development in the United States is carried out by the Bureau of Reclamation, which is a civilian authority, and the relationship of this body to the Corps of Engineers is not clear. Apparently, the two organisations at times prepare rival plans for the same piece of work. The charge which is made against the Corps is that it defies the authority even of the President and carries out works in conjunction with local councils, and even of commercial companies, which are not in the interest of the country as a whole; State funds are said to be diverted to private ends. The Corps is accused of maintaining its authority by lobbying in Congress. These are matters on which outsiders will refrain from expressing opinions, but it may be suggested that the tone of this book is hardly in keeping with the impartiality that might be expected from its academic publishers. Mr. Ickes, who died on February 3, was a distinguished man who carried out with ability important civilian tasks during the war and was described by *The Times*, in its obituary notice, as "an incorruptible politician", but when he described the Corps of Engineers as an "insubordinate secret society" and accused it of having "wantonly wasted money on worthless projects" he was indulging in language more suited to a political pamphlet than to a publication bearing the imprint of Harvard University.

The Science of Flames and Furnaces.

By M. W. THRING, M.A., F.INST.P., F.INST.F. Chapman and Hall, Limited, 37, Essex-street, Strand, London, W.C.2. [Price 42s. net.]

THE furnaces with which this book is concerned are those of the fuel-fired type employed in the metallurgical, glass, pottery, brickmaking and other industries for heating materials to temperatures above 400 deg. C. Boiler furnaces are therefore excluded. The author predicts that "the furnace of the future will be a precision tool of the highest accuracy" and his aim has been to present a summary of those physical, chemical and thermodynamic principles upon which good furnace practice should be based. After a brief review, with illustrations, of the principal kinds of industrial furnace, heating processes are considered in the light of the First and Second Laws of Thermodynamics. The point is made that, when the processed material is finally required in the cold state, the heat consumption might be almost negligible if losses were minimised and the hot product cooled by the recovery of its heat. To avoid the notion of entropy—a word that appears only in a footnote—the author introduces what he calls the "virtue" of heat, this being defined as the proportion that could be turned into work by a Carnot engine rejecting heat at the room temperature. Thus the loss of "virtue" is the same thing as the increase of entropy in a heating process. A good deal of space is given to diagrams in which virtue is represented by the area under a curve of which the co-ordinates are, respectively, heat and the inverse of the absolute temperature, the amount of virtue being obtained by counting the squares under the curve. The procedure appears unnecessarily troublesome and tedious when compared with the simple computation of the entropy change. The chemical reactions and the liberation of heat in combustion are next explained, but, as elsewhere in the book, the reader who would like a straightforward statement of the author's own conclusions often has to content himself with summaries of the possibly conflicting ideas of innumerable other people. He will find, for example, in a single paragraph of 25 lines, a condensation of the various opinions expressed by nine different investigators on the process of combustion in fuel beds. This apparent anxiety not to omit the name of anybody who has ever published anything about combustion or furnaces may irritate the practical man whose only concern is with established facts.

The methods of measuring furnace temperatures, and of calculating the rates of heat transfer by conduction, convection and radiation are dealt with at considerable length, with many nomograms and useful tables of data. Then a chapter of the flow of hot gases through furnaces leads to a consideration of the principles involved in the construction of furnaces and the control of their operations. In connection with the design of catenary arches for furnace roofs, the reader is told that such arches can be readily drawn by marking them off from a small-link chain suspended against the drawing paper, but the author does not say whether he has ever tried to do this. The usual and much more sensible way is to draw a parabola of the required span and rise, for the two curves are indistinguishable on a drawing board and the parabola lends itself to an extremely simple graphic construction. The book is one that is likely to interest both designers and users of furnaces, and its value as a work of reference is enhanced by the summaries of facts and formulæ relating to particular subjects, provided at the ends of the appropriate chapters.

THE INSTITUTE OF METALS.

(*Concluded from page* 513.)

Continuing our report of the annual general meeting of the Institute of Metals, held in London from March 24 to 27, we have now to deal with the proceedings on the last day of the meeting, Thursday, March 27. In the morning, parties visited the works of the Ford Motor Company, Limited, Dagenham, and J. Stone and Company (Charlton), Limited. Other members remained in London and took part in a technical session arranged by the Metal Physics Committee and presided over by Professor A. G. Quarrell. Five papers were presented, the theme of the first two being "Fatigue," and that of the last three, "Plastic Deformation."

Fatigue of Metals.

The two papers dealing with fatigue were considered jointly and were presented by a member of the Metal Physics Committee, Dr. F. C. Frank. The first paper was entitled "Some New Observations on the Mechanism of Fatigue in Metals." The authors, Dr. W. A. Wood and Mr. A. K. Head, of Melbourne, Australia, stated that the response of the crystalline structure of a metal to static stressing had been compared, by X-ray diffraction methods, with its response to cyclic, or fatigue, stressing. The essential difference was that static stressing produced an extensive and progressive disorientation of the internal structure of the grains, whereas under cyclic stressing this derangement was largely suppressed. It was inferred from the observations made that, if a grain were subjected suddenly to a stress greater than the normal yield stress and then allowed to deform in its own time, there was a delay period before any appreciable plastic strain occurred. It would appear reasonable to assume also that this inhibition of unidirectional deformation at rates of cyclic stressing above the critical rate, in effect, transformed a normally ductile metal into a brittle medium, and thus accounted for some of the basic factors in the failure of metals by fatigue.

The other paper on fatigue, "Some Metallographic Observations on the Fatigue of Metals," was by Mr. P. J. E. Forsyth, of the Royal Aircraft Establishment. Mr. Forsyth stated in his paper that a metallographic investigation of the effects of cyclic stresses on the microstructure of an aluminium-silver alloy containing 0·5 per cent. silver had shown that factors other than simple slip were involved in the mechanism of fatigue at room temperature. There was evidence of a recovery process associated with the production of deformation bands and crystallites during the fatiguing of the metal and it was suggested that the observed anomalies in the effect of stress concentration on crack progress were the result of crystallite formation at the roots of the cracks.

Plastic Deformation.

The three papers on "Plastic Deformation" were also considered jointly and were presented by Mr. F. R. N. Nabarro. The first was by Dr. R. W. Cahn, of the Atomic Energy Research Establishment, Harwell, and dealt with "Slip and Polygonisation in Aluminium." Dr. Cahn stated in his paper that aluminium crystals, in the form of plates 20 mm. wide, 2 mm. thick and 150 mm. long and of predetermined orientation, had been produced, from the molten state, in the laboratory. The development of slip lines during the stretching of these crystals had been studied in detail, with particular reference to cross slip and to deformation bands. While always maintaining the same slip direction as the principal slip, cross slip took place on several distinct planes and the proportion of cross slip increased with the deformation and with rising temperature of deformation. Annealing at high temperatures caused progressive polygonisation within the bands; new grains, formed by recrystallisation, tended to advance preferentially along the bands. Polygonisation of the deformation bands was associated with a local rumpling of the free surface of the specimen. The formation of these markings was accelerated by the application of a tensile or compressive stress while annealing, and this implied that polygonisation was accelerated by an applied stress.

The second paper, by Dr. R. W. K. Honeycombe, described work carried out at the Cavendish Laboratory, Cambridge, on "Inhomogeneities in the Plastic Deformation of Metal Crystals." In the first section of the paper, Dr. Honeycombe stated that a study had been made of the occurrence of X-ray asterisms from deformed single crystals of a typical hexagonal metal (cadmium) and a typical cubic metal (aluminium). Cadmium could be extended by more than 100 per cent. elongation in tension without the appearance of asterisms in X-ray Laue photographs; asterisms occurred only when the crystals were macroscopically bent or kinked. On the other hand, asterisms were present in photographs from aluminium crystals after less than 4 per cent. elongation in tension. The experiments conducted during the investigation suggested that tensile deformation caused crystals of aluminium, but not of cadmium, to break down into a series of slightly disoriental blocks connected by regions of distortion or lattice curvature.

In the second section of his paper, Dr. Honeycombe stated that he had used a technique of X-ray microscopy in conjunction with optical micrography to investigate the structure of large aluminium crystals deformed by small amounts in tension. Two types of microscopic inhomogeneity occurred, and these caused local variations in orientation. The first consisted of narrow regions of curvature or "kink bands" which separated slightly disoriented lamellæ of the crystal. The second type of inhomogeneity comprised bands of secondary slip which were almost parallel to the primary slip planes in the early stages of deformation. The inhomogeneities played an important role in the deformation of aluminium and accounted for many of the differences between this metal and cadmium, such as the occurrence of X-ray asterisms, the marked differences in strain-hardening, and the extent to which recovery could occur on annealing.

The last of the three papers concerned with plastic deformation was entitled "Slip Bands and Hardening Processes in Aluminium." It was by Dr. A. F. Brown and described work carried out in the Cavendish Laboratory, Cambridge. The author stated that slip bands in aluminium increased in number during plastic deformation and, at the same time, further slip occurred within each band. At higher temperatures and lower rates of deformation, as well as with increasing strain under all conditions, the latter of the two processes became increasingly predominant. This had been interpreted on the basis of the fine structure of slip bands which had been resolved by the electron microscope. The differences in density and inner structure of slip bands formed under different conditions had been compared with the differences between stress-strain curves, and it had been found that slip which formed a new band involved much more macroscopic hardening than slip within an existing band. A consequence of this conclusion was that a mechanical equation of state could exist only at very small strains.

In the afternoon, the members who had taken part in the morning Metal Physics session visited the research laboratories of the British Iron and Steel Research Association at 140, Battersea Park-road, London, S.W.11; the research laboratories of the General Electric Company, Limited, Wembley, Middlesex; and the precious-metal refinery of the Mond Nickel Company, Limited, Acton, London, N.W.10.

A Development in Core-Binding Technique.—Aero Research Ltd., Duxford, Cambridge, have recently introduced a new form of synthetic resin core-binder. This product, marketed as "Resolite" 400, is said to have overcome the difficulty of stickiness commonly associated with resin-bonded mixes and to facilitate core-making on the bench and in core-blowing machines. With the new binder, mixers can be run at a much greater capacity than with conventional urea-formaldehyde binders and it is claimed that drying out does not occur during normal periods on the bench. These advantages are obtained without affecting the rapid stoving times, good breakdown properties and other well-known characteristics of synthetic-resin core-binders.

LEONARDO DA VINCI, THE ENGINEER (1452-1519).

By K. R. Gilbert, M.A., D.I.C.

(*Concluded from page* 561.)

Nothing about Leonardo is more strikingly modern than his striving to invent automatic machinery, especially for the high-speed production of useful commodities. The only automatic machine then known was the clock; and the upper turnspit shown in Fig. 12, on Plate XXVIII, uses clockwork to turn the roast. It is actuated by the fall of a weight and the speed is limited by the wind-brake with four vanes, shown at the top. The lower apparatus is a heat engine, since it is driven by a fan impelled by the hot air ascending the chimney. The file-cutting machine is also a simple weight-driven automatic machine. A heavy chisel is repeatedly raised and allowed to fall on the blank, which is caused at the same time to travel by means of a lead-screw geared to the drive.

When Leonardo was in Rome he was interested in improving the production methods of the Mint and in this connection designed one of the most complex of his automatic machines. This is the machine for hammering the gold bars from which the coins were to be stamped (Fig. 14, Plate XXIX). The hammer, raised four times for each revolution of the shaft, is mounted on a movable carriage. An anti-friction roller, by engaging a flange, which partially encircles the shaft, makes the carriage move to the left against the pull of the counterweight on the right. At the completion of a revolution the carriage slips back, momentarily raising the clamps which hold the gold bar. At the same moment the ratchet-wheel at the bottom is moved on by one tooth and winds the bar along. The details of the machine are made clear by several other sketches and notes. All parts of the bar thus come under the hammer in turn. The machine was intended to be one of eight, driven by the same prime mover, probably a water wheel. To avoid any unnecessary expenditure of energy, Leonardo directed that "The machine must be so arranged that, when the hammer gives the last blow, an object is touched, which makes a weight fall down, by means of which the gear is withdrawn from the wheel of the motor."

Leonardo left many designs for a machine to grind sewing needles. He expected it to achieve a rate of production which would be surprising even to-day. Reference was made to this project in Engineering of April 11, on page 465, *ante*, but the passage is worth quoting again. Leonardo wrote: "Tomorrow morning on the 2nd of January, 1496, I shall have the broad band made and make the test. 400 (needles) each time a hundred times per hour comes to 40,000 per hour and 480,000 per 12 hours. Let us say, however, 4,000 thousands (corresponding to ten machines), which, at 5 soldi per thousand, gives 20,000 soldi, that is a total of 1,000 Lire per working day, and if one works 20 days per month, that is 60,000 ducats per year." This would have been a princely income. Incidentally, though the working hours were to be long, they were to be worked in a five-day week.

It was in the textile industry that factory methods of production, based on the processing of fibres in a continuous series of machines, first came into being in the Industrial Revolution. It is almost prophetic, therefore, that Leonardo gave so much attention to the design of textile machines. He attempted to co-ordinate the motions of a loom and left a highly schematic representation of a power-loom, which he regarded as "a most profitable and most beautiful and subtle invention." The shuttle was to be carried halfway across the shed by an arm entering from one side and then to be transferred to another arm, which would bring it out to the other side. The world had to wait until 1785, however, before the power-loom, at the hands of Edmund Cartwright, became an actuality.

If a textile operative has more than one machine to attend to, it is most desirable to have some automatic means of stopping the machine or part of it, if a thread breaks; otherwise, much material may be wasted. Leonardo expressly recognised the need for stop-motions and designed alternative forms for use with silk doubling machinery. Such

ENGINEERING DESIGNS OF LEONARDO DA VINCI.

(*For Description, see Page 580.*)

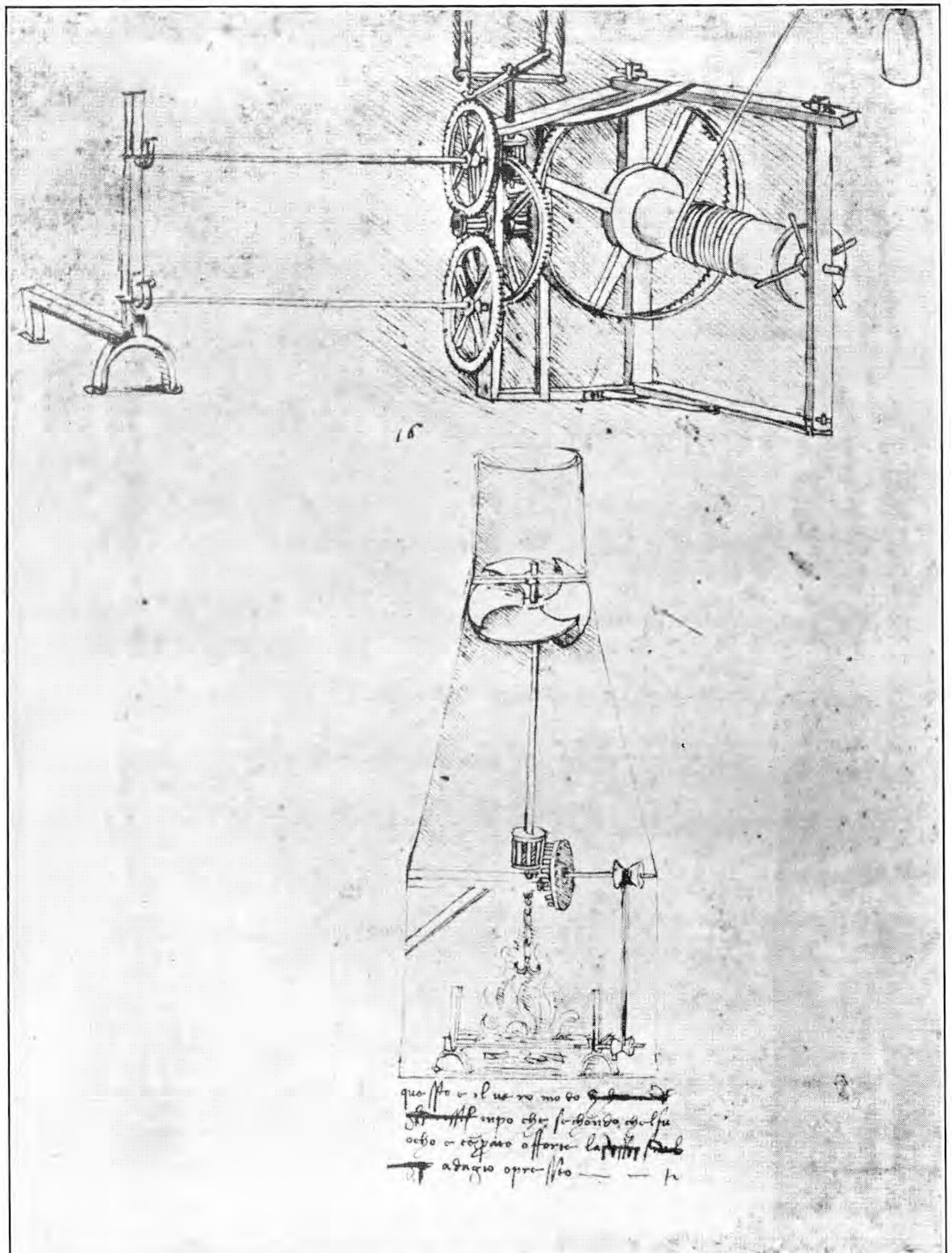

FIG. 12. TURNSPITS.

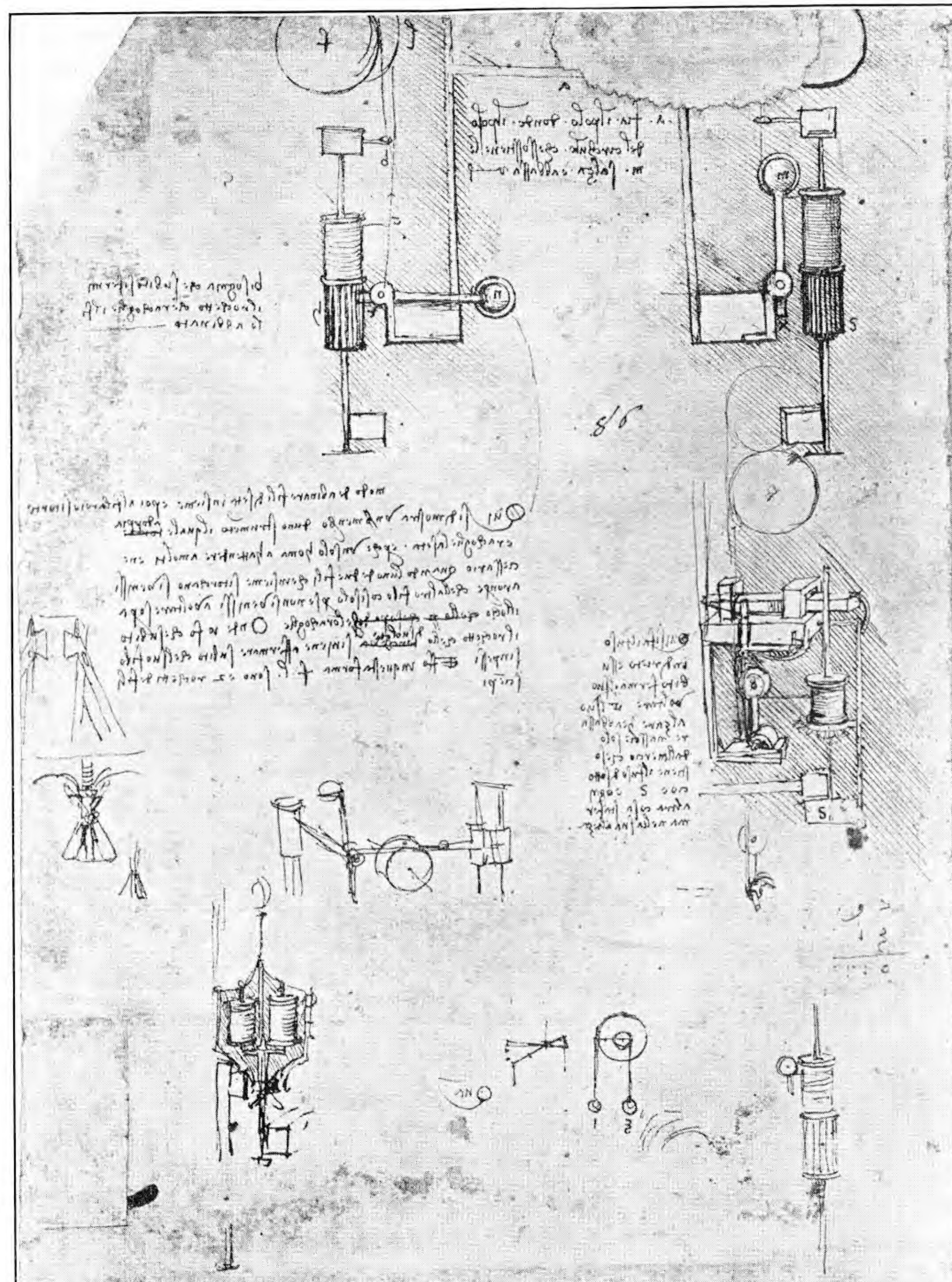

FIG. 13. STOP MOTIONS.

ENGINEERING DESIGNS OF LEONARDO DA VINCI.

(*For Description, see Page* 580.)

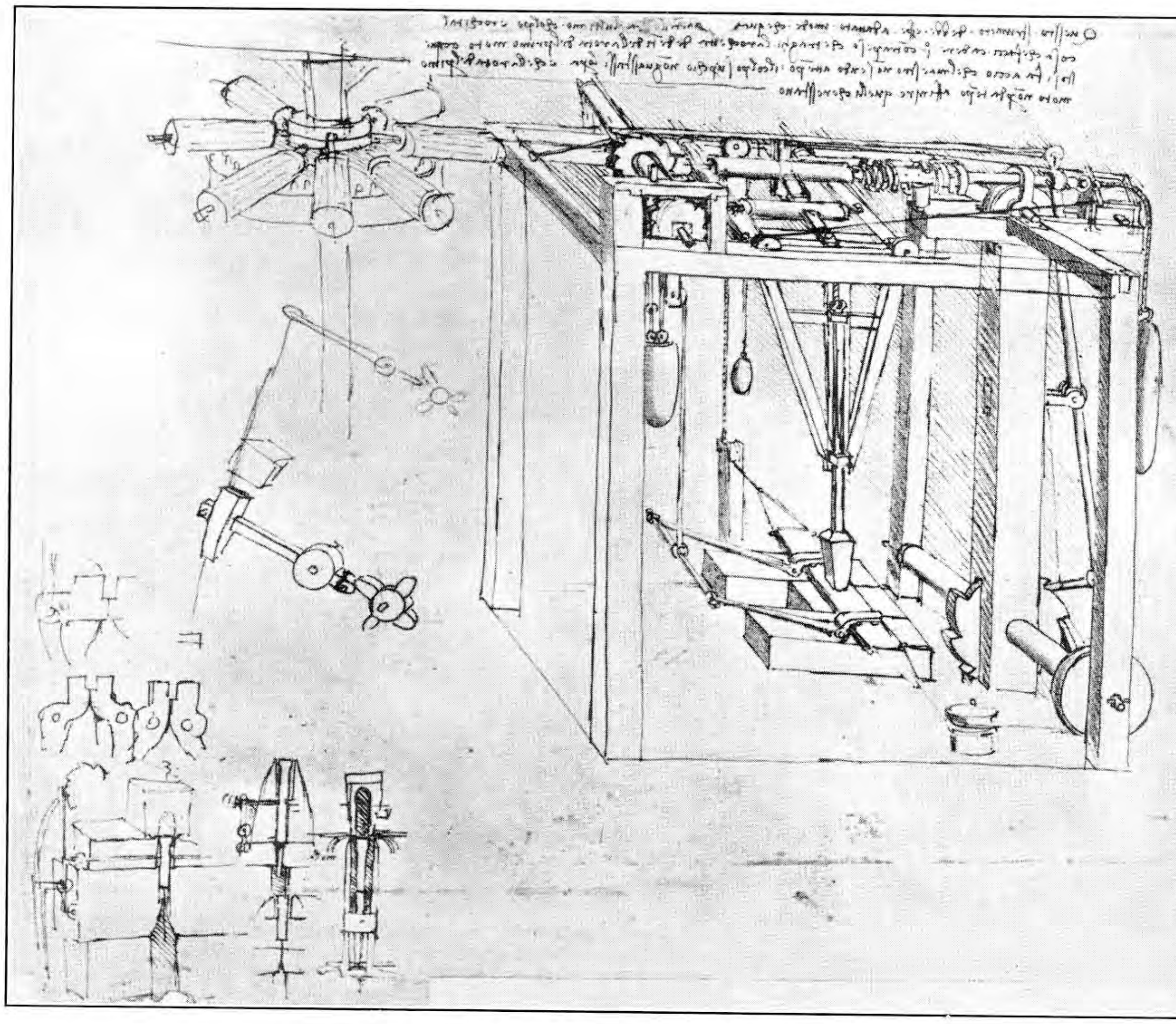

FIG. 14. HAMMERING MACHINE.

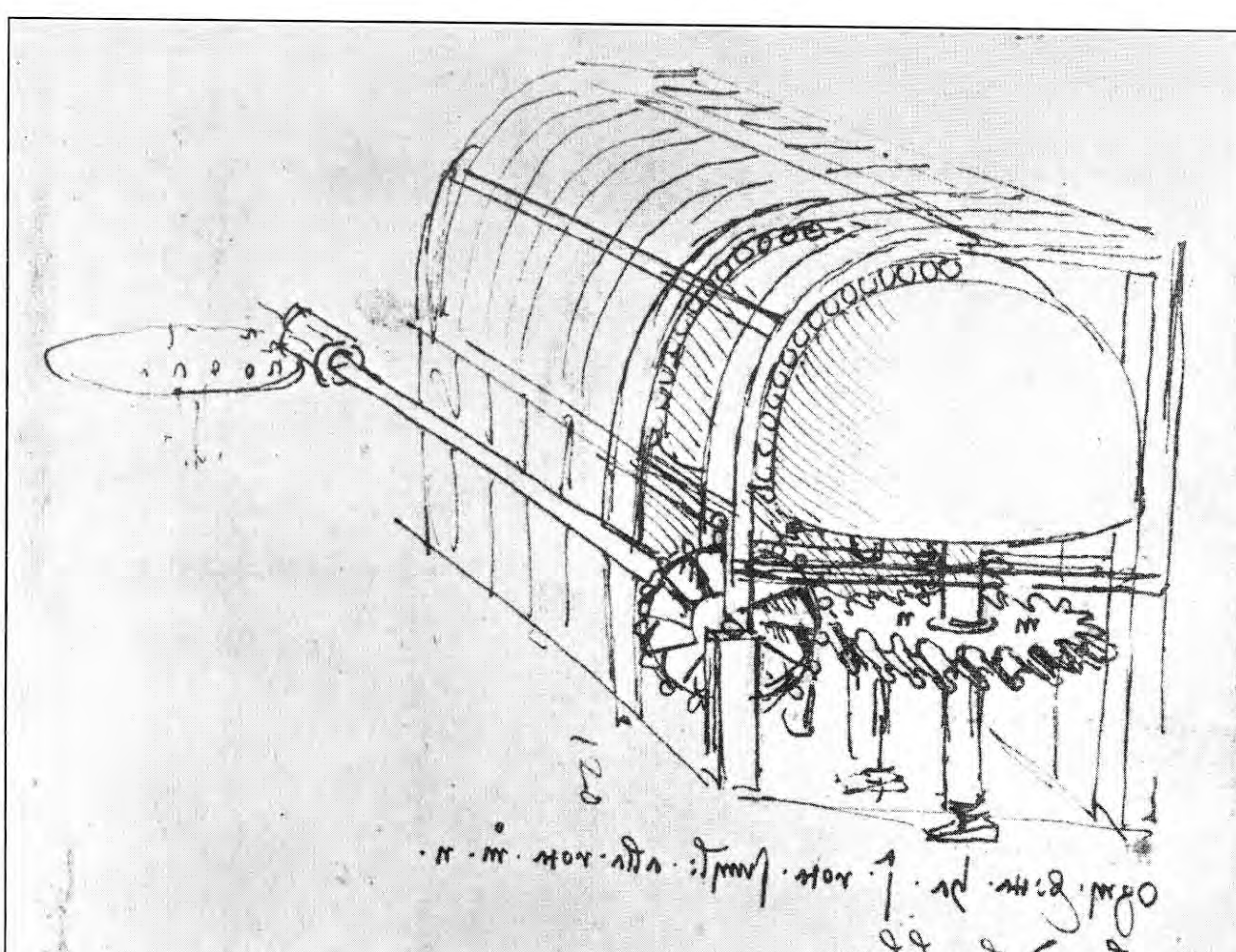

FIG. 15. NAP-RAISING MACHINE FOR CAPS.

DESIGNS OF LEONARDO DA VINCI.

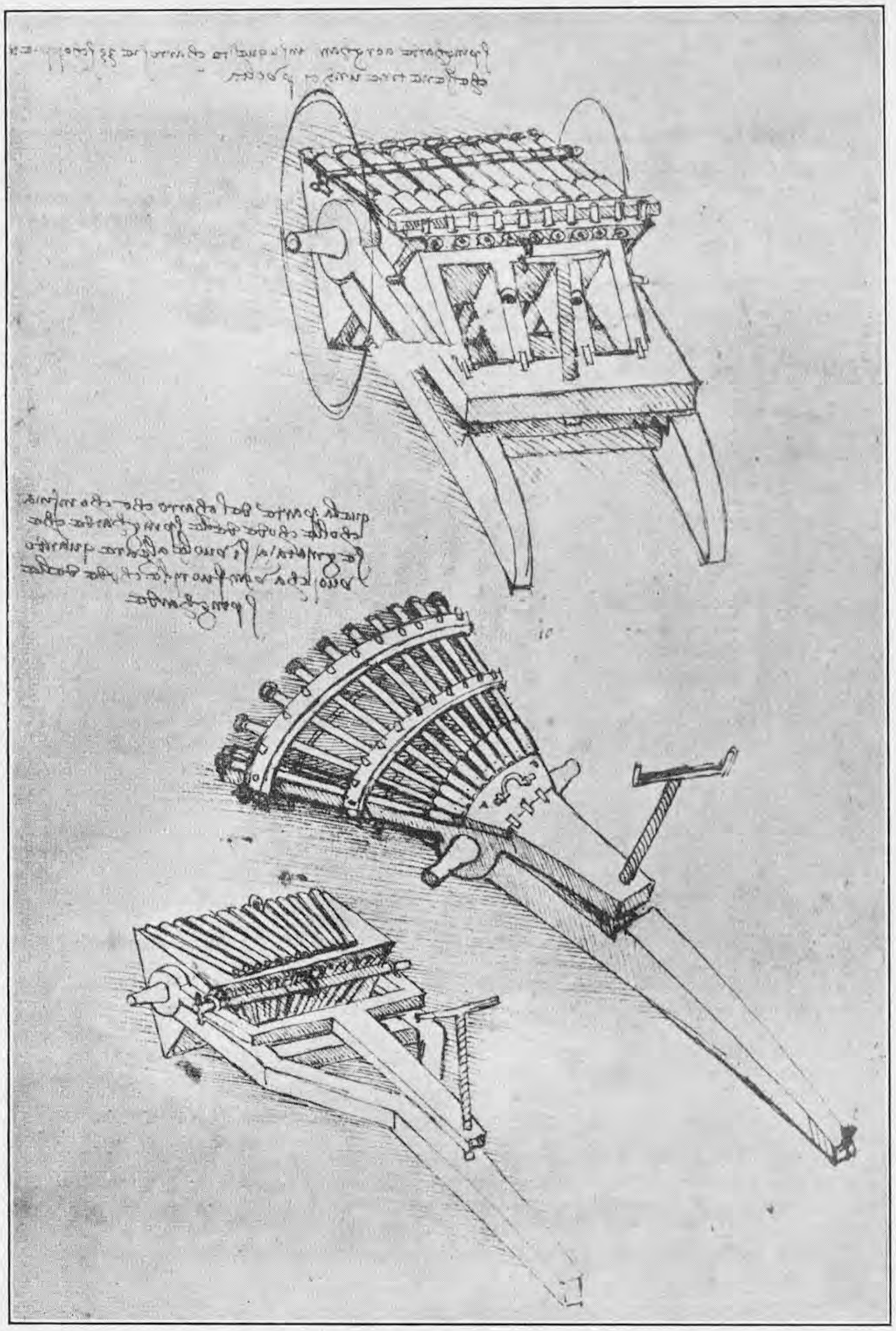

FIG. 16. MULTI-BARRELLED GUNS.

machinery was in use in Lucca and later in Florence, well before Leonardo's time.* Two threads were wound together on to a bobbin. The bobbin was then placed on another machine and the threads reeled off in such a way as to insert twist. Fig. 13, on Plate XXVIII, shows two stop-motions that he designed for the former machine. In the first arrangement, each thread on its way to the bobbin passes under a roller *m*, which is attached to an arm *a*, which moves up and down to distribute the thread evenly. Should a thread break, its roller drops and the other end of the lever rises and engages the teeth of the wheel *s*, thus stopping the bobbin. The diagram shows a working spindle on the right and one in the stopped position on the left. The lower diagram shows a similar mechanism for use in the case where the bobbin, instead of the guide-roller, moves up and down.

In his design of shearing machines, Leonardo did not advance beyond the idea of operating a number of hand-shears simultaneously by mechanical means. There are several drawings of cloth-raising machines, among which the most interesting is for raising the nap of cloth caps (Fig. 15, Plate XXIX). The caps are rotated in contact with teasels set in the inner wall of the machine. The accompanying note reads: "Each cap has a similar wheel to the wheel *mn* and each turns the other round." Mass production in manufacture found its parallel, in the sphere of war, in the designs of multi-barrelled guns such as are depicted in Fig. 16, herewith.

The extent to which Leonardo's designs were actually realised is a question to be judged from the internal evidence of the notebooks, as the reports of the period do not help. Vasari refers only to trivial experiments, which were more in the nature of practical jokes, and details are lacking in Cardano's laconic comment: "Leonardo da Vinci also attempted to fly, but misfortune befell him from it. He was a great painter." There are several references in the notebooks to workshops and to the workmen he employed in them. Leonardo's employment as a constructor of canals and as a military engineer would have been an occasion for the building of such machine-tools as the screw-cutting machine. There are also references to models, as, for instance, to this one of a flying machine: "Close up with boards the large room above, and make the model large and high, and you will have space upon the roof above, and it will be more suitable in all respects than the Piazza d'Italia. And if you stand upon the roof at the side of the tower, the men at work upon the cupola will not see you." Again, after describing an air-screw or helicopter, 28 ft. in diameter, presumably intended to be capable of lifting a man, but for which the motive power did not then exist, he wrote: "You may make a small model of pasteboard, of which the axis is a thin piece of iron and as it is released it will turn the screw."

In 1517, Leonardo was visited by the Cardinal of Aragon, whose secretary, describing the visit, wrote: "He has also written of the nature of water, and of various machines, and of other matters, which he has set down in an endless number of volumes, all in the vulgar tongue, which, if they be published, will be profitable and delightful." Unfortunately, he never found time to do the work of editing and rewriting. Irresistibly urged on by his thirst for knowledge to fresh research and invention, he wrote more and more notes. The Leicester Manuscript contains the plan of a book on the properties of water and he intended to write books on mechanics, the flight of birds and other such subjects. On the first page of a manuscript in the British Museum he wrote: "This will be a collection without order, made up of many sheets which I have copied here, hoping afterwards to arrange them in order in their proper places according to the subjects of which they treat." The manuscripts have, in fact, not been collated yet. The form of the notes must have discouraged Leonardo's heirs and successors from attempting to edit and publish them, for they are written with a peculiar system of abbreviations, and in mirror-writing, to conceal his inventions from the inquisitive.

The scientific aspect of Leonardo's nature was lost sight of for more than two centuries until G. B. Venturi, in 1797, published an essay, which, however, dealt mainly with mathematical topics. Line drawings of some of the mechanical designs were published by Hermann Grothe in 1874, but the quality and range of Leonardo's thought in the field of engineering became widely known only with the publication of the notebooks in facsimile, a work which began 70 years ago. The interpretative studies in a series of papers* by Theodor Beck, which appeared at that time, remain, apart from the notebooks themselves, the most valuable source of information on Leonardo's engineering.

An examination of the technical books published in the century which followed Leonardo's death shows that his influence was not entirely lost. Some familiarity with the notebooks or a tradition derived from his pupils accounts for the influence, which is clear in the books of such writers as Ramelli, Zonca and Veranzio. Zonca went so far as to give a version of the automatic turnspits and Veranzio drew a parachutist, erroneously describing him as a "man flying." This influence was, however, only superficial and the implications of Leonardo's work were lost on his immediate successors.

Fra Pietro da Novellara, writing in 1501, reported that: "In brief, his mathematical experiments have made painting so distasteful to him that he cannot even bear to take up a brush." The mainspring of Leonardo's life was his consuming desire to understand the world and all it contains. Perhaps his impatience with painting arose from a feeling that, in this domain at least, he had solved his problems, while the achievement of flight, to name an example, presented a fascinating challenge to his ingenuity. We can only regret that his art suffered so much from the pursuit of problems which lesser men were in the course of time to solve. Engineering in the Fifteenth Century was the lore of gunmakers, builders and craftsmen. Leonardo was the first to insist on an experimental approach to scientific problems. He saw science and engineering as a great and logical structure, built on experiment and deduction, and welded together by mathematics.

* *C.I.B.A. Review*, June, 1950.

* *Beiträge zur Geschichte des Maschinenbaues* (1899), three chapters; and *Z.V.d.I.* (1906), Part I, four papers.

THE INSTITUTION OF NAVAL ARCHITECTS.

(*Continued from page* 551.)

THE second of the two papers presented on the afternoon of April 3, when the Institution of Naval Architects (following what has now become the practice at their Spring Meetings) held a joint session with the Institute of Marine Engineers, dealt with "High-Powered Single-Screw Cargo Liners" and was contributed by Mr. W. H. Dickie, manager of Messrs. Alfred Holt and Company's Blue Funnel Line. The chair was taken by Viscount Runciman, the President of the Institution.

HIGH-POWERED SINGLE-SCREW CARGO LINERS.

Mr. Dickie's paper outlined the design considerations, the eventual hull and machinery particulars, and the service performance of two broadly similar classes of 18½-knot cargo liners—the "P" and "H" classes—ordered by the Blue Funnel Line for their Far East and Australian services, respectively. Four of each class were built, and all were propelled by double-reduction geared turbines, driving a single screw. The dimensions of the "P" class were 515 ft. 6 in. in length overall and 478 ft. between perpendiculars, with a moulded breadth of 68 ft. and a summer loaded displacement of 18,920 tons (gross tonnage, 10,093); and of the "H" class, 523 ft. overall and 485 ft. between perpendiculars, 69 ft. breadth moulded, and 19,507 tons displacement (10,125 tons gross). The forms of the vessels were the subject of extensive tank tests. Alternative proposals were considered for the propelling machinery, comprising twin-screw two-stroke Diesel engines; but this arrangement was found, after tank tests, to be 2 per cent. less favourable than the single-screw turbines, 18 per cent. more costly for the complete ship, and to require more space, at the expense of cargo capacity. These factors greatly outweighed the lower fuel consumption of the Diesel engines. In service, some trouble was experienced with wear of the secondary pinions and the main gearwheels. This was reduced by hand dressing and eliminated by giving additional tip relief to the teeth, in one case by a change in the design of the hobs and in another by a post-hobbing process. Another trouble that arose was excessive consumption of lubricating oil, traced to pressure in the gearcase, generated by windage of the main gearwheel; this was cured by fitting baffles over the pinion-bearing caps and modifying the drains. In the "P" class, the condensers were entirely free from defects; but the "H" class, on the Australian run, had a number of tube failures, for which no adequate explanation could be found. In the early ships of the classes, difficulty was experienced in obtaining more than 10·5 per cent. CO_2; but alterations to the oil-burner air registers and to the burners themselves brought an immediate gain of 2 per cent. in fuel economy.

DISCUSSION.

The discussion was opened by Mr. R. B. Cooper, who, as a combustion engineer, expressed particular interest in the improvement obtained by changing the design of the oil burners; it was remarkable that, in an economic ship, with economisers and air heaters, there could be a saving of nearly 2 per cent. of fuel. How much more saving could possibly be made in other ships which have not air heaters or economisers? He knew of at least 40 ships in which the burners had been converted to a more modern design; in every one, the saving had been well worth while. He knew also, however, of a case where that was not so, because the subject was not approached from basic principles. It was necessary to think not only of how to obtain good combustion, but also in terms of the operating crew. In regard to the ships discussed in the paper, the engineers were extremely good and the crews followed out their instructions. That was not the case in all ships.

The air pressure available from the fans was an important feature. The author's table on superheat gave the number of burners per boiler and the steam temperature. The air pressure, after modification of the oil-burning technique, was 8 in., and yet the steam temperature was down; the reason was that combustion was being completed in the furnace. There was also much less excess air. That indicated clearly that there was a higher draught loss through the burners, thereby giving a higher velocity of air to mix with the oil, producing better combustion. The point made by the author about running from Liverpool to Singapore without changing a burner for cleaning was interesting. Good combustion necessitated a precision-made atomiser with very fine clearances and a knife-edge orifice, which was easily damaged. It is also important to introduce into the burner a device whereby the sprayer remained clean. But if a sprayer with a knife-edge orifice became dirty, it might give poorer atomisation after cleaning than before. Burners in ships should be changed more often than they were. In the average ship, one burner consumed about 8 tons of oil a day, costing nearly 50*l*. If a really good atomiser could be made and mass-produced, and if, by its use, 0·5 per cent. of fuel could be saved, that saving would pay for an atomiser each week. The author mentioned that soot deposits in superheaters had been so far reduced as to be no longer significant; that question was tied up with atomiser cleaning. If only 1 per cent. of large drops came from the atomiser, and that 1 per cent. was only half burned when it reached a cold surface, an average burner, consuming 8 tons of oil per day, would deposit 5 cwt. of soot in the boiler in a week.

Mr. H. N. Pemberton said that the paper was of considerable interest in view of the large-power single-screw tankers projected in Europe and the United States. Those ships, up to 40,000 tons deadweight and transmitting 20,000 to 22,000 shaft horse-power through a single screw, presented operational problems of which there was little previous experience; for example, large-diameter propellers of low revolutions were necessary for good propulsive efficiency at high powers, but they brought in their train difficulties of stern-frame design in ships having the machinery aft. In such cases, adequate propeller-aperture clearance was essential to avoid excessive propeller excitation—torsional, lateral and axial—of the dynamic system comprising the turbines, gearing, shafting and propeller. The experience of the Research Department of Lloyd's Register had shown that, where aperture clearance was less than about 6 per cent. of the propeller diameter, there was danger of serious torque and thrust variations, of such proportions as might cause trouble with shafting, bearings and gearing. In addition, substantially large transverse forces become available for causing vibration of the ship's hull. Apart from the question of manœuvrability, the propeller, stern frame and rudder comprised the factors governing the maximum power which could be used conveniently in single-screw ships, particularly with engines aft. No other serious engineering factor seemed to arise.

The author mentioned that, in one ship, the tailshaft liner seized in the stern tube, the shaft revolving within the liner. The tailshaft in question was 23¾ in. in diameter, and it might be that the shrinking of liners on shafts of such a size involved manufacturing difficulties. However, slackening of the liner had occurred occasionally with new ships having shafts of normal size, and was generally attributed to insufficient clearance in the stern-tube bush, or to the swelling of the lignum vitæ when the fitting-out period has been unduly prolonged. It might be that, with very large shafts, the bush clearances and the size of water grooves were not adequate if based on established practice for shafts of normal diameter. Similar trouble had been associated with the use of laminated plastic bearings, and it was generally understood that a very ample supply of forced water-lubrication was essential with those synthetic bearings. He asked whether the author had experienced such trouble with bearings of that type. The author stated that, as the result of the experience described, his company now required an interference fit of 0·5 to 0·7 thousandths of an inch per inch diameter, which was in accord with representative American and British practice. He asked what shrinkage allowance was made in the case of the liner which became slack.

With reference to the tailshaft liner which, the author stated, had been "destannified"—presumably meaning that the tin had been taken out of the material—Mr. Pemberton thought that the explanation was that an electro-chemical process had been set up which caused selective corrosion of the tin in the alloy, and the solution and redeposition of copper. It was a similar process to dezincification, which attacked copper alloys containing silicon, aluminium, tin, arsenic and manganese. Could the author give the complete composition of the material, before and after the trouble occurred? It was unusual for that type of corrosion to occur with the zinc and tin contents normally used for tailshaft liners; so far as the electro-chemical interaction was concerned, he understood that tin had an inhibiting effect and, therefore, did not promote or encourage cathodic reaction. Tin was cathodic to iron and steel, and therefore the potential difference between the shaft and the ship's structure should lead to corrosion of the steel, and not to the "destannification" of the brass. Further details of that trouble would be valuable. Lloyd's Register had an active Engineering Research Department, which had a wide experience in investigating troubles in the machinery of ships, and though the author confessed to being mystified by this example of "destannification," there was no reason why the matter should be allowed to remain a mystery.

Mr. G. J. Innes suggested that the reason why some owners still adhered to twin-screw propulsion was that they did not wish to have all their eggs in one basket; it was very difficult to persuade the owners of a fleet of twin-screw vessels to change to single screws. Manœuvrability, he thought, especially swinging, was always related to the fineness of lines of the craft and to the length, rather than to the arrangement of the screw. The Mersey pilots always considered that the fine-lined ship did not swing so freely as the full-lined ship. The reference to tank tests and rudder thicknesses recalled to his mind some tank tests made on semi-balanced rudders of different shapes, where the results showed appreciable differences; an aerofoil form produced much better results than did any of the alternatives.

From the point of view of machinery efficiency, the ordinary shipowner was concerned with determining the amount of fuel needed to transport a specified quantity of cargo a specified distance, and over a course of voyages there were fractional differences in speed—half a knot as the extreme; if the differences were corrected to a common mean they disclosed that the fouling of the hull was quite the most serious factor in the running of a ship, where the machinery was behaving on a uniform basis of reasonable economy. For example, in a fleet where the docking cycle was a period of nine to ten months, the figures showed that there was always a heavier fuel consumption after one docking, heavier still after two, and again heavier still after three. That showed that hull fouling started from the first day after docking, and that it was a continuous phenomenon.

Professor L. C. Burrill said that, when the design was considered, 14,000 brake horse-power in a single screw represented a definite step forward, though the propeller makers had had some experience with powers not greatly inferior, in several ships for both foreign and British owners. The owners, builders, engineers and propeller makers co-operated for a period of two years before the final decision was taken. Twin-screw and single-screw alternatives were worked out in detail and the question of optimum revolutions for both kinds of propulsion was looked into. The preliminary investigations, which were made on the basis of systematic data, were confirmed by the comparisons made in the tank between the three-bladed and four-bladed propellers, and the performance figures deduced had been confirmed in the ships; which went a great way to counter the suggestion that control of the propeller problem by calculation had not advanced considerably in the past 20 or 30 years. The design of a single-screw propeller of such size and power involved a great deal of common sense, experience and compromise, in addition to the purely hydrodynamic problems; for example, the question of the size and weight of the propeller introduced new problems of handling, fitting and slewing, and the intensity of pressure on the tailshaft liner was also of extreme importance. For that reason, the final screws were made smaller than the optimum diameter indicated by the normal approach to propeller design. Furthermore, less blade surface was adopted than would be indicated by the usual analysis; the surface indicated was 200 sq. ft., and the actual surface was 195 sq. ft. Steps were taken to reduce weight by investigating the strength of the blades at each radius; obviously, that practice would obtain in the future, when larger powers were required. The performance of the propellers was extremely good and they had stood up remarkably well to the high loading they had been carrying. The blades were of aerofoil type throughout, despite the high loading, and it had not been found necessary to change to a less efficient type of section.

Mr. F. McAlister, saying that his particular interest in the paper lay in the choice of the mode of propulsion, commented on the way that history repeated itself. In the early days of marine engineering, slow-running paddle-wheel engines were geared up to turn the first screw propellers. Development proceeded quickly until, in 1879, the largest vessel was the Arizona, 450 ft. long, with a single screw and 6,350 indicated horse-power; in 1881 came the City of Rome, 560 ft. long, single screw, of 11,900 indicated horse-power, followed in 1885 by the Etruria and Umbria, Cunard liners, 501 ft. long, single screw, of 14,500 indicated horse-power, giving 19 knots. Further advances in the size and power of ships inevitably produced twin-screw propulsion, with consequent disadvantages in propulsive efficiency and manœuvring from rest. In the middle of the 1930's, much attention was paid to the development of high-powered single-screw vessels, as the advantages of that mode of propulsion were being increasingly appreciated. His own company had designed and made propellers up to 50,000 shaft horse-power with success; but there was a difference between multiple screws and single screws in that the wake behind a single screw was much more varied than behind the multiple-screw shaft bracket. It was that large variation in wake which brought propellers of about 15,000 h.p., designed with reasonable area, thickness and other normal features, up to the borderline of trouble. He was pleased, therefore, to see Mr. Dickie's comments that the propellers were reasonably satisfactory. To-day, designing offices and shipyards were concerned with single-screw vessels of 20,000 h.p., with possibly higher powers in prospect. Propellers for such vessels could easily weigh 45 tons, requiring a total melt of up to 70 tons of bronze, and they were bound to cause more than usual thought concerning design, material and manufacture.

Mr. S. Archer said that one of the chief difficulties with gearing defects, such as pitting, wear and scuffing, was to know with certainty whether the trouble was progressive or static. It was interesting, therefore, to note the author's use of sulphur casts. That material, however, was messy and required just the right amount of heat in melting. Furthermore, it was brittle when set, and usually needed some mechanical stiffening such as a core wire. A more convenient material was a synthetic resin of the semi-thermo setting type, known as "Marco"; it was applied cold, took a faithful impression, and set in less than half an hour with an initial expansion of less than 1 per cent. and a subsequent contraction of 6 per cent. It would seem that, where scuffing occurred, it most frequently led to accelerated wear. Many owners, especially those operating American war-built tonnage, did not fit torsionmeters, and, in consequence, cases of serious gear-tooth wear, pitting and scuffing caused by over-driving were by no means uncommon. There was reason to believe that many gearing troubles were initiated when operating conditions imposed heavy fluctuations of loading on the gears, as under torsional vibration or when pitching heavily in a seaway. In the latter case, owing to the high inertia of the rotors and gears, practically the whole of the propeller torque variation would be transmitted to the gears, with a negligible change of speed. Thus, under severe conditions, with the propeller periodically losing and regaining immersion, the load on the gears might vary from almost zero to full-load torque, perhaps several times a minute for long periods.

Another suspected source of trouble, particularly scuffing, had been the sudden or heavy-handed operation of the main steam controls during manœuvring, causing excessive tooth loads at relatively low speed when oil films had not built up sufficiently, i.e., under conditions approaching boundary lubrication. That was particularly liable to cause trouble before the gears are properly run in. Most existing torsionmeters did not indicate the magnitude of such torque variations. There was a real need for a direct-indicating torsionmeter to supplement the normal meter and give a visual warning of the instantaneous values of the torque fluctuations. A British torsionmeter manufacturer had a prototype instrument of that nature on experimental service, and the indications were distinctly hopeful that it would soon go into commercial production. It was expected that accuracies of the order of $2\frac{1}{2}$ per cent. should be obtainable, although, when it was used as a warning device in conjunction with the conventional nul-reading instrument, such extreme accuracy would not be essential.

Mr. H. F. Sherborne, referring to condenser circulating-water inlet pipes coated with sprayed rubber, asked whether such pipes were fabricated from sheets or were solid-drawn; also, whether the rubber was put on before fabrication. It was becoming almost universal practice to specify the corrosion-resisting alloys for that purpose, in substitution for copper. If the rubber coating was going to make the use of special alloys unnecessary, it was a matter for serious consideration. The problem was largely financial. Some people were specifying thicknesses of copper tubing which were used 50 years ago, when there was plenty of copper; to specify the same thicknesses to-day in a relatively resistant alloy was not sensible. As to the tube failures in the main condensers in the Australian ships of the Helenus class, he hoped that that was not the beginning of another epoch of trouble with condenser tubes. So much of the problem of corrosion of condenser tubes was regarded as solved that the Institute of Marine Engineers decided to discontinue their subscription to the British Non-Ferrous Metals Research Association. He was associated with the Institute and was a member of the Council of the Research Association, and he was in complete agreement, because he thought the matter was finished with. But the problem had raised its ugly head again, and the cases mentioned by Mr. Dickie were not the only instances of corrosion of metals, which was occurring also in other than Australian waters.

Professor E. V. Telfer asked why Mr. Dickie was worried about the rudder area being too big. He could not see why that should be troublesome, unless Mr. Dickie feared that it would take too long to put the rudder over, as compared with one of less area. In his own paper to the Institute of Marine Engineers, on seakindliness, he gave a formula to determine the area of rudders, and the figure obtained from that formula was exactly the value Mr. Dickie had used. He felt that Mr. Dickie's experiments, to decide whether the single-screw ship suffered any penalty as compared with the more normal twin-screw ship, were not sufficient to decide the issue. It was his belief that two models of the same size would not determine the true ship comparison between the single-screw and the twin-screw types, because the beneficial effects of weight were much more evident on the single-screw model than on the twin-screw model, and the benefit of the single screw on the model size would disappear on the full-size ship. It was still more essential, in view of the extraordinary powers now proposed for single screws, to develop the efficiency of the design. He hoped that closer attention would be given to the improvement of twin-screw design, because he felt that the single screw was being pushed too hard.

The author, in reply to the discussion, said that he would deal with it in writing, but added that the propellers were about 25 tons in weight. He supposed that the tenders, submitted in 1945, could be regarded as estimates of the final cost, but the actual costs proved to be about 34 per cent. higher.

(To be continued.)

THERMAL EFFICIENCIES OF BRITISH POWER STATIONS.

THE British Electricity Authority announce that the overall average thermal efficiency of their steam power stations for the calendar year 1951 was 21·79 per cent., compared with 21·53 per cent. in 1950. The difference between the two figures, 0·26 per cent., represents a saving in coal consumption of 400,000 tons on what otherwise would have been needed, and an economy in cost of over 1,000,000*l*. In the three years up to and including 1951, the improvement in power-station overall thermal efficiency has secured a saving of about two million tons of coal. This was achieved despite deterioration in the quality of the coal consumed.

The following are the 20 steam power stations of the Authority, with the highest overall percentage thermal efficiency for 1951:

	Per cent.
Dunston "B" II, Newcastle-upon-Tyne	29·39
Battersea "B," London	28·62
Stourport "B," Worcestershire	28·38
Littlebrook "B," Dartford, Kent	28·32
Poole, Dorset	27·79
Agecroft (high-pressure), Salford	27·79
Cliff Quay, Ipswich	26·86
Fulham, London	26·83
Brimsdown "B" (high-pressure), near Enfield	26·78
Hams Hall "B," near Birmingham	26·44
Staythorpe, Newark	26·42
Llynfi, Bridgend	26·38
Stuart Street (high-pressure), Manchester	26·33
Meaford, near Stoke-on-Trent	25·91
Kearsley (high-pressure), Lancashire	25·78
Dunston "B" I, Newcastle-upon-Tyne	25·72
Battersea "A," London	25·71
Barking "B," London	25·66
Earley, Reading	25·55
Little Barford, near St. Neots, Huntingdonshire	25·48

As would be expected, the higher efficiencies were obtained in new power stations or in older stations where modern plant has been put into service. Dunston "B" station is a case in point. In No. II station, which heads the above list, the new plant has an efficiency of 29·39 per cent., while No. I station, with older plant, lies sixteenth in the list with an efficiency of 25·72 per cent. Nine new power stations which were brought into service for the first time during 1951, and which have not operated over the full year, are not included in the list. These are Blackwall Point, London; Plymouth "B"; Rye House, Hertfordshire; Nechells "B," Birmingham; Bromborough, Birkenhead; Skelton Grange, Leeds; North Tees "C," Middlesbrough; Westwood, Wigan; and Braehead, Renfrew.

It is pointed out that new power stations and new plant in older stations make a highly important contribution to national fuel economy. A total of no less than 1,255 MW of plant, or nearly 10 per cent. of the present total output capacity of the Authority's stations, is over 25 years old. When these old machines are replaced by modern plant, about one million tons of coal a year will be saved. Moreover, in the next five years further plant of about the same aggregate capacity will also become over 25 years old. Replacement of this will produce a similar saving. The present plant programmes of the Authority aim to reach an overall average thermal efficiency of generation of 26 per cent. in 1960.

SHELL FACE MILLING CUTTER.—Protolite, Ltd., Central House, Upper Woburn-place, London, W.C.1, have recently introduced a new series of shell face milling cutters for use on steel, cast iron and non-ferrous metals. The cutters have positive radial rakes, and are stated to cut with a smooth, easy action, the power consumption being lower than that required by cutters using negative or zero radial rakes. The bores for mounting the cutters on the arbor conform to British Standards, being $\frac{3}{4}$ in. diameter for the 2 in. cutter and $1\frac{1}{4}$ in. for the 3 in. and 4 in. cutters.

SIEVE FOR CINDERS, COAL, SOIL, ETC.—A manually-operated sieve for cinders, coal, soil, etc., suitable for use in factories, hotels, and other large establishments, has been introduced by E. H. Lange & Co., 9, Eley-drive, Rottingdean, Sussex. The unit consists of a rotatable cage, a wire-mesh tray below it, and a sheet-metal tray below both; all are contained in a rectangular case 30 in. high, $15\frac{1}{2}$ in. wide and 17 in. deep. The material to be sieved is placed in the cage; the lid is then closed and the cage rotated by means of an external handle. The siftings fall through the cage and wire-mesh tray into the sheet-metal tray. The contents of the cage are then emptied into the wire-mesh tray by opening doors in it, after which both trays can be removed, as drawers, from the front of the unit.

DIESEL-ENGINE FACTORY OF THE NATIONAL GAS AND OIL ENGINE COMPANY.

The National Gas and Oil Engine Company, Limited, Ashton-under-Lyne, was founded in 1889, when Mr. H. N. Bickerton took over the Isaac Watt Boulton works in Wellington-road, Ashton. He was joined, soon after the firm was founded, by Mr. Dugald Clerk, later Sir Dugald Clerk, and, working together, they soon built up a successful business. The earlier gas engines were designed to run on town's gas but the National Company were quick in appreciating the advantages to be gained by using the then new producer gas, and by 1906 had developed their own gas producer subsequently awarded a Gold Medal at that year's Royal Show. In 1908, it was found that, owing to competition from the electric motor, the demand for small engines was diminishing. As a consequence, the firm decided to embark on the production of large vertical gas engines, and by the outbreak of the first World War many large tandem gas engines had been supplied, some of which were operated on blast-furnace gas. In 1914, the company took another forward step by building the first sewage-gas engine, which was installed at the works of the Birmingham Tame and Rea Drainage Board. A further notable achievement at that time was the production of blast-furnace blowers having four cylinders 45 in. in diameter and delivering 24,000 cub. ft. of free air per minute at a pressure of 12 lb. per square inch.

The manufacture of oil engines, however, was not started until 1924, when the first horizontal engines were produced, to be followed, in 1926, by vertical-type engines. Development of these engines was rapid, and by 1936 they were able to offer a standard range of oil engines, pressure-charged on the Buchi principle. In 1938, the company produced the first dual-fuel engine, an eight-cylinder unit developing 440 brake horse-power when running on town's gas with a small quantity of oil injected for ignition purposes. At the same time, a small vertical engine was supplied to the Iraq Petroleum Company to run at a compression ratio of 15 to 1 with spark ignition. During the second World War, the company were fully occupied in meeting the requirements of the Services and supplying a large number of engines for many different purposes. Development went ahead, however, even during the war years, and in 1943 they pioneered the production of engines with four-valve cylinder heads, the first order being for four 500-kW auxiliary generating sets for H.M.S. Eagle. Production continued to expand after the war but the demand increased to such an extent that, when the firm joined the Brush-ABOE group of companies in 1949, it was decided to re-equip the factory and lay it out for the intensive production of both horizontal and vertical oil engines. A large part of this programme has now been completed and the section of the factory devoted to the production of smaller horizontal engines has been re-equipped. Owing to the difficulty in obtaining large machine tools, however, the progress in re-equipping the vertical-engine shops has not been so great; nevertheless, although not so spectacular, steady progress is being made and delivery of the various machines is improving.

The National Gas and Oil Engine Company are now making horizontal Diesel engines from 3 h.p. to 80 h.p. and horizontal gas engines from 9 h.p. to 27 h.p. The vertical engines cover a much wider field, the outputs of the Diesel engines ranging from 62 h.p. to 2,000 h.p. and the gas engines from 56 h.p. to 1,000 h.p. Vertical dual-fuel engines range in size from 56 h.p. to 1,000 h.p. and marine propulsion units, also, of course, of the vertical type, from 66 shaft horse-power to 1,600 shaft horse-power. All these engines operate on the four-stroke cycle and the vertical series are fitted with four-valve cylinder heads. The smallest horizontal engine, namely, the AH1, is a totally-enclosed machine provided with a single flywheel and capable of developing from 3 to 5 h.p. at 1,000 to 1,500 r.p.m., respectively. Tank or hopper cooling can be employed and the drive taken from the full-speed or half-speed shaft as required, a hand-operated clutch being available. The remaining outputs up to 80 h.p. are covered by the B and NA series. Units up to 30 h.p. can be started by hand but provision is made for cartridge starting; engines with ratings above 30 h.p., however, are fitted with compressed-air starting equipment.

Vertical multi-cylinder engines are made in four series, namely, M4A, R4A, F4A and B4A, the bore and stroke ranging from 6 in. by 8½ in. for M4A series to 17 in. by 21½ in. for the B4A series. The M4A, R4A and F4A models are available with from three to eight cylinders and the B4A with from five to eight cylinders. All these engines are available in the pressure-charged form with, of course, appropriately higher outputs; the B4A eight-cylinder engine with normal aspiration, for example, has an output of 1,335 h.p. at 333 r.p.m. whereas in its pressure-charged form the output is 2,000 h.p. The M4A, R4A and F4A series are also available as marine-propulsion units, in which case they are fitted with the maker's oil-operated reverse-reduction gearbox. Oil-gas engines are available as dual-fuel types where ignition is effected by the injection of a small quantity of fuel-oil when running on gas; as alternative-fuel types which employ spark ignition; and as convertible types, which require a change of compression plates when changing over fuels. The equipment available with the various vertical engines is comprehensive and includes circulating-water pumps, fuel and lubricating-oil filters, lubricating-oil coolers and fuel-service tanks.

WORKS OF NATIONAL GAS AND OIL ENGINE CO.

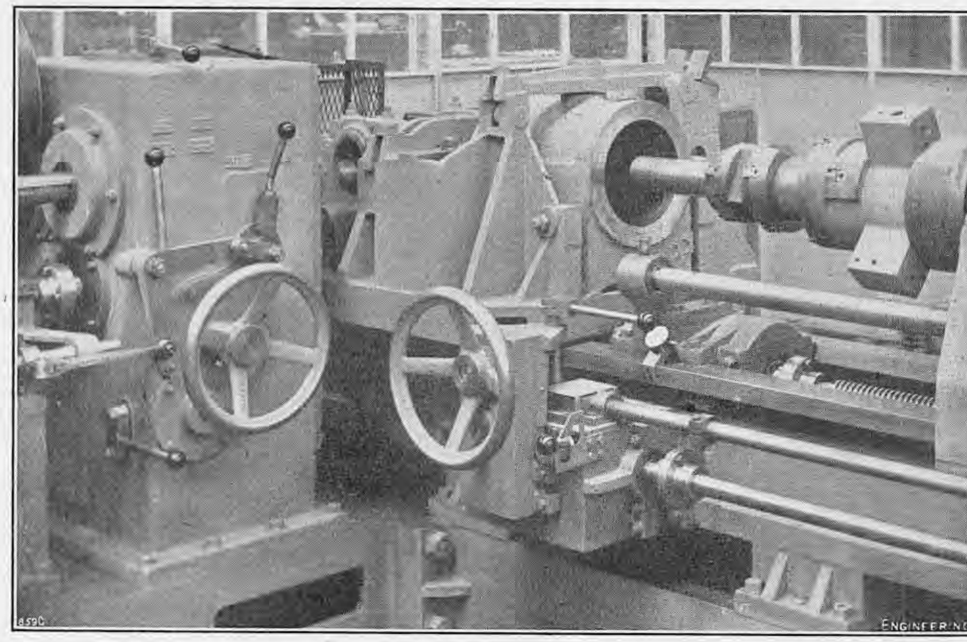

FIG. 1. BORING MACHINE FOR HORIZONTAL ENGINES.

As they are at present, the works bear little resemblance to those taken over by Mr. Bickerton in 1889. Expansion started almost at once and the original single bay has been expanded into a factory covering 30 acres. The horizontal and vertical engines are produced in two separate parts of the factory, the shops dealing with the former, as previously mentioned, having been re-planned and equipped with a wide range of modern machine tools, several of which were designed and constructed in the firm's own tool room. Ten sizes of horizontal engines ranging in power up to 80 brake horse-power are erected and tested, and the heavier parts machined, in the horizontal-engine section, the four smaller sizes being assembled on a roller track in seven stages which are timed to supply an engine to the test beds approximately every twenty minutes. The main castings are shot-blasted and dressed and then given priming, filling and first coats of paint before they are delivered to the machine shops associated with the horizontal section. It is the intention of the company ultimately to finish-paint the main castings before they are dispatched to the machine shop and with this in view the castings are being modified so that they can be slung and turned over without chipping the paint.

It should be mentioned here that the main frames and cylinder-head castings for the horizontal engines are machined separately in an area close to the assembly lines, whereas other parts such as the connecting rods, pistons, liners, crankshafts, etc., are machined in a large general machine shop situated between the two main sections of the factory. On arrival in the special machine shop attached to the horizontal section, the main-frame castings are placed in a sighting jig and location holes drilled and spot-faced for locating the casting during subsequent machining operations. They are then passed to a large Kendall and Gent vertical plano-miller on which the bottom and side surfaces are machined. A Kendall and Gent horizontal milling machine is used to "gash" the main-bearing housings, after which the castings are fitted with their bearing caps and passed to special boring machines for machining of the bearing housings and the facing and boring of the liner recess. These machines, one of which is illustrated in Fig. 1, herewith, consist basically of two separate boring heads arranged at right angles to each other and, like several other machines in the factory, were designed and constructed by the National Gas and Oil Engine Company. On completion of boring, the stud holes are drilled and the castings then passed to a Dawson washing machine situated at the head of the assembly line, the castings being suspended from an overhead runway, as shown in Fig. 2, opposite.

The first processes carried out on the cylinder heads consist of facing the flange and boring the cone. These are accomplished in a No. 9B Herbert combination turret lathe equipped with a special tapering device. The top and side faces are then machined on a Cincinatti milling machine, after which the heads are passed to another Herbert No. 9B combination turret lathe for machining the inlet-valve and exhaust-valve bores and the combustion chamber. An Asquith vertical drilling machine is then used to drill the stud holes, etc., after which the heads are passed to the Dawson washing machine. The flywheels are machined in a separate bay equipped with a number of Webster and Bennett vertical-boring mills with indexing toolholders, one of which has been modified so that the smallest flywheels, that is, those with a diameter of 27½ in., can be machined in 18 minutes. Some of the boring mills can be seen in Fig. 3, opposite, which shows part of the flywheel-machining bay. At present, the keyways are being cut with slotters but a horizontal broaching machine has now been installed and will be used for this purpose in the near future.

On leaving the washing machine, the heads are not passed directly to the assembly line but to the sub-assembly area, illustrated in Fig. 4, on page 588, where parts such as valves, etc., are fitted in position, much use being made of air-operated hand tools, manipulating tables, etc., to ease the work of the fitters and thus accelerate production. The liners also are fitted to the cylinder heads in this area as, unlike most engines of this type, they are bolted directly to the heads, a series of lugs integral with the outer surface of each liner, and through which the securing bolts pass, being provided for this purpose. The cylinder-head sub-assembly area is used also for fitting the pistons and big-end and gudgeon-pin bearings to the connecting rods, a special jig being employed for this purpose. This unit consists of a mandrel round which the big-end is clamped, the connecting rod being supported by an air-operated jack. When bolting-up of the big end is completed, the jack is lowered and a further mandrel inserted in the gudgeon-pin bearing makes contact with a series of clock gauges which indicate the alignment of the connecting rod. Any necessary corrections are then made and, with the rod in the raised position, the piston is moved into position on a cradle and the gudgeon pin inserted.

The washing machine and the cylinder-head sub-assembly area are sited so that the frames and cylinder-head, piston and connecting-rod assemblies can be delivered with the minimum of handling to the head of the assembly conveyor. This is of the roller type, and as the frames pass down the various components such as the camshaft-driving gears, camshafts, crankshafts, flywheels, etc., are fitted in position. At present, the sub-assemblies are being fitted together in an area situated a short distance away from the conveyor, but future plans envisage the transfer of this department to a position beside the conveyor. On completion of assembly, the engines pass directly to the test bay, electric dynamometers being employed for the smallest engines, ordinary rope brakes for the medium engines, and Heenan and Froude water brakes for the larger

WORKS OF NATIONAL GAS AND OIL ENGINE CO.

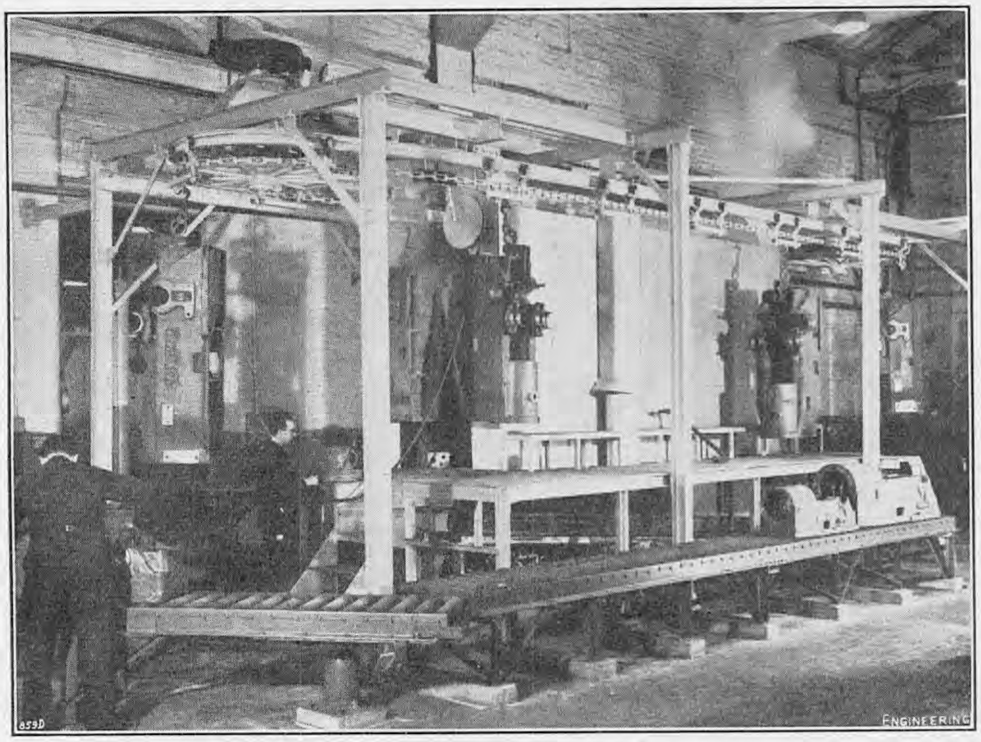

FIG. 2. DAWSON WASHING PLANT.

FIG. 3. FLYWHEEL MACHINING LINE.

engines. Part of the test area in which rope brakes are used is illustrated in Fig. 6, on page 588. After test, the engines are conveyed to the painting and packing department on bogies but arrangements are being made so that they can be prepared for dispatch in a continuous flow on roller tracks as they leave the test beds.

Grouping of the machines for the production of the main frames and cylinder heads for the larger horizontal engines has not yet been completed. Eventually, the larger single-cylinder engines will be replaced by more compact twin-cylinder units and the machine tools have been designed, therefore, so that single-cylinder and twin-cylinder units can be machined with equal facility. At present, the larger engines are being produced in batches, but when re-grouping has been completed they will be produced in much the same manner as that described for the smaller sizes. Re-organisation of the vertical-engine department is also in the preliminary stages, but some progress has been made with the installation of new machine tools for the production of the M4A and R4A series of engines. One of the bays, for example, is now partly laid out with the machines in groups for the production of such parts as connecting rods, crankshafts and cylinder heads, and some of the heavier new machine tools, such as the Gildemeister plano-milling machine illustrated in Fig. 7, on page 588, have been installed. When the scheme has been completed, production of the M4A and R4A vertical engines will follow much the same lines as for the horizontal engines, with groups of special-purpose machines supplying an assembly line. This procedure, however, does not lend itself readily to the larger engines, which will continue to be erected on the test beds as at present. The assembly line for the M4A and R4A engines has already been laid down ; the assembly procedure follows normal practice, the engines being supplied with sub-assemblies and components from benches located at one side.

The other departments of the factory include a modern iron foundry which has recently been re-organised and, so far as practicable, mechanised, the size of casting limiting developments in the latter direction. The mechanical equipment installed includes a group of six Pneulec ram-jolt turn-over moulding machines with capacities ranging from 1,500 lb. to 4,000 lb. Each of these machines is arranged so that, after ramming, the mould is rolled over on a trunnion fixture and the underside is supported on a pattern draw plunger which rises to meet it. The pattern is then withdrawn and returned to its original position, while the mould is lowered by the plunger to a roller conveyor leading to the mould-drying stoves. Some of the Pneulec machines and their associated conveyors can be seen in Fig. 5, on page 588. The drying stoves are of the gas-fired continuous type, the time cycle being such that the moulds are skin-dried to a depth of 1 in. to $1\frac{1}{2}$ in. After casting, the moulding boxes are returned to an automatic knock-out, which is arranged so that the sand is fed first to a storage hopper and then to a conditioning plant before being returned to bins situated over the moulding machines. Larger parts, such as vertical-engine bedplates and columns, are cast in moulds formed in the foundry floor and in this case the cores are removed after casting by means of a hydro-blast plant. This employs a high-pressure jet of water which is directed at the cores, use of this equipment not only reducing the dust but lowering the time taken to remove the core ; the time is actually one-sixth of that when conventional methods are employed. Other mechanical equipment installed in the foundry includes three small moulding machines used for making green-sand moulds and, in the core shops, a Coleman core blower, a sand slinger and a roll-over stripping machine.

Molten metal is supplied by two cupolas with capacities of 5 and 6 tons, respectively, assisted by a 5-ton Sesci rotary furnace : the Sesci furnace is also used to melt cast-iron shavings, which are subsequently cast into pigs for use in the cupolas. There are also three Morgan oil-fired crucibles which are used for special melts, much use being made in the factory of acicular iron. Commercial production of castings from this type of iron started in 1937, the earlier applications including engine valve-rocking levers with operating stresses up to 9,100 lb. per square inch. Gearwheels for the larger horizontal engines, bed-caps for vertical engines, valve-seat inserts, and compressor and pump crankshafts were also made from this material. In the case of gearwheels for the smaller horizontal engines, it was found necessary to oil-harden them to give service that was comparable with that of case-hardened steel parts. Later, small Diesel-engine crankshafts were made from acicular-iron castings, and as experience was gained this application was extended to cover crankshafts for the M4A engines ; these range from three to eight cylinders and develop up to 55 brake horse-power per cylinder, the crank journals being $5\frac{5}{16}$ in. in diameter. Recent developments include the introduction of new horizontal engines of both single-cylinder and twin-cylinder types with powers of from 45 h.p. to 90 h.p., and these engines are being fitted with acicular cast-iron crankshafts. Difficulties in obtaining alloy steels have accelerated the use of these irons, which are now being used for such parts as inlet and exhaust valves with complete success. Tensile tests made on valve stems have shown that, even at temperatures as high as 650 deg. C., the tensile strength is 10 tons per square inch. A six-throw crankshaft made from this material has been run for five years at speeds up to 1,500 r.p.m. and cylinder pressures of 1,100 lb. per square inch without showing any signs of failure, and has passed successfully a test in which it was held at a sixth-order critical speed for eight hours.

The company have maintained their own experimental department for a number of years. Notable developments have included the introduction of the four-valve cylinder head and the dual-fuel and high-compression gas engines. Work at present in hand in this department includes investigations into the burning of heavy fuel oils in Diesel engines. A single-cylinder R4A engine of 50 h.p. is being used for this purpose and, so far, it has run for 2,000 hours on fuels varying in viscosity from 600 seconds Redwood to 3,000 seconds Redwood, and has completed a 1,000-hour endurance run on 1,500 seconds fuel. Other work in progress in the experimental department includes an examination of additives in lubricating oils, investigations into bearing materials, combustion research and the development of the two-cylinder horizontal engines.

COMBINED MERCURY-ARC AND TUNGSTEN LIGHTING FOR INDUSTRIAL BUILDINGS.—New fittings, which have been designed by the General Electric Co., Ltd., Kingsway, London, W.C.2, to blend the light from mercury-arc and tungsten lamps to the best advantage, have been installed recently in the turbine room of the Oxford generating station. Each contains a 250-watt mercury lamp and a 500-watt tungsten lamp. The fittings are mounted on the roof trusses, 35 ft. above the floor of the 96 ft. by 54 ft. turbine room; nevertheless, the vertical surfaces of the meters and of the plant generally are well illuminated.

NOTES FROM THE INDUSTRIAL CENTRES.

SCOTLAND.

The Position in the Steel Industry.—A seasonal increase in the volume of scrap deliveries, coupled with the maintenance of the improved scale of pig-iron production locally, has made for a slight easing of the steelmakers' problem of securing adequate supplies of metal for melting-furnace charges to prevent a further curtailment of ingot outputs. There is no indication, however, that any of the idle melting capacity will be brought back into operation. The pressure on makers and re-rollers for finished steel remains heavy on home account, but the export trade is in a state of change following the Australian and New Zealand policy of import restrictions. Canadian business has fallen away almost entirely.

The Need for Metallurgical Coke.—An expansion of pig-iron production would require more coking coal, and the production of coking coal in Scotland might well become a limiting factor if the development of available Scottish resources was not pursued with determination and urgency, according to Sir Andrew McCance, D.Sc., F.R.S., deputy chairman and joint managing director of Colvilles Ltd., in his annual statement for 1951. The new coke ovens building at the firm's Clyde Iron Works, Tollcross, are nearing completion, but it will be a few months yet before they are in operation. The ovens were ordered 4½ years ago.

Cost of Shipyard Welding Installation.—The cost of converting a four-berth yard to enable a reasonable amount of welding to be conducted was nearly 700,000*l*., said Mr. John Rannie, of John Brown & Co., Ltd., Clydebank, in a paper dealing with shipyard changes, read on April 25 before the Institute of Welding at their Glasgow meeting. The increasing use of welding rendered X-ray equipment a necessity.

Glasgow Engineering and Shipbuilding Museum. —The first step towards establishing a separate engineering and shipbuilding museum in Glasgow was taken on April 29, when the appointment of Mr. P. H. Tanner, B.Sc., as its curator was approved at a special meeting of the Art Galleries and Museum Committee of the Glasgow Corporation. A design draughtsman with William Denny & Brothers, Ltd., shipbuilders, Dumbarton, Mr. Tanner graduated at Glasgow University in 1945 with first-class honours in naval architecture.

Industrial Posts for University Graduates.—The University of Glasgow Appointments Committee state in their annual report for 1951 that they have received many more requests for engineers and scientists than they have been able to meet, and that most of the science and engineering students who wished to obtain industrial posts have received offers from more than one firm. Engineering graduates are in demand for research and development work, for productive industry, and for plant work.

Renfrew-Yoker Ferry Boat.—A new vehicular and passenger ferry boat for the Renfrew-Yoker crossing of the River Clyde is expected to come into service during the summer. The vessel will be Diesel-electrically driven, and will have larger accommodation for passengers and vehicles than the present ferry vessel.

CLEVELAND AND THE NORTHERN COUNTIES.

The Steel Position.—North-East Coast steel producers hope to maintain supplies for export at as near as possible the present level. The curtailment of deliveries to home customers outside the high-priority class, however, is severe and, in some cases, occasions industrial embarrassment. At the same time, while temporary unemployment during the turn over from home to export work is unavoidable, the opinion prevails that industry in North Yorkshire and County Durham will require all the labour obtainable for a considerable time to come.

Tractor Manufacture on Tyneside.—The first of the heavy tractors being made by Vickers-Armstrongs Ltd., Walker-on-Tyne, have been delivered to the British firm responsible for their distribution throughout the world. So far, the United States have been almost the sole manufacturers of tractors of this type. The tractor is being made by Vickers-Armstrongs in conjunction with Rolls-Royce Ltd. The former produce the machine and the latter the oil engine. The output of the new tractor will be at the rate of 1,000 annually, and it is also proposed to construct a smaller model.

New Coke-Oven Plant at Burnmoor.—A start is being made on the erection of a 2,000,000*l*. coke-oven and by-product plant at Burnmoor, County Durham, for the Durham Divisional Coal Board. The plant will be completed within three years and will use 7,000 tons of coal weekly. It will produce 5,000 tons of coke a week, in addition to by-products. The plant will replace the existing Burnmoor plant.

North-East Metallurgical Society.—About 100 metallurgists in the North-East, at a meeting at Middlesbrough, have formed the North-East Metallurgical Society. The President is Mr. W. W. Stevenson, chief metallurgist, Dorman Long & Co., Ltd., and the vice-presidents are Mr. F. H. Keating, chief metallurgist, I.C.I. Ltd., Billingham, and Mr. J. W. Gailer, of Constantine Technical College. Mr. Gailer is also secretary and treasurer. The aims of the Society are to promote the study of metallurgy and the interests of metallurgists.

Improvements at Harecrag Quarry.—The Northumberland County Council are to carry out a 63,000*l*. improvement scheme at Harecrag Quarry, near Alnwick. The work includes the installation of additional plant, and the quarry will be closed for 12 months while the work is being done.

LANCASHIRE AND SOUTH YORKSHIRE.

Export Difficulties.—The lighter steel trades of Sheffield have had to dispense with some labour on account of new export difficulties, not the least of which is the drastic limitation of imports into Australia. The new President of the Sheffield Chamber of Commerce, Mr. W. G. Ibberson, a cutlery and tool manufacturer, however, has expressed the opinion that the difficulties will not be a bad thing in the long run. He stated that firms would have to overhaul their sales procedure and production methods. Manufacturers would be cautious not to buy for stock and emphasis was likely to be on early delivery. Many materials were still short, but the demand was lessening as orders were cancelled and those fortunate enough to have orders to execute were getting their materials more readily.

Improving Coal Position.—On the last day of the official coal winter, Yorkshire's stocks of coal for industry power, and gas were 440,000 tons greater than at the corresponding period last year. The total distributed stocks in Yorkshire for the three purposes amounted to 1,165,000 tons, compared with 722,000 tons a year ago. Industry had an average of 4·1 weeks' supply in reserve, power stations 4·9 weeks and gasworks 3·1 weeks.

Mo-i-Rana Steelworks, Norway.—A 100-in. long model of a rolling-mill plant which is being built in Sheffield by Davy and United Engineering Co., Ltd., for a new steelworks 25 miles from the Arctic Circle, is to be sent to Norway for public exhibition as evidence of the great industrial developments now taking place in that country. The model, which is to an exact scale, was built initially for study purposes to find the most efficient and economical layout for the plant. The mill, 1,100 ft. long and needing 7,000 tons of finished plant and machinery for its erection, will be built at Mo-i-Rana, and the new steelworks will be one of the most northerly in the world.

College of Commerce and Technology.—Sheffield is to build a new College of Commerce and Technology at a cost estimated to exceed 1,000,000*l*. The 11-storey building will be 80 yards long and will be on a triangular site bounded by Pond-street and Arundel-street. It is hoped to start building operations next year. The College of Commerce section is planned as a complete unit linked closely with the main building. Heavy laboratories will be housed below the ground floor and light laboratories, lecture rooms and drawing offices in upper floors.

THE MIDLANDS.

Iron and Steel Industry.—In spite of the reduced output in some Midland factories, caused by the Australian and other import restrictions, there is no sign of a lessening of the demand for iron and steel. The position in the steelworks remains what it has been for some time, with several of the works unable to operate at full capacity on account of scrap shortage. Foundries are fully occupied, and could increase their output if sufficient pig iron were available. Any expansion of pig-iron production is at present impossible because the coke supplies are only just sufficient to maintain the present rate of output. The steel re-rollers, who have very heavy demands for their products, are still working short time, as the shortage of semi-finished products persists.

Coal Supplies in North Staffordshire.—After a meeting of the North Staffordshire Chamber of Commerce and the West Midlands Division of the National Coal Board, held at Himley Hall on April 27, it was announced that the Coal Board had decided to set up a divisional selling organisation, and to investigate the question of supplying gas coal to North Staffordshire from the North-Eastern Division.

The Lower Avon Navigation.—The Lower Avon Navigation Trust, continuing their work of restoring the Avon navigation works from Tewkesbury to Evesham, have now turned their attention to Chadbury Lock, about two miles downstream from Evesham. The lock gates are in a very dilapidated condition, and if they should fail, the water level at Evesham would be reduced from the present 6 ft. to about 18 in. The restoration of the navigation is a co-operative effort, organised by the Trust, and assistance is being given, in the case of Chadbury Lock, by the Army. The summer exercise of the detachment of Royal Engineers quartered at Long Marston, near Stratford-on-Avon, will be the building of a steel dam across the mouth of the lock. This will be left in position during the summer, and will hold the water while a special effort is being made by the Trust to raise funds for the permanent repair of the lock gates.

Pre-Cast Concrete Sections for a Culvert.—Wolverhampton Corporation are reconstructing a 100-year old culvert under the London Midland Region main line of British Railways at Ettingshall. The culvert is 70 yards long and takes Ettingshall brook under six railway tracks carrying heavy traffic. The lines could not be closed to traffic, and it was decided to use pre-cast concrete sections instead of mass concrete for the culvert, in order to cause as little interference as possible. The method adopted has proved completely successful, and the work, which is nearly finished, is two weeks ahead of schedule.

The Late Mr. E. H. Johnson.—We regret to learn of the death, on May 1, of Mr. Edward Harry Johnson, chief designer and a director of Keelavite Rotary Pumps and Motors, Ltd., Coventry. Mr. Johnson, who was only 55 years of age, had been in poor health for about a year. He joined the Keelavite Company at its formation in 1937, and had been previously with Morris Motors, Limited.

SOUTH-WEST ENGLAND AND SOUTH WALES.

The Necessity for Coal Exports.—Mr. H. T. Norton, who has been installed as President of the Cardiff Chamber of Commerce, has said that a regular coal-export trade of substantial proportions is essential to the national economy. In order to preserve the trade, it would become a matter of policy to economise to a greater extent in the inland use of coal and to ensure that there would be a larger consumption of the low-grade fuels at home, so that the best qualities could be exported. Already coal exporters are beginning to find that competition from other coalfields is making foreign consumers more critical of quality and prices.

New Work for South Wales.—The Welsh Board for Industry has been told that contracts have been placed by the Admiralty in Welsh shiprepairing yards to the extent of more than 1,000,000*l*. in the past quarter. It was further reported that a new industry is shortly to be established at Pembroke Dock, where an engineering firm from Coventry is taking over the old Market Hall to undertake re-armament work.

Town Planning at Newport.—A 20-year plan for Newport, discussed by members of the Town Council, states that a second bridge across the River Usk will have to be considered if a complete blockage of traffic in the middle of the town is to be avoided. Mr. H. H. Jones, chairman of the town-planning committee, said the programme had been framed by reference to the estimated availability of labour, and also dealt with possible developments by private enterprise and Government departments as well as by the Council.

Towy Water Scheme, Llanelly.—The first sod has been cut of Llanelly's 350,000*l*. Towy water scheme. The work is expected to be completed in 15 months, when the Corporation will be in a position to supply 11,000,000 gallons a day. The water requirements of the Trostre cold-reduction plant will be met by the scheme.

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.—*North Midland Students' Section:* Saturday, May 10, 2.30 p.m., Offices of the British Electricity Authority, 1, Whitehall-road, Leeds, 1. Annual General Meeting. *Radio Section:* Wednesday, May 14, 5.30 p.m., Savoy-place, Victoria-embankment, W.C.2. "A Phototelegraphy Transmitter-Receiver Utilising Sub-Carrier Frequency Modulation," by Mr. R. O. Carter, and Mr. L. K. Wheeler. *South Midland Students' Section:* Wednesday, May 14, 6.45 p.m., James Watt Memorial Institute, Great Charles-street, Birmingham. Annual General Meeting. *Institution:* Thursday, May 15, 5.30 p.m., Savoy-place, Victoria-embankment, W.C.2. Annual General Meeting. (For corporate members and Associates only.) *London Students' Section:* Monday, May 19, 7 p.m., Savoy-place, Victoria-embankment, W.C.2. Annual General Meeting and Film Display. *Education Discussion Circle:* Tuesday, May 20, 6 p.m., Savoy-place, Victoria-embankment, W.C.2. Discussion on "The Teaching of Engineering Economics," opened by Professor R. O. Kapp.

INSTITUTE OF PACKAGING.—*Northern Area:* Monday, May 12, 6.30 p.m., Old Nag's Head Hotel, Manchester. "Multiwall Paper Sacks," by Mr. G. M. Hobday.

SHEFFIELD SOCIETY OF ENGINEERS AND METALLURGISTS.—Monday, May 12, 7.30 p.m., University Building, St. George's-square, Sheffield. "The Solidification of Metals," by Professor Bruce Chalmers.

INCORPORATED PLANT ENGINEERS.—*Dundee Branch:* Monday, May 12, 7.30 p.m., Mathers Hotel, Dundee. Films on "Electric Ship Propulsion Equipment," and "Safety First." *East Midlands Branch:* Wednesday, May 14, 7 p.m., The Welbeck Hotel, Nottingham. Various short papers by members. *Kent Branch:* Wednesday, May 14, 7 p.m., The Bull Hotel, Rochester. Various short papers by members. *Liverpool and North Wales Branch:* Monday, May 19, 7.15 p.m., Radiant House, Bold-street, Liverpool. "Pumps and Pumping," by Mr. C. N. Hillier.

CHADWICK TRUST.—Tuesday, May 13, 2.30 p.m., Royal Society of Tropical Medicine and Hygiene, Manson House, 26, Portland-place, W.1. "Food and Health," by Dr. E. L. Sturdee.

INSTITUTE OF MARINE ENGINEERS.—Tuesday, May 13, 5.30 p.m., 85, The Minories, E.C.3. "Steam Pipe Materials," by Mr. D. W. Crancher.

INSTITUTION OF PRODUCTION ENGINEERS.—*Birmingham Graduate Section:* Tuesday, May 13, 7 p.m., James Watt Memorial Institute, Great Charles-street, Birmingham, 3. "The Design and Wrapping and Cardboard-Box Making Machinery," by Mr. John W. Smith. *London Graduate Section:* Wednesday, May 14, 7.15 p.m., 36, Portman-square, W.1. "A Comparison of Product Finishes with Some Reference to Costs," by Mr. B. Workman and Mr. C. D. S. Bridgett. *Wolverhampton Graduate Section:* Thursday, May 22, 7.30 p.m., Wolverhampton and Staffordshire Technical College, Wulfruna-street, Wolverhampton. "Principles of Drop, Press and Upset Forgings," by Mr. J. D. Gutteridge.

NORTH WESTERN FUEL LUNCHEON CLUB.—Wednesday, May 14, 12.45 p.m., Engineers' Club, Albert-square, Manchester, 2. Luncheon Meeting. "Getting Coal from Pits by Road," by Dr. A. A. Hirst.

INSTITUTE OF PETROLEUM.—Wednesday, May 14, 5.30 p.m., Manson House, 26, Portland-place, W.1. "The Distribution of Oil Reserves in the World," by Dr. G. M. Lees, F.R.S., and Mr. D. C. Ion.

BRITISH INSTITUTION OF RADIO ENGINEERS.—*North Eastern Section:* Wednesday, May 14, 6 p.m., Neville Hall, Westgate-road, Newcastle-upon-Tyne. Annual General Meeting and Film Display.

ROYAL STATISTICAL SOCIETY.—*Study Group:* Wednesday, May 14, 6 p.m., The E.L.M.A. Lighting Service Bureau, 2, Savoy-hill, Strand, W.C.2. Discussion on "Prediction of Economic Indices." *Research Section:* Wednesday, May 21, 5.15 p.m., London School of Hygiene and Tropical Medicine, Keppel-street, W.C.1. "Some Statistical Aspects of Anthropometry," by Mr. M. J. R. Healy.

SOCIETY OF CHEMICAL INDUSTRY.—*Corrosion Group:* Wednesday, May 14, 6.30 p.m., Chemical Society's Apartments, Burlington House, Piccadilly, W.1. "The Prevention of Corrosion in Packaging," by Mr. E. G. Stroud and Mr. W. H. J. Vernon. *Road and Building Materials Group:* Thursday, May 15, 6 p.m., Institution of Structural Engineers, 11, Upper Belgrave-street, Westminster, S.W.1. Annual General Meeting and Address by the chairman of the Group, Mr. J. C. Warr.

INSTITUTION OF MINING AND METALLURGY.—Thursday, May 15, Geological Society's Apartments, Burlington House, Piccadilly, W.1. 4 p.m. Annual General Meeting (Open to members only). 5.15 p.m., Presidential Address on "The Responsibilities of Metallurgists to Industry," by Mr. Vernon Harbord.

INSTITUTION OF CHEMICAL ENGINEERS.—*London Graduates' and Students' Section:* Friday, May 16, 9 a.m., Alliance Hall, Palmer's-street, Westminster, S.W.1. All-Day Symposium on "Chemical Plant Construction." *Midlands Graduates' and Students' Section:* Wednesday, May 21, 6.30 p.m., The University, Edmund-street, Birmingham. Symposium on "The Research Work of the University of Birmingham Chemical Engineering Department."

INSTITUTION OF SANITARY ENGINEERS.—Friday, May 16, 11 a.m., County Hall, St. Helen's-street, Ipswich. Joint meeting with the *Eastern Region* of the RURAL DISTRICT COUNCIL SURVEYORS' ASSOCIATION. (i) Address by the President of the Institution, Mr. S. Brassey-Edwards. (ii) Discussions on "Free Water Connections" and "Cathodic Protection of Water Mains," to be opened by Mr. John W. Good.

ROYAL INSTITUTION.—Friday, May 16, 9 p.m., 21, Albemarle-street, W.1. "The Structure of Proteins," by Professor Linus C. Pauling.

INSTITUTE OF ROAD TRANSPORT ENGINEERS.—*Midlands Centre:* Tuesday, May 20, 7.30 p.m., Crown Inn, Broad-street, Birmingham. Annual General Meeting.

ROYAL SOCIETY OF ARTS.—Wednesday, May 21, 2.30 p.m., John Adam-street, Adelphi, W.C.2. Shaw Lecture on "Industrial Accidents," by Mr. H. R. Payne.

ROYAL METEOROLOGICAL SOCIETY.—Wednesday, May, 21, 5 p.m., 49, Cromwell-road, South Kensington, S.W.7. (i) "A Statistical Model for Water-Vapour Absorption," by Mr. R. M. Goody. (ii) "An Essay on the General Circulation of the Atmosphere over South-East Asia and the West Pacific," by Mr. B. W. Thompson.

ROYAL SANITARY INSTITUTE.—Friday, May 23, 10.15 a.m., Town Hall, Bangor. Various papers, including "Anglesey County Water Scheme," by Mr. W. H. Austin. Afternoon: Visit to Anglesey to inspect the Cefni water scheme and dam.

SOCIETY OF INSTRUMENT TECHNOLOGY.—Tuesday, May 27, 7 p.m., Royal Society of Tropical Medicine and Hygiene, Manson House, 26, Portland-place, W.1. "Recent Advances in the Industrial Use of the Microscope," by Mr. E. W. Taylor.

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.

Welded Steel Boilers for Hot-Water Central Heating, and Hot-Water Supply.—A first revision of B.S. 855, originally published in 1939, has now been issued. It applies primarily to hot-water central-heating and hot-water supply welded steel boilers, of over 5 sq. ft. heating surface, for operation on systems vented to the atmosphere and working at pressures not exceeding a 150 ft. head (65 lb. per square inch) and at temperatures not exceeding 212 deg. F., namely, gravity or accelerated systems. The present publication is divided into two parts. Part 1 deals with fuels, rating, heating surface, fire grates, dampers and doors, ashpit, boiler openings, inspection and cleaning holes and provisions for emptying. Clauses relating to materials and to marking are also included in Part 1. In Part 2 are given particulars of the method of testing boilers for the determination of the water-heating efficiency at their rating. An overload test is also included. The present revised specification contains additionally stringent requirements for the control of air entering the ashpit damper of a boiler installation. Moreover, the damper is now required, to fit more closely, so that, when it is closed there is little, if any, air leakage. The fire grates may be of the fixed, shaking or rocking types. [Price 6s., postage included.]

Code of Practice on Painting.—The Council for Codes of Practice for Buildings, Construction and Engineering Services, Lambeth Bridge House, London, S.E.1, have now published, in final form, Code No. 231, entitled "Painting." It has been drawn up by a committee convened on behalf of the Council by the Royal Institute of British Architects, and the present Code is a revision of drafts previously issued for comment. The Code relates to the painting of buildings for the purpose of decoration, protection or hygiene and includes a head code dealing with general considerations and sub-codes on particular aspects of painting wood; building boards, sheets and slabs; iron and steel; non-ferrous metals; plaster, concrete, brick and stone and similar materials. A comprehensive list of definitions of terms relating to materials, and a fully descriptive schedule of paint types are included. Recommendations on the selection and application of paints are given. The causes of defects on finished work are set out and recommendations made for avoiding them. [Price 10s., postage included.]

PERSONAL.

Owing to continued ill health COMMANDER SIR ROBERT MICKLEM, C.B.E., R.N., has relinquished his offices of joint managing director of Vickers Ltd., chairman of Vickers-Armstrongs Ltd., and his directorships of other companies in the Vickers Group.

SIR HARRY RAILING, M.I.E.E., has been elected President of the British Electrical and Allied Manufacturers' Association, 36 and 38, Kingsway, London, W.C.2. MR. T. F. LISTER has been re-elected chairman and MR. D. D. WALKER, M.A., M.I.E.E., has been elected vice-chairman. MR. JAMES OLDROYD, T.D., M.A., A.C.I.S., has been appointed secretary in succession to the HON. J. R. REA, M.A., Comp.I.E.E.

PROFESSOR W. T. MARSHALL, B.Sc., A.C.G.I., D.I.C., Ph.D., M.I.C.E., M.I.Struct.E., who has occupied the chair of engineering at the University of St. Andrews since 1946, has been appointed Regius Professor of Civil Engineering in the University of Glasgow, in succession to the late PROFESSOR GILBERT COOK.

MR. HENRY SPURRIER, M.I.Mech.E., M.I.P.E., has been elected President, for the year 1952-53, of the Society of Motor Manufacturers and Traders, 148, Piccadilly, London, W.1, in succession to MR. G. E. BEHARRELL, who now becomes deputy president. DR. F. LLEWELLYN SMITH, M.Sc., and MR. A. B. WARING are the two new vice-presidents, the retiring vice-presidents being Mr. Spurrier and SIR JOHN BLACK. MR. W. R. BLACK has been re-elected treasurer of the Society.

MR. P. G. CRABBE, F.R.Ae.S., M.I.P.E., who became a director of the Gloster Aircraft Co., Ltd., Hucclecote, Gloucester, in 1947, has been appointed managing director of the firm.

MR. H. R. BRUNYEE, at present superintendent, rolling mills, at the Steel, Peech and Tozer branch of the United Steel Companies Ltd., is to be works manager, production departments in this branch, and MR. G. N. F. WINGATE, at present superintendent of services, is to be works manager, services departments, both appointments will take effect on July 1. The new superintendent, rolling mills, will be MR. P. WRIGHT, M.C., and the superintendent of Ickles departments, MR. C. H. HAYTER, O.B.E. MR. J. LEES has been made cold-rolling mill manager and MR. C. S. WILKINSON, assistant cold-rolling mill manager. The last two appointments became effective on May 5.

MR. G. GILLESPIE, M.I.E.E., engineer and manager for Scotland for Johnson and Phillips Ltd., Charlton, London, S.E.7, has retired after 33 years of service but will remain available for consultation. His successor is MR. BRUCE RUSSELL, M.I.E.E. who is now manager of the company's Edinburgh branch. MR. R. L. STANLEY has been appointed manager of the firm's Glasgow branch.

PROFESSOR ALBERT MARCEL PORTEVIN, of Paris, who has gained distinction for his contributions to the science of ferrous and non-ferrous metallurgy and its applications to industry, has been elected a Foreign Member of the Royal Society, London.

MR. W. REGAN, assistant chief education officer to Richard Thomas and Baldwins Ltd., has been elected President of the Staffordshire Iron and Steel Institute for the session 1952-53.

MR. J. C. M. BAILLIE, development engineer of the North of Scotland Hydro-Electric Board, has been appointed chairman of the Scottish Centre of the Institution of British Agricultural Engineers. MR. W. J. WEST has been elected vice-chairman and MR. W. WILSON, of the West of Scotland College of Agriculture, secretary.

MR. SELBY T. ROBSON has requested the boards of Head, Wrightson & Co., Ltd., and of Head, Wrightson Processes Ltd., to allow him to resign. They have agreed with regret and Mr. Robson's resignation took effect as from April 30, 1952.

MRS. E. D. RUSSELL JONES, widow of the later managing director of A.C.E. Machinery Ltd., her son MR. G. R. JONES, and MR. E. R. SUMMER have been appointed to the board of that Company. MR. P. B. LAWSON is relinquishing his directorship on account of ill health.

SQUADRON-LEADER J. ZURAKOWSKI, test pilot of the Gloster Aircraft Co., Ltd., since 1947, is to join A. V. Roe Canada Ltd., Malton, Ontario, as test pilot.

MR. BASIL H. TRIPP has been appointed information and Press officer to the Council of Ironfoundry Associations, Crusader House, 14, Pall Mall, London, S.W.1.

MR. R. D. YOUNG, hitherto sales director of T.I. Aluminium Ltd., has been appointed a director and general manager of T.I. (Export) Ltd.

MR. CHARLES HERVEY has succeeded MR. E. T. SARA as public relations officer of the United Steel Companies Ltd., 17, Westbourne-road, Sheffield, 10. Mr. Sara is now commercial research manager of the firm.

MR. E. H. OUSTON, B.Com., A.C.A., has been appointed an executive director and joint secretary, with MR. H. L. JARVIS the present secretary, of the Plessey Co. Ltd.

The Parliamentary Secretary to the Ministry of Civil Aviation, MR. R. MAUDLING, M.P., has appointed MR. W. A. PENN to be his private secretary.

WORKS OF THE NATIONAL GAS AND OIL ENGINE COMPANY, LIMITED, ASHTON-UNDER-LYNE.

(*For Description, see Page* 584.)

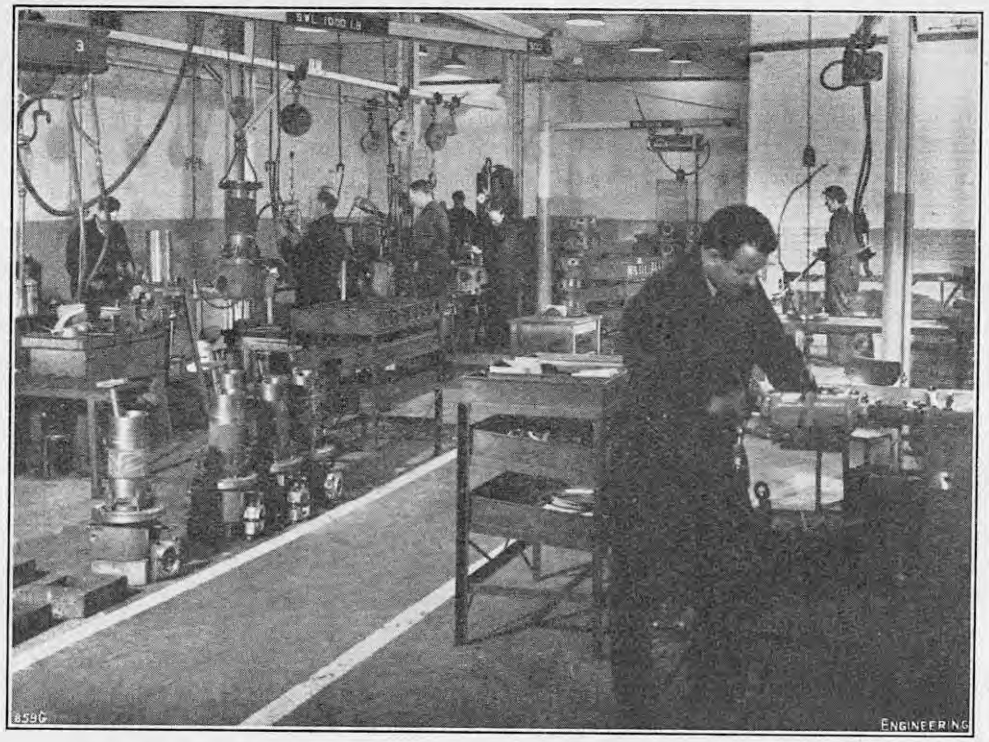

Fig. 4. Sub-Assembly Area for Cylinder Heads, Liners and Pistons.

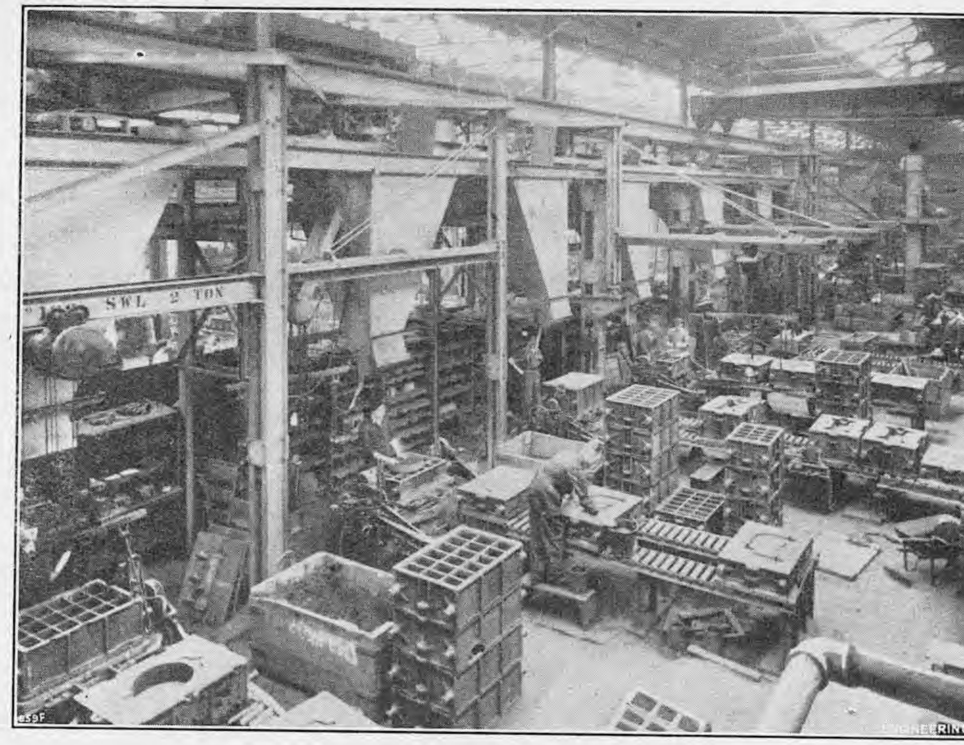

Fig. 5. Machine-Moulding Section of Iron Foundry.

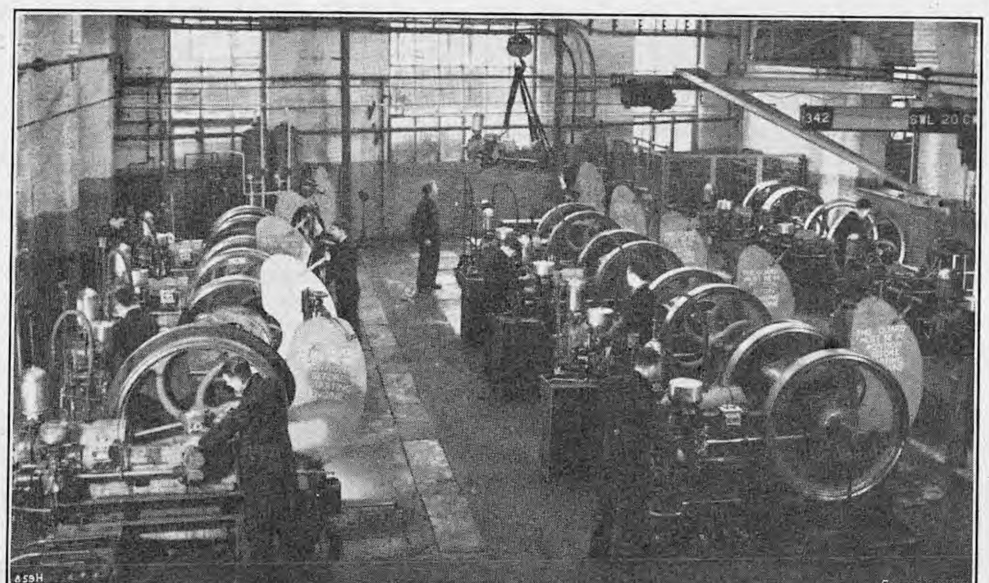

Fig. 6. Test Bay For Horizontal Engines.

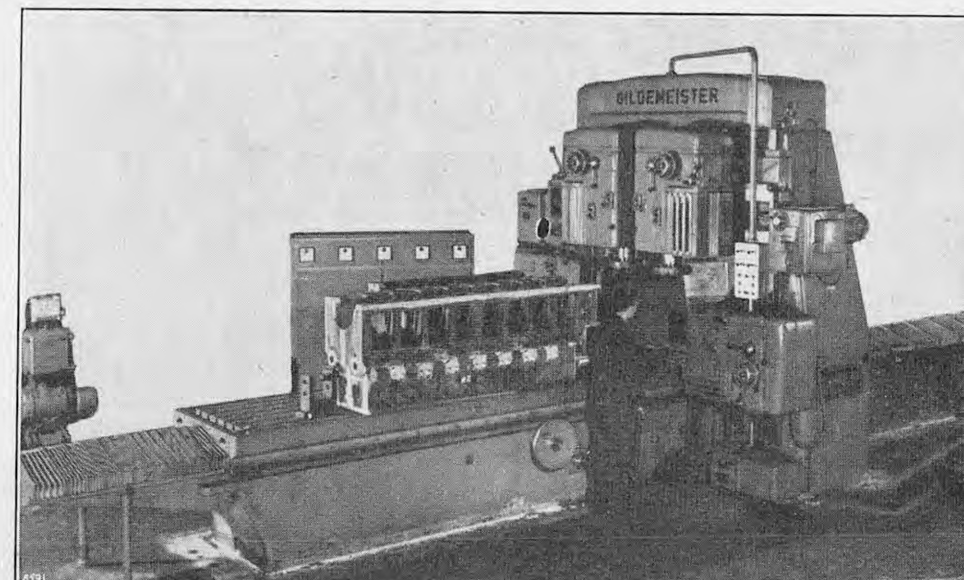

Fig. 7. Plano-Milling Machine.

ENGINEERING

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ENGINEERING

FRIDAY, MAY 9, 1952.

VOL. 173. No. 4502.

RESEARCH PROGRAMMES.

THE Department of Scientific and Industrial Research was created during the first World War largely because the industries of this country had been relying on foreign sources for important scientific apparatus and plant, and for some processed materials. A White Paper issued at the time stated that "it appears incontrovertible that, if we are to advance or even maintain our industrial position, we must as a nation aim at such development of scientific and industrial research as will place us in a position to expand and strengthen our industries and to compete successfully with the most highly organised of our rivals." This view is still sound, but there is some doubt whether those who control financial policy realise the implication conveyed. The latest annual report* of the Department refers in frank terms to the ill effects of the delay in giving full effect to the Department's post-war plans. The delay is partly due to difficulties in the recruitment of staff, but particularly to a financial policy which restricts its building and equipment programme.

It is now realised that the continued existence of the present population of this country can only be ensured by a highly efficient and competitive industry. Many factors go to the creation and maintenance of the manufacturing activity of a community, but in these days of scientific development, the practical application of the latest advances and investigation leading to new ones, are items of the first importance in the building up and sustentation of industrial leadership. The business of the Department of Scientific and Industrial Research is to foster these activities. Some five years ago, when these considerations were becoming more generally realised, the Department prepared a post-war programme of development which provided for the extension of existing establishments and the creation of three new ones. The programme received the general approval of the Government.

The post-war plans included a substantial building programme which, at to-day's prices, would cost some 10*l.* million. Some progress has been made and, for instance, some of the buildings for the Mechanical Engineering Research Organisation at East Kilbride have been completed, but, in general, progress has been slow and "extremely disappointing." Year by year, expenditure has lagged behind schedule and "when at length it seemed possible that the rate of expenditure could be raised to the agreed level of 1*l.* million per annum, a severe cut was imposed and it is doubtful whether expenditure will reach 500,000*l.* for the year 1951-52." The Department is not the only organisation which has been subjected to a "severe cut," but it may be suggested that those in control of public finance do not always give the attention they might to the relative values to the community of the varied activities to which they apply their restrictions. The 10*l.* million of the complete programme, which would have been considerably less if the original building schedule had been adhered to, is a substantial sum, but may fairly be described as trivial when compared with the magnitude of some items of public expenditure which certainly do not contribute towards the building-up of an efficient industry, as scientific research does. Activities, fostering a prosperous industry might usefully be given special consideration.

What are described as the most urgent items in the post-war programme are the building and equipment of the Mechanical Engineering Research Laboratory, the construction of a Hydraulics Research Station, re-housing of the Water Pollution Research Laboratory, the construction of a new Road Research Laboratory on a new site, extension of the Building Research Station, provision of a "properly designed" Radio Research Station, and the construction of an "up-to-date" ship tank. Of these various projects, the Mechanical Engineering Laboratory appears to be making most progress, and expenditure in the current financial year is expected to be about 250,000*l.* The relative magnitude of this sum compared with the value of the output of the industries which it serves is indicated in the report, which points out that mechanical engineering exports are valued at over 744*l.* million per year. The Hydraulics Research Station will be concerned with problems of coast erosion, river training, and the design of dock and harbour works in such a way as to avoid silting. It is stated that important contracts have been lost to this country through the absence of research facilities to investigate the problems raised.

Water pollution research is at present carried on in an old house in Watford and in some huts in the grounds of the Building Research Station. The accommodation is quite inadequate. A site has been secured for a laboratory at Stevenage and tenders for the building were obtained at the end of 1950, but work has been postponed on Government instruction. This is not an expensive project, and as the creation of the new River Boards is likely to increase the demands on the laboratory in connection with the treatment of works effluents, it might well be allowed to proceed. The Road Research Laboratory forms a more formidable item in the programme. Most of the existing site of the laboratory at Harmondsworth will be absorbed by the extension of London Airport and a new site has to be found and a new laboratory built. The cost is estimated at 1,250,000*l.* The work of the Radio Research Board is carried on partly at the

* *Department of Scientific and Industrial Research Report for the Year* 1950-51. H.M. Stationery Office. [Price 7*s.* 6*d.* net.]

National Physical Laboratory and partly in some huts at Datchet. The construction of a properly-designed laboratory at this latter site is considered to be an "urgent need." In connection with a new ship tank, it is stated that this country, which builds one-third of the world's shipping, lacks the testing facilities available in the United States, Russia, Holland and Sweden; the two existing tanks at the National Physical Laboratory are described as "obsolescent." The cost of a modern tank is estimated at 2,000,000*l*. A suitable site has been secured and it is recommended that construction should be begun without delay.

The reconstruction and extension of the Building Research Station, the remaining "most urgent" item, will involve the acquisition of additional land. One of the reasons for extending this establishment is that responsibility for sociological and economic research has been transferred from the Ministry of Works to the Department of Scientific and Industrial Research; and the Building Research Board, among other matters, are now required to study "the physiological sensations and subjective reactions of housewives" set up by "such tasks as cooking and clothes washing." In this, and cognate matters, the Building Research Station is working in conjunction with the London School of Hygiene and Tropical Medicine, but the enlargement of its field of work necessarily demands more accommodation and more staff.

The assignment of new tasks of this kind to the Department necessarily involves the recruitment of more staff, if they are to be effectively carried out. As is well known, there is a shortage of trained scientific workers throughout the country but the engagement of such as can be secured is not at present being encouraged by the Government. The total staff is now about 3,000 and the post-war plan was based on a total of 4,000. The average net annual recruitment for the post-war years was about 150, but it dropped to 110 in the last two years. A point made in the report is that matters should not be made more difficult by transferring individuals from civilian to defence establishments. Staffs should be kept together and defence problems assigned to the existing civilian laboratories.

The report contains brief accounts of the work of the various stations, and a later section of the report describes the work of the Research Associations, of which there are now 42. It was a far-seeing provision which led to the setting up of these Associations; they have had much to do with the creation of a climate of opinion, in industry generally, that research is a basic necessity. The granting of public funds to these Associations, without direct public control over the way they are spent, is now taken as a matter of course, but the original decision to permit such grants was unprecedented. In one respect, the Research Associations are probably able to utilise public funds more effectively and economically than the Stations of the Department. Under its constitution, the Department is authorised to make grants of public money to Research Associations to undertake capital expenditure for building, say, a new laboratory. As an activity of this kind may extend over a number of years, the Association concerned may build up a financial reserve and carry forward to the next year any part of the fund not expended in the current one. The Department cannot do this; any part of a grant for capital works not expended in the year for which it is made lapses, and a new grant must be obtained. This system may be satisfactory for current expenditure, but when it is applied to capital works extending over a number of years may well lead to delay and waste of money; it is not possible definitely to determine the exact capital expenditure on a major work in a rigidly-determined period. The system may be a necessity of public finance, or public financiers may think it is, but it seems very unbusinesslike.

LOCOMOTIVES AND COAL.

It has long been a favourite gambit of engineering critics to express dismay at the low thermal efficiency of steam locomotives. When the available supplies of coal are as marginal as they are to-day, it is not unreasonable to question the wisdom of continuing to run machines which, at best, waste 90 per cent. of the heat supplied to them, but no one has yet found a way of increasing the efficiency without introducing greater complications and costs, due to one cause or another, which offset the saving in fuel. Pulverised fuel, mechanical stoking, feed-water heaters, condensers, compounding, poppet valves, turbines, high-pressure boilers and steam-heat conservation have been tried; but all except poppet valves have been rejected in Britain. The fact is that, though coal supplies are barely adequate for the nation's needs, so, too, are man-power (or, more accurately, man-hours), money for capital expenditure and steel for new works. Thus, not only is there little opportunity to improve the steam locomotive, but British Railways are denied the chance of extending the application of electric, Diesel or gas-turbine locomotives.

In the circumstances, therefore, it was not surprising that half of the paper on "The Railways and Coal," presented to a joint meeting of the Institution of Locomotive Engineers and the Institute of Fuel on May 1 by Mr. R. G. Jarvis, B.Sc.(Eng.), was a record of past failures to reap benefits from modifications to the steam locomotive; the other half was a résumé of work now being undertaken on British Railways to improve locomotive design and the operating department's use of motive power. It is easy to overlook the fact that, even in the past 25 years, much has been done in this respect. The consumption of coal per drawbar horse-power-hour, as revealed in dynamometer-car tests, has been reduced from about 5 or 6 lb. to 3 or 3½ lb., and since nationalisation the good practices of the former railway companies have spread throughout the whole system. The training of drivers and firemen has received special attention; in particular, "controlled firing" is now standard. With this method, about six to ten shovelfuls of coal are placed on the fire every two minutes or so, the number of shovelfuls depending on the rate at which the locomotive is working. Each application of coal is allowed just enough time to burn through, and the light smoke haze to clear, before the next application. Thus, the boiler is worked at a more or less constant rate, and the steam consumption by the cylinders is adjusted correspondingly by means of the cut-off.

Controlled firing is bound up with the scientific train timing which British Railways are examining. As a result of locomotive tests which showed that there is a rate of working for each speed which is more economical than all others, it was established that there is a most economical speed at which a particular train can be hauled by a particular locomotive, and that this speed varies according to the inclination of the track. In practice, it is not possible to construct a precise curve of optimum speed, but a narrow band of optimum-speed tolerance is prepared, with the intention of ensuring that the speed of the train is kept within this band. Such speed bands are being drawn up for locomotives of the principal types, and it is possible that, some time in the future, time-tables will be revised to conform to this conception of economical train working. The practicability of the scheme must depend, to some extent, on the ability of the operating and motive-power departments always to use locomotives of one class on a given train. For the same reason also, it will depend on the Railway Executive allowing each standard locomotive design to remain standard for a reasonably high proportion of the normal life of a locomotive.

The use that British Railways can make of coal of inferior quality is hampered by the existence of a large number of engines which have comparatively small grate areas. The average life of a locomotive is 40 years, so that there are to-day many engines which were designed in the days of good locomotive coal. They still require good coal, because of their limited grate area; it would be uneconomic to scrap them prematurely, nor is it practicable to enlarge their grates. Tests carried out by the L.M.S. Railway before the war showed that fuel consumption with the poorest coal was 65 per cent. higher than with good coal. The new standard locomotives have large grates, with rocking firebars for removing ash, but for many years yet the older small-grate engines will remain in traffic.

It was significant that Mr. Jarvis was able to point to only one feature of locomotive design which has given a positive economy—and that not a particularly recent innovation—namely, the exhaust-steam injector, which has shown economies of 10 to 12 per cent. compared with a live-steam injector. The exhaust-steam injector is unique in that, so far, it is the only complicated mechanism, not essential for the ordinary functioning of a locomotive, which has proved to be acceptable to British Railways. In other respects, locomotive design has been developed gradually (though appreciably, as the figures for coal consumption per drawbar horse-power-hour show) and mainly by improving the proportions and layout of cylinders, valves and valve gears. Mechanical stokers, which, on very large engines, are a necessity, have not shown up well on British locomotives. Mr. Jarvis reported that a skilful fireman can save 25 per cent. of fuel compared with the mechanical stoker that was fitted experimentally to a Southern Region locomotive in 1948. Pulverised fuel, when it was tried in 1918 and 1931, gave an excessively high fuel consumption. Feed-water heaters, though they saved about 9 per cent. of coal when the equipment was in good condition, required too much maintenance and did not show any ultimate saving in day-to-day traffic. Condensing was a failure when applied to locomotives, chiefly due to the limited space, the difficulty of providing adequate cooling, and the elimination of the normal exhaust-blast action. Compounding has been rendered almost valueless on British locomotives by improvements in valve gears, and experiments with turbines and high-pressure boilers have not been a success. The principle of steam-heat conservation, which was applied to a 2-6-0 locomotive of the Southern Railway in 1931, was found to lead to increased coal and water consumption, though in theory it offered substantial savings.

In view of this rather discouraging record of trial and error, the Railway Executive attach great importance to the training of footplate staff in making the most efficient use of engines and coal. The motive-power department have 90 instructors who teach good firing methods to some 88,500 men who are in the line of promotion from cleaners to drivers. They also have an instructional film on firing; coal-weighing tenders are used to demonstrate to firemen the economy that can be achieved in the use of coal; and a train fitted out for instructional purposes tours motive-power depots. Welcome though these measures are, they are not strictly engineering solutions to the problem. The cost and availability of coal, in relation to all the other factors in running a railway, have altered since most of the experiments to which Mr. Jarvis referred were undertaken, and it may now reasonably be asked whether some of those experimental designs could not, with advantage, be examined afresh. There is no valid reason for giving up all hope of making a significant alteration to locomotive thermal efficiency, particularly when thermal efficiency is as important as it is in Great Britain to-day.

NOTES.

THE INSTITUTION OF CIVIL ENGINEERS.

THE annual dinner of the Institution of Civil Engineers was held on Thursday, May 1, at the Dorchester Hotel, London, W.1, the chair being taken by the President, Mr. A. S. Quartermaine, C.B.E., M.C. The principal guest was Air Chief Marshal Sir Roderic Hill, K.C.B., Rector of the Imperial College of Science and Technology, who proposed the toast of "The Institution." The President, in reply, said that the need to-day was for a higher standard than ever among engineers, when there was so much work to be done to meet the world's requirements. To produce engineers of the necessary quality meant more than merely academic and practical training; it called for energy and resourcefulness, character and leadership, and some of the old pioneering spirit. It would be a national misfortune if, for any reason, this country did not continue to retain the leading place in the design and construction of big engineering projects overseas. Mr. Quartermaine went on to propose a toast (additional to the printed toast-list) to the American Society of Civil Engineers, whose centenary is to be celebrated in Chicago in September, and, on behalf of the company present, sent a cablegram of congratulation and greeting to the American Society; a reply was received later in the evening. He then invited Mr. George R. Clemens, M.A.S.C.E., who had come from Paris, to respond to the toast. Mr. Clemens, who was welcomed with acclamation, said that the Engineering Centennial at Chicago, which would mark the centenary, was a joint endeavour of the five American engineering institutions forming the Engineers' Joint Council, who were being supported by nearly 50 other engineering organisations in preparing the Convocation of Engineers to be held in September. "As engineers," he said, "we have the responsibility to impress upon politicians that we have only scratched the surface of the things that we can do. In the past, we have been forced to devote much of our engineering endeavour to attempts to exterminate each other. We should prefer, in the future, to be turned loose to make this world a better place in which to live." Sir Harold Hartley, K.C.V.O., President of the Institution of Chemical Engineers, in responding to the toast of "The Guests," proposed by Dr. W. H. Glanville, C.B.E., said that the civil engineer overseas was a great ambassador for his country, and still enjoyed that complete confidence everywhere in his skill and integrity that had been established by British engineers in the past.

INDUSTRIAL GAS CONFERENCE AT BIRMINGHAM.

In connection with the Gas Section of the British Industries Fair at Castle Bromwich, the second annual Industrial Gas Conference was held at the Queen's Hotel, Birmingham, on Monday, May 5, under the chairmanship of Colonel Harold C. Smith, C.B.E., M.I.C.E., chairman of the Gas Council. In his opening address, Colonel Smith said that the gas industry in the United Kingdom had some 114,000 industrial consumers, representing about 4,000 trades and industries, who consumed a quarter of the total amount of gas sold. In the area of the West Midlands Gas Board, industrial sales in 1951 were about 45 per cent. of the total, an increase of 11 per cent. over those of the previous year. In the East Midlands area, industry took 43 per cent. of the gas, and in the Sheffield and Rotherham division, the proportion was 69 per cent. Following the chairman's introductory remarks, Mr. J. Walker, A.R.S.M., B.Sc.(Eng.), delivered an address entitled "What Industry Wants from the Gas Industry." In his opinion, Mr. Walker said, industry wanted to see a proper recognition of the role that the gas industry had to play in the national economy; much more gas, with constancy in supply, pressure, calorific value and burning qualities; a high standard of gas cleanliness, and freedom from sulphur; practical, simple, flexible and robust gas-burning appliances, or improved performance; inexpensive, robust and foolproof safety devices; and "plenty of practical consumer service on the shop floor." On the conclusion of the address, the conference adjourned for luncheon. In the afternoon, many of the members visited the British Industries Fair, while others, under the chairmanship of Mr. H. F. H. Jones, M.B.E., deputy chairman of the Gas Council, attended a meeting *in camera* to discuss "The Gas Industry—Service to the Industrialist," at which Mr. H. R. Hems reviewed the relationship of the work of the Industrial Gas Development Committee to the Area Boards, Divisions, Groups and District Undertakings.

CENTENARY OF THE LONDON ASSOCIATION OF ENGINEERS.

The London Association of Engineers—originally the London Association of Foreman Engineers—was founded in May, 1852, by five foremen—George Sheaves, John Briggs, and three others named Tillot, Ross and Allison, whose Christian names appear not to be now recorded—who met in the George Inn, in the Borough. In the preface to the rules of the new association they observed that "the want of co-operation among foremen of the engineering trade was long and deeply deplored"; that "there existed between them no public and recognised channel of communication, and as a body they were unable to consult for their general interests and mutual advantage." These disabilities the Association set itself to remove, and succeeded in removing to an extent that probably exceeded the founders' most sanguine expectations; certainly, they could hardly have visualised such a gathering as met in the Connaught Rooms, London, on Friday, May 2, to celebrate the centenary of the Association. The chair was taken by Mr. Emile L. M. van Gelder, the President. To report the many speeches at length is unnecessary, even if space were available; what is of greater import, as indicating the status that the Association has acquired in its 100 years, and the wide range of its members' affiliations and interests, is the list of the speakers themselves. Grace was said by the Very Rev. the Dean of St. Paul's (Dr. W. R. Matthews, K.C.V.O.), chaplain to the Association. The toast of "The Engineering Industry" was proposed by Mr. Norman Crump, city editor of the *Sunday Times*, and acknowledged by Mr. John Paget, manager of Messrs. D. Napier and Son, Limited, and Mr. James A. Lane, Chief of the Materials and Industry Division of the Mutual Security Agency of the United States. Sir Ronald M. Weeks, K.C.B., chairman of Messrs. Vickers Limited, proposed the toast of "The London Association of Engineers," to which the President responded; and that of "Her Majesty's Ministers," proposed by Sir Frederick Handley Page, C.B.E. was replied to by the Rt. Hon. the Earl de la Warr, Her Majesty's Postmaster General. Finally, Major-General K. C. Appleyard, C.B.E., President of the Institution of Production Engineers, acknowledged that of "The Guests," proposed by Mr. F. C. J. Bartlett, past President of the Association. A feature of particular interest was the souvenir history of the Association, compiled by Mr. D. Peeler, which was presented to each diner. Many of the early records were lost when the library was destroyed by enemy action during the recent war, but sufficient authentic information had been collected to show how the Association began, and how, through various vicissitudes, it continued to grow steadily and to build up the benevolent fund which is now one of its major activities.

THE IRON AND STEEL INSTITUTE.

The annual dinner of the Iron and Steel Institute was held at Grosvenor House, London, W.1, on Wednesday, April 30, the chair being taken by the President, Captain H. Leighton Davies, C.B.E. The toast of "The Iron and Steel Institute and Industries" was proposed by the Rt. Hon. Lord Brabazon of Tara in a speech characteristically composed of badinage, legend, anecdote, and, only thinly disguised, a penetrating grasp of the real problems of the industry and the tasks still awaiting it. The President, in reply, suggested that what the country and the whole world needed was courage to change those things that should be changed, security to accept those that could not be changed, and wisdom to distinguish between the two. The Iron and Steel Institute, with its international interests and membership, must always maintain its position in the forefront of scientific researches and changes; the greater the efficiency of the industry, the better it would be for the economy of the world in general. The Institute would continue to welcome into membership members of the metal industries from all parts of the world. The same theme was developed by Mr. James Mitchell, C.B.E., honorary treasurer of the Institute, in proposing the toast of "The Guests," to which responses were made by the Rt. Hon. Lord Mackintosh of Halifax and Mr. Lincoln Evans, C.B.E.

METROPOLITAN-VICKERS APPRENTICES.

The continuing prosperity of the engineering industry depends on a constant, and growing, supply of recruits to its scientific and administrative staffs. At various times, there has been criticism of the quality of the men trained in universities and technical colleges; they are, or were, accused of being of too theoretical a type and lacking in the practical outlook essential in industrial life. Rectification of this state of affairs, if it exists, or existed, has long been provided for by the system under which men educated in technical and scientific institutions are accepted as graduate apprentices by manufacturing firms. That the practice is now widespread owes much to the example and pioneering work of the Metropolitan-Vickers Electrical Company and, in particular, to the foresight and administrative ability of Sir Arthur Fleming. The extent to which this company has contributed to the trained man-power of the country is shown by the fact that it has been able to publish *A Register of Ex-Apprentices and Ex-Trainees of the Metropolitan-Vickers Electrical Company, Limited*, containing the names, and in most cases some record of the careers, of 10,219 men trained at Trafford Park between 1902 and 1949. Not all of these were graduate or college apprentices; many were trade apprentices, but this latter class constitutes an important part of the man-power of the engineering industry. Curves forming a chart showing the number of apprentices completing their training from 1902 to 1949 show the number of college apprentices to exceed that of trade apprentices up to the year 1914; the numbers became equal in 1930, but in recent years, apart from a fall during the war, college apprentices have considerably exceeded trade apprentices in number. The records contained in the register naturally show that many ex-apprentices are still in the employment of the Company, but large numbers are engaged with other firms. Lists and maps show that Trafford Park men are now employed in most of the countries of the world, and emphasise that the training facilities provided have been, and are, a major contribution to the progress of British engineering.

INAUGURATION OF JET AIR-LINER SERVICE.

On Friday, May 2, the world's first commercial jet-propelled air liner service, was inaugurated by the British Overseas Airways Corporation (B.O.A.C.). Shortly after 3 p.m., the Comet air liner took off from London Airport on the first stage, to Rome, of its 6,724-mile journey to Johannesburg, with a full load of 36 passengers. Subsequent stages in the journey are Beirut-Khartoum-Entebbe-Livingstone-Johannesburg; at Beirut and Khartoum the crew, consisting of captain, first officer (who combines the duties of second pilot and navigator), flight engineer, radio officer, steward and stewardess, is changed. At each intermediate stage, a stop of about an hour is made. Until the inauguration of the Comet service, the London-Johannesburg journey, by B.O.A.C. Hermes air liners via the shorter western route, has occupied 32 hours 25 minutes, including ground stops. The corresponding time for the Comet is 23 hours 40 minutes, the actual flying time being scheduled at 18 hours 40 minutes. As experience is gained in operating the Comet, the length of time spent on the ground will be shortened. Credit for this accomplishment is due both to the de Havilland Aircraft Company, Limited, for their remarkable achievement in producing a highly advanced aircraft, involving many technical problems as a result of its high speed and operating altitude, fully developed for commercial service within six years of initiating the design; and to B.O.A.C. for their courage and foresight in ordering an untried aircraft while still in the design stage.

LETTERS TO THE EDITOR.

PROFESSOR SIR CHARLES E. INGLIS, O.B.E., F.R.S.

To the Editor of Engineering.

Sir,—May I add a few lines to the admirable tribute which you paid to the late Sir Charles Inglis in your issue of April 25? He and I were undergraduates together at King's College, Cambridge, and I kept in touch with him more or less to the end of his life, though our ways in life tended to lead us far apart. I last met him in the Fellows' common room at our old College when he was Vice-Provost. His conversation was delightful, and a note of something he then said may be of interest.

We talked of teaching, of which art (as you have pointed out) he was a great exponent. I mentioned a man named Wedd, who taught classics when Inglis and I were undergraduates. Inglis said: "Wedd was one of our great teachers. He told me something I have never forgotten. It is this: 'If you are about to correct the essay of a student, always begin by praising some part of it—if there is anything that ought to be praised. You can then criticise in a more congenial atmosphere'."

I asked Inglis if he had anything to do with the blowing up of great dams during the war; he said not. I then asked him about the Boulder Dam—"A marvellous piece of work!" as he described it, which formed a lake over 100 miles long; and so we came to the subject of bridges, more especially the suspension bridge over the St. Lawrence River. Much of what he told us is, of course, common knowledge to those who read your paper, but I think it is worthy of record that a great engineer could, with his clear explanations and apt comparisons, so interest a layman in the subject to which he had devoted the greater part of his life.

Yours truly,
W. Valentine Ball.

The Athenæum,
London, S.W.1.
April 27, 1952.

EXPERIMENTAL PEAT-FIRED CLOSED-CYCLE GAS TURBINE.

To the Editor of Engineering.

Sir,—In regard to the letter from Mr. Richard Wiebe on page 527 in your issue of April 25, it is not entirely clear in what way the wet carbonisation process re-discovered by the director of the Engler-Bunte Institute at Karlsruhe is novel. A very good account of the working of this process during the 1914-18 war at Dumfries is contained in the final report of the Peat Committee appointed by the Dominion of Canada (1925). The efficiency appears to have been somewhat less than zero, and this, together with the corrosion difficulties encountered, caused the plant to be abandoned, though some relics and other evidence of the very considerable capital expenditure still remain on the bog.

Yours truly,
B. Wood.

16, Park House-gardens,
Twickenham,
Middlesex.
April 30, 1952.

The Future of the Flying Boat: Erratum.—It has been brought to our notice that on page 383, *ante*, the captions to Figs. 7 and 8 have been interchanged. Fig. 7 is, in fact, the Saunders-Roe water-based fighter design, and Fig. 8 is the Convair.

British Motor-Car Plants Overseas.—The Austin Motor Co. of South Africa Pty., Ltd., have started work on a new factory near Capetown. The factory will produce private and commercial vehicles from parts imported from this country, at first, but it is planned to change over gradually to South African components as they become available. A similar undertaking is planned by the Standard Motor Co., Ltd., of Coventry, but their developments will take place in Australia. The Standard Company already have an assembly factory at Melbourne, but it is their intention to produce complete cars and tractors from locally-made parts.

THE IRON AND STEEL INSTITUTE.

As stated on page 558, *ante*, the 83rd annual general meeting of the Iron and Steel Institute opened on Wednesday morning, April 30, at the Royal Institution, Albemarle-street, London, W.1, and was concluded on the afternoon of the following day, at the Institute's offices, 4, Grosvenor-gardens, London, S.W.1. The retiring President, Mr. R. Mather, occupied the chair at the outset of the proceedings.

Report of Council.

The main features of the report of Council for 1951 were outlined by the President. The report stated that the total membership of the Institute, on December 31, 1951, was 4,776, compared with 4,882 on December 31, 1950. The further drop in total membership had again been due to a reduction in the number of associate members, which had declined from 702, on December 31, 1950 (857 in 1949), to 552 on December 31, 1951. The Council recorded with regret the deaths of 43 members, 24 of whom had died during 1951. Among these, were Mr. F. Clements, Mr. S. G. Coade, Mr. Arthur Crooke, Mr. G. Glenn, Mr. T. F. Mills, Mr. H. M. W. Royce and Professor T. Turner. Mention was also made of the death, on February 24, 1952, of Mr. W. J. Brooke, and on March 30, 1952, of Sir Andrew Duncan, G.B.E. Seven volumes of drawings of considerable interest, relating to the patents granted to Sir Henry Bessemer, had been presented to the Institute by his grandson, Mr. H. W. Bessemer. The volumes had been placed in the Institute's library. The close collaboration between the Institute and the British Iron and Steel Research Association had continued throughout the year, and the good relations between the Institute and other scientific and technical societies, at home and abroad, had been maintained. The Joint Committee on Metallurgical Education had held four meetings during 1951 and had received and considered comments on their "Recommendations on University Full-Time Degree Courses in Metallurgy," published in 1950. The Joint Committee for National Certificates in Metallurgy had also held four meetings in 1951 and had approved four schemes for Ordinary National Certificate Courses and six schemes for Higher National Certificate Courses (including one new "sandwich"-type scheme for the Higher Certificate with additional endorsement subjects).

Report of Honorary Treasurer.

The statement of accounts for 1951 prepared by the honorary treasurer, Mr. James Mitchell, C.B.E., showed that the income for the year ended December 31, 1951, had been 64,686*l*., and the normal expenditure 61,180*l*. After charging certain non-recurring expenditure, the excess of income over expenditure, for the year, was 718*l*.

Changes in Council and Announcements.

The secretary announced the changes which had taken place on the Council since the last general meeting in November, 1951. He stated that Mr. W. B. Baxter, C.B.E., had been elected an honorary vice-president, and that Sir Charles Bruce-Gardner, Bt., and Mr. C. R. Wheeler had been made vice-presidents, and Mr. E. J. Pode and Mr. B. Chetwynd Talbot members of Council. The following had been made honorary members of Council during their tenure of office: Mr. H. Allison, the President for this year of the Manchester Metallurgical Society, in succession to Mr. A. B. Ashton; Mr. E. W. Colbeck, President of the Sheffield Metallurgical Association, in succession to Mr. E. T. Gill; Mr. G. Baker, O.B.E., President of the Sheffield Society of Engineers and Metallurgists, in succession to Professor H. W. Swift; Mr. W. Regan, President of the Staffordshire Iron and Steel Institute, in succession to Mr. K. H. Wright, and Mr. E. Taylor-Austin, chairman of the newly-affiliated North Wales Metallurgical Society. Moreover, in accordance with by-law 10, the three vice-presidents, namely, Mr. G. H. Latham, Mr. J. Sinclair Kerr and Mr. H. H. Burton, and five members of Council, namely, Dr. J. W. Jenkin, Mr. W. F. Cartwright, Mr. F. Saniter, Mr. T. Jolly and Mr. R. A. Hacking, O.B.E., who, as announced at the autumn meeting of 1951, were due to retire in rotation, were declared to be re-elected, no other nominations having been received.

Among other announcements, it was intimated that a second grant of 150*l*. had been awarded to Mr. B. Cina, of Sheffield University, the holder of an Andrew Carnegie Scholarship, for his research work on nickel-chromium steels; that a special meeting of the Institute would be held in Swansea from October 7 to 10, and that the autumn general meeting of the Institute would take place in London on November 26 and 27. As stated on page 558, *ante*, the President-elect, Captain H. Leighton Davies, C.B.E., was inducted into the chair at the conclusion of the business of the meeting and the remainder of the morning of April 30 was given over to the delivery of the presidential address and of the sixth Hatfield Memorial Lecture, by Professor E. N. da C. Andrade, which is reprinted on page 601 of this issue.

(*To be continued.*)

THE GEORG FISCHER "IRON LIBRARY" AT SCHAFFHAUSEN.

In a note published in our issue of February 9, 1951, on page 176, we mentioned that the iron and steel and engineering firm of Georg Fischer, Limited, Schaffhausen, Switzerland, would celebrate in the present year the 150th anniversary of their foundation by Johann Conrad Fischer in 1802. As a part of the celebration proceedings, a ceremony of international interest and importance was enacted at Schaffhausen on Saturday, May 3, when a fine, possibly unique, collection of books and MSS., forming a chronological record of iron metallurgy from the earliest times to the present day, was dedicated to the public service by Mr. Ernst Müller, managing director of the Georg Fischer Company. It was largely due to the energy and enthusiasm of Mr. Müller, continued over a period of several years, that the collection was made and its future determined, his efforts being ably supported by the chairman of the company, Mr. E. Homberger, and by the other members of the board.

Now known as the Iron Library, the collection is housed in the Paradise Convent, which is situated on the bank of the Rhine about three miles upstream from Schaffhausen. The convent and the surrounding land were purchased by the company in 1918, when it was in a state of delapidation and neglect, but it has since been restored and adapted to its present purpose under the direction of the architect, Mr. Martin Risch, of Zürich. Its external appearance and the nature of its surroundings may be visualised from the photograph reproduced in Fig. 1, opposite. In addition to the rooms occupied by the library proper, the building contains a reading room, guest rooms for visitors, several self-contained flats occupied by superannuated employees of the firm, and living accommodation for the manager of a modern dairy farm, for which part of the grounds is utilised. The interior of the library is shown in Fig. 2, and it may be mentioned that over the doorway entrance to this room is a carved plaque which will form a permanent record of the work done by Ernst Müller in inaugurating, developing and completing the scheme. The building also includes a conference room in which members of the firm may hold meetings and conferences, and part of it has been reserved as a museum for the display of the company's products of historical interest.

The Iron Library now contains about 8,000 volumes, but the number is being added to as and when opportunity offers, and it is proposed to continue this practice indefinitely. We may mention a few of the notable works in the Iron Library, which were referred to in a broadcast by Dr. Arthur Fürer over the Swiss radio system on April 29, 1950. He quoted a passage from *Regnum Minerale*, by Valentine Kräutermann (1726), which, though hardly true to-day, is nevertheless interesting. He wrote: "Of all metals, iron

THE GEORG FISCHER IRON LIBRARY.

FIG. 1. PARADISE ESTATE BUILDINGS.

FIG. 2. INTERIOR OF LIBRARY.

is the least noble and perfect, yet, at the same time, the most useful and excellent, so that no one could spare it without very great damage and it would be far easier for man to dispense with gold, silver, copper, tin and lead than with iron; quite apart from the fact that no other metal could be taken out of the earth or rendered useful to man if iron and steel were not there to do the main work." One of the works in the library, written by Vegetius Renatus in 1534, describes, with many illustrations, how troops were armed in those days, and shows that iron then formed part of all military implements, as it does to-day. What may be regarded as the first systematic text-book on metallurgy was written in 1540 by an Italian, Vanuccio Biringuccio, and gives information on the assay of ores and their preparation for smelting, as well as on bellows, furnaces, smelting, moulding, the casting of cannon and the minting of coins.

A little later, in 1550, a German physician, who adopted the name of Georgius Agricola, completed his book *De Re Metallica*, which was first published in Basle in 1556; it was mainly concerned with mining. Copies of the works of both Biringuccio and Agricola are in the Library, and a famous book on assaying by Lazarus Erker, 1598, may also be seen. During the Eighteenth Century, many books appeared, written by such famous authors as Réaumur, Swedenborg, Bruckmann (the title-page of whose *Magnalia Dei in Locis Subterraneis* is reproduced in Fig. 3), Valerius, Cramer, Diderot, d'Alembert and others, all of which are represented in the Iron Library. Later works are, of course, too numerous to mention, although students of the history of metallurgy may be glad to examine them.

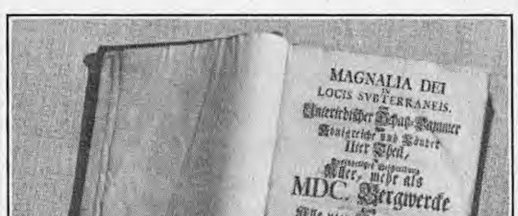


FIG. 3. TITLE PAGE OF BRUCKMANN'S BOOK "MAGNALIA DEI IN LOCIS SUBTERRANEIS."

The management of the Iron Library is in the hands of a Trust founded by the Fischer Company in 1948, by which the directors formed the Library into an independent body and made it a public institution. The objects of the Trust are to acquire, collect and keep in safe custody historical and modern literature on the production and manufacture of iron, including appropriate publications on geology, mineralogy, mining, chemistry, metallurgy, etc., and covering also the applications of manufactured iron in trades and industry. The trust deed states that the Library is to be accommodated in rooms provided by the founders in their Paradise Estate, where study and ancillary rooms are provided for those using the Library, which is placed free of charge at the disposal of those interested in scientific and industrial research. Grants are also to be made to students at universities and public schools wishing to study in the library. The administration of the Trust is conferred by the deed upon an executive committee of three to five members, who are supervised by a board of trustees to be nominated by the directors of Georg Fischer, Limited, including representatives of some foreign countries. The British representative is Lieut.-Gen. B. M. Burrows, C.B., D.S.O., M.C., and the American representative is Dr. W. H. Worrilow, of Lebanon, Pa., U.S.A. The assets of the Trust are the Library and a donation of 250,000 Swiss francs, which will be added to at intervals.

The dedication ceremony, on Saturday, May 3, in the grounds of the Paradise Convent, was attended by about 150 guests. Speeches were delivered by Mr. Müller, Mr. Risch, Professor Hans Pallmann, Dr. E. Reiber and Dr. Worrilow, who concluded his remarks by expressing the hope that the Library would become "the shrine towards which the minds and feet of peoples of all nations would be turned in their quest for knowledge of a great industry." The guests were afterwards entertained to luncheon in the G.F. house in Schaffhausen.

At present the books are in the care of Mr. O. Merz and Mr. A. Kleiner. We understand that suitable persons of any nationality are welcome to make use of the Library, and of the available living accommodation, on application to Georg Fischer, Limited, Schaffhausen, Switzerland. Those privileged to take advantage of the facilities will be able to study in the peaceful and comfortable conditions which are so conducive to the acquisition of knowledge.

HAWKER "HUNTER" AIRCRAFT.—It has been announced by the Hawker Siddeley group that the Gloster Aircraft Co., Ltd., Hucclecote, Gloucestershire, are to construct Hunter fighter aircraft, designed by Hawker Aircraft Ltd., Canbury Park-road, Kingston-on-Thames, Surrey, for the Royal Air Force.

MIDGET CONTACTOR FOR STARTING-MOTORS.—There are many instances in practice where Diesel or petrol generating or pumping sets are started electrically by means of a low-voltage direct-current motor. The starting current is often large and it is usually convenient to employ an electrical relay to close the circuit. A contactor suitable for the purpose, though having wider applications, is obtainable from the Electrical Remote Control Co., Ltd., 13 and 15, Evanston-avenue, Higham's Park, London, E.4. Known as Type HDD, this contactor employs the familiar combination of electromagnet and spring-loaded armature to close the main circuit when the magnet is energised, but, by attention to design, its overall dimensions and operating current have been kept small although its current-switching capacity is high. The main contacts are two large domed studs mounted on Paxoline and furnished with copper connecting-tags. When the relay is energised, the studs are short-circuited by means of a copper bar attached to the armature by means of a phosphor-bronze spring, and the circuit is broken again by the action of a coiled spring which returns the armature to its initial position as soon as the magnetising current is interrupted. The gap at the main contacts is adjustable and the device may be used either continuously or intermittently. In the former case, a direct current of 200 amperes may be passed at 24 volts pressure under suitable conditions; in the latter, the current may be as much as 450 amperes. Coils to suit a range of currents, and voltages less than 250 can be supplied for the electromagnet, the power requirements of which range from 2 watts to a maximum of 6 watts at full rating. The overall dimensions of the unit, which can be supplied open, or mounted on a Paxoline panel and fitted with a dust-cover, are $4\frac{1}{2}$ in. by $3\frac{1}{4}$ in. by $1\frac{5}{8}$ in.

WAR ON WEAR.*

By PROFESSOR H. BLOK.

SINCE man "wore" his first crude clothes and his first primitive tools, war on wear has been waged at an ever-increasing rate. This is understandable because, whenever and wherever the greed for consumption goods is satiated, wealth is essentially accumulated by producing capital goods, that is, goods subject by their use to damage, including wear. The stage may ultimately be reached, where the amount of capital goods reaches a ceiling at which production just offsets losses due to damage. In determining the height of the ceiling, the rate of dissipation (*inter alia*, by wear) is just as important as the rate of production.

Another way of looking at the economic problem of wear is that the amount of material removed by wear, that renders articles unfit for further use, usually is annoyingly small as compared with that of the weight or volume of the article itself. Outstanding examples are cutting implements (razor blades, knives, turning tools, etc.) and measuring gauges. Almost without exception, the loss of material through wear, possibly in conjunction with that through more or less periodic reconditioning, is minute relative to what is left recoverable as scrap. This is a fortunate circumstance, the material lost being in forms as irrecoverable as the wear dust dispersed from ploughshares into the soil. On the other hand, the labour involved in bringing back the scrap into a form suitable for the recirculation of material necessary for replacing worn articles counts far more heavily. All in all, in the wear problem the waste of energy would appear to be economically of even greater concern than the waste of material.

The conclusion to which we are inevitably led, even after due allowance for inaccuracies in estimates of the most important items of the wear budget and of their sum total, is that war on wear is well worth waging. However, there is no room for counsels of perfection when it comes to making efforts to diminish rates of wear. There is no sense in prolonging the material life of an article far beyond its economic life; this applies especially to articles which become outdated, either by engineering development still going on rapidly (e.g., metal-cutting machinery), or by changes in fashion (as in clothes).

One field of wear is characterised by the set-backs inflicted in the established type of service of the goods concerned. An outstanding example of this field is provided by the wear of that most important asset of mankind, the soil on and from which we live; in fact, soil erosion deserves increasingly greater attention because of the steady increase of the world's population. There are also many examples of another field where engineering progress was severely hampered by wear; several among them are still with us, e.g., cavitation erosion, the wear of rock bits in the drilling of deep oil wells, etc.

Before going into strategy and tactics, i.e., the principles and methods suitable for combating wear, it is desirable to reconnoitre the theatre of wear by differentiating and interrelating the various types of wear. To this end, the following definition of wear provides a useful starting point: Wear is the undesirable migration of the material of a solid surface, essentially due to the overstressing caused by mechanical forces, if these are exerted in a direct way on the surface by its continuous or repetitive motion relative to a fluid or solid in contact.

The migration of surface material may occur in two main forms. The first is complete migration, or, say, removal of surface material; this is the most radical form. In cases where there are two solid surfaces mating, material removed from one surface may be deposited on the other; even this undesirable deposition by transfer of material is included under the above definition of wear. The second form is partial migration of material, which may take place either in the form of plastic deformation or in that of rearrangement of atoms—within one surface layer as well as between it and its mating surface or other contacting medium, such as the atmosphere or a lubricant—into new physical units (recrystallisation) or into new chemical constituents. The process of migration by rearrangement, into the surface material, of atoms of a contacting medium may considerably complicate the mechanism of wear involved. In this process, physical aspects such as diffusion and mutual solubility, as well as diverse chemical aspects, may enter as factors implicit in the above definition of wear.

Despite the complexity inherent in most wear phenomena, and their consequent wide diversity, they centre on one characteristic in common, that is, the mechanical overstressing of the surface material. A rational approach to the problem of classifying the different types of wear consists, therefore, in classifying them according to the different ways in which the overstressing can be brought about. The various types of wear can be grouped, accordingly, into two broad classes which conform to the two possible states, either the fluid or the solid state, of the contacting medium which causes the mechanical forces.

"Single-sided" wear (or erosion), which is the first class, comprises the types of wear occurring in cases where the contacting medium is a flowing fluid; accordingly, fluid mechanics is involved in judging the forces exerted on the solid surface attacked. The only solid surface concerned generally serves to direct the flow of the fluid medium, for instance, a turbine blade directing the flow of steam, or a centrifugal-pump impeller directing the flow of water. Overstressing, and thus wear, of flow-directing surfaces is rather the exception than the rule.

One of the best-known types of single-sided wear is cavitation erosion (such as that on the blades of ships' propellers), which is caused by the impacts due to the "implosion" of cavitation bubbles in the flowing liquid. Another, closely related, type of this "liquid" erosion is well known in turbines, the blades of which are affected by the impingement of droplets present in wet steam. Fluid contact and impact are obviously characteristic of these types of erosion. A limiting case of erosion arises when the flowing medium is a powdered solid which is more or less fluidised. This case provides a transition between single-sided and double-sided wear, in that solid contact is occurring.

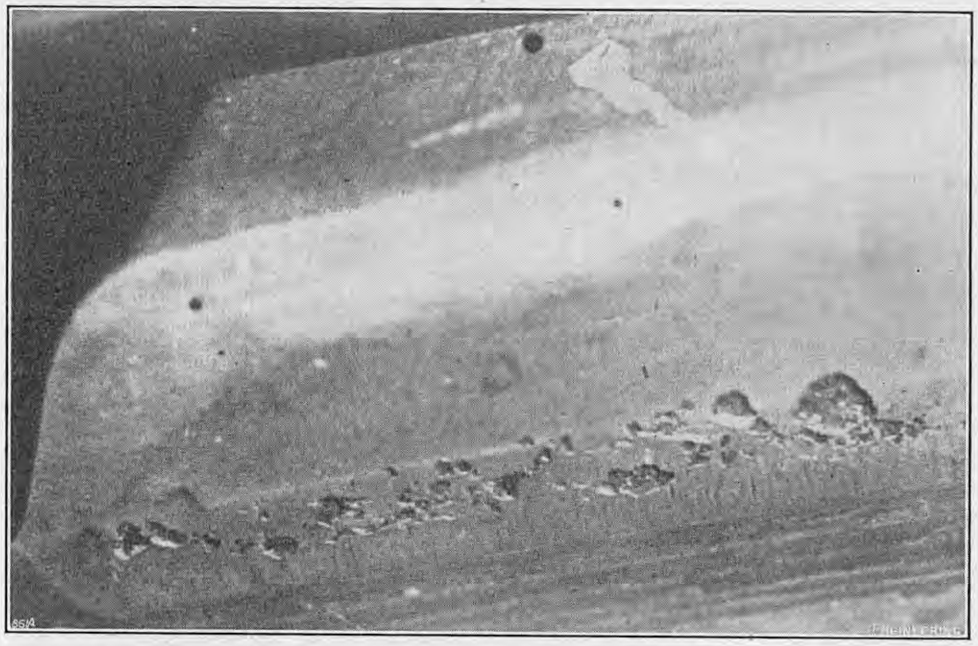


FIG. 1. PITTING ON A GEAR TOOTH.

Double-sided wear, the second class, comprises the remaining types of wear, which are characterised by the presence of two mating solid surfaces, rubbing on each other. Here, one surface is guided by the other; thus, forces are created which serve, say, for transmitting power, as through the teeth of gears, or for dissipating power into frictional heat, as in brakes. In any case, the frictional energy is converted into heat, and the temperature rise thereby caused at the rubbing surfaces introduces an important factor determining the type of double-sided wear obtained; in fact, temperature affects the properties of the surface materials and the rate of their chemical reactions.

Besides the rise in surface temperature, the nature of the solid contact also proves useful in studying certain features of, as well as in classifying, the types of double-sided wear.* There are two kinds of solid contact, which correspond with two extreme degrees of geometric conformity of the two mating surfaces.

At one extreme, the surfaces are macro-geometrically conformal or nearly so, that is, they fit on or in each other. The two representative examples are a plane surface on another plane surface, and a convex surface enveloped by a concave one; with perfect conformity, sliding is the only relative tangential motion possible. Further, the overall shape, i.e., the macro-geometry, of the surfaces here recedes into the background, and their micro-geometry, i.e., their finish, constitutes the decisive factor in determining the nature of contact. In fact, contact takes place preferentially between summits of instantaneously opposing surface irregularities; because of the comparatively wide spacing of the summits, it is "disperse contact" that obtains. It is known from the work of various investigators* that the summits tend to deform plastically, so that the pressures in the tiny areas of real contact correspond with the hardness of the softer of the two mating surfaces. At the other extreme, the two surfaces are macrogeometrically non-conformal. This—e.g., when both surfaces are convex—results in "concentrated contact," as contact tends to concentrate in one contact area. A feature common to both cases of contact is that the real contact pressures usually are very high indeed, i.e., often of the order of at least a few thousand atmospheres. One consequence of this feature is that, in both cases, overstressing, and thus wear, of surface material can hardly be avoided; this is contrary to what is normal in fluid contact, on flow-directing surfaces. Another important consequence of the high contact pressures is that, whenever sliding speeds are high enough, the intensity of frictional heating can become so great that high temperatures are generated in the contact areas.

One of the simplest types of double-sided wear is that which is characterised by the effects of frictional forces being negligible as against those of the compressive forces, repetitively or, say, cyclically, exerted by one surface on the other, and vice versa. The ensuing type of wear, pitting, thus is typical of rolling motion and, therefore, of concentrated contact; it follows that temperature rise by solid-frictional heat cannot be great. All of this is confirmed by the occurrence of pitting principally in machine elements such as rolling bearings, and at or near the pitch circle of gear teeth (see Fig. 1, herewith).

Pitting is recognised to be caused by "surface fatigue," and actually, like any fatigue, it does not develop until load has been applied for an incubation or induction period, i.e., for a critical number of cycles that depends on the magnitude of the compressive stresses exerted on the surface, and, of course, on the nature of the surface material. Remarkably enough, it is not unusual for pitting to be arrested, so that surface deterioration does not go on to the bitter end. This is presumably owing to the strain-hardening of the surface material, which may offset the increase in stresses caused by the diminution of the bearing area remaining in between the pits. Here we encounter the self-restoring capacities of surface materials, which play a large part also in many other types of wear.

(*To be continued.*)

* Paper read at the International Symposium on Abrasion and Wear, held at the Rubber Stichting, Delft, Holland, on November 14 and 15, 1951.

* Cf. "Fundamental Mechanical Aspects of Boundary Lubrication," by H. Blok. *Jl. S.A.E.*, vol. 46, page 54 (1940).

* Cf. *Die Technische Physik der elektrischen Kontakte*, by R. Holm, Springer, Berlin (1941); and *The Friction and Lubrication of Solids*, by F. P. Bowden and D. Tabor, Clarendon Press, Oxford (1950).

IMPORT LICENSING CONTROL OF IRON AND STEEL.—The Board of Trade announce that as from May 2 individual licences are required for the import, from any country, of iron and steel forgings and single-strand wire of iron or steel. The import licensing of iron and steel is operated to control the pattern of imports, so that the best advantage may be obtained from available foreign supplies, and not to reduce the total amount of material entering the country. Applications for import licences should be made to the Board of Trade, Import Licensing Branch, Romney House, Tufton Street, London, S.W.1.

TEST OF PRESTRESSED CONCRETE BRIDGE.

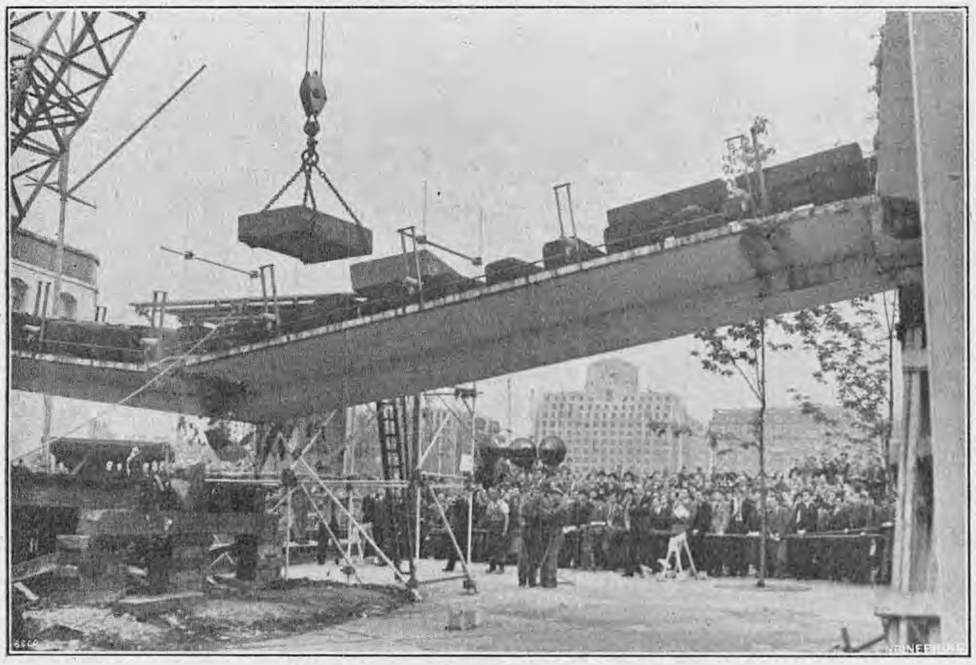


FIG. 1. BRIDGE COLLAPSING.

Fig. 2. LAYOUT OF BRIDGE AND COLUMNS.

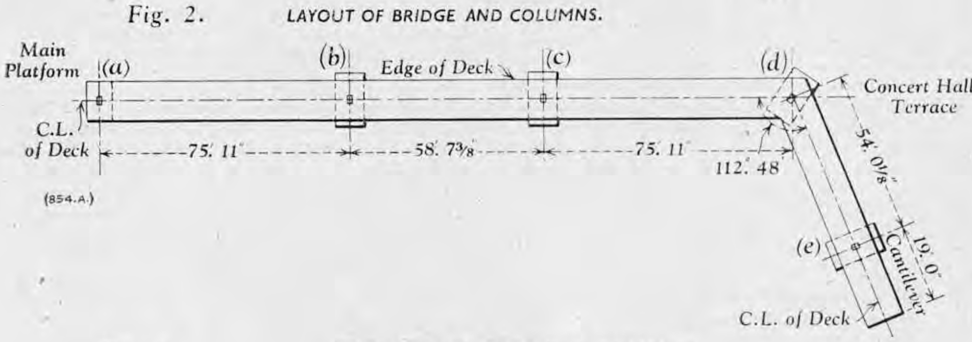
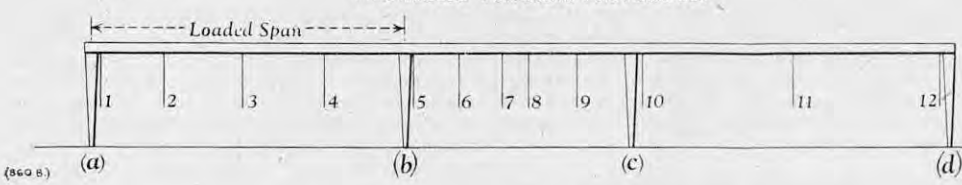
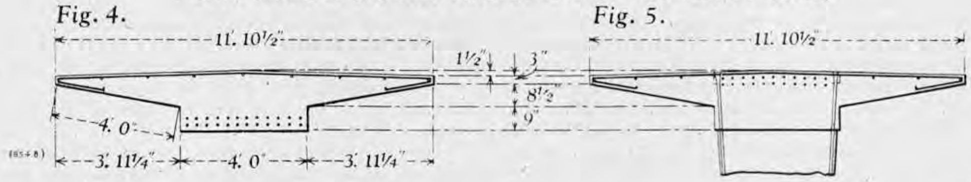


Fig. 3. POSITION OF 12 DEFLECTION GAUGES ON PRESTRESSED CONCRETE FOOTBRIDGE.



DECK SECTIONS SHOWING ARRANGEMENT OF PRESTRESSING CABLES.

Fig. 4. Fig. 5.



TEST TO DESTRUCTION OF PRESTRESSED CONCRETE BRIDGE.

CIVIL engineers can gain much valuable information about the strength and performance of structures by tests of scale models or full-size structural elements, especially when these are loaded to destruction. It is seldom, however, that an opportunity occurs to determine the strength of a complete full-size engineering structure in this way, and for obvious reasons. Such an occasion was provided recently, however, in London, by the need to demolish a prestressed-concrete footbridge as part of the work of clearing the site of last year's Festival of Britain exhibition on the south bank of the Thames. Prestressed-concrete structures, though by no means novel, are still sufficiently uncommon and untried for engineers to be glad of any opportunity to gain more information about them, and the valuable opportunity provided by the enforced destruction of this bridge was not to be missed. Arrangements were therefore concluded by the Cement and Concrete Association and the Prestressed Concrete Development Group with the London County Council for a series of controlled tests and a final test to destruction of a portion of the bridge to be made. The preliminary tests were carried out on April 29 and 30, and the final loading to collapse on the afternoon of May 1. It was the first occasion in Britain, and possibly in the world, when a complete prestressed-concrete structure had been tested to destruction, and the event, illustrated in Fig. 1, herewith, aroused considerable interest.

The bridge, which ran from the terraced entrance to the exhibition off Waterloo Bridge to a point near the main entrance to the Royal Festival Hall, was constructed by Messrs. Kirk and Kirk, Limited. Atlas Works, 287, Upper Richmond-road, London S.W.15, and the consulting engineers were Messrs Ove Arup and Partners, Limited, 8, Fitzroy-street, London, W.1. Its total length was 284 ft. and the greater part consisted of three straight spans, about 76 ft., 59 ft., and 76 ft. long, and supported at an average height of 16 ft. above the ground on four columns, *a*, *b*, *c* and *d*, as shown diagrammatically in Figs. 2 and 3, on this page. Access to the bridge from the exhibition entrance on Waterloo Bridge was afforded by a reinforced-concrete stairway anchored to the bridge deck at column *a*, but the concrete connection was broken away prior to the tests. At column *d*, the footway changed its direction abruptly and the bridge terminated in a 54-ft. span, supported by columns *d* and *e*, and a final 19 ft. long cantilever.

Other details of the structure are as follows. The bridge deck and beam were combined in the form of a T-beam with a wide shallow rib, as shown in Fig. 4. The deck was 11 ft. 10½ in. wide, 12½ in. thick at the faces of the rib, and 3 in. thick at the outer edges. The rib itself was 4 ft. wide and 1 ft. 10 in. deep. The supporting columns were tapered downwards and measured 3 ft. 9 in. by 2 ft. 3 in. in cross-section at the top and 1 ft. 9 in. by 1 ft. 6 in. at the base, except that column *d* was slightly thicker. All the columns were supported on reinforced-concrete bases and were prestressed by cables in slots at their sides. Columns *a* and *c* were hinged, top and bottom at their junctions with their bases and the bridge deck; columns *b* and *d*, however, were rigid.

Owing to the progress of other constructional work on the site, the bridge had to be built in two stages. The first part to be built, which was also that tested to destruction, was the section adjoining the exhibition entrance, and consisted of the span between columns *a* and *b* and approximately half that between columns *b* and *c*. The latter was constructed as a cantilever. The remainder of the bridge, with the exception of a small gap in the middle of the second span and another at the corner, was constructed in the second stage. Finally, the two cantilevers forming the second span were joined, and a corner slab inserted at column *d*.

This mode of construction, unavoidable at the time, had its advantages when the structure came to be prestressed, as then shorter lengths of cable sufficed. The Freyssinet system of prestressing was employed, high-tensile steel cables being passed through ducts in the concrete, tensioned and held fast in conical grips at their ends. Moreover, the ducts were not straight but undulatory in order that the tension might always be applied as effectively as possible. With this type of construction, the friction between duct and cable, which increases as the latter is tightened, may be very great on a long cable and limit the amount of prestressing possible. The theory of prestressed-concrete structures was the subject of a symposium last year which was reported in ENGINEERING, vol. 172, pages 676 and 707 (1951).

The long straight section of the bridge between columns *a* and *d*, which was the part of importance from the point of view of the tests, was prestressed by means of 24 twelve-wire cables. Precast reinforced concrete anchorage blocks, incorporating the anchoring cones, were cast into the deck rib, one at each end of the first section to be built, that is, the span between columns *a* and *b* and rather less than half that between columns *b* and *c*. Twenty of the 24 cables were put under tension and anchored at their ends on completion of the structural work, and the same was done subsequently on the other half of the straight run when that was constructed. The gap in the middle of the second span was then filled, after which the remaining four cables, which were continuous throughout the three spans from column *a* to column *d*, were tightened and anchored. The arrangements of the cable ducts at two representative sections of the deck are shown in Figs. 4 and 5. Fig. 4 relates to the centre of a span and Fig. 5 to a section over a column.

The object of the tests was fourfold, namely, to determine the behaviour of the bridge under the loading for which it was designed, and up to 50 per cent. overload; to determine the extent of the recovery of the bridge after a 50 per cent. overload; to determine the behaviour of the bridge under 100 per cent. overload; and to determine the collapse load.

The loading was confined to the span between columns *a* and *b*, but the resulting deflections were determined at 12 stations disposed along the whole of the three-span length, as indicated in Fig. 3. Since

VERTICAL DISPLACEMENTS IN CENTIMETRES.

Gauge Stations.	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.
Design load	—	1·9	2·6	1·8	0	−0·4	−0·5	−0·4	−0·2	—	0	0
25 per cent. overload ..	—	2·7	3·7	2·4	0	−0·6	−0·9	−0·6	−0·2	—	0·05	0
50 per cent. overload ..	—	3·8	5·2	3·3	0	−0·9	−1·25	−0·9	−0·3	—	0·1	0
50 per cent. overload ..	−0·1	4·6	8·2	4·0	−0·1	−1·5	−2·35	−1·8	−0·6	0·1	0·4	0
Design load	0·2	2·9	3·9	2·2	0	−0·7	−1·2	−1·0	−0·4	0	0·3	0
100 per cent. overload ..	0·4	7·1	10·0	5·4	0	−1·7	−2·7	−2·2	−0·5	0·2	0·6	0·1

the deflections were comparatively large, gauges of relatively simple form sufficed, and those employed consisted of thin cables attached to hooks in the underside of the deck rib and held taut by hanging weights. For reasons of safety and convenience, however, each cable was passed round two pulleys mounted on trestles, the first being vertically under the hook and the second some distance out to the side of the bridge. The second trestle also carried a metre stick as a scale, and the cable in this region was furnished with a pointer which registered against the scale. By this means the deflection could be determined to the nearest 0·5 mm., which was considered sufficiently accurate.

The deflections in centimetres measured during the preliminary tests on April 29 and 30 are contained in the table on page 595, the stations being numbered as in Fig. 3. In every case the deflection quoted is the increment from that under zero load, a positive increment indicating a downwards deflection. On the first day, the first span of the bridge was loaded uniformly up to the design load (37 tons). A crack was then observed in the concrete near the centre of the span. It extended upwards in the rib to a height of about 7 in. Other cracks were found to have started on the outer side of each column-head supporting the loaded span. The load was then increased by 25 per cent., after which three cracks were apparent near the centre of the span. When the overloading was increased still further, to 50 per cent., several cracks were noticeable within a central region amounting to 25 per cent. of the span.

At this stage, the overloading was halted till the following day, when it was found that the deflections had increased overnight, as indicated in the table. There is some doubt about the correctness of the value quoted for station 3, in this case. The load was then removed to determine the extent of the recovery of the structure, and the closure of the cracks was noted and photographed. The span was then reloaded up to the design load and then to 100 per cent. overload, with the results shown in the table. The results of the tests on the final day have not so far been announced completely, but, when readings were resumed on May 1, the deflection at the centre of the span (station 3), under 100 per cent. overload, had increased to 12·5 cm., and was 13·5 cm. one hour later at the same load; the upwards deflection at the centre of the second span had decreased slightly to between 1·6 cm. and 2 cm.; and the downwards deflection at the centre of the third span was practically unchanged. The final loading of the bridge to destruction was commenced in the afternoon of May 1.

A block of cast iron weighing 3½ tons was placed at the centre of the first span, bringing the load up to 77½ tons. This caused the central deflection to increase to 15 cm. It was obvious, however, that the maximum deflection was not quite at the centre of the span, but at a point about 0·4 of the span from column *a*, as would, indeed, be expected on theoretical grounds, since the end conditions at columns *a* and *b* were not the same. It was also noticeable that the deck had bent down sufficiently on its hinge at column *a* for the rib to rest on the inner edge of the column and cause considerable spalling of the concrete of the latter. On the addition of a further 3½-ton load, bringing the total load to 81 tons, the central deflection became 20 cm., and it was 28 cm. (11 in.) shortly afterwards at a loading of 84½ tons. When, however, another 3½-ton block was placed on the bridge, the latter immediately collapsed, as illustrated in Fig. 1, breaking near the centre of the span with a loud crunching noise and, in its fall, dragged over column *a*, which broke away from its base, causing some of the reinforcing bars there to snap. Column *b* remained upright, but fracture of the deck occurred there also, on the inner side of the column, the type of failure indicating that a plastic hinge had formed. The growth of this hinge had indeed been obvious from the readings obtained at stations on the second span, for the progressive relaxation of the bending stresses had caused the upwards deflections to decrease some time before the final failure.

Failure of the first span was accompanied by a momentary violent oscillation of the remainder of the bridge, and this caused the second span to fracture at one end of the short joining section in the neighbourhood of station (7). This span did not collapse, however, for the four prestressing cables which ran throughout the whole length of the three spans sufficed to hold it up. The disturbance of the structure was appreciable as far as column *d*, which was slightly displaced. As far as could be ascertained at the time, none of the prestressing cables broke. A full report of the tests and the conclusions to be derived from them is expected to be issued by the Cement and Concrete Association later. In the meantime, it can be stated that the collapse load was approximately 85 tons, or 2·3 times the load for which the bridge was designed.

LABOUR NOTES.

PLEAS for the exercise of as much restraint as possible in the presentation of claims for higher wages were made by Mr. R. A. Butler, the Chancellor of the Exchequer, in a speech to his constituents at Halstead, Essex, on May 3. He said that it was the duty of everyone to show such restraint and to realise that extra wages, if they were not earned by increased production, must result in increases in prices. The Government's policy had been designed to reduce expense, limit taxation and create confidence in the pound. There remained one major task and this was, to reduce the cost of living. The big surplus on the Budget was necessary because the Government had to find money for capital expenditure. If the Government's plans for keeping down expenditure were successful, as it was hoped that they would be, then taxes could be further reduced and savings would increase. This, in turn, would mean that the Government would require a smaller surplus. It was essential that the vicious circle of high taxation, leading to a small scale of saving, which required still more taxation, should be broken. The Government's credit policy would, in due time, have its desired effect and there was no doubt, Mr. Butler stated, that the tendency of some prices, already, was to decline.

Concern at the possible reactions of denationalisation on the conditions of employment among some sections of professional persons was expressed by Miss B. Anne Godwin in her presidential address to the annual conference of the National Federation of Professional Workers in London on May 3. In her address, which was read in her absence through illness, Miss Godwin declared that it was not in the interests of non-manual trade unions that the standing of the nationalised industries should be weakened in any way. It was the general experience of the Federation that the boards of these industries had been prepared to co-operate with trade unions in establishing fair conditions of employment. It could not be said, however, that "private sections of industry," as a whole, had taken so enlightened a view of the trade-union aspirations of their staff employees. The Federation was still confronted with the spectacle of employers trying to undermine trade-union organisation by the development of bodies of the staff association type. This state of affairs applied particularly to the banking and insurance industries.

The importance of developing joint consultation in all industries was stressed by Lord Citrine, the chairman of the British Electricity Authority, in a speech delivered later in the conference. He considered that, unfortunately, suspicion still existed in some quarters, mainly on account of the controversial past. Persons in administrative positions, in general, had not taken too kindly to joint consultation, as they considered it to be an invasion of their managerial responsibilities. He felt, however, that the awakening of the average person to the fact that he was doing a worth-while job could be more easily stimulated by joint consultation than by any other means.

Lord Citrine referred also to the unnecessary aloofness to the normal processes of trade unionism and collective bargaining that appeared to exist among certain sections of office employees. The Federation continued to recruit such persons, however, and now had a membership of 505,000. He said that the British Electricity Authority had been faced originally with a fragmentary and incomplete organisation among its various groups of employees, but steps had been taken by the Authority to bring the groups together. The conference deferred a decision on the question of extending the age for retirement and passed a resolution instructing its executive committee to prepare a factual report on the subject for consideration at a later date.

A meeting of the three principal railway unions has been arranged to take place in London to-day to consider the presentation of joint demands for wage increases. It is understood that the National Union of Railwaymen will suggest to the other two bodies, the Associated Society of Locomotive Engineers and Firemen and the Transport Salaried Staffs' Association, that they should apply jointly for an increase on a percentage basis. Mr. J. B. Figgins, the general secretary of the N.U.R., said at the annual conference of the union's permanent-way and signal grades at Blackpool on May 3 that the union's executive was not entirely satisfied with the wage award conceded to employees in the industry in September last, owing to the continued rises which had taken place in the cost of living. It was hoped, he added, that the amount of the new wage claim would be settled very shortly.

Warnings of the grave difficulties which would confront Great Britain if there was any collapse of the country's export trade, were given by Mr. Herbert Morrison in a speech at Cardiff on Sunday last. It had to be realised, he said, that a substantial amount of the unemployment which occurred in Britain during the period between the two world wars was a consequence of the partial collapse of the nation's export trade, and this arose as a result of trade depression in other countries. It must be expected that competition between nations for export trade would intensify as the years passed. No one must assume, therefore, that full employment and the busy utilisation of British factories and industrial resources would be automatic in future. The former Labour Government had achieved, Mr. Morrison considered, a "high degree of success" in its economic planning, but it must not think that it had nothing to learn. All ranks of industry, whether employed by publicly-owned or by private undertakings, should do an energetic and honest day's work. Inefficiency could not be afforded. Costs and prices must be such as to enable Britain to meet world competition, without becoming a nation with a low standard of living.

Wage demands in the engineering industry were discussed at length on Tuesday and Wednesday last at the annual policy conference of the national committee of the Amalgamated Engineering Union at Blackpool. Originally, the committee's agenda contained no fewer than 71 resolutions on wage questions and 18 of these included demands for increases up to 40*s*. a week. Most of them, however, were rendered superfluous as a result of the recent decision of the Confederation of Shipbuilding and Engineering Unions to present a wage demand to the Engineering and Allied Employers' National Federation for a substantial increase for all male employees in the industry. Preliminary consideration was given to wage resolutions at the morning session on Tuesday, when many of the proposals put forward by the union's branches were consolidated, and it was decided to submit three main resolutions on the subject to the delegates on the following day for final decision.

In the first of these resolutions, the 52 delegates were asked to instruct the union's executive council to press for a wage increase of 40*s*. a week for all adult employees in the engineering and shipbuilding industries, with all merit rates and district and craft differentials to be maintained in full. This demand, if ultimately approved by the Confederation, would constitute one of the largest wage claims in British trade-union history. Nearly three million workpeople would be affected and the addition to the nation's wage bill would be in the region of 300 million pounds annually. Another resolution asked for the consolidation of the basic rate and bonus applicable to pieceworkers, the removal of the difference of 19*s*. between the basic rates of pieceworkers and time-rate employees, and for all piecework earnings to be based on the industry's full consolidated rate, with the employees' earnings to be guaranteed at not less than 50 per cent. on the consolidated time rate. The third resolution requested the introduction of automatic increases in wages to correspond with advances in the cost of living, as recorded in the index of retail prices.

Also on Tuesday, the committee approved a resolution asking that women employees in the engineering industry should receive a minimum wage rate not less than that paid to adult unskilled men and that women's piecework earnings should be based on one-third of the consolidated rate paid to time-workers. This demand, if accepted in full, is expected to increase women's earnings by about 26*s*. a week. Against the advice of the executive council, the delegates approved a request to the Confederation that that body should, in future, conduct all national negotiations on women's rates.

In the discussion on wages on Tuesday, the union's leaders had advocated that the first of the three resolutions referred to above should not refer to any specific amount, but they were over-ruled. Mr. Jack Tanner, the President, was among those who counselled the delegates to exercise caution regarding fixing any definite amount. He pointed out that the Amalgamated Engineering Union had a large proportion of votes on the Confederation and had only to obtain the support of one or two of the smaller affiliated unions in order to secure a majority vote. He also stressed the resentment which the other unions in the Confederation would feel if the policy of the A.E.U. were to become automatically the policy of the Confederation and he appealed to the delegates not to leave themselves open to a charge of "wielding the big stick." Mr. Ben Gardner, the union's general secretary, informed the conference that the engineers' wage claim already presented by the Confederation provided that any increases granted as a result of it should become payable as from the date of the application. The conference, which opened on Monday last, will continue until May 16.

MECHANICS OF CAVITATION.

Fig. 19.

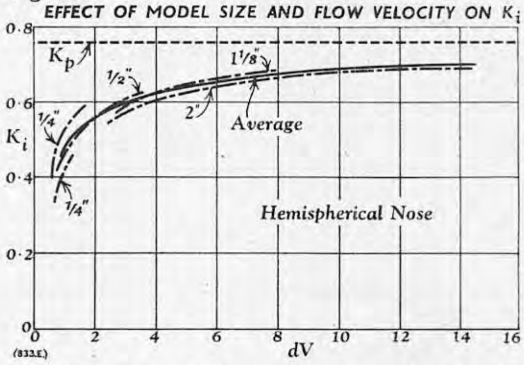


Fig. 21.

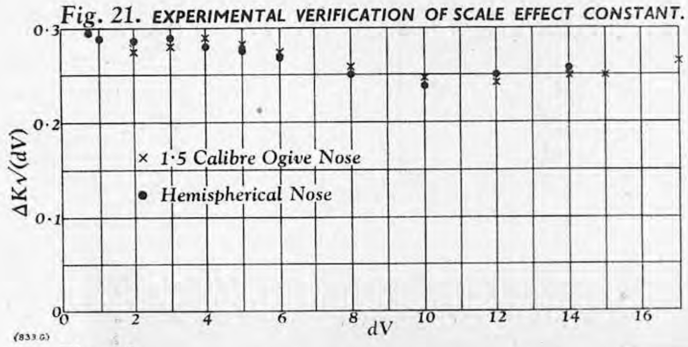
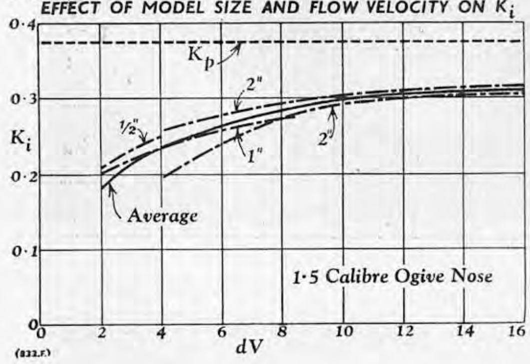
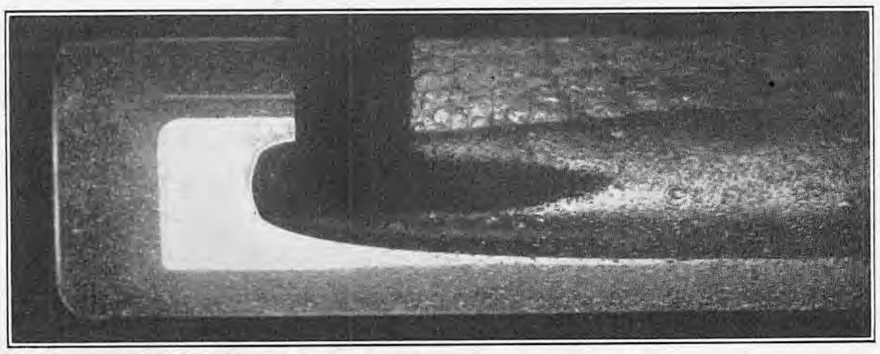


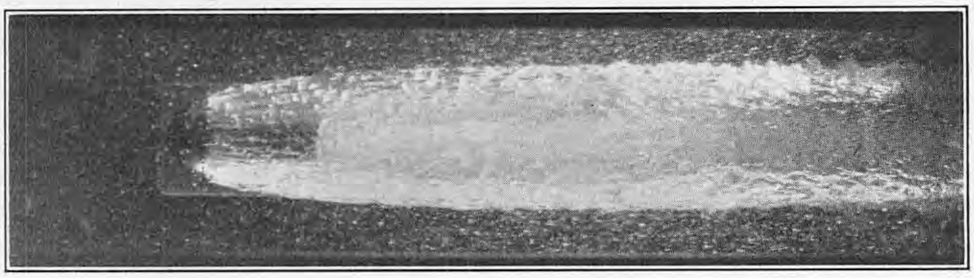
Fig. 20.



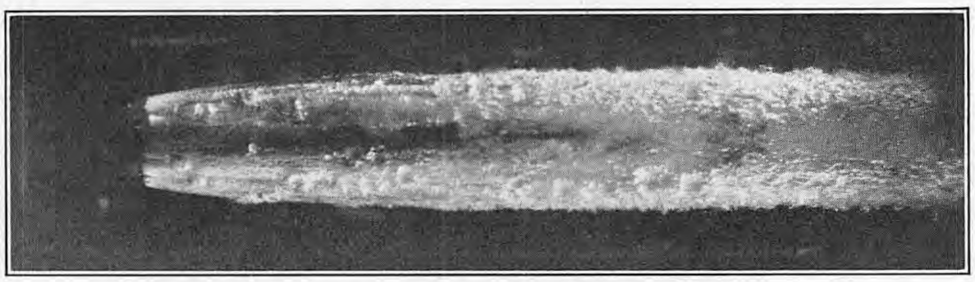
(*a*) Square-ended Cylinder, K = 0·55.



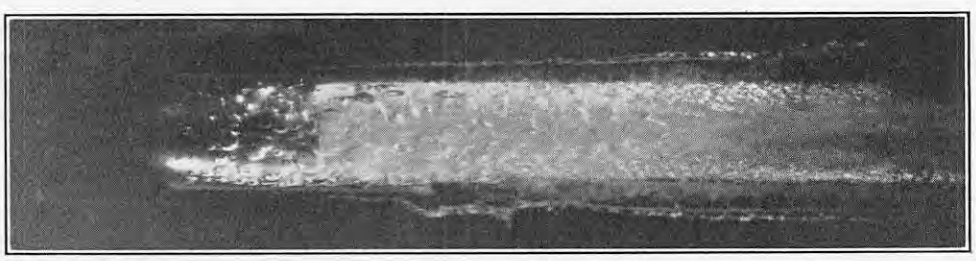
(*b*) Blunt Ellipse, K = 0·44.



(*c*) Hemisphere, K = 0·28.



(*d*) 1 Calibre Sphereogive, K = 0·21.



(*e*) 2·5 Calibre Sphereogive, K = 0·23.

FIG. 22. EFFECT OF NOSE SHAPE ON CAVITY DIAMETER.

CAVITATION MECHANICS AND ITS RELATION TO THE DESIGN OF HYDRAULIC EQUIPMENT.*

By PROFESSOR ROBERT T. KNAPP, Ph.D.†

(*Concluded from page* 569.)

Cavitation Scale Effect.—One of the constant difficulties experienced by both the laboratory research man and the designer is the effect of size or scale in the application of experimental results. The problem is as follows: here are some measurements made on small-size equipment under laboratory conditions; how must they be modified if they are to be used to predict field performance where the size of the equipment will be many times as great? When cavitation is involved it is beginning to appear that this question is intimately related to the properties of the liquid, particularly to the concentration and size distribution of the nuclei. It is probably too early to make the positive assertion that nuclei do exist, that they can be found in a wide range of sizes, and that they are responsible for the otherwise anomalous cavitation performance frequently observed in the laboratory. However, it can be said that cavitation experiments, carried out under carefully controlled conditions, do indicate that at least water exhibits properties that can be explained by the presence of nuclei, and that if the existence of nuclei were ruled out, some other explanation would have to be found for these properties. Therefore, for the present it seems justifiable to accept tentatively their existence, and to see how much help can be obtained from this concept toward increasing the understanding of the behaviour of cavitation.

If the effect of size be considered on this basis, some simple inferences can be drawn. Consider first a liquid containing an ample supply of large nuclei. (It will be remembered that the nuclei are considered large if visible cavities form as soon as vapour pressure is reached.) To all intents and purposes this liquid behaves as an idealised liquid of zero tensile strength. There is no reason to expect any appreciable scale effect with such a liquid, i.e. laboratory and field equipment should have the same cavitation performance. Furthermore, in the laboratory the same results should be obtained at different velocities or with different sizes of apparatus. Under such conditions the cavitation characteristics will be a function purely of the geometry of the body; the properties of the liquid have no effect (assuming sufficiently high Reynolds numbers to ensure similarity of velocity distributions).

Consider next a liquid containing an ample supply of small nuclei, so small that the time required to form a macroscopic cavity would represent an appreciable distance of travel along the surface of the body. If a series of bodies of the same geometric shape but of different size were tested for cavitation characteristics in a stream of this liquid at a series of different velocities, a definite pattern of performance would be expected. Assume first that all the bodies were tested at the same speed. Since the time required for a fluid element to pass through similar pressure zones will vary directly with the size of the body, it would be expected that for equal values of K less relative amounts of cavitation would be observed on the smaller bodies, and, furthermore, that the smaller bodies would have lower values of K_i, i.e. they would have higher resistance to cavitation. In large-scale field equipment

* James Clayton Lecture, delivered to the Institution of Mechanical Engineers, London, on April 18, 1952. Abridged.

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operating with liquid containing the same size and concentration of nuclei, it would be expected that this trend would continue: the larger the equipment the higher the K_i and the poorer the effective cavitation resistance.

It is a little more difficult to predict what might be expected to happen if one given body were tested in the laboratory at a series of different velocities. For the same value of K with the higher velocities, the time of traverse of the low-pressure zone will be shorter, since it is inversely proportional to the velocity. On the other hand, for the same value of K, the absolute pressure differences will increase with the square of the velocity. These effects are in opposite directions, since the decreased traverse time tends to reduce the amount of cavitation; whereas, the greater pressure difference tends to increase it. There are some physical and analytical reasons to believe that the effect of the pressure is more significant than that of the time. If this is true, then K_i should rise and the relative amount of cavitation for a given K value should increase as the velocity is increased. Figs. 19 and 20, on page 597, show the measured value of K_i for two series of different sized models, each tested at several different velocities. The experiments on which Fig. 19 is based were made by Kermeen of the Hydrodynamics Laboratory, California Institute of Technology,* and those used in Fig. 20 were made by the author. In each series the models are geometrically similar. In Fig. 19, the body is a cylinder with a hemispherical nose. In Fig. 20 it is a cylinder with a 1·5 calibre ogive nose. The test runs of Fig. 19 were taken over a considerable period of time. Some of the runs of Fig. 20 were taken before, and some after, the entire charge of water in the system was changed. It is probable, therefore, that within each series the average size and concentration of the nuclei varied appreciably and major changes might have taken place in these two quantities between the two series.

At first sight it appears that in each series there is evidence of some systematic difference between the curves for the different sized models. However, in each series there are also runs on the same sized model that differ in value as much as the total spread between the runs for the different sized models. Furthermore, the direction of this trend is not consistent between the two series. Thus the question may be raised whether the differences shown between the characteristics of the various models are due to the variations in size or to differences in the properties of the water used in the individual runs. In both diagrams the full-line curve is the average for all of the runs. Since both of these curves show the same type of variation of K_i with dv, and since it is in the direction to be expected from the reasoning just advanced concerning the properties of nuclei, it seems probable that this represents the basic relation between K_i, the guide surface size, and the flow velocity. As this evidence indicates a pronounced scale effect, it would be valuable to have some measure both of the magnitude of this effect and its variation with changes in size and velocity. Both Figs. 19 and 20 include a horizontal dotted line K_p showing the value of K_i as determined from the pressure distribution on the surface. This can be considered as a limiting K_i as the body size approaches infinity. Reflection will show that the difference between this value and the observed value of K_i is proportional to the effective liquid tension acting to cause the cavity to form and grow. When the concepts and method used by Lord Rayleigh to calculate the time of collapse of a cavity are applied to estimate the time of growth of a nucleus to a small finite cavity, it is found that this time is proportional to the cavity size divided by the square root of the pressure difference causing the growth. Except for small radius ratios of cavity to nucleus the relation may be expressed as follows:—

$$\frac{t\sqrt{(\Delta p)}}{R_0} = \text{constant.} \quad . \quad . \quad (1)$$

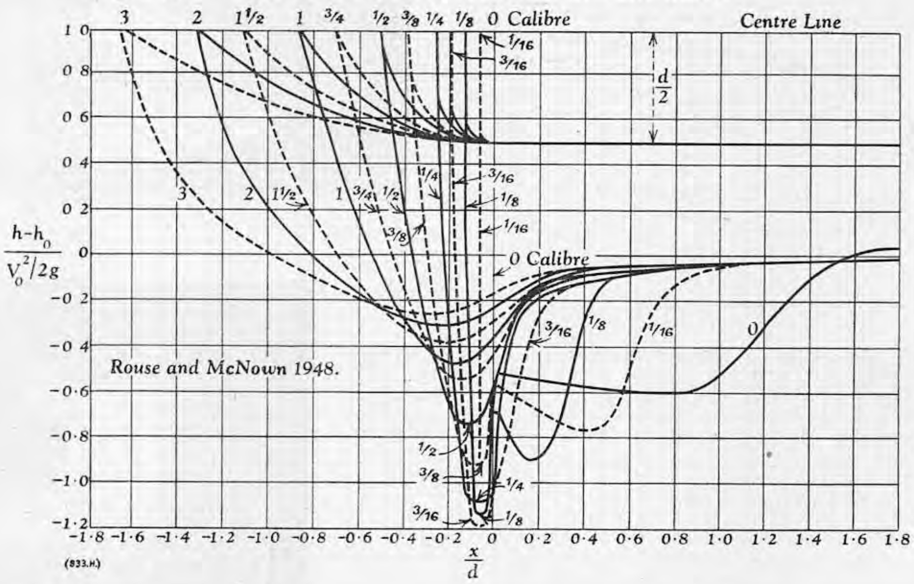
where t is the time of growth of nucleus to radius R_0 and Δp is the effective liquid tension, i.e. the pressure difference causing growth. In accordance with the previous remarks, Δp may be expressed as

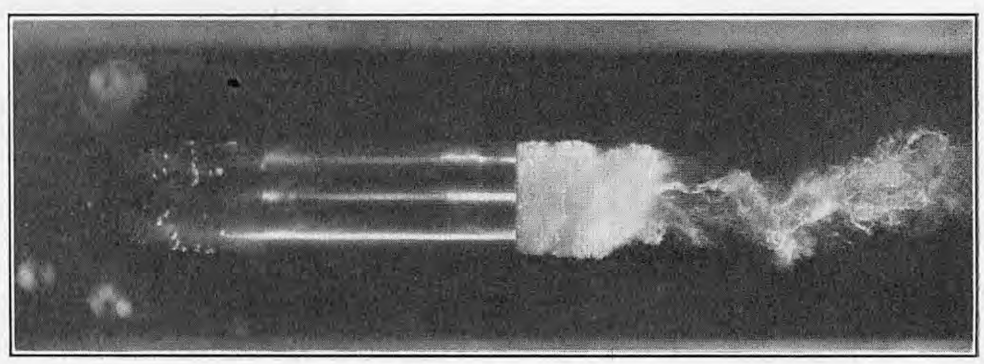
$$\Delta p = (K_p - K_e)\,\rho\frac{V^2}{2} = \Delta K\,\rho\,\frac{V^2}{2}, \quad . \quad (2)$$

where K_p is the value of K_i as estimated from the pressure distribution diagram and K_e is the value of K_i determined from a given test. The time available for growth may be considered to be the length of the negative pressure zone on the body at the relative pressure level K_e, divided by the flow velocity V. An examination of the series of pressure distribution diagrams shown in Fig. 23 shows that this length is roughly proportional to $d\sqrt{(\Delta K)}$, where d is the body diameter. If these expressions for time and

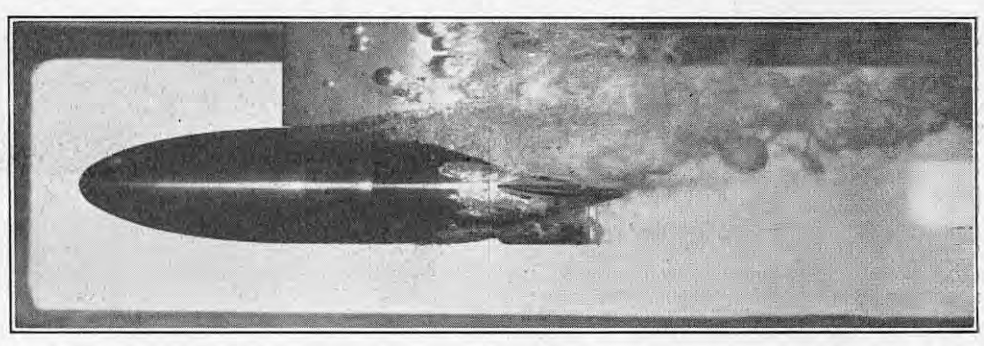
MECHANICS OF CAVITATION.

Fig. 23. PRESSURE DISTRIBUTION ON FAMILY OF OGIVE NOSES.

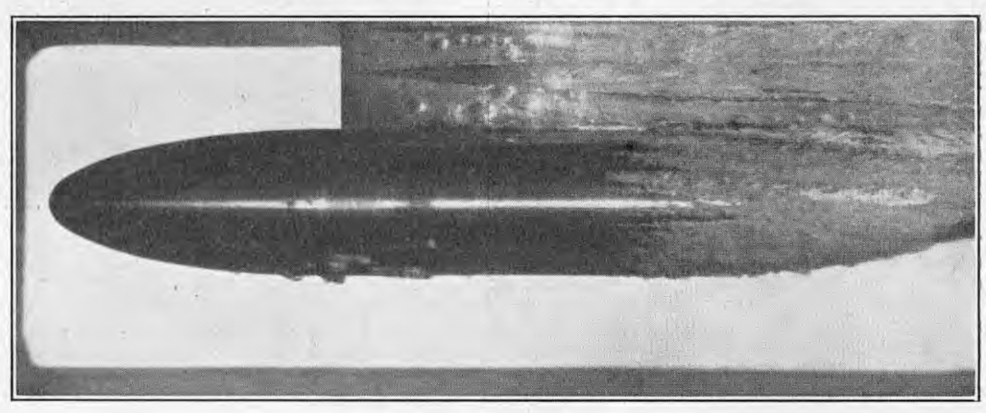




(a) SQUARE-ENDED CYLINDER, K = 0·29.



(b) SPECIAL CURVE, K = 0·20.



(c) SPECIAL CURVE, K = 0·18.

FIG. 24. CAVITY ON AFTERBODY.

pressure difference are substituted in equation (1), it becomes

$$\frac{\frac{d\sqrt{(\Delta K)}}{V}\sqrt{(\Delta K\,V^2)}}{R_0} = \frac{d\Delta K}{R_0} = \text{constant.} \quad . \quad (3)$$

If the cavitation photographs of the tests (Fig. 20) are examined, it is apparent that the average cavity size at incipient cavitation varies both with the diameter of the model and the flow velocity. Apparently the larger the model and the lower the flow velocity the larger is the average cavity size. However, these

* "Scale Effects in Cavitating Flow," Report No. 21-7, by B. R. Parkin. Hydrodynamics Laboratory, California Institute of Technology (1951).

MECHANICS OF CAVITATION.

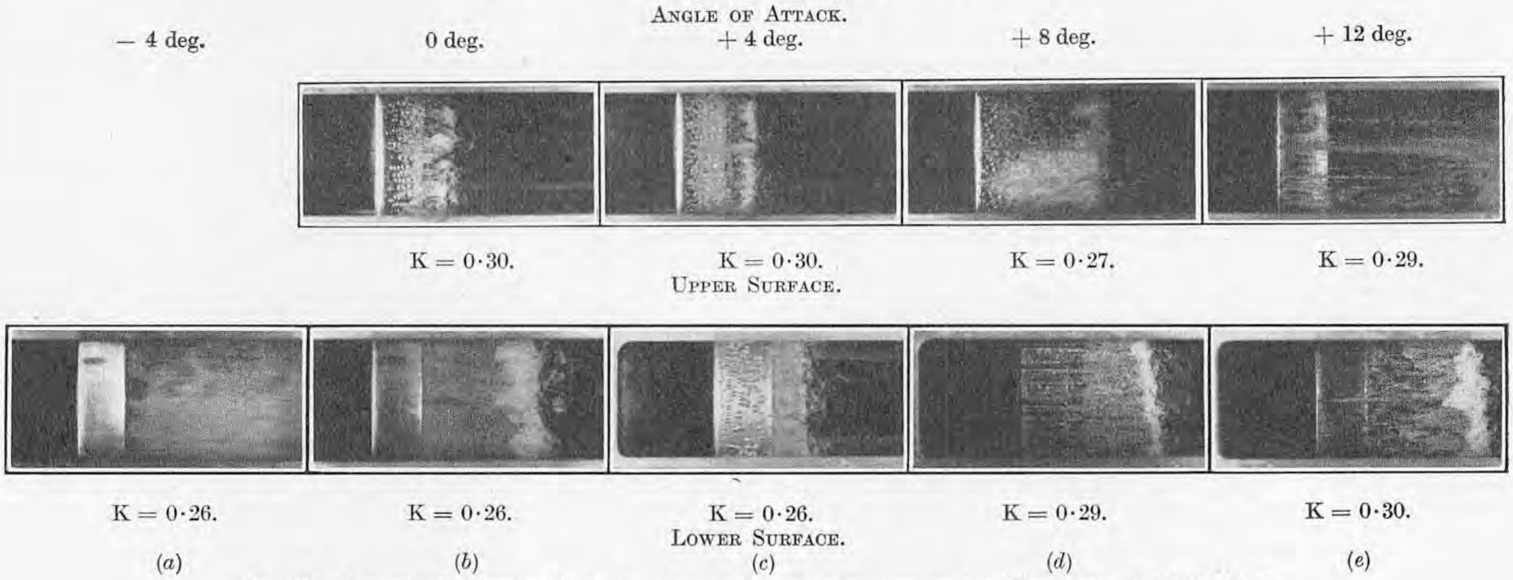


FIG. 25. EFFECT ON CAVITATION OF VARIATIONS IN ANGLE OF ATTACK FOR HYDROFOIL N.A.C.A. 4412.

variations do not seem to be linear with d and V, but are apparently less rapid. If the arbitrary assumption is made that R_0 varies as $\sqrt{\left(\frac{d}{V}\right)}$, then equation (3) becomes

$$\frac{d\,\Delta K}{\sqrt{\left(\frac{d}{V}\right)}} = \Delta K\,\sqrt{(dV)} = \text{constant} \quad . \quad . \quad (4)$$

Values of $\Delta K\sqrt{(dV)}$ are calculated from the data of Figs. 19 and 20. The results, plotted against the product d V, are shown in Fig. 21,* on page 597. It is seen that both series are constant within 10 per cent. This suggests the tentative use of equation (4) for predicting the effect of changes in scale on the inception of cavitation. For this use, d would represent a characteristic dimension of the body or flow passage, and V the associated velocity.

Effect of Shape on Cavitation Characteristics.—Fig. 22, on page 597, shows the fully-developed cavities produced on cylinderical bodies having different nose shapes. It will be observed that these noses are arranged in the order of increasing fineness, from the square-end cylinder to the 2·5 calibre sphereogive. Fig. 23 shows the pressure distributions on a family of ogive noses which includes several of the models shown in Fig. 22. These pressure distribution measurements were made at high enough pressure to ensure no cavitation. A careful study of this diagram shows that the area over which the pressure is positive is greater for the blunt-nosed shapes than for the finer nosed shapes, while at the same time the magnitude of the negative pressure is greater. The kinematic requirements are the same in all. The liquid must be moved laterally relative to the solid body just far enough to permit the body to pass through the liquid or the liquid to pass around the body, depending upon which is considered moving and which fixed.

One way of interpreting the effect of the body shape on these pressure diagrams is to say that more than enough force (positive pressure) is applied by the blunter bodies to the liquid and that consequently a high force in the opposite direction (negative pressure) must be exerted to prevent the liquid from going too far. From this point of view the ideal nose shape would apply just sufficient force to the liquid to cause is to move out of the way of the body without requiring any negative force to keep it from going too far, i.e., the pressure distribution diagram would fall only to the zero line but would not go below it at any point on the body. It is interesting to note that the pressure distribution on the new laminar-flow airfoils approaches this ideal. If Fig. 22 is re-examined, it will be observed that the maximum diameter of the cavity is largest for the square-ended cylinder and decreases as the fineness of the end increases. This is very consistent with the concept just discussed, since the negative pressure zone is greatly reduced by the cavitation. Indeed, in the limiting case of operation with a cavitation parameter of zero, the negative pressure zone is eliminated.

* The product d V was selected for this calculation and diagram instead of the Reynolds number, because the assumed characteristics of the nuclei do not involve the viscosity and the density of the liquid. The use of Reynolds number would have the advantage of making the equations dimensionless. The laboratory experiments throw new light on this choice since the temperature of the water was practically constant for all of the investigations.

Fig. 26. CAVITATION CHARACTERISTICS OF HYDROFOIL.

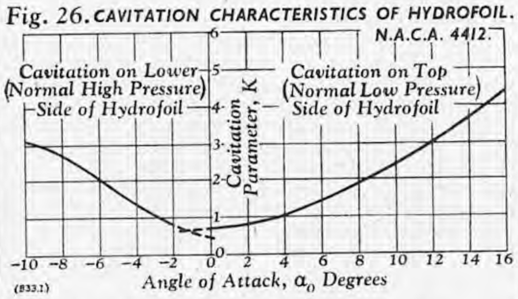
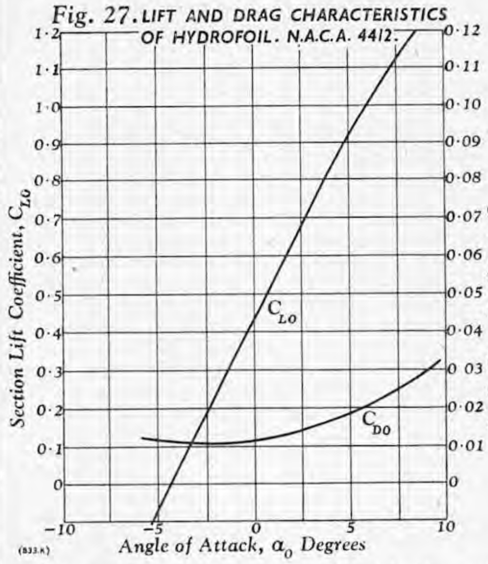


Fig. 27. LIFT AND DRAG CHARACTERISTICS OF HYDROFOIL. N.A.C.A. 4412.



In the examples shown thus far, cavitation has occurred towards the front end of a guiding surface. The pattern for these cases has been that there is an initial pressure rise which causes the flow to move away from the surface. This is followed by the cavitation-producing pressure drop as the guiding surface curves away from the newly established direction of flow. Another common flow condition in which cavitation is often observed is that in which the guiding surface curves away from a parallel flow. In this case there is no pressure rise. Since the pressure in the parallel flow is fixed, the pressure on the curved surface must decrease until the pressure gradient required to cause the liquid to follow the surface is obtained or until cavitation ensues. Fig. 24 (a), (b) and (c), opposite, give examples of cavitation produced under these flow conditions. Although the physical configuration of the guiding surface is quite different in the two flow conditions, the reason that cavitation takes place is still the same, i.e., there is not enough available force to cause the liquid to follow the surface as the latter curves away from the prevailing direction of flow.

In this discussion it is assumed that there is no general pressure rise in the direction of flow. In the case of a diverging passage, such as the recovery section of a Venturi meter, there is such a general pressure rise. This decreases but does not necessarily eliminate the possibility of cavitation, since the general pressure rise may not be great enough to keep the pressure on the diverging surfaces from falling below vapour pressure.

The illustrations presented thus far show bodies oriented parallel with the flow. However, most guiding surfaces do not operate in this manner, but are oriented with a finite angle of attack at the leading edge. This has a pronounced effect on the cavitation characteristics of the flow system. Fig. 25, on this page, shows the effect of variations in angle of attack on cavitation for a hydrofoil operating under severe cavitation conditions. These photographs were selected for as nearly the same flow velocity and cavitation parameter as could be obtained, the angle of attack varying from positive to negative. It will be observed that, for positive angles of attack, cavitation occurs on the upper surface of the hydrofoil, and for negative angles of attack, on the lower. Fig. 26 shows the effect of variations in angle of attack on the inception of cavitation on this airfoil (N.A.C.A.-4412). As would be expected, the cavitation resistances of the two surfaces are not the same since this is not a symmetrical section. This asymmetry also explains why the optimum angle of attack for cavitation resistance is not zero but − 1·5 deg. Fig. 27 shows the lift and drag characteristics of this airfoil. It will be noted that − 1·5 deg. is by no means the zero lift angle for this airfoil although it is nearly the minimum drag angle.

DESIGN IMPLICATIONS.

This discussion has obviously been growing more and more specific; in fact, in the last few sections the implications regarding design of hydraulic equipment are quite clear. In the remaining sections an attempt will be made to apply more of these concepts to the general principles of hydraulic design.

Prevention of Cavitation in Hydraulic Equipment.—The sure way to prevent cavitation in hydraulic equipment operating under critical flow conditions is to avoid any changes of velocity either in magnitude or direction, and to eliminate all fluid friction losses. This exaggerated statement is made to emphasise the fact that it is impossible to design a useful hydraulic machine without some danger of cavitation if the operating conditions are made sufficiently severe. Most hydraulic machines depend for their action on changing the velocity of the liquid. If that cannot be done then the machine cannot operate. Thus the prevention of cavitation must be concerned primarily with finding out just how much the velocity of the liquid can be changed without reducing the local pressure to or below the vapour pressure. Now a change in velocity, as accomplished by a guiding surface which is inclined toward or is concave to the direction of flow, has been seen to produce an increase rather than a decrease in pressure, and hence is not the cause of cavitation at that point. However, if its use demands that it be followed by a portion of the guiding surface which is turned away from or is convex to the direction of flow, then it may be the real cause of cavitation even though the cavitation zone is on the second portion of the surface.

One thing that should be borne in mind is that centrifugal pumps and turbines depend for their operation upon a change of momentum of the fluid that flows through them. However, the local pressure on critical surfaces is determined not only by the total momentum change, but also by the local radius of curvature. It is, of course, possible to design an infinite number of passages with different radii of curvature, all of which will produce the same total momentum change. Another fact which should be remembered is that the centre-line of a guiding vane may be designed to have ideal curvatures for the prevention of cavitation, but still the vane may cavitate badly if its cross-section is not properly designed. Too sharp a radius of curvature from the leading edge to the point of maximum thickness can prevent the realisation of the potentially good performance of a well-designed centre-line. One practical difficulty in the design of cavitation-resistant pumps, turbines, propellers, etc., is that none of these machines operates all of the time under its best performance conditions. Each one must work satisfactorily under a range of lower and higher loads. Thus the angle of approach of the liquid to the guiding surface must vary. To meet these conditions it is necessary to choose a guide-vane profile that will have the smallest variation of the minimum pressures over this range of angle of approach. If a profile is chosen that is sensitive to variations in angle of attack, then there is danger of serious cavitation in a part of the operating range, even if the cavitation performance is very good for operation at the design load.

In the consideration of the cavitation performance of various types of hydraulic machine, there are inherent differences in the adaptabilities of these machines for satisfactory operation under off-design conditions. The usual type of centrifugal pump has no adjustable guide surfaces. Thus it is the least adaptable to variations in operating conditions. The Francis turbine has a set of adjustable guide vanes just upstream from the runner. They increase considerably the adaptability of the machine to variations in operating conditions. The Kaplan turbine not only has similar adjustable guide vanes in the casing, but also has adjustable runner blades. Therefore, it has the greatest adaptability to changes in the conditions of operation. For this reason the skill required to design a machine well adapted to cavitation-free operation over a wide range of conditions is greatest for the centrifugal pump. The operator can compensate, at least in part, for mistakes in the original design if he has one set of adjustable guide vanes, and can accomplish even more if he has two sets.

The hydraulic designer can profit greatly from a study of the pressure distribution on the many aerofoil profiles for which measurements are available. For fixed guide vanes the aerodynamic data are directly applicable. For the calculation of K_i care must be taken to use the correct Reynolds number and to make allowance for interference effects. Moving guide vanes are another matter. They can be divided into two broad classes: those operating at constant stream pressure, and those in a variable pressure field. The free stream propeller, that is, the ship's propeller, is typical of the first class. In this and similar applications aerodynamic data can be used quantitatively. The direct application of aerodynamic pressure distribution data to moving guide vanes operating in a variable pressure field is another matter. Airfoil data are obtained experimentally in constant pressure flows. The technique for extrapolating to variable pressure flows is not clear; hence for the time being, such data can be used most profitably in a qualitative manner. Moving guide vanes of this type are typical of the runners of hydraulic turbines and centrifugal pumps. In such machines there are many other complicating factors, such as mutual interference between the vanes, interference between the vanes and the shrouds, and last, but by no means least, variations due to the flow being definitely three-dimensional. Although these complications make it impossible to calculate the details of the pressure distribution on vanes of hydraulic machines, they do not prevent the application of the general principles which have become clear from the study of the cavitation process. A few such conclusions will now be enumerated.

(1) In most hydraulic designs it is possible at an early stage to estimate both the average pressure and the average velocity at all cross-sections of flow. The cavitation parameter calculated from these estimates will serve to indicate the danger zones in the design. It will be found that these zones are not always restricted to the minimum pressure regions, but may sometimes occur where the pressure is relatively high, provided that the velocity is likewise high.

(2) The leading edges of all guiding surfaces should be examined for all required conditions of flow, particularly those which may result in an angle of attack that deviates markedly from the optimum. In this connection a second glance at Fig. 25 is illuminating. The N.A.C.A.-4412 is a relatively thick vane, so its cavitation parameter for the optimum angle of attack is 0·7, a moderately high figure. However, for a positive angle of attack of 10 deg. this increases to 2·5, and for − 10 deg. it is about 3·1. The latter is about four-and-one-half times the parameter for the optimum conditions. Consider the behaviour of this vane in a relatively high-pressure flow, as for example, if it were used as the casing tongue in a centrifugal pump. Assume the abolute pressure of the fluid, measured in feet, is 100. At the optimum angle of attack this vane would not cavitate until the velocity exceeded 96 ft. per second. If the angle of attack were changed to − 10 deg., cavitation would begin when the velocity reached 45 ft. per second.

(3) For moving guide vanes operating under critical cavitation conditions, the load on the low-pressure side should be kept small. As the flow cavitation parameter increases, the load on this side of the vane may be increased.

(4) Guide vane curvature should be watched carefully in all critical regions. Discontinuities in slope are very serious. Although the effects are less marked, discontinuities in the radius of curvature produce pressure disturbances even though the two sections of the curve are tangent. It is probable that discontinuities in the rate of change of curvature, that is, the second derivative, also produce undesirable disturbances, but they should not be as serious as the other two. Although discontinuities in slope may be detected easily, the eye is not a good judge of discontinuities in radius of curvature or rate of change of curvature.

(5) The surface roughness, if its scale approaches or exceeds that of the laminar boundary layer, will probably cause local cavitation on an otherwise cavitation-free surface.

Prediction of Cavitation Performance from Laboratory Tests.—The above items are concerned primarily with questions of design. An additional comment may be in order with regard to the testing of hydraulic machinery to determine its cavitation characteristics. During the discussion of the mechanics of cavitation, the effects of variations of both size and velocity were considered. It was seen that there was some experimental evidence to indicate that for a given geometrical configuration, the relation expressed in equation (4) holds for variations in both pressure and size, and that therefore it might form the basis of an empirical method that could be used tentatively for predicting the effect of changes in scale. One of the serious questions which arise in connection with the laboratory testing of a small-scale model of a large hydraulic machine such as a pump or turbine, is concerned with the prediction of the cavitation performance of the large machine from the laboratory test results on the small one. At first sight it might be concluded that it would be impossible to use equation (4) to make this extrapolation, since it would seem necessary to know the value of K_p. In many cases it might require a prohibitive amount of time and effort to determine the pressure distribution experimentally. In the model tests it is quite easy to determine the operating conditions at which cavitation commences, but the measurements do not necessarily give a clue as to the point within the machine at which the cavitation is occurring. If investigation showed the cavitation to be located on a fixed guide surface, the extra work required for the installation of a series of piezometer openings might be justified. On the other hand, if the cavitation first occurred on one of the moving guide surfaces, the experimental difficulties would be magnified greatly.

A further examination of the proposed method of extrapolation shows that there is a simple alternative. If similar tests can be made at two different operating conditions, but with the identical liquid, the results may be expressed in the two parallel equations:—

$$C = (K_p - K_{e1})\sqrt{(d_1 V_1)}$$
$$C = (K_p - K_{e2})\sqrt{(d_2 V_2)},$$

where d and V are characteristic dimensions and velocities for the two tests. The test conditions should be chosen to give the maximum difference between d_1V_1 and d_2V_2 that is consistent with good test accuracy. In these two expressions the two unknowns are C and K_p. If C is eliminated, the following expression is obtained for K_p:—

$$K_p = \frac{K_{e1}\sqrt{(d_1V_1)} - K_{e2}\sqrt{(d_2V_2)}}{\sqrt{(d_1V_1)} - \sqrt{(d_2V_2)}}.$$

Obviously, the required variation in the $\sqrt{(dV)}$ may be obtained by varying either the size of the model or the velocity of the flow. With K_p determined in this manner the way is clear for the prediction of the cavitation performance of the prototype. Before this final step is taken, however, it would be well to consider whether or not the pertinent characteristics of the prototype liquid can be expected to be the same as those of the liquid used in the laboratory. If the constant, C, determined from the two laboratory tests, is used directly to predict the K_e value for the prototype machine, it implies that the two liquids are identical. This assumption is probably acceptable if the values of K_{e1} and K_{e2} differ only slightly from that of K_p, or if there are physical measurements available to confirm the similarity of the two liquids. However, as previously pointed out, most natural water supplies probably contain a sufficient number of large nuclei for cavitation to be expected to appear when the pressure reaches that of vapour pressure. If the values K_{e1} and K_{e2} differ appreciably from that of K_p, it is implied that the laboratory water supply does not contain the normal concentration of large nuclei. Thus the more conservative method of extrapolation to the field operating condition would be to assume that the machine will cavitate at K_p.

Effect of Cavitation on Performance.—Little can be added to the statements in the introductory paragraph concerning the effects of cavitation on the performance of hydraulic machines. The typical effects which accompany the onset of cavitation are loss of efficiency and decrease of power output or head produced. These are the effects that would be expected from local cavitation, as it acts to increase the resistance in the passages and to decrease the change in angular momentum produced by the rotating element. As cavitation develops more fully the performance of the unit completely breaks down. There seem to be two possible explanations for this breakdown. If the machine is poorly designed as regards cavitation, it is probable that, as cavitation develops, the volume occupied by the cavities originating at the guiding surface decreases the useful area of the passages to such an extent that it effectively limits the flow. In this case the average pressure in the main body of the stream at this cross-section may be considerably above the vapour pressure. Under such conditions the breakdown performance of the machine could be improved by the employment of better vane cross-sections and angles of attack.

The second explanation for the performance breakdown would apply to a machine having a very good design. In this case the average pressure at a given cross-section would approach closely that of the minimum pressure on the guiding surface. Under such conditions, as cavitation develops the pressure in the entire stream may drop to vapour pressure. Vapour bubbles would then form, not only on the guiding surface, but also throughout the cross-section, and their volume would be limited only by the pressure differential available to cause vaporisation. This sets an absolute limit for the performance of the machine. Even for a perfect design there would be, for each system pressure, a certain rate of flow at which this performance limit would be reached.

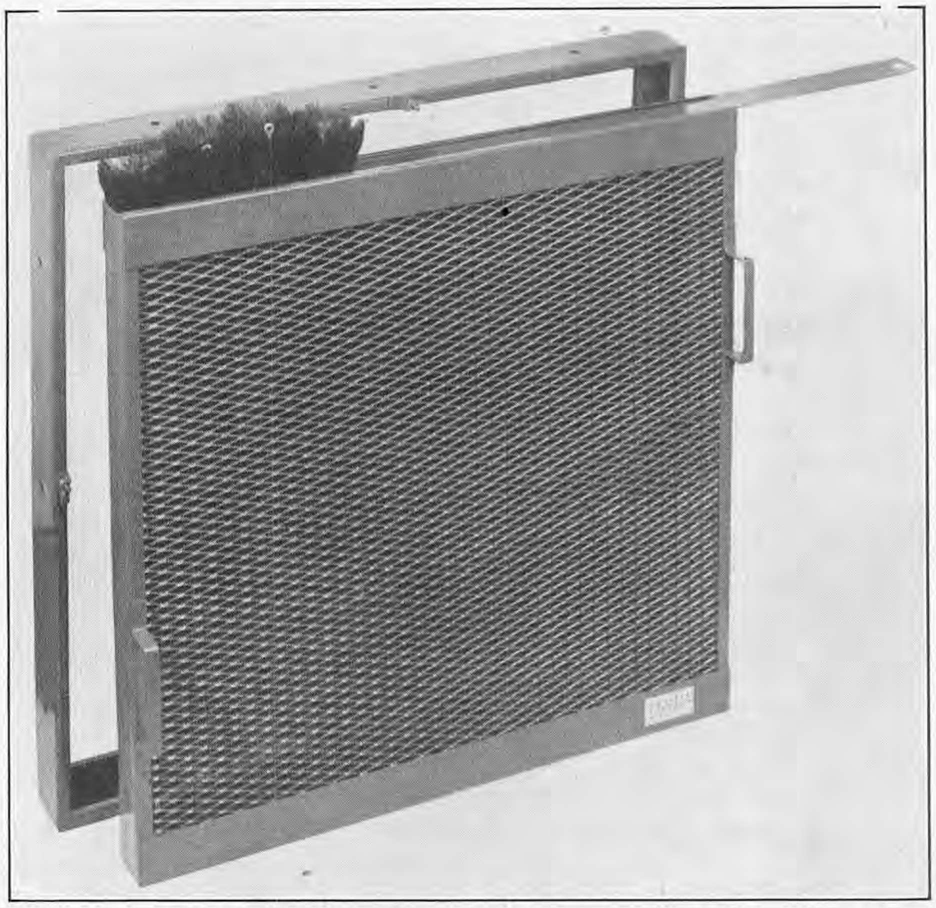
CAVITATION DAMAGE.

With our present understanding of the cavitation process, the most plausible cause of cavitation damage seems to be the high local pressures which occur at the completion of collapse of a cavity due to the "water-hammer" effect, i.e., the storing of the kinetic energy as elastic compression of the liquid. Lord Rayleigh's calculations of this collapse pressure show that it varies as the three-halves power of the cavity diameter and the square root of the system pressure. For a given velocity in a specific liquid the average cavity dimension probably varies with the lateral dimension of the cavitation zone. It has been seen that this dimension is relatively large for blunt bodies with high K_i values and decreases as the cavitation resistance increases. Also, the fact that cavitation occurs at a relatively high value of K means that the collapse zone will be at a higher pressure than it would be if the surface had a better shape and, consequently, a lower K_i value. All of this points to the conclusion that a well designed machine which has a low K_i value will probably be subject to less cavitation damage than will a similar machine having a high K_i value, even though both machines are operated at approximately the same degree of cavitation. This is fortunate, if true, because it implies that the design which would be the most effective in preventing cavitation should also, if operated at the same load but under cavitating conditions, be expected to show the minimum degradation of performance and the least cavitation damage.

There has been considerable speculation concerning the scale effect, i.e., the effect of absolute size, on cavitation damage. This is an even more complicated subject than the effect of scale on the inception of cavitation. It will be remembered that earlier in the paper, when this effect was discussed, it was pointed out that there were two independent elements involved: the geometry of the flow, and the properties of the liquid. Since as yet it is not definitely known what are the pertinent properties of the liquid, all statements regarding the effect of scale on the inception of cavitation must be considered speculative. The situation is even worse in the case of cavitation damage. Another element has to be considered, i.e., the properties of the material that is being damaged.

The present state of knowledge of the mechanics of cavitation, although far from complete, is beginning to form a consistent picture, and may now be adequate to justify preliminary investigations of the inception of cavitation damage.

MULTI-BRUSH AIR FILTER.



MULTI-BRUSH AIR FILTER.

THE load imposed upon an air filter can vary over a wide range, according to circumstances. Ambient conditions can affect the dust concentration to an extent that, in average or normal atmospheres, it will probably range around 300,000 particles per cubic foot. In many industrial areas it will amount to as much as 4 to 5 million particles per cubic foot, and in very bad areas, 20 million particles have been recorded. To cater satisfactorily for these differing conditions, an air filter must be capable of operating at high efficiency, irrespective of the dust concentration, and must be designed for speed and ease of maintenance, particularly when it is employed to remove dust and dirt from heavily contaminated air. This requires filtering elements, of durable materials, which can be cleansed without the need for special equipment or fluids and will withstand repeated cleaning without loss of filtration efficiency. Simplicity of maintenance is a feature particularly claimed for the type of multi-brush air filter illustrated herewith, which has been developed by Heather Filters, Limited, 28, St. James's-place, London, S.W.1. It employs as the filtering element a series of brushes, which present a screen of finely graded intermingling hairs to intercept and trap dust from the air in its passage through the filter. The material used in the filter brushes is selected to ensure maximum durability and efficiency, and to withstand the varying humidity and conditions of the dust-laden air. If the dust is impregnated with oil, this does not impair the efficiency of the filter; furthermore, the initial filtering efficiency of the brushes is still retained after cleaning, which is carried out by means of a vacuum cleaner when the entrained dusts are dry, or, where the dust is of an oily nature, by washing the brushes in warm soapy water or a detergent solution. The brushes can be quickly removed from the filter panel for cleaning. The procedure is to remove the panel from the frame in which it is retained by catches against felt packing to ensure air-tightness. These catches are released, the panel is removed from the frames by means of the handles and the brushes are exposed by withdrawing the slide in the end of the frame. The brushes can then be removed from the compartment in which they are housed.

Each filter unit is designed for low resistance to the flow of air and a recommended duty of 1,000 cub. ft. per minute at 0·25 in. w.g. Where necessary, higher or lower duties may be handled, with a corresponding increase or decrease in pressure; for a duty of 1,200 cub. ft. per minute, the pressure would not exceed 0·4 in. w.g. The units are made to a standard size which has been found, in practice, to be most suitable for general use; they are employed singly or as a combination of several units to give a correct filter area for a given air flow. The frames may be designed to accommodate any number of units, for erection and assembly on the working site, and these may be incorporated in a system to present a flat face to the flow of air, or where space is limited, for arrangement in cabinet or V formation, so providing a larger filtering area and a lower air velocity through the filter than would be otherwise possible.

The convenient size of the units also permits their use in ships' ventilation systems or dust-recovery units, etc., and in conjunction with machines which require a supply of dust-free air for their efficient operation, such as high-frequency induction heaters, Diesel engines and generator sets. For the latter purpose they can be built up to form part of the structure in which the equipment is housed, as in the engine compartment of Diesel-electric locomotives; incorporated in the ventilation circuit serving electrical and other equipment; or constructed into complete units for attachment by ducting to the air intake of compressors, Diesel engines or electric machinery. Where compactness is essential, filters on the same principles are made for direct attachment to the induction ports of compressors and Diesel engines. They also function as silencers, particularly when fitted to the air intakes of high-speed engines. Although designed for dry operation, all of these multi-brush filters can be impregnated with oil without loss of efficiency for use where conditions, or the particular requirements of plant engineers, require a filter of the "wet" type.

ARMSTRONG SIDDELEY "SAPPHIRE" ENGINE.—The Sapphire ASSa 6 jet engine, designed and constructed by Messrs. Armstrong Siddeley Motors, Limited, Coventry, has completed successfully the British 150-hour type test at 8,300 lb. thrust.

STRUCTURAL STEEL DESIGN.—The British Constructional Steelwork Association have issued a brochure entitled *Examples of Structural Steel Design* [*Part* 3] *to Conform with the Requirements of British Standard* 449 : 1948, prepared by Mr. V. H. Lawton. The design of stanchion bases is illustrated by three examples. The design of a single angle rafter for a roof truss is also considered. Parts 1 and 2 were issued in 1950. The practical design of steel-framed building was discussed in Part 1, and Part 2 dealt with the design of stanchions. Copies may be obtained *gratis* from the offices of the Association, Artillery House, Artillery-row, London, S.W.1.

THE FLOW OF METALS.*

By PROFESSOR E. N. DA C. ANDRADE, D.Sc., F.R.S.

THE problem for the practical engineer and the metallurgist interested in creep is to be able to predict the slow movement of stressed metals in diverse circumstances, over a long period, from a limited range of tests, frequently of the short-time type. The problem for the physicist is, starting with the simplest metals, to break down creep into its compound factors and to discover how they are governed by temperature, crystal form, grain size, the process of recrystallisation, the distribution of external stress and local stress, and other circumstances. Only when these are understood can the effect of alloying and the structural modifications that it produces be profitably studied from the point of view of fundamental properties. When, as a young man, I first took up the subject, I was convinced that matters would be greatly simplified if the observations were carried out under conditions of constant stress. The simplest way of testing a metal for creep would appear to be to load a rod or wire specimen and measure the rate of extension, but if the load is a constant weight, and extensions of some per cent. are in question, with a corresponding decrease of area of cross-section, the load per unit area, or the stress, will increase, and, since certain factors in the creep are very sensitive to stress, the increase of stress is an added complication.

In the early days, I used a device which consisted of a weight in the form of a hyperboloid of revolution, which sank in a suitable liquid as the wire specimen extended, the upthrust reducing the load in the required proportion. The disadvantage of this method, which works well, is that, with a given initial length of wire, one weight can be used for a small range of stresses only. A second method, first used in work which Dr. Bruce Chalmers and I carried out together, has the advantage that, with a given initial length of the test specimen, one unit of apparatus will suffice for all loads. A very useful modification has been made by Dr. L. M. T. Hopkin and a battery of these instruments is in use at the laboratories of the British Non-Ferrous Metals Research Association. Another constant-stress device employed is intended for extending the two ends of a horizontal specimen equally in opposite directions, so that the centre remains in position for microscopic observation.

The results of the measurements made in the years before the war of 1914-18 was that the creep of a variety of metals, measured as the extension of a normal polycrystalline wire under constant stress, could be expressed by one simple equation:—

$$l = l_0 (1 + \beta t^{\frac{1}{3}}) e^{\kappa t}.$$

The exponential nature of the term $e^{\kappa t}$ is due to the fact that the length of the wire which is creeping is continually increasing, so that a constant rate of creep per unit length gives an increasing rate for the wire as a whole. Taking $\beta = 0$, we have:—

$$\frac{1}{l} \frac{dl}{dt} = \kappa;$$

or, at a given stress, κ expresses a flow of constant rate per unit length, which may be called a quasi-viscous behaviour. This analysis thus distinguishes creep into two physically distinct components, the β or transient creep, which, being proportional to the cube root of the time, diminishes rapidly in rate as time goes on, and the κ, or permanent creep, which proceeds at a constant rate per unit length. There is an immediate extension, expressed by the fact that l_0 is not the original length of the wire. This immediate extension is important, but I shall not discuss it in this lecture.

Since the creep, under tension, of the various pure metals tested, namely, lead, tin, copper, iron, cadmium and solid mercury—the last-named being selected for its particular purity—obeys the same equation, it may be asked why, for instance, copper and lead are generally taken to behave quite differently, as far as creep is concerned. The reason is that experiments are usually carried out at atmospheric temperature, at which the two metals are certainly in marked contrast. If, however, we compare copper at a high temperature with lead at room temperature, or lead at a low temperature with copper at room temperature, we find the behaviour very similar. For example, the flow of lead at − 180 deg. C. closely resembles that of copper at 15 deg. C., and the flow of lead at 17 deg. C. closely resembles that of iron at 444 deg. C. The one formula covers all cases, but the relative importance of l_0, β and κ varies markedly with the temperature. A rough rule which I have found of use in considering many aspects of the mechanical behaviour of metals is to take as the significant, or reduced, temperature θ,

* Sixth Hatfield Memorial Lecture, delivered at the Royal Institution, London, W.1, on April 30, the first day of the annual general meeting of the Iron and Steel Institute. Abridged.

the ratio of the temperature in question to the temperature of melting, both measured on the absolute scale:

$$\theta = \frac{T}{T_m}.$$

Thus, for lead at −180 deg. C., θ is 0·16, for copper at 15 deg. C., θ is 0·21, and for lead at 15 deg. C. and iron at 444 deg. C., θ is, respectively, 0·48 and 0·40. The criticism has been raised that my experiments are of relatively short duration, namely, of a few hours only, which is true. Dr. L. M. T. Hopkin, however, has carried out experiments on the creep of pure lead, using a constant-stress device, and has found very close agreement with my formula over a duration of 1,000 hours, the total extension being 28 per cent. With a lead containing tin he likewise verified the formula, the duration of the test being 500 hours.

The transient and the permanent flow, expressed by β and κ, have different physical mechanisms. Broadly speaking, the β flow is attributable to slip on glide planes within the crystal grains; it is a matter of adjustments within the grains. The permanent creep, on the other hand, is due to a relative adjustment of grains as a whole relative to one another; it is a boundary effect.

The general lesson for the practical man from experiments under simple shear is that the type of creep that occurs depends essentially on the system of stressing; that, for instance, a marked permanent creep shown by tensile experiments may not occur at all when the metal is stressed so that the free surface remains in the same plane and of the same area, while the stress is entirely transmitted through massive metal. Further, that the creep under reversed shear stress may be essentially different from that under direct stress. There is another aspect of creep which may be of interest to practical men, namely, creep under intermittent stressing, on which Dr. A. J. Kennedy has just completed an interesting study. When polycrystalline lead is unloaded after a short period of creep it softens progressively, so that when the load is restored the metal starts a new period of creep at a greater rate than that which prevailed just before unloading. Dr. Kennedy has worked out the creep under alternate periods of loading and unloading, and he has shown that this can be calculated in terms of one constant n in addition to β. From his results it is clear that, after a short initial period, the total creep in the interrupted-loading specimen is greater than that in the uninterrupted-loading specimen after the same time of load, which might have been expected in general considerations of recovery. What is surprising is that, within a certain range of ratio of on-load and off-load periods, the creep in the interrupted case, for a given total time, including the off-load periods, may exceed that for the same time under constant load.

My object in the present lecture has been to persuade you that there are certain simple laws which underlie the study of creep in metals and that a general explanation of many features of the process can be given in terms of the mechanical properties of the crystal grains and of their boundaries. We are, of course, a long way from the knowledge that will enable us to predict the creep behaviour of the complicated alloys that dominate the engineering field at the present time. We do not really understand the mechanism of such processes as re-crystallisation under strain nor that by which transient flow is effected. I think, however, that we have reached a stage at which we can set out what are the fundamental problems and to understand the nature of a problem is always an important step towards its solution.

PRICE OF LEAD.—The Ministry of Materials announce that from May 3, 1952, the price of imported good soft pig lead is decreased from 155*l*. to 147*l*. per ton, delivered at consumers' works.

INSTRUCTIONAL FILMS BY THE SHELL FILM UNIT.—Two films recently produced by the Shell Film Unit are entitled, respectively, "An Introduction to the Heat Engine" and "Machining of Metals." The former, which is suitable for a non-technical audience, illustrates how mechanical energy has been produced from heat from the time of Hero to the present day, explains the meaning of thermal efficiency and shows how it has been increased during the period, and clarifies the distinction between heat and temperature. The second film, which was made in collaboration with the Production Engineering Research Association of Great Britain, surveys the principles of machining operations and illustrates methods by which their efficiency may be increased. The effects of variations of feeds and speed are illustrated and also the effects of various cutting fluids. Those parts of the film showing chip formation in slow motion are particularly interesting and instructive. The first film runs for 23 minutes and the second for 27 minutes. Both are 16-mm. sound films and can be borrowed, free of charge, from Shell-Mex and B.P. Ltd., Shell-Mex House, Strand, London, W.C.2, or from the Petroleum Films Bureau, 29, New Bond-street, London, W.1.

13-TON STANDARD WAGONS; BRITISH RAILWAYS.

FIG. 1. MEDIUM GOODS WAGON.

Fig. 2.

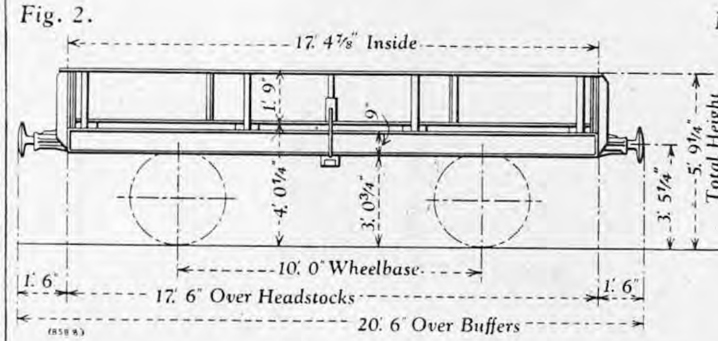
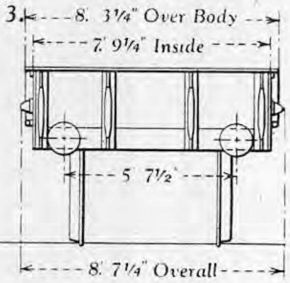


Fig. 3.



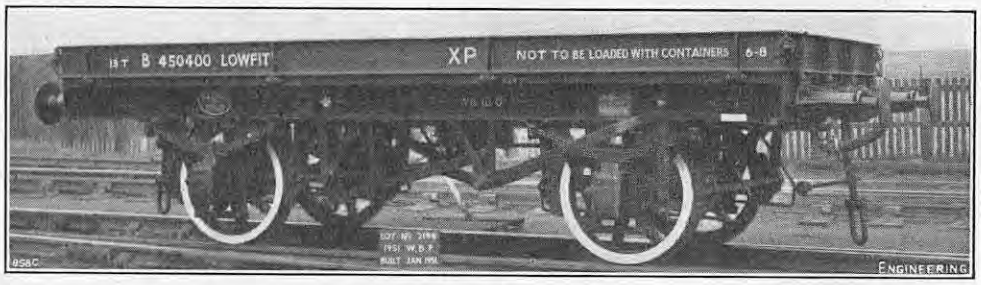


FIG. 4. LOW GOODS WAGON.

Fig. 5.

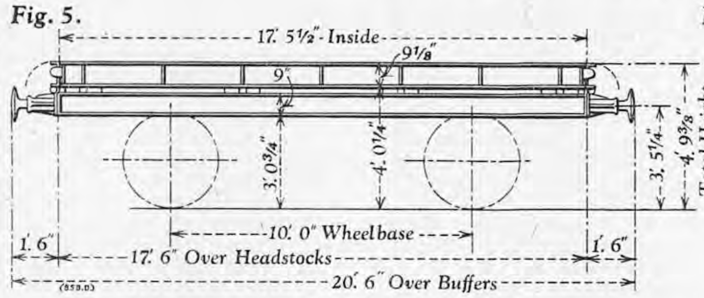
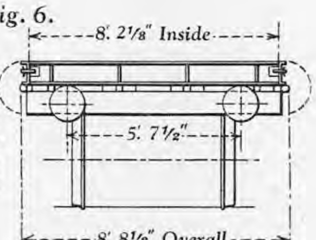


Fig. 6.



13-TON STANDARD GOODS WAGONS; BRITISH RAILWAYS.

Two further types of British Railways standard wagons recently introduced are the 13-ton medium goods wagon and the 13-ton low goods wagon, which have been designed at Derby to the requirements of Mr. R. A. Riddles (member of the Railway Executive for mechanical and electrical engineering) and are being built at Ashford and Shildon, respectively. The 13-ton medium goods wagon is shown in Fig. 1, above, and Figs. 2 and 3 give the general layout. The wagon is 17 ft. 6 in. long over the headstocks, with a 10-ft. wheelbase; the tare weight is 7 tons 1 cwt. and the load 13 tons. It is mainly of riveted construction, the underframe and body members being of British Standard rolled steel sections. The body is of all-metal construction with the exception of the floor, which is of timber. The ends are fixed and the sides comprise one-piece hinged doors which are fitted with spring door controllers.

The 13-ton low goods wagon, which is illustrated in Figs. 4, 5 and 6, is also 17 ft. 6 in. long over the headstocks, with a 10-ft. wheelbase; the tare weight is 6 tons 9 cwt., and the load 13 tons. The underframe is of all-welded construction and the body is of metal with the exception of the timber floor. The sides and ends are fitted with one-piece hinged doors made up of 9-in. by 3-in. channel. The sides, when lowered on to a loading deck, present a practically flush floor, and the ends, when dropped, form loading ramps over the buffers.

The buffing and draw gear of both vehicles are similar. The spindle-type buffers, 1 ft. 1 in. in diameter and projecting 1 ft. 6 in., are fitted with rubber or steel coil springs behind the headstocks, and the short drawgear is used in conjunction with either all-rubber or rubber and steel springs. "Instanter" couplings are fitted, allowing either long or short connections. The wagons are fitted with vacuum brakes for fast freight working, and hand brakes which can be actuated from either side. Eight clasp brakes are used on each wagon. The wheels are 3 ft. 1½ in. in diameter and have 9-in. by 4½-in. journals; standard laminated bearing springs are fitted which, in the case of the 13-ton medium wagon, are 4 ft. 6 in. long and have rubber auxiliary springs, but in the 13-ton low wagon have 3 ft. 6 in. springs with the normal type of spring shoe. The minimum radius of curve that can be negotiated is 1 chain.

METALLURGICAL LECTURES IN AUSTRIA.—Professor F. C. Thompson, of Manchester University, is delivering a course of lectures for the British Council in Austria. His subjects are "Investigation of Plastic Flow," "Research in Wire Drawing," "Dalton, Faraday and Newton as Metallurgists" and "Effect of Strain on Metals." He is lecturing (in German) at Graz, Leoben, and in Vienna.

THE BRITISH CONTRIBUTION TO TELEVISION.

(*Concluded from page* 553.)

THE meetings of the convention on "The British Contribution to Television," which had been organised by the Radio Section of the Institution of Electrical Engineers, continued from Tuesday, April 29, to Friday, May 2. We give below extracts from the "survey papers" which were read at each session. These were based on a number of supporting papers, which dealt with the subjects in greater detail.

The subject dealt with at the meeting on Tuesday morning, April 29, was "Programme Origination" on which a survey paper was presented by Mr. D. C. Birkinshaw. The development of the engineering technique associated with the pre-war television service of the British Broadcasting Corporation was first described and the origin of the White City scheme, the Lime Grove studio building and the marked progress in outside broadcasts, which had been such a feature of the period from 1946 to 1950, were then discussed. The technique of television engineering operations was, it was pointed out, completely bound up with the properties of camera tubes and their associated circuits and was therefore treated in some detail. The problems of the associated sound equipment, of the design of control and apparatus rooms and of presentation were then mentioned.

TELEVISION BROADCASTING STATIONS.

At the first meeting on Tuesday afternoon, Mr. P. A. T. Bevan presented a paper on television broadcasting stations. This surveyed the scheme by which the British Broadcasting Corporation hope to serve the greater part of the population of the United Kingdom. The basic factors underlying the choice of scheme were discussed, as were the arrangements for dividing the available 41 to 68 megacycle frequency band into five separate operating channels. The proposals for operating two geographically-separated transmitters, one high-power and the other low-power, on each channel to complete a ten-station plan were explained, as were the precautions which it would be necessary to take to minimise co-channel interference. Some of the problems of site selection for transmitting stations were mentioned and an account was given of the source of the propagation phenomenon which influenced the estimation of service area. The general design of the equipment at both high-power and low-power transmitting stations was described, with particular reference to the different types of vision and sound transmitters, combining circuits and aerial systems, in order to indicate the progress made and the trend of future developments.

WAVE PROPAGATION AND TELEVISION.

At the second meeting on Tuesday afternoon, Dr. R. L. Smith-Rose pointed out that the planning and successful operation of a national television service involved an understanding of the mode of propagation of the radio waves concerned. At the present time, the frequency bands provisionally allocated for television broadcasting purposes were between the limits of 41 and 960 megacycles per second, and the service at present under development in the United Kingdom was confined to the use of five channels in the 41 to 68 megacycle band. For this service to be successful, each transmitting station must establish a satisfactory ratio of the wanted signal to the prevailing noise or other interfering signals over the normal reception area. This involved, first, understanding in detail the manner in which the waves carrying the programme signals were propagated within the service area of the station to a radius of between 30 and 60 miles; and, secondly, establishing on a statistical basis the manner in which the waves from any other station operating in the same frequency channel were propagated to considerable distances, and in sufficient strength to impair by interference the reception of the wanted programme.

The paper next reviewed the results of investigations conducted in the United Kingdom on the propagation of radio waves of the frequencies assigned for the existing and future television services. Within the service area this propagation was largely determined by the nature of the terrain over which the waves travelled, including the effects of hills and valleys, trees, buildings and similar departures from the ideal smooth-earth condition. The effect of the diffraction of waves round the curvature of the earth or over hills had been studied, as well as the bending of the waves due to the vertical gradient of refractive index in the atmosphere. Within the service area the field strength from the transmitter remained reasonably constant, but variations might occur as a result of interference between the direct wave and the waves reflected from, or scattered by, moving objects such as aircraft.

In recent years, considerable investigation had been carried out in the 1-metre waveband at distances of a few hundred kilometres. At such ranges propagation was affected to a major degree by meteorological conditions. The general level of field strength and the variations superimposed upon it were determined first by the changes in the gradient of the refractive index of the atmosphere and, secondly, by the presence of temperature inversions which, at heights of one or two kilometres, might act as reflecting layers. Furthermore, at distances approaching the limits of practical reception, regions of discontinuity of refractive index in the atmosphere might be a source of scattering waves and result in an extension of the normal range of transmission. Under suitable conditions, transmission of waves in the 1-m. waveband might also take place to distances of several thousand kilometres by way of the ionosphere, but such occurrences were comparatively rare for normal transmitter powers and receiver sensitivities. Comparatively little opportunity had so far arisen for the study of radio-wave propagation in the 490 to 960 megacycle band in which much of the future development of television was likely to take place. Several investigations had been made at frequencies between 3,000 and 10,000 megacycles, but it seemed likely that the use of these in television would be confined to radio links for point-to-point distribution.

POINT-TO-POINT TRANSMISSION.

On Wednesday morning, April 30, a paper on "Permanent Point-to-Point Links for Relaying Television" was presented by Mr. H. Faulkner. The object of the point-to-point relaying of 405-line television signals was, he said, to provide a transmission system with a vision-frequency bandwidth of 3 megacycles or more. The gain and delay of such a system must be substantially constant and must satisfy certain requirements with respect to noise, linearity and gain stability. Experience in the United Kingdom had shown that excellent results could be obtained by cable or by radio transmission and the choice between the two was therefore largely a question of economics. The cost of transmission by cable depended largely on how the provision of a system fitted in with the development of the trunk telephone network. Where a television relay system and a large number of new telephone channels were required over the same route, composite cables could be laid to carry both services, thus spreading the costs. On routes where there was no telephony requirement a radio link was generally cheaper than cable. When radio links for the simultaneous transmission of both television and multi-channel telephony had been developed, the present economic advantage of cable links might be nullified.

INDUSTRIAL TELEVISION.

In a paper on "Industrial Television," which was read on Wednesday afternoon, Dr. R. C. G. Williams reviewed the various applications of television technique which fell outside the field of broadcasting. Essentially, television provided two means of extending our sense of sight: first, by making use of the camera as an "extension eye," which was connected to one or more viewing points; and, second, by employing the properties of photo-emissive materials to extend the electromagnetic wavelengths to which the eye responded into the infra-red and the ultra-violet regions. The first had obvious applications in providing a sense of sight in situations where it was either dangerous or physically impossible for the head and body of the observer to be present, while the second had its uses in analysis and examination. Historically, Britain had pioneered in industrial television no less than in broadcast television. Applications might be divided into three classes: those associated with broadcast television; those of use in industry; and those with special characteristics. The first included educational and training applications and large screen television; the second such applications as the transmission of documents and maps, remote metering, surgical demonstrations, handling or observation of dangerous processes and under-water television; the third included the use of the scanning principle in the flying-spot microscope and in the preparation of printing blocks or stencils.

CATHODE-RAY TUBES AND VALVES.

On Thursday morning, May 1, the progress made in the design and manufacture of valves and cathode-ray tubes for television was surveyed by Messrs. J. D. Stephenson, F. H. Powell, T. W. Price and F. M. Walker. In the earliest days, most television valves were variations of existing types, but the development of special valves had been hastened by the adoption of the present transmitting system in 1937. Meanwhile, tube design had also progressed and 10- to 12-in. magnetically-focussed tubes were used in 1939. During the war, service demands speeded up the production of miniature and all-glass valves, but cathode-ray tubes only benefited indirectly, and a fresh start was necessary in 1945. A number of methods had been devised for making the valves and tubes used in television receivers reliable, efficient and cheap; and a number of new types had been designed. Valve production had been mechanised so that the output speeds rivalled those of any other country. Mass-production methods had also been introduced into tube manufacture.

At the meeting on Friday morning, May 2, Mr. A. J. Biggs and Mr. E. O. Holland gave an account of the typical British domestic receiver of the present day.

TELEVISION AND COMMUNICATIONS.

The final meeting on Friday afternoon was devoted to the consideration of a paper by Mr. L. C. Jesty on television as a communications problem. It was becoming increasingly important, said the author, to achieve maximum efficiency in the transmission of television signals. In broadcast television the choice of the system was limited by the cost and maintenance of the receiving equipment, while with the television relay the cost and complication of the equipment were relatively unimportant so long as the service could be established. In the first case, the terminal equipment, particularly in the receiver, was likely to exert a deciding influence on the type of system adopted. In the second case, novel, but probably expensive, methods of transmitting television signals might find application. The limitations of normal television must be fully exploited, that is, the television system must be "matched" to the eye/brain mechanism to give maximum economy. In appraising a standard, the full theoretical performance must be approached in practice. It was often only under these conditions that defects such as spurious patterns became seriously visible and annoying. The system must have all the necessary corrections incorporated and an adequate signal/noise ratio.

AIRWAYS' OPERATING AND TRAFFIC STATISTICS FOR 1951.

ON page 376, *ante*, we published a summary of the traffic statistics, issued by the Ministry of Civil Aviation, of the British Overseas Airways Corporation (B.O.A.C.) and British European Airways Corporation (B.E.A.) for the six months between April and November, 1951. Since then, the statistics for the whole year 1951 have been issued; a summary of the main traffic statistics, compared with those of 1950, is given in the accompanying table. The total passenger miles flown during the year rose by 35 per cent. to over 1,000 million; freight short-ton miles increased by 26 per cent. and mail short-ton miles increased by 28 per cent. to 31 million and 17 million short-ton miles, respectively. These results were achieved with an increase of 19 per cent. in capacity short-ton miles flown and a 12 per cent. increase in aircraft miles. The overall load factor (i.e., the ratio of number of passengers carried to seats available) for the corporations rose from 58 per cent. in 1950 to 65 per cent. for B.O.A.C. and 64 per cent. for B.E.A. in 1951; the overall load factor for associate companies also rose, from 48 per cent. in 1950 to 59 per cent. in 1951. The total number of passengers carried by United Kingdom air lines reached nearly 1½ million, 22 per cent. more than in 1950, of which B.E.A. carried 1,121,000, B.O.A.C. 236,000, and the associate companies 54,000.

—	Year.	B.O.A.C.	B.E.A.	Total of Corporations.	Associates.
Capacity short ton-miles flown ..	1951	180,974,000	59,940,000	240,914,000	3,181,000
	1950	150,086,000	52,323,000	202,409,000	2,482,000
	Per cent. change	+20·6	+14·6	+19·0	+28·2
Freight short ton-miles flown ..	1951	25,293,000	5,236,000	30,529,000	874,000
	1950	20,063,000	4,195,000	24,257,000	306,000
	Per cent. change	+26·1	+24·8	+25·9	+185·4
Mail short ton-miles flown	1951	14,909,000	2,479,000	17,388,000	10,000
	1950	11,429,000	2,159,000	13,589,000	8,000
	Per cent. change	+30·4	+14·8	+28·0	+32·1
Passenger-miles flown	1951	735,291,000	329,452,000	1,064,743,000	10,773,000
	1950	525,296,000	259,046,000	784,342,000	9,691,000
	Per cent. change	+40·0	+27·2	+35·7	+11·2
Aircraft-miles flown	1951	29,407,000	22,833,000	52,240,000	1,423,000
	1950	26,286,000	20,409,000	46,695,000	1,604,000
	Per cent. change	+11·9	+11·9	+11·9	—11·3

RESEARCH ON IRON AND STEEL.

Founded in 1945 to take over and broaden the scope of co-operative research in the iron and steel industry, two important aims of the British Iron and Steel Research Association are to conserve scarce materials and to make the best possible use of available resources. Many of the projects directed to these ends have now reached the development and application stages, and one of these is a pelletising pilot plant for preparing otherwise intractable imported iron-ore concentrates for the blast furnace. Some particulars of this are given in the recently-issued annual report of Council of the British Iron and Steel Research Association, for 1951, and also in the current issue of the Association's publication, *Bisra Survey*. The process is intended to pelletise Sierra Leone concentrates and involves grinding the ore to a fineness such that 50 per cent. will pass a 200-mesh sieve, balling it in an inclined drum with a weak solution of an inorganic binder, and firing the balls, which are nearly as large as golf balls, to 1,300 deg. C., in an oxidising atmosphere. The plant has a capacity of half a ton per hour and has been built in the Redcar Works of Dorman, Long and Company, Limited. The process, it is stated, yields a satisfactory product and the problems to be solved now centre on grinding the concentrates and ensuring a continuous flow of material through the balling drum and into, and out of, the firing kiln.

A pilot plant for the regeneration of sulphuric acid from the residue of the waste product from the pickling plants at sheet and strip rolling mills is being installed at the Old Castle Works of the Steel Company of Wales, Limited. By the end of 1952 it is expected that the plant will be making one ton of 40 per cent. sulphuric acid per day, using the Autoxidation process. The raw material employed will be the so-called "copperas" residue from waste pickle liquor from which the free acid has already been recovered. Copperas is another name for green vitriol or ferrous sulphate ($FeSO_4.7H_2O$). In the Autoxidation process, the copperas is roasted to obtain sulphur dioxide, which is passed, with air, through water containing manganese sulphate. The manganese sulphate acts as a catalyst between the gas, air and water, which react to form acid of up to from 40 to 50 per cent. strength. The problem of finding materials of construction for the pilot plant which will not "poison" the catalyst used in the Autoxidation process has been greatly simplified by the discovery that ozone kills many catalyst poisons. This means that certain materials, which are comparatively cheap, can now be used.

A patent application has been filed by the Association to cover instruments for the automatic control of the gauge of the rolled product in sheet and strip rolling. Apparatus is being fitted to a four-stand tandem wide-strip mill in the works of John Summers and Sons, Limited, for the purpose of conducting a series of trials. The system has worked successfully on the Association's 10 in. by 10 in. two-high experimental mill in Sheffield and has been demonstrated there to many members of the Association. It depends on the continuous measurement of roll force and, for this purpose, loadmeters have been developed to measure loads of up to 1,200 tons under each screw-down gear. In automatic gauge control a regulator actuated by the loadmeters causes a greater or lesser degree of strip tension to be applied to the strip to maintain the load constant during the passage of the strip between the rolls. For any particular setting, a constant value of load will ensure constant thickness in the rolled strip. On the two-high experimental mill the variation in the mean thickness of the strip, with the gauge controller in circuit, was about 0·0001 in. and, on similar passes without gauge control, 0·001 in.

The continuous coating of steel strip and wire with aluminium by hot-dipping is being investigated at the Association's South Wales Laboratories, Swansea. The material is fed first into a tank of trichlorethylene to remove oil and grease, then into a second tank containing copper sulphate, where it acquires a thin film of copper to prevent oxidation. The material is then rinsed and passed through a pair of squeegee rolls before it enters the molten aluminium or aluminium-silicon alloy. On emerging it is led upwards to a height sufficient to ensure the solidification of the coating, after which it descends to the coiler. Steel strip 2 in. wide and 0·020 in. thick has been successfully "aluminised" by this process and some measure of success has been achieved with the batch hot-dip aluminising of tubes, angles and other small structural shapes. It is pointed out that the application of the process to industry would relieve pressure on scarce and expensive supplies of zinc. It is computed that, at current prices, hot-dip aluminium-coated sheet would be cheaper by 12*l*. a ton than galvanised sheet.

An interesting investigation now under way at the Association's Sheffield Laboratories concerns the desulphurisation of iron by means of lime and it is hoped to develop a full-scale method external to the blast furnace. It is pointed out that fairly rapid desulphurisation is possible when only the surface layers of the lime lumps are concerned in the reaction, and lime fired at 1,200 deg. C., is more efficient than that fired at 1,400 deg. C. From the experiments it has been possible to obtain an estimate of the lime surface needed to achieve a given degree of desulphurisation. Since the most effective desulphurisation is produced by the surface layers, a logical development of this work is to coat the lime on to lumps of coke. This procedure saves both lime and coke, since the lumps of coke may be washed and re-coated for further use. The report states that this would permit the collection of a slurry for the subsequent recovery of sulphur if necessary. Pilot-scale trials of both lumps of lime and lime-coated coke are shortly to be made at the B.I.S.R.A. Sheffield Laboratories.

The elimination of ingot moulds, soaking pits and cogging mills is the ultimate object of the continuous-casting research carried out at the Association's Battersea Laboratories. The report records that good progress has been made using new melting equipment and a new casting unit with a mould 3 in. in diameter. Billets, limited by the depth of the casting pit to 6 ft. in length, have been made at speeds of about $1\frac{1}{2}$ ft. per minute, and the adoption of a spring mounting for the mould has eliminated billet ruptures. Another interesting investigation relating to casting has been made by a member firm and this has shown that, for high-speed steels, feeder heads lined with vermiculite or with recessed tiles produce less piping in the ingot. At a price difference of 20*l*. per ton between good ingot steel and scrap, the saving per ton is estimated at 4*s*. for every 1 per cent. of increased yield.

Much work on the most efficient manner of handling imported iron ore continues to be conducted as this is a matter of importance in face of the world-wide diminution of the supply of iron and steel scrap. Studies of berthing facilities and unloading equipment at 16 of the principal overseas ports, supplementing previous studies of the tidal conditions and berthing limitations at ports in this country, and studies of journey time and turn-round time, have made it possible to recommend the most suitable size of ore-carrying vessel for particular trade routes. It is considered that three sizes of ships able to carry 8,000 tons, 14,000 tons and up to 20,000 tons of ore, respectively, might meet all requirements.

In the section of the report concerned with plant engineering it is stated that the acquisition of extensive premises at Battersea, early in 1951, provided the staff with much needed laboratory and drawing-office accommodation. The difficulties in obtaining suitable staff, remain great, however, and the numbers available during the year were below those sanctioned on the estimates. Research work carried out under the direction of the mechanical-engineering committee includes the consideration of such diverse matters as the fundamental problems of rolling-mill manufacture and the bundling and other preparation operations to be carried out on scrap before charging it into the open-hearth furnace. An investigation into the blowing requirements of typical blast furnaces has been completed. It has proved difficult to specify blower capacities, as these are largely dependent on individual works practice. It is found, however, that, in many cases, a very much larger blower than current requirements justify is installed to allow for future developments. A conclusion reached as a result of the investigation is that it is cheapest to install a blower sufficient only for current requirements, unless it is anticipated that increased blowing capacity will be required immediately after the first campaign.

Work conducted on behalf of the civil-engineering committee includes the study of works traffic organisation. This has been continued by an analysis of train size and incidence of arrivals at works and their effect on reception and holding sidings. Based on the costs of handling materials and stocking on the one hand, and demurrage charges on the other, consideration has been given to the economical balance between stocking and holding wagons under load in sidings. It has been found that the greatest economy is usually obtained by holding wagons in the works for not much longer than the free standage period of $1\frac{1}{2}$ days. A simple formula has been suggested to give adequate siding capacity in relation to the time wagons are kept in works and the irregularity in train arrivals.

Engineering Training Mission to Latin America.—A mission led by Sir Arthur Fleming left this country on Tuesday, April 29, to inaugurate the overseas scholarship scheme of the Federation of British Industries in Latin America. This scheme, which is financed by British engineering firms and the Board of Trade, provides training facilities for engineering graduates of all classes from countries throughout the world. The objects of the mission are to make the scheme more widely known; to study how it can best be adapted to Latin American needs; and to make preliminary arrangements for the selection of suitable candidates. The countries to be visited include Mexico, Cuba, Venezuela, Colombia. Peru, Chile, Argentine, Uruguay and Brazil.

ANNUALS AND REFERENCE BOOKS.

The Aeroplane Directory of British Aviation, 1952.

Temple Press, Limited, Bowling Green-lane, London, E.C.1. [Price 15s. net.]

In order to combat rising costs, the current edition of the *Aeroplane Directory* contains fewer pages, of larger size, than previous editions, and the information has been re-arranged under nine headings. Part I is a guide to the British and Commonwealth military aviation services. Part II gives particulars of the British civil ministries and establishments concerned with aviation and aircraft, the Air Registration Board, and corresponding Commonwealth organisations. A directory of the British and Commonwealth aircraft industries is given in Part III; the British section is classified under such headings as aircraft constructors; aircraft distributors and concessionaires; aircraft maintenance, repair and wheels, tyres and brakes; flying clothing, survival equipment, etc.; tools and workshop equipment, etc. Only a few typical headings have been picked out to illustrate the wide range which this directory of industry covers. Within each subdivision the firms are arranged in alphabetical order, and in addition to a brief note on their activities, the names of the directors and principal executives are given. The remaining sections cover commercial operators in Great Britain and the Commonwealth; international civil organisations; learned bodies, professional societies and clubs; the British and Commonwealth aeronautical press; aeronautical training; and who's who and obituary notices. A list of abbreviations which occur in the book is given. It appears, therefore, that the compilers have provided an answer to practically any enquiry concerned with the existence and location of British and Commonwealth aviation organisations. In the aircraft-industry section, the sub-section headings were given at the top of the pages on which they appeared in the previous edition. This practice has been discontinued in the present volume, and as a result, it is more difficult to locate the manufacturers of a particular type of product. Although the index has been considerably expanded (in previous editions it was a mere skeleton), it is still far from complete and is lacking in cross-references. If, for instance, it is desired to know who manufactures undercarriages in the United Kingdom, the index is of no use; neither are there any entries under "engine" or "propeller," to mention only two major components which should certainly have a place in the index, even though the compilers prefer to think in terms of "aero-engine" and "airscrew."

BOOKS RECEIVED.

Safe Working Loads of Lifting Tackle. By L. Linder. Second edition. Coubro and Scrutton, Limited, 11, West India Dock-road, London, E.14. [Price 42s.]

Corrosion Testing Procedures. By Dr. F. A. Champion. Chapman and Hall, Limited, 37, Essex-street, Strand, London, W.C.2. [Price 36s. net.]

Tungsten. A Treatise on its Metallurgy, Properties and Applications. By Dr. Colin J. Smithells. Third edition. Chapman and Hall, Limited, 37, Essex-street, Strand, London, W.C.2. [Price 75s. net.]

Wire Rope Lubrication. By E. V. Paterson. Scientific Publications, 8, Walker-street, Wellington, Shropshire. [Price 3s., post free.]

Theory of Naval Architecture. By Professor Andrew McCance Robb. Charles Griffin and Company, Limited, 42, Drury-lane, London, W.C.2. [Price 8 guineas.]

Ministry of Fuel and Power. Report of H.M. Inspectors of Mines and Quarries under the Metalliferous Mines Regulation Act, 1872, *and the Quarries Act*, 1894, *for the Year* 1950. H.M. Stationery Office, Kingsway, London, W.C.2. [Price 2s. net.]

The Elements of Thermodynamics. By Professor Charles Fabry. Translated by G. F. Herrenden Harker. Quality Press Limited, Bouverie House, 154, Fleet-street, London, E.C.4. [Price 15s. net.]

Electric Arc and Oxy-Acetylene Welding. By the late E. Arthur Atkins and A. G. Walker. Fourth edition, revised by W. A. Atkins and A. G. Walker. Sir Isaac Pitman and Sons, Limited, Parker-street, Kingsway, London, W.C.2. [Price 30s. net.]

Extrusion of Plastics, Rubber and Metals. By Herbert R. Simonds, Archie J. Weith, and William Schack. 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.]

The Heat Treatment and Annealing of Aluminium and its Alloys. Part I. Practice. Information Bulletin No. 3. Third edition. Aluminium Development Association, 33, Grosvenor-street, London, W.1. [Price 2s.]

Waves and Tides. By R. C. H. Russell and Commander D. H. Macmillan, R.N.R. (rtd.). Hutchinson's Scientific and Technical Publications, Stratford-place, London, W.1. [Price 25s. net.]