THE INTERNATIONAL MACHINE TOOL EXHIBITION AT OLYMPIA.

(*Continued from page 333.*)

THE International Machine Tool Exhibition opened on Wednesday this week (September 17). The addition of the word "International" to its title since the last exhibition was held in 1948 is fully justified in view of the large number of foreign machine tools that are being exhibited, and it is also expected to be reflected in the attendance of many overseas visitors. The exhibits include, in addition to lathes, planers, borers, shapers, slotters, grinders, etc., engineers' small tools, gauges, measuring equipment, testing equipment, presses and power hammers, heat-treatment plant, and wood-working machinery. In this, the second article on the exhibition, we describe further selected exhibits which are likely to prove of interest to many visitors. In an exhibition of this kind, where over 2,000 machine tools are being shown, no amount of written description can be as useful as a personal visit, but for those who are unable to make a tour of the stands, these notes, it is hoped, will reveal much that is significant.

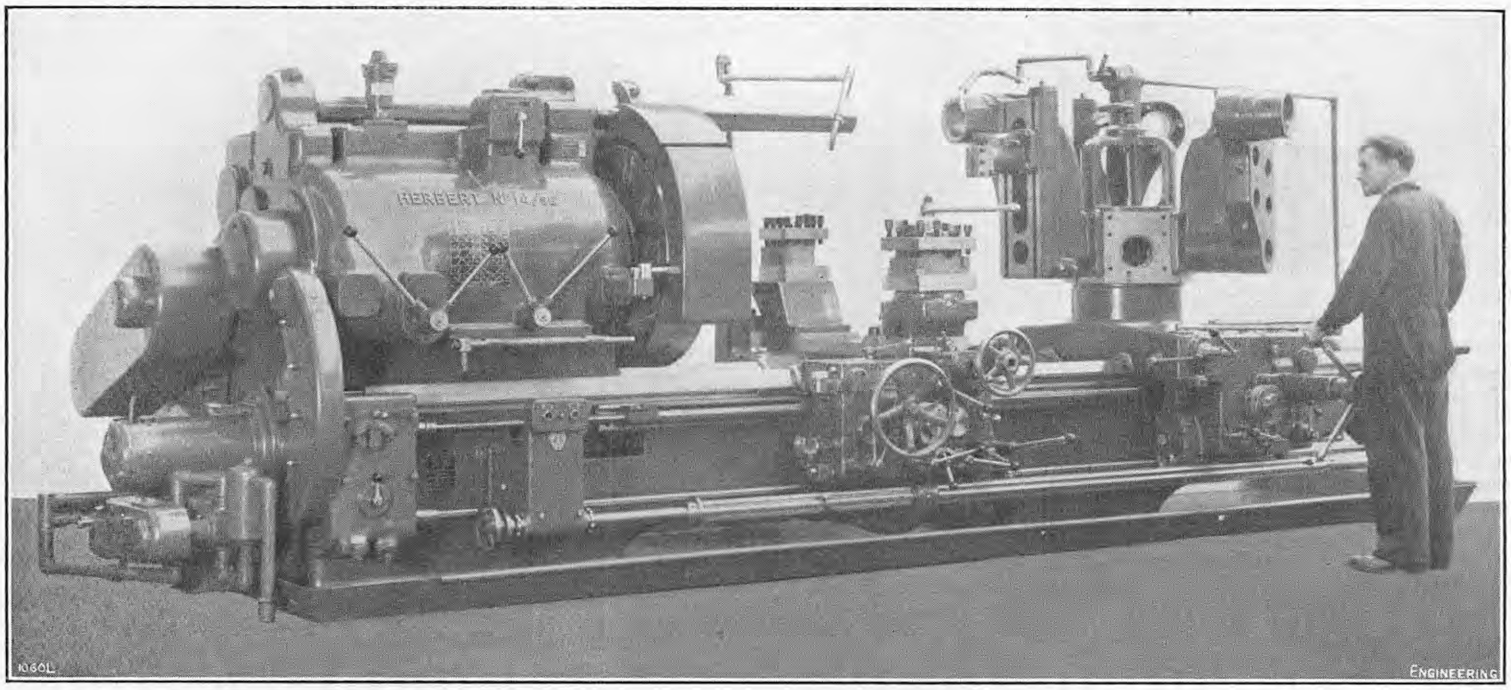

FIG. 36. COMBINATION TURRET LATHE; ALFRED HERBERT, LTD.

COMBINATION TURRET LATHE.

At the last Machine Tool Exhibition, in 1948, Messrs. Alfred Herbert, Limited, Coventry, exhibited 67 machine tools, all of which were in operation. In view, however, of the urgent demands associated with defence production and the export drive, this year they have deliberately restricted their exhibits to two machines from their complete range. One of these, namely, the Herbert No. 14/36 combination turret lathe, is illustrated in Fig. 36, on this page. This machine is the largest of the Herbert lathes for dealing with heavy work and is capable of accepting work with a 36-in. swing. The bed is equipped with Flamard prismatic guiding surfaces and these are protected by sliding covers, the surfaces, acting in conjunction with the ball and roller bearing spindle, giving outstanding accuracy and alignment. The headstock is driven by a two-speed electric motor which, operating in association with a gearbox, gives 16 reversible speeds ranging from 12 r.p.m. to 480 r.p.m. for turning, and five additional slow speeds, namely, from 4 r.p.m. to 11 r.p.m., for screwing and reaming. Speed changes are made by two groups of two levers arranged to operate sliding gears.

The saddle has 16 reversible automatic sliding and surfacing feeds ranging from 12·4 to 482 cuts per inch longitudinally and from 13·8 to 540 cuts per inch transversely. Feeds are independent of the turret-slide feeds and a backlash eliminator is fitted to the cross-slide so as to enable accurate tapers to be machined regardless of the direction of feed. An accurate indicator is fitted to the longitudinal motion and a large micrometer dial on the cross-slide handwheel is calibrated in thousandths of an inch. Chasing mechanism is provided, the chasing gearbox giving three ratios for the leadscrew. A quick-withdraw mechanism removes the chaser from the work at the same time as the nut is withdrawn from the leadscrew. The maximum length of thread that can be chased is 15 in. The turret slide has sixteen automatic feeds ranging from 12·4 to 482 cuts per inch. Quick power-traversing gear is incorporated in all motions and all controls are mounted on the associated aprons. The turret is easily rotated and can be moved by hand in either direction regardless of the weight and mounting of the tools.

CAPSTAN LATHE FOR NON-FERROUS COMPONENTS.

The second machine exhibited by Messrs. Alfred Herbert, Limited, is illustrated in Fig. 37, on page 362. Known as the Flashcap No. 2 lathe, it has been designed specially for high-speed production of brass and other non-ferrous components having internal or external threads, or both, and requiring frequent spindle reversals at high speeds. The motor control gear provides for instantaneous starting, stopping and reversal of the spindle by means of a handwheel and knob situated at the front of the headstock. Automatic change from forward or reverse can also be effected by movement of the capstan slide, this latter feature being of great advantage when tapping blind holes or threading close to a shoulder. Automatic changes from forward to reverse are effected by push rods mounted above the capstan, which actuate a spring-loaded plunger in the headstock to operate the motor switch. These rods can be set to effect an instantaneous change of direction at any required point of the capstan-slide travel, and an adaptor can be fitted to the push rod which enables two spindle reversals to be obtained during a single forward and return motion of the capstan slide.

The machine is driven by a 3-h.p. motor running at 1,430 r.p.m., and six spindle speeds, ranging from 630 r.p.m. to 2,560 r.p.m., are available through pick-off gears, a single speed being used for any one set-up. With the spindle running at 1,240 r.p.m. and fitted with a 6-in. air-operated chuck, 30 spindle reversals can be made per minute. Heavier chucks, of course, reduce the number of reversals that can be made in a minute, and the makers recommend that higher speeds than that quoted should not be used for tapping. For work such as hot brass pressings and small castings, special jaws and liners are recommended. These are designed so that the liners can be interchanged without disturbing the jaws. The standard machine is supplied with a hand-operated capstan slide and without a saddle but a fixed-type saddle is available as an optional extra and this can be clamped in any position on the bed; it incorporates a screw-operated cross-slide with front and rear toolposts. A six-hole capstan is normally fitted but a two-hole rocking capstan is available as an alternative, both types being fitted with automatic indexing arrangements. Other additional units available include a feed box, which can be installed to give three rates of automatic feed to the capstan, namely, 80, 160 and 320 cuts per inch.

The machine is being shown in operation, having been set up to machine gland nuts. The capstan is being used to load the brass stampings and the machine is fitted with two sets of tools to enable two gland nuts to be machined per cycle in 10 seconds. The sequence of operations is: load; simultane-

THE INTERNATIONAL MACHINE TOOL EXHIBITION.

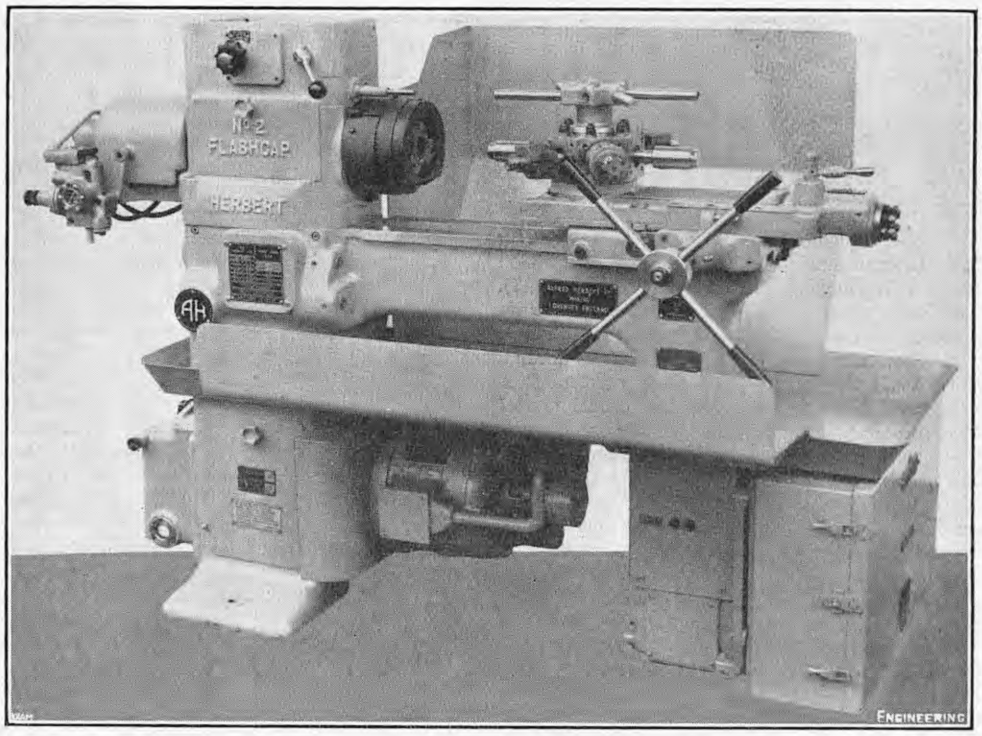

FIG. 37. CAPSTAN LATHE FOR NON-FERROUS COMPONENTS; ALFRED HERBERT, LTD.

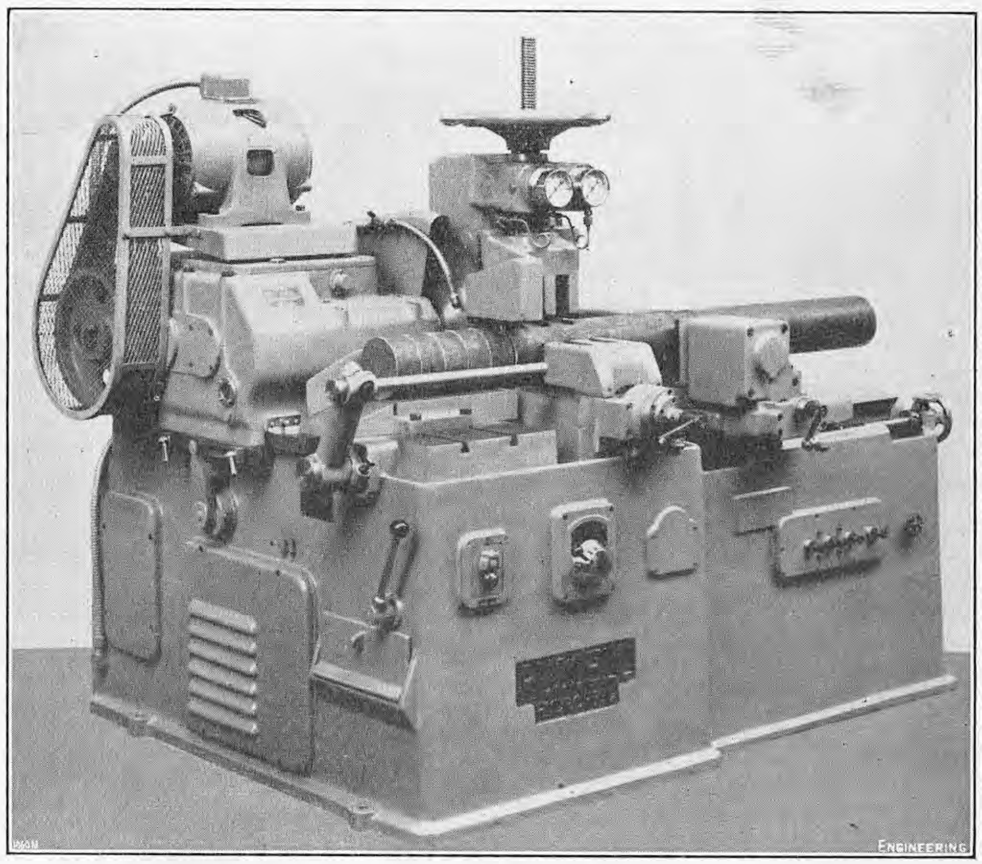

FIG. 38. AUTOMATIC COLD-SAWING MACHINE; S. RUSSELL & SONS, LTD.

ously bore two diameters; face and form internal and external chamfers; and tap the 1¼-in. diameter gas thread. The nut is then ejected automatically and the sequence repeated to complete the cycle. A dummy turret is also being shown and this is equipped to carry out two operations on a union, both ends of which can be machined in a total time of 12 seconds.

AUTOMATIC COLD-SAWING MACHINE.

Four types of their Hydrofeed high-speed cold-sawing machines are being shown by Messrs. S. Russell and Sons, Limited, Bath-lane, Leicester. One of these, the 16/20, is illustrated in Fig. 38, on this page. This is the middle size of a range of three such machines and will accommodate work up to 6 in. in diameter or squares with a side of 6 in. The cycle of operations, i.e., feeding the required length of the bar, clamping, engagement of saw feed, quick return of the saw saddle at completion of cut and unclamping, is entirely automatic, requiring no attention from the operator. This automatic cycle of operations is controlled hydraulically, the mechanism being designed so that it is impossible for the sequence to be carried out incorrectly. The material to be cut is carried between jaws, and at the commencement of the automatic cycle these jaws grip the stock, which is then moved forward a distance equivalent to the cut-off length required, compensation for loss of material during cutting being made automatically. The interlocking vices then clamp the material securely and the saw feeds forward at a rate selected by the operator, the gripping jaws automatically being released and returned to their original position during the cutting operation. On completion of sawing, the saddle holding the saw returns at a faster rate and, at the same time, the gripping jaws close on to the stock. As soon as the saw returns to the starting, or rearmost, position, the vices are released and the stock moved forward ready for the next cut.

While being sawn, the stock is held by hydraulically-operated interlocking vertical and horizontal vices, a method that enables all sections to be clamped without recourse to packing pieces. When the machine is not being operated on the automatic cycle, movement of the feed lever into the "feed" position closes the vices before cutting commences, and after the saddle returns to the rearmost position the vices open automatically, thus leaving the stock free to be either fed forward or removed from the machine. The pressure cylinder is built into the body of the vertical vice and the press-block is forced down on to the stock by means of a toggle motion, the clamping pressure, as a consequence, being transferred to mechanical components. An attachment is used for gripping short lengths during cutting, which prevents risk of damage to the saw blade as the cut length is severed from the stock. No work stop is required for automatic operation but one is supplied to assist in setting up the machine and for use when the machine is operated semi-automatically. The standard machines permit lengths up to a maximum of 12 in. to be cut from the stock, but machines capable of cutting lengths up to 36 in. can be supplied. The makers, however, recommend the use of a straightforward non-automatic machine where long cut-off lengths are required.

The bed of the machine consists of a heavy box-section iron casting. It is provided with broad ways on which the saddle moves and incorporates large work-holding tables, a coolant-tank, a chip compartment and a space for the hydraulic unit. An iron casting is also used to form the saddle and this contains the drive to the saw spindle, the drive consisting of a chain of spur and double-helical gears. A four-speed gear is included in the reduction gearing so that the cutting speed can be altered to suit different materials. All fast-moving shafts in the gearbox are supported by ball or roller bearings, but the saw spindle and the slower-moving shafts are provided with gunmetal bearings. The main motor is mounted on the saddle and the drive is transmitted to the gearbox through multiple V-belts, provision being made for the correct tension to be obtained. The circuit for the hydraulic feed has been designed specifically to suit metal-sawing conditions and ensures that a steady but positive approach is made by the saw blade to the material, with an equally steady break through at the end of a cut. The pump and its associated tank, as previously indicated, are located in the bed of the machine and are arranged so that access is gained to them easily for maintenance. Relief gauges are incorporated in the circuit to prevent overloading, and gauges indicating the feed and clamping pressures are fitted just above the clamping device. An automatic two-motor control panel is supplied with the machine. This is designed so that, by pressing one starter button, both the main motor and that for the hydraulic pump are started in their correct sequence. The main motor starts first and an automatic timing relay gives delayed-action starting for the pump motor, thus preventing the saw blade from being damaged by premature feeding.

HORIZONTAL BORING AND FACING MACHINE.

A wide selection from their range of horizontal and vertical boring and facing machines is being shown by Messrs. George Richards and Company, Limited, Broadheath, near Manchester. A good example of the former type of machine is furnished by that shown in Fig. 39, opposite. This shows their No. 3 Hydrabore travelling-column model, an entirely new design, which is capable of facing up to 42 in. diameter. It has been developed to meet the demand for a travelling-column machine

EXHIBITS AT THE INTERNATIONAL MACHINE TOOL EXHIBITION.

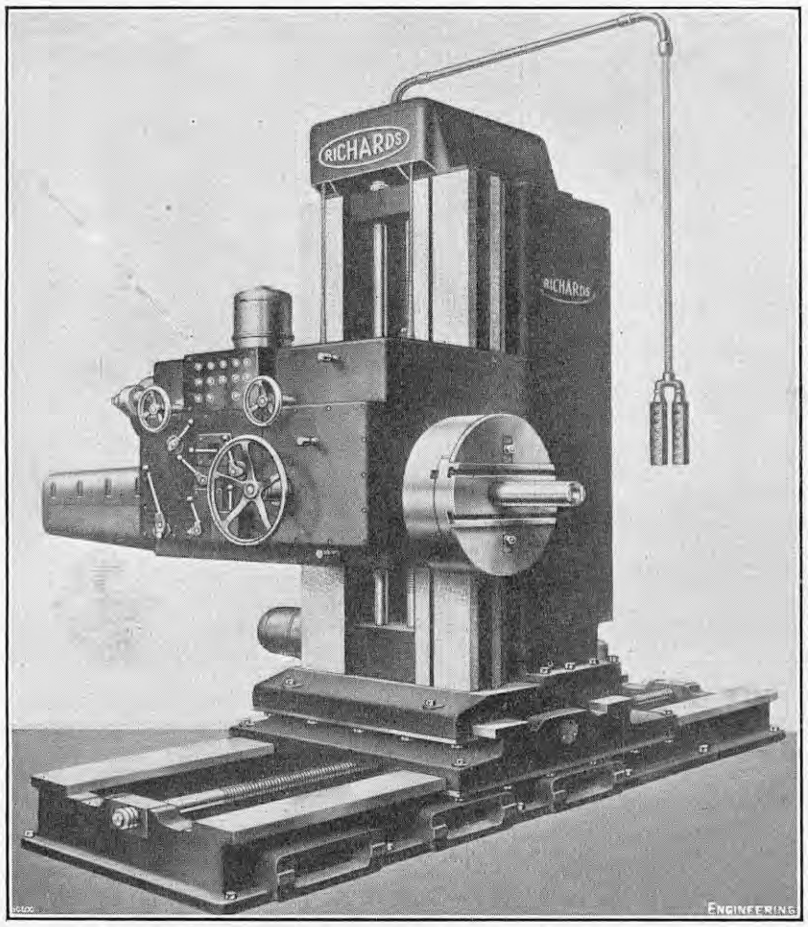

FIG. 39. HORIZONTAL BORING AND FACING MACHINE; GEORGE RICHARDS & CO., LTD.

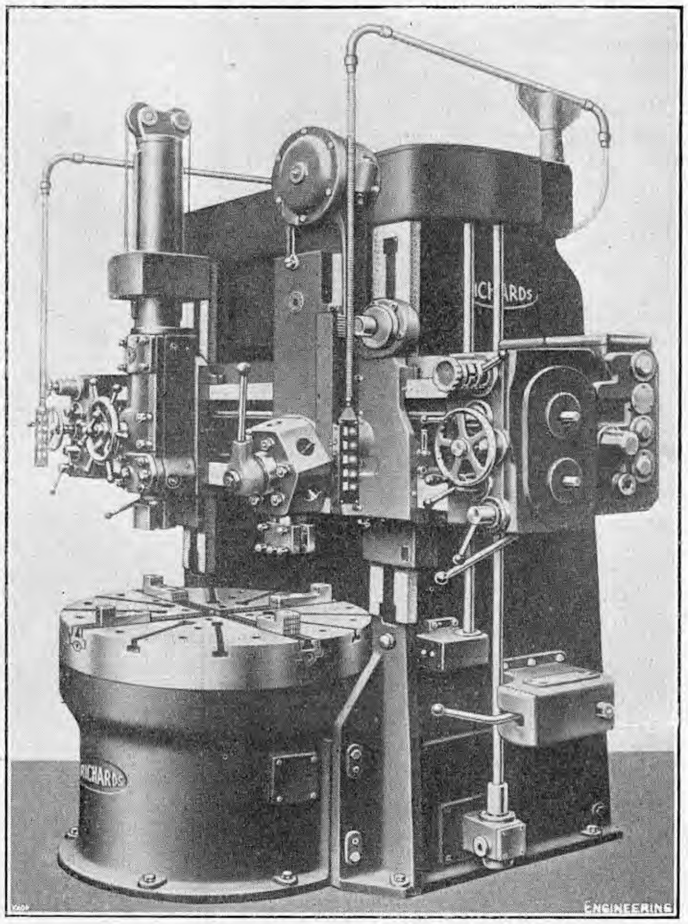

FIG. 40. VERTICAL TURNING AND BORING MILL; GEORGE RICHARDS & CO., LTD.

which, although capable of dealing with large work-pieces having bores set considerable distances apart, is of medium size in its capacity for boring and facing, and is therefore able to run at comparatively high speeds. The spindle frame is entirely new in that the main driving motor is mounted directly on it and all gearing necessary to obtain the range of speeds is contained in the frame, being controlled by two handwheels. The two main parts of the machine, namely, the bed and the upright, are machined from iron castings suitably ribbed internally to give the requisite rigidity. The bed is 4 ft. wide and is sufficiently long to enable the upright to have a traverse of 8 ft. A cross-adjustment of 6 in., which is operated by hand, is also provided. Machined facings are provided at one side of the bed for bolting up to a suitable baseplate. The upright is fitted with the maker's patent form of slide; this is known as the Prismatic slide and is designed so that the cutting forces are distributed over a large area, an important feature when the machine is taking intermittent cuts or is used on heavy work.

The main spindle is made from high-carbon steel and has integral with it a solid flange to which the facing head is bolted. It is mounted in the spindle frame, which is given vertical motion relative to the upright by means of a centrally-located screw mechanism. Particular attention has been paid to the spindle bearings; these are of the Churchill Hydrauto type, in which the conventional solid phosphor-bronze bearing is replaced by a split bearing, the lower portion of which is fixed in the housing and the top portion held in contact with the spindle by hydraulic pressure. To ensure stability of the spindle regardless of the speed of operation, the oil is supplied by a separate motor-driven pump, the actual pressure being determined by a relief valve. The facing head has 12 speeds ranging from 5 r.p.m. to 220 r.p.m., and the mechanism within the head is designed to give eight reversible feeds to the tool slide ranging from 0·005 in. to 0·1 in. per revolution. A 12·5-h.p. constant-speed electric motor is used for driving the main spindle, the motor, as previously indicated, being mounted directly on the spindle frame.

The traversing spindle is made from Nitralloy steel, is ground all over, and is supported in pre-loaded roller bearings. A total of 18 speeds is provided, ranging from 5 r.p.m. to 500 r.p.m., and the six independent traversing spindle speeds range from 100 r.p.m. to 500 r.p.m., all speed changes to the spindle being made by one lever fitted to the spindle frame. Lubricant for the bearings on the spindle frame is provided from the electrically-driven pump which, as previously mentioned, supplies the hydraulic pressure for the spindle bearings. The main motor and rapid power-traverse motors are controlled by push-buttons grouped together on the spindle frame, the buttons being duplicated on the pendant switch, which can be moved to any position convenient for the operator. Dynamic braking is provided for the main motor so as to eliminate mechanical brakes. Control levers are reduced in number to the minimum and the danger of engaging conflicting motions is eliminated by the incorporation of interlocking devices.

VERTICAL TURNING AND BORING MILL.

The vertical turning and boring machines being shown by Messrs. George Richards and Company, Limited, Broadheath, near Manchester, include the 4-ft. machine illustrated in Fig. 40. It is a new design and can accept work up to 4 ft. in diameter, the height of work admitted under the cross-slide being 2 ft. 11 in., under the standard head 2 ft. 5 in., and under the turret head 3 ft. 0½ in. The base of the machine consists of a substantial iron casting reinforced by internal ribbing, and the main spindle is mounted on two large-diameter ball bearings with an extra bearing at the base. It is driven by a variable-speed direct-current motor through a mechanically-operated three-speed gearbox, final drive to the table being through spiral-bevel gears and a single-helical gearwheel and pinion. Infinitely-variable speeds are available between the limits of 9·26 r.p.m. and 250·28 r.p.m., mechanical speed changes being effected through a lever situated at the right-hand side of the machine and the speed of the motor controlled from the desk at the front of the machine. Two pendant push-button stations are provided, and they can be moved to any position convenient for the operator.

The feeds to each head are obtained from units at each end of the cross slide, 16 independent and reversible feeds ranging from 0·001 in. to 0·102 in. per revolution being provided, the various feeds being selected by levers at the front of each unit. Index dials, calibrated in thousandths of an inch, are provided on the inner sides of the feed boxes and, if required, these can be supplied calibrated in millimetres. A four-jaw independent-chuck table is fitted but a three-jaw self-centring chuck is available if required. The machine is also provided with a left-hand standard swivelling head and a six-sided non-swivelling turret head. The latter is released, rotated, indexed and relocked by a single lever and can be equipped with a variety of toolholders, bars, etc., to suit individual requirements.

A constant cutting-speed device is incorporated in the machine; this can be applied to either head and is controlled electrically in conjunction with the main driving motor, various constant cutting speeds being obtainable from a selector on the control desk. Particular attention has been paid to the design of the lubricating system. An electrically-driven oil pump is contained in the base of the machine and this supplies filtered oil under pressure to all main bearings and driving gears. When the machine is started, the pressure built up by the pump operates a switch connected to an indicator light which remains illuminated so long as the oil pressure does not drop below 5 lb. per square inch. If the pressure drops below this figure, however, the light is extinguished, thus giving adequate warning that the system is functioning incorrectly. The mechanism at the rear of the saddle is contained in an oil bath and all the feed gearing in the units at the ends of the cross slide are lubricated on the splash system from a reservoir in

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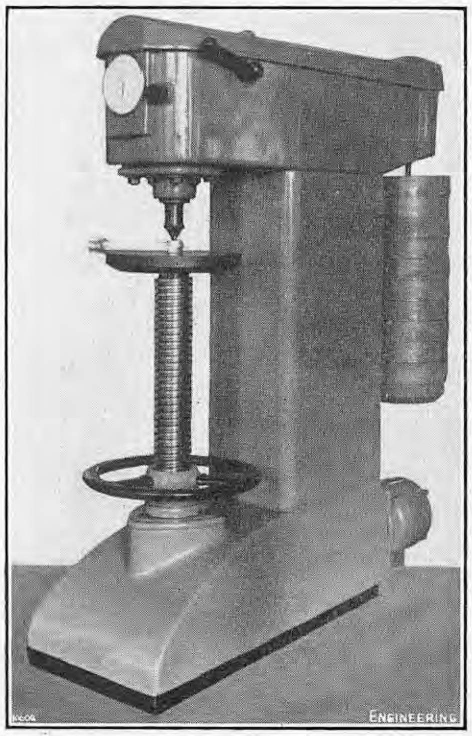

FIG. 41. DIRECT-READING HARDNESS-TESTING MACHINE; W. & T. AVERY, LTD.

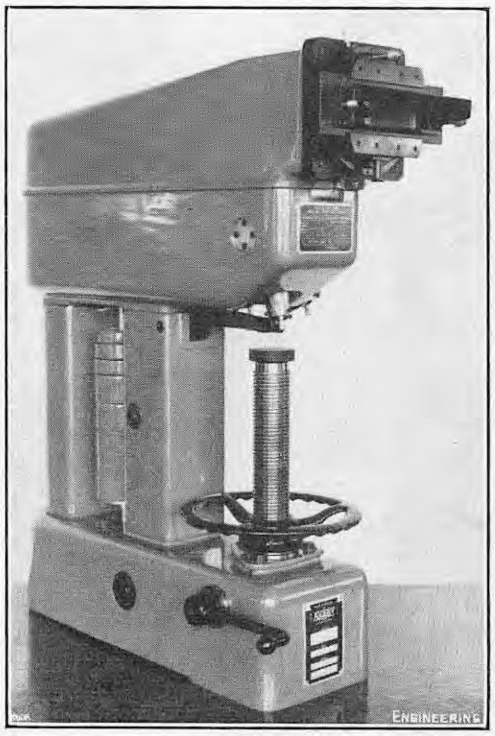

FIG. 42. VISUAL HARDNESS-TESTING MACHINE; W. & T. AVERY, LTD.

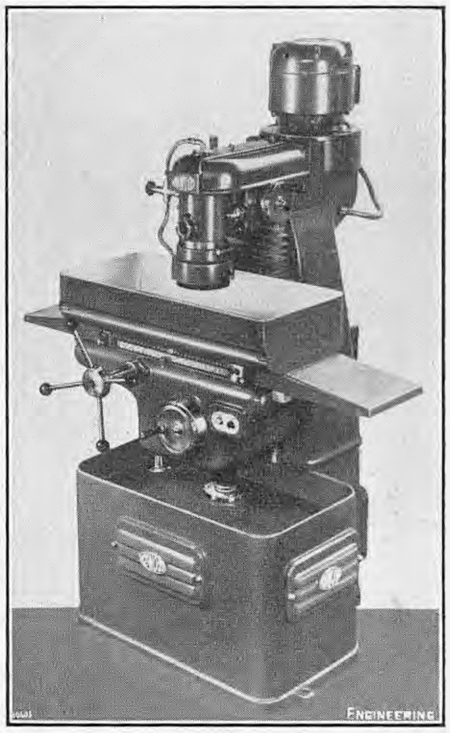

FIG. 43. PRECISION SURFACE GRINDER; ABWOOD TOOL & ENGINEERING CO., LTD.

the base of the feed box. Splash lubrication is employed also for the main driving gearbox.

DIRECT-READING HARDNESS-TESTING MACHINE.

The testing machines shown by Messrs. W. and T. Avery, Limited, Soho Foundry, Birmingham, 40, include two newly-developed direct-reading hardness testers. One of these, known as the No. 6405 direct-reading Brinell hardness-testing machine, is illustrated in Fig. 41, above, from which it will be seen that it is a development of the firm's standard Brinell machine. The load is applied to the specimen through a lever and proportional weights acting on a floating, frictionless penetrator, the load being applied and removed by means of a motor-driven hydraulic pump and ram, the action of which is controlled by a small lever. The unit remains a true Brinell machine in that the impressions produced are in accordance with B.S.S. No. 240, part 1, and can be read at any time by a microscope in the usual manner. It is provided, however, with a dial gauge that indicates the depth of the impression and this reading can easily be converted into the appropriate Brinell number. The depth recorded is not the depth from the surface of the material to the bottom of the impression but the difference between the depth of an initial impression under a load of 250 kg. and the final depth under a major load of up to 3,000 kg., the depth being read after the major load has been removed so that frame and test-piece distortions do not confuse the result. It will be appreciated that the system is similar to that used in the Rockwell test but, due to the greater loads imposed and the greater depth, therefore, of penetration, most of the difficulties associated with this form of test are overcome. Tests carried out on the machine have shown an outstanding measure of reproduceability and the ease with which it may be operated enables 300 or more tests an hour to be carried out without difficulty.

VISUAL HARDNESS-TESTING MACHINE.

The second of the new direct-reading hardness-testing machines being shown by Messrs. W. and T. Avery, Limited, is illustrated in Fig. 42, above. Known as the Model 6406, it has been designed for making hardness tests on a wide variety of materials, ranging from lead to hardened steel. Specimens can be varied in form from thin sheet to the finished component, and a built-in microscope is arranged so that an enlarged image of the impression is projected on to a ground-glass screen installed in the head of the machine, where measurements to a thousandth of a millimetre may be made. The machine is eminently suitable, therefore, for rapid repetition tests on the production line or for tests on varying individual specimens. As will be seen from the illustration, it is a compact unit and has been designed for bench mounting; it is 2 ft. 9½ in. high and requires a bench space measuring 2 ft. 1 in. by 1 ft. 1 in. The loading mechanism, microscope projector, transformer and penetrator are located in the top housing and the elevating screw and load-release mechanisms in the base casting. When in use, specimens are placed on the table, which is subsequently raised to make contact with a spring clamp before the surface is brought into focus with the microscope and the load applied, the action of clamping automatically switching on the projector lamp, which, to economise in lamp life, is on only for the duration of each test.

The load is applied by raising the hand lever at the left-hand side of the base, the speed at which the load is placed on the specimen being controlled by an adjustable oil-filled dashpot. When raised above an angle of 30 deg., the lever continues upwards automatically under control of the dashpot, and during this time the microscope and penetrator move backwards until the penetrator is in line with the optical centre of the microscope, after which the impression is made. When movement of the lever ceases, it is pulled forward to raise the weight; at the same time, the penetrator moves forward to allow the impression in the specimen to be projected through the microscope. The clamp situated below the measuring head is entirely automatic in operation and provides sufficient pressure to hold the specimen rigid during a test; a detachable side clamp is provided, however, to hold long round specimens in position. Accommodation is provided for specimens up to 8 in. maximum height and 10 in. in diameter, and proportional weights allow loads of from 5 kg. to 120 kg. to be applied. The microscope has a magnification of 70, and the screen is graduated in 0·1 mm. and 0·01 mm. The machine is provided with a wide selection of equipment, which includes 1-mm. and 2-mm. ball indenters, a Vickers diamond 136-deg. surface angle, a V-table for round specimens, and calibrated hardness-test blocks for both Vickers and Brinell tests.

PRECISION SURFACE GRINDER.

The range of equipment being shown by the Abwood Tool and Engineering Company, Limited, Princes-road, Dartford, Kent, includes the new surface grinder illustrated in Fig. 43, above. This machine has a capacity of 20 in. by 8 in. by 10 in. under a 6-in. diameter wheel, and has been developed to meet the need for a precision machine of medium capacity suitable for use either in the toolroom or in the production shop. The grinding head is driven from a 3-h.p. motor through twin V-belts, and is fitted with an improved design of Hydrocol main bearing, which, as its name suggests, is water cooled. Cutting compound, or coolant, is delivered through the centre of the grinding-wheel spindle and also to the leading edge of the wheel, deep coolant trays being provided to deal with the large quantities in circulation. All coolant circuits have been built into the body of the machine and the swarf is separated in a weir-type sludge drawer in the base. To exclude dust from the bearings, etc., the feed handwheels are shrouded and the sliding ways protected by bellows-type coverings. An interesting feature of the machine is the provision of a detachable high-speed spindle operating at 13,100 r.p.m., which can be fitted with quills of various sizes for intricate tool and die work. A suitable bracket is provided for mounting the high-speed spindle at the side of the main spindle head, the drive being transmitted by a flat belt from a special pulley fitted to the spindle nose. Other equipment available with the machine includes a cutter-grinding attachment for handling the general range of cutters and a radiusing and angle wheel-dressing attachment for wheel forming.

CHRISTEN SENSITIVE DRILLING MACHINE.

An extensive range of Swiss and Italian machine tools is being exhibited by Acbars, Limited, Cecil House, 57a, Holborn-viaduct, London, E.C.1. An Italian gear-hobber on this stand was described on page 331, *ante*. The Swiss machines on view include centre lathes, milling machines and post and bench drilling machines manufactured by Christen and Company, Limited, Berne; a vertical-spindle surface grinder made by Henri Kaeser, Renens, Lausanne; a turret lathe manufactured by Liechti and Company, Langnau, Berne; and a precision toolmakers' lathe produced by Simonet, Salothurn. The Christen drilling machines on view include a new type which is being shown in this country for the

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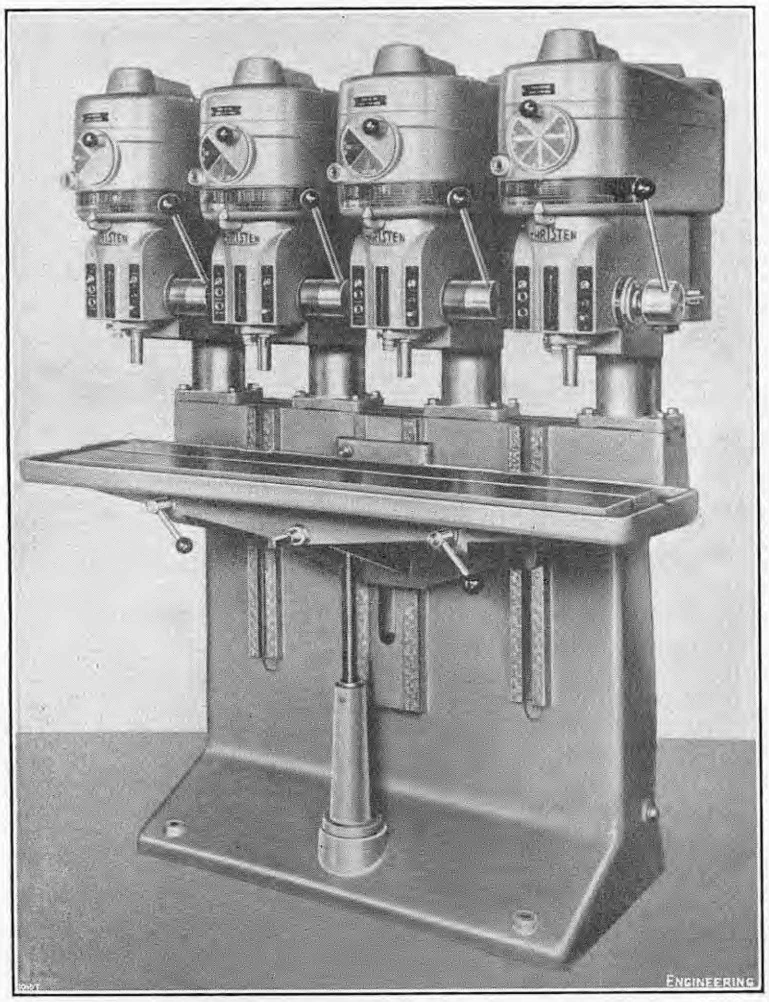

Fig. 44. Christen Sensitive Drilling Machine; Acbars, Ltd.

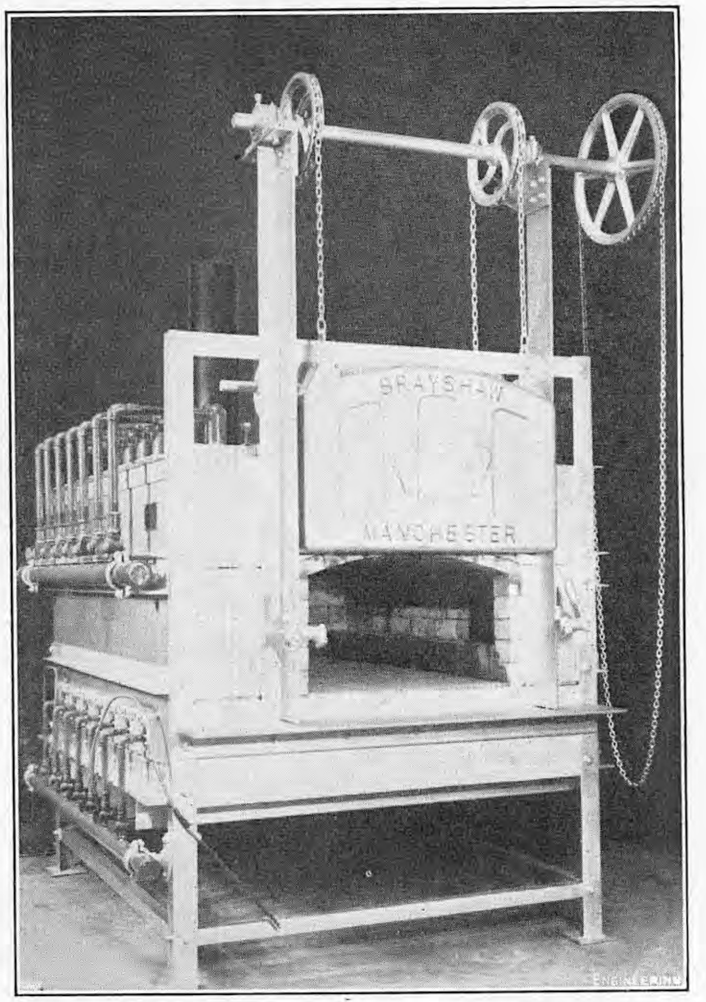

Fig. 45. Recuperative Gas-Fired Oven Furnace; Brayshaw Furnaces & Tools, Ltd.

first time. Known as the Variator drilling machine, it can be used singly or erected in banks on a common base, as shown in Fig. 44, herewith. Each unit is driven by a built-in electric motor arranged to drive the spindle through V-belts and a new type of stepless speed changer designed to give two infinitely-variable speed ranges of from 70 to 700 r.p.m. and 700 to 7,000 r.p.m., respectively. It is claimed that the arrangement used gives rapid selection of the required speed and that, once adjusted, the speed remains constant. In accordance with modern practice, all rotating parts are mounted in ball bearings and the drive arranged so that no belt tension is borne directly by the drill spindle. Downward feed of the drill is by a sensitive hand lever in the normal manner, the spindle being returned by a tension spring; the hand-lever attachment, however, is designed so that the lever can be set at the most convenient working position. The machine is started either by hand or automatically by pressing down the hand-feed lever, the motor being protected by a thermal overload relay. Each spindle head and column is, of course, a separate unit, and they are located in T-slots formed in the base of the machine so that their distance apart can be varied. Two sizes of machine are available, namely, the No. 7, with a drilling capacity in steel of $\frac{13}{32}$ in., and the No. 8, with a drilling capacity of $\frac{7}{8}$ in. Both sizes can be fitted with automatic reversing gear for tapping.

Recuperative Gas-Fired Oven Furnace.

A selection from their range of standard industrial heat-treatment furnaces, together with sample engineer's small tools, is being shown by Brayshaw Furnaces and Tools, Limited, Belle-Vue Works, Manchester, 12. Larger furnace installations which cannot be accommodated on the main stand are dealt with by a photographic display on an adjoining stand, the display covering typical installations of the bogie-hearth, horizontal and vertical-pit automatic furnaces, of the conveyor, pusher and walking-beam types, as well as special process plant and furnaces of the recirculation type designed specially for precision low-temperature heat treatment. Five of the furnaces on view, namely, two oven furnaces, two high-speed steel-hardening furnaces and an air-recirculation vertical-tempering unit, are in operation. The largest standard furnace being shown, a gas-heated Lopress recuperative-type oven furnace, is illustrated in Fig. 45, herewith. This type of furnace is of high thermal efficiency, and has been designed for treating work with the minimum of scaling and oxidation. Generally, they are employed for annealing, hardening, preheating and carburising between temperatures of 650 deg. C. and 1,000 deg. C. Lopress burners suitable for use with town's gas in conjunction with air under pressure are employed, each burner being fitted with separate gas and air controls. The burners are arranged along one side of the furnace so as to permit combustion to take place under the furnace hearth, the products of combustion passing up the opposite side and under the furnace roof to a recuperative chamber situated above the burner nozzles. Low-pressure air is used and this, it is claimed, leads to rapid heating, permits efficient recuperation and gives a positive pressure in the working chamber, thus preventing the entry of cold air. Metal recuperators of a special design are used and they are designed to extract the maximum possible heat from the products of combustion and to be effective immediately the furnace is put into operation. Particular attention has been paid to accessibility: the working parts of the recuperators and burners, for example, are easily removed for inspection and cleaning and, if necessary, this operation can be carried out while the furnace is working, thus avoiding interruption of production. The furnace shown is fitted with a capstan-operated door.

Wet-Honing Attachment.

In contrast to the heavier exhibits of many of the manufacturers are those shown on the stand of Messrs. Delapena and Son, Limited, Zona Works, Cheltenham, Gloucestershire. Their principal exhibits include three Delapena eddy-current heaters having outputs of $2\frac{1}{2}$, 6 and 15 kilowatts, respectively; demonstrations held on the stand show interesting applications of eddy-current heating to such tasks as experimental melting, hardening of gear teeth, sintering of tungsten carbide and brazing operations. A large selection of the firm's internal and external hones, and their "MA" precision honing machine are also being demonstrated, together with ancillary equipment such as their wet honing attachment, shown in Fig. 46, on page 366, which is claimed to make for longer life of the stones and cleaner conditions for the operator. In the same class of work as the honing machine is the industrial cylinder grinding equipment, the complete range of sizes consisting of four separate grinding heads suitable for cylinders of between 1 in. and $14\frac{1}{2}$ in. diameter. Delapena are also exhibiting their torque wrenches, which automatically release when the predetermined torque, set on a scale calibrated in inch-lb., is reached; the capacity of this tool is 1,200 inch-lb.

Cold-Chamber Die-Casting Machine.

The exhibits on the stand of the Projectile and Engineering Company, Limited, Acre-street, Battersea, London, S.W.8, include two new die-casting machines, namely, the Peco Model 2C and the Peco Model 5C. The latter machine, which is illustrated in Fig. 47, on page 366, has a capacity ranging from 13·75 cub. in. with a $1\frac{1}{2}$-in. diameter plunger to 42·20 cub. in., with a $2\frac{5}{8}$ in. diameter plunger. It is a cold-chamber machine suitable for aluminium, magnesium and brass, but the injection unit can, if required, be replaced with a hot-chamber unit suitable for zinc, tin or lead. The machine base

EXHIBITS AT THE INTERNATIONAL MACHINE TOOL EXHIBITION.

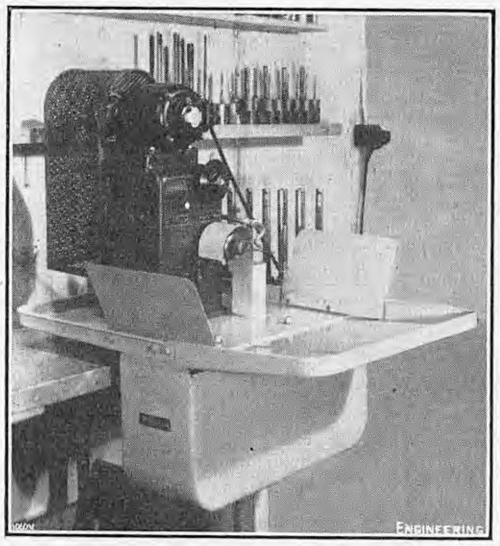

FIG. 46. WET-HONING ATTACHMENT; DELAPENA & SON, LTD.

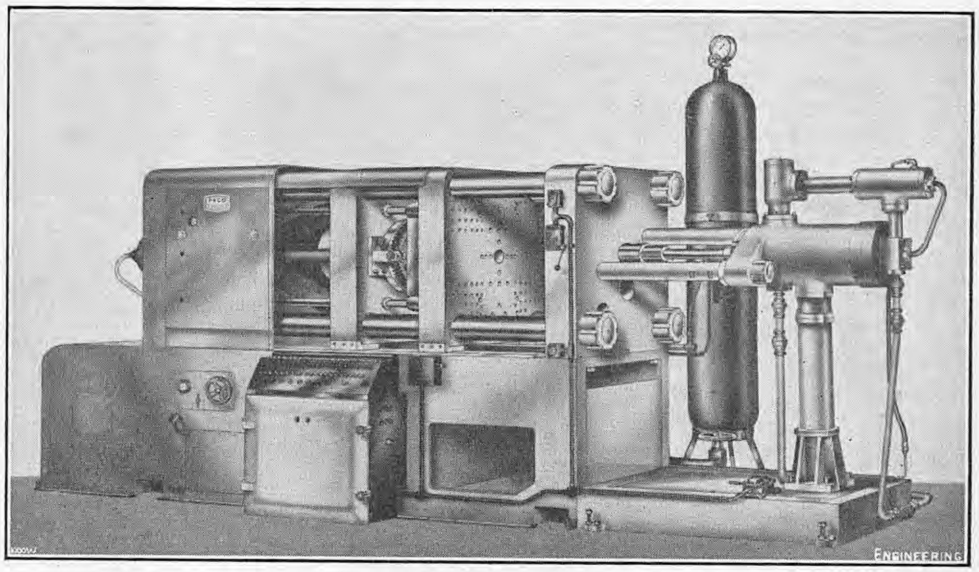

FIG. 47. COLD-CHAMBER DIE-CASTING MACHINE; PROJECTILE AND ENGINEERING CO., LTD.

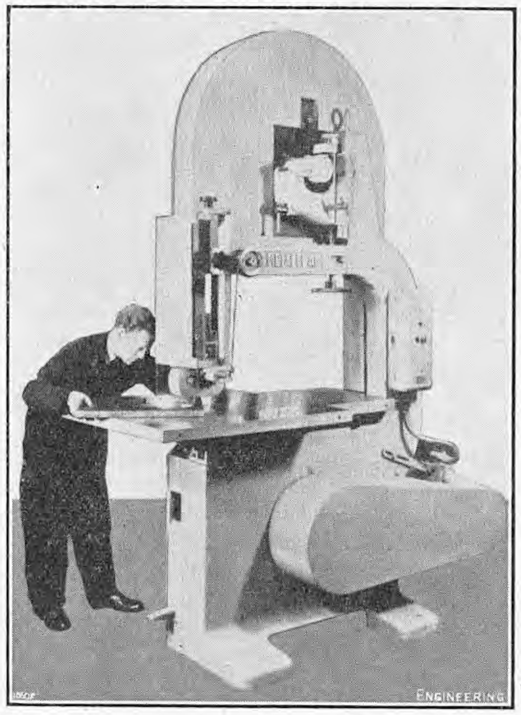

FIG. 48. FUSION-CUTTING MACHINE FOR STAINLESS STEEL, ETC.; METALCLAD, LTD.

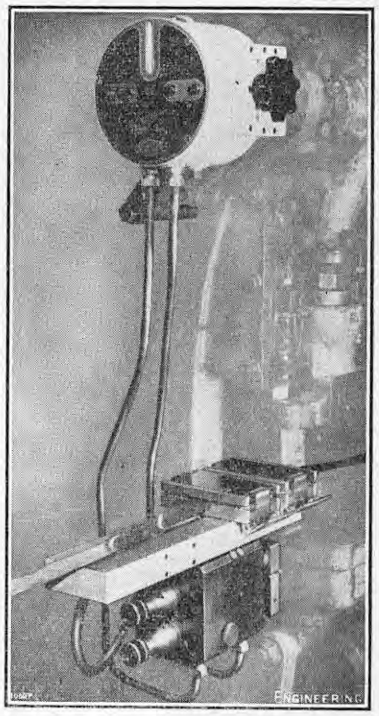

FIG. 49. STRIP-FEEDING UNIT; BIRMINGHAM TOOL & GAUGE CO., LTD.

consists of a robust welded-steel frame with the lower part constructed to form the oil reservoir for the hydraulic system. The electric motor and hydraulic-pump unit are installed in an accessible position at the closing-cylinder end of the base and the control valves on a plate at the rear of the hydraulic base, so that it is only necessary to remove a single cover to gain access to the complete hydraulic circuit, valves, etc.

The locking of the die is achieved by means of a quick-acting toggle mechanism fitted with hardened and ground toggle pins operating in similarly-treated sleeves. Adjustment of the die space is carried out by a 9¼-in. diameter central screw with a buttress thread, the adjustment being effected through an accessible handwheel. The thrust imposed by the hydraulic lock is taken by four high-tensile steel bars 4 in. in diameter, the moving die platen being guided by four phosphor-bronze bushes and the weight taken by two further bearing shoes mounted on the platen and moving on slides incorporated in the base. The injection unit is mounted on a pedestal fixed to the hydraulic base, the main thrust of the unit being taken by two 2¼-in. diameter tie-bars anchored to the fixed platen. Both the injection sleeve and plunger are designed so that they can be removed easily, and the sleeve and the tip of the plunger are made from nitrided heat-resisting steel. The injection-cylinder unit is constructed to give a fast initial rate of injection followed by a high-pressure slow-speed "squeeze," the change from high-speed to high-pressure injection occurring only when the molten metal in the die cavity is consolidated, and is virtually instantaneous.

Particular attention has been paid to the ejection equipment, which has been designed to cater for all foreseeable developments. The ejector cylinder is built into the machine and is capable of exerting a force of 11,000 lb.; it is interlocked with the other machine movements and ejection can only occur at the correct time during the cycle of operations. The electrical sequence-control gear is designed, however, so that the ejector may be used as a central core puller, thus allowing the core to be withdrawn when the dies are closed. Four ejector rods, two at each side of the platen, may be adjusted to strike the ejector plate, from which the ejection movement can be transmitted to the die ejectors through any of a number of holes spaced vertically and horizontally on the platen.

The electrical equipment has been designed to eliminate manual control by the operator and to maintain continuity and uniformity of production. At the same time, care has been taken to keep the equipment as simple as practicable and easy to maintain. All operations are initiated by push-buttons and the sequence in which the various operations take place during the cycle, both before and after injection has taken place, is variable. A system of interlocks is provided, however, which ensures that, when casting, no operation can be initiated until that immediately preceding it has been completed. Although the machine is operated semi-automatically, it is designed so that it can be operated manually when required. Push-buttons are provided for manual control, each one being provided with a lamp which indicates the button to be pressed for the next operation in the cycle. The machine may also be set to by-pass any operation. Several safety devices have also been incorporated in the control system apart from the interlocks already mentioned. To close the die, for example, it is necessary for two push-buttons to be operated simultaneously, the buttons being located so that the operator must stand clear from the die parting line to depress them. A third button is provided at the rear of the machine for use when a second operator is at work on the machine, it being necessary for this button to be depressed as well before the dies can be closed. Should any one of these three buttons be released while the die is being closed, the platen will be brought to rest immediately. The rear operator's button can, of course, be switched out of circuit when not required, and can, if needed, be replaced by an interlocked safety gate. The control system is also arranged so that injection cannot take place until each operation in the die-closing half-cycle has been completed.

FUSION-CUTTING MACHINE.

The most interesting exhibit on the stand of Metalclad, Limited, Foundry-lane, Stanningley, near Leeds, is, undoubtedly, their new fusion cutting machine, which has been developed for the high-speed cutting of metals ranging from mild steel to stainless steel and armour plate. It is illustrated in Fig. 48, above, from which it will be seen that, basically, it is a band saw. It operates, however, on the principle that if a band is run at a sufficiently high speed and exerts a steady constant pressure on the material to be cut, intense heat is generated immediately in front of the cutting edge of the band which plasticises the material at the point of contact thus permitting exceptionally rapid cutting. The blade, or band, moves at upwards of 10,000 ft. per minute so as to generate the high temperatures needed to cut the tougher and thicker materials, but as the blade is moving rapidly through the air, the heat generated therein is dissipated immediately by air cooling. In most respects, the band is of standard form but the teeth are of a special shape and act more as air scoops to take in air which assists in combustion. The machine has, in fact, been operated with a plain band, but the results obtained with a toothed band are better, particularly when cutting thicker materials. After cutting, the metal has a clean edge and requires no further dressing, an important feature so far as stainless steels are concerned, as it is difficult to cut such materials by ordinary means and at the same time obtain a clean edge. It is possible to work to reasonably close limits and circles having a radius as small as 3 in. can be cut in ½-in. thick stainless steel. Substantial savings of time can be effected, savings of the order of 90 per cent. having been recorded. Thin sheets of stainless steel up to ⅛ in. thick, for example, can be profiled as fast as the material can be offered to the blade and ¼-in. stainless steel at over 2 ft. a minute. Stainless steel up to a thickness of ½ in. can be cut at 16 in. per minute, 1-in. stainless steel at approximately 9 in. per minute and 1⅝-in. thick armour plate of 60-ton tensile strength at 3 in. per minute. In its present form, the maximum capacity of the machine is in the neighbourhood of 1½-in. thick armour plate, but the full capabilities have not yet been assessed fully. So far as it can be ascertained, the materials that can be cut by this process are determined by their melting points, the maximum at present being 2,500 deg. C. Pure tungsten, for example, cannot be cut but tungsten carbide can, as the matrix melts. Metals having a low thermal conductivity can, of course, be cut much easier than those with a high thermal conductivity.

As will be seen from Fig. 48, the machine in most respects resembles a standard bandsaw. The main body is a one-piece casting well ribbed so as to eliminate, so far as possible, vibration. Owing to the high speed of the band, special attention has had to be paid to the design of the bearings and the tensioning arrangements. The top-wheel spindle revolves in ball bearings totally enclosed in a cast-iron housing and this unit is supported by a tensioning device which can be adjusted by turning a handwheel. Band-tracking equipment also is incorporated in the top-wheel mounting unit. The bottom-wheel spindle is mounted in totally-enclosed ball bearings and is driven by V-belts from a 12·5-h.p. electric motor. Pressed-steel band-wheels, suitably dished to combine lightness with strength, are employed. They are dynamically balanced and are fitted with vulcanised-rubber rims which act as cushions for the blade and assist in preventing band slip. The guides fitted above and below the cutting station, which give support to the cutting band, are of special design and are fitted with ball-thrust and journal bearings. The machine table, which is 3 ft. square, is rigidly attached to the main frame and the design is such that the maximum width that can be accommodated to the left of the band is 2 ft. 10 in. The top and bottom band-wheels are 3 ft. in diameter and are fitted with brakes. Normally, the machine is brought to rest by pressure on a pedal, but if the band breaks a trip switch cuts off the supply to the motor and both brakes are then applied automatically.

STRIP-FEEDING UNIT.

The exhibits on the stand of the Birmingham Tool and Gauge Company, Limited, Birmingham, include an interesting new type of unit for feeding strip and coil materials to power presses. This unit, which is known as the Productafeed, is illustrated in Fig. 49. It consists, basically, of an impeller, two ½-in. diameter pipes and a slide assembly. The impeller is a positive-displacement oil pump the delivery from which can be varied infinitely; it differs, however, from the generally accepted principle of a hydraulic pump in that it has sufficient capacity to feed the slide unit one complete cycle in one revolution. It is joined to the slide assembly by ½-in. diameter pipes and the slide can thus be mounted in any position on the machine. There are two grippers, one on the slide or moving portion and the other on the stationary portion of the assembly. The gripper fitted to the slide holds the strip by hydraulic pressure and moves forward a positive distance, the stationary gripper remaining open during this period. At the end of the forward movement the slide dwells, during which the grippers change over duties, the slide returning with its associated gripper open while the stationary gripper remains closed. When the slide has returned to its full extent, the cycle is repeated.

The strip can be loaded quite easily as the grippers open out flat in the manner of a book, and when the strip is in position the hinged upper portions are snapped down and automatically locked in the closed position. There is an infinite adjustment from zero to the maximum for the blank pitches and this adjustment is carried out merely by turning a control wheel on the impeller; if necessary, the adjustment can be carried out when the unit is feeding. This is a most useful feature as, when the unit is being used in conjunction with simple tools without pilots, it is possible for the setter to adjust the pitch correctly merely by inspecting the scrap and altering the feed accordingly. The grippers are designed to have a wide area of contact and operate at comparatively low rates of pressure; in the case of the unit used for 6-in. wide strip, for example, the areas of the stationary and moving grippers are 14 sq. in. each. The pressure is imposed on the strip through a hydraulically-loaded pad and, if required, this can be made from a soft material which will accommodate itself to any irregularities on the metal surface. The design of the grippers permits several narrow strips to be fed side by side, or alternatively they can operate through a rigid pad and exert the total load on a narrow strip. Both the stationary and moving grippers can be adjusted separately to give the required gripping load, the limits being from zero to just over 1,000 lb. Full adjustment is provided for thicknesses up to $\frac{3}{16}$ in., and under normal conditions the accuracy of feed is $\pm 0{\cdot}002$ in. The standard unit will feed strip up to 6-in. wide and a maximum thickness of $\frac{3}{16}$ in. but other units capable of handling 9-in. and 12-in. strip are available. Normally, the maximum feed forward is 6 in., the range between this and zero being infinite, but it is possible for units to be made with feeds up to a maximum of 12 in.

ROUNDNESS-MEASURING INSTRUMENT.

Messrs. Taylor, Taylor and Hobson, Limited, Stoughton-street, Leicester, are exhibiting a number of high-quality instruments and machine tools of special value for accurate machining, measuring and testing. The Talyrond roundness-measuring instrument, illustrated in Fig. 50, on Plate XXI, is particularly useful and is described below, but in addition there are displayed a 3-in. turning and thread-chasing lathe, a pantograph milling and die-sinking machine, engraving machines and cutter grinders, an alignment telescope, an autocollimator, and an attachment for use with the firm's Model 3 Talysurf surface-measuring instrument which enables the texture of convex and concave surfaces to be measured.

The Model 1 Talyrond roundness-measuring instrument (Fig. 50) records errors in the roundness of parts such as balls and rollers, ball and roller races, pistons and cylinders. It produces a graph of the type shown in Fig. 51 (actual size), the radial magnification of which is × 4,000, i.e., 0·1 in. on the graph represents 0·000025 in. in depth of the workpiece. A radial magnification of up to 10,000 is possible. To enable general errors of shape to be distinguished from errors due to surface texture, electrical filters are incorporated which eliminate either at will. In Fig. 51, two traces are shown of the track on the outer race of a taper-roller bearing; one, taken with the normal circuit, reveals all errors, while the superimposed trace, recorded with a filter in use, shows more clearly the major errors of shape (i.e., seven lobes), the closely-spaced detail being eliminated. The instrument's range of external diameters is $\frac{1}{16}$ in. to 12 in., and of internal diameters, ⅛ in. to 12 in. The maximum height of specimen is 18 in., the work-table is 18 in. by 23 in., and the distance between the axis of the measuring spindle and the face of the column is 8 in.

An electric displacement indicator, carried on an optically-worked precision spindle of extreme accuracy, is rotated round the inside or outside of the part to be examined, the part itself remaining stationary on the work-table. The signal from the indicator is amplified and then applied to a new form of polar co-ordinate recorder, giving straight radial ordinates on inkless Teledeltos paper. The rotation of the chart is synchronised with that of the indicator spindle. A centring device of new design can be mounted on the work-table to facilitate the initial centring of rings and other small parts. Adjustments situated round the spindle housing provide for fine centring. Provision is made for a limited movement (½ in.) of the work-table relative to the spindle to enable heavy specimens to be set with the minimum of time and effort. The instrument is simple to manipulate, and generally a ring type of specimen can be inserted and centred, and the graph obtained, within a minute or two.

The graph shows the amount by which the periphery of the work departs from a truly circular form, with an accuracy limited only by the residual error in the spindle, i.e., not more than 0·000003 in. To facilitate the assessment of graphs which are not perfectly centred (perfect centring not being essential), a transparent template marked with concentric lines is "floated" over the graph until the best position is obtained. The removable stylus arm is attached to a knuckle joint and can be inclined at any angle to the spindle between 0 deg. and 90 deg., so that cones and shoulders can also be checked. The stylus can be used up to 10 in. below the top of the work.

KODAK CONTOUR PROJECTOR.

The great variety of machines shown by Messrs. Gaston E. Marbaix, Limited, Devonshire House, Vicarage-crescent, London, S.W.11, includes a King vertical boring mill, Barnes vertical honing machines, a Gisholt Fastermatic turret lathe, a Pellow nut-slotting machine, a Colonial Broach Company broaching machine, a Delta Milwaukee centring machine, and two which are illustrated and described here, namely, the Kodak contour projector and the Barnes H4 hydraulic vertical boring machine.

The Kodak model-2A contour projector, shown in Fig. 52, on Plate XXI, is stated to be the most up-to-date instrument of its kind in the world. The design is unique and incorporates several new principles. A clearance of 8 in. is provided between the workpiece and the first lens at all magnifications. Vertical projection can be carried out by the addition of a 45-deg. mirror bracket. The light beam for the episcopic illumination is projected through the first lens of the optical system and enables masked surfaces, deep blind holes, counterbores, etc., to be inspected. A special lens covering the whole screen area provides even illumination and permits operation in normal shop lighting. The magnifications available are 10, 20, 31·25, 50, 62·5 and 100 × The projection lenses are mounted in a turret which is operated by a control knob on the front of the projector; thus no changing of lenses, adjustment of mirrors or refocusing is necessary. The work-table is 21½ in. by 8 in. and has a cross traverse of 4½ in., vertical traverse of 4¼ in. and focusing traverse of ¾ in. Standard accessories, e.g., centres, vice, V-blocks, can be mounted on the table. Micrometer attachments, reading to 0·0001 in., are provided for measuring horizontal and vertical displacements of the work-table. A really sharp image is obtained when projecting workpieces of considerable depth, e.g., wide gearwheels. Various types of screen are available for radii, grid forms, screw threads, etc., and there are also two forms of blank screen on which outlines may be either drawn or scribed. The versatility of the Kodak contour projector makes it invaluable for tool-room and standards-room work, but its robustness and simplicity of operation enable production inspection to be carried out as well.

BARNES HYDRAULIC VERTICAL BORING MACHINE.

Fig. 53, on Plate XXI, shows the Barnes H4 Hydram hydraulic vertical boring machine, in which the drilling tool is fixed near the base, pointing upwards, and the workpiece is rotated by a chuck, in which it is held, and is fed down by hydraulic pressure. It is made by the Barnes Drill Company, Rockford, Illinois, U.S.A., and will take high-speed drills up to 4 in. in diameter. The hydraulic thrust is more than 18,400 lb., and the feed rate is variable between 1 in. and 25 in. per minute. The maximum distance from the spindle nose to the table is 33½ in. The machine on Messrs. Gaston E. Marbaix's stand has been ordered for drilling and boring high-tensile steel billets for jet-engine compressor or turbine shafts. The billet is held in a self-centering three-jaw chuck at the upper end, and its lower end runs in a roller-bearing steady. The whole of the workpiece, steady and chuck is fed downwards, the inverted method of machining easing the extraction of swarf. Coolant is delivered through a hollow boring bar and drill-bit holder; there is also a magnetic swarf conveyor. The advantage of this type of machine is stated to be its ability to machine long cores at high feed rate. The difficulty of producing hollow forgings of small diameter and considerable length, especially where the bore of the forging alters in shape and diameter, is eliminated.

17-in. Swing Precision Tool-Room Lathe.

On page 326 of last week's issue of Engineering, a general note was given on the lathes being shown by Messrs. Dean, Smith and Grace, Limited, Keighley. As we inadvertently captioned the 24-in. surfacing and boring lathe, on Plate XVII, as the 17-in. swing tool-room lathe, we now illustrate the latter machine in Fig. 17, on Plate XXII. It actually swings 18 in. over the bed, 10 in. over the saddle with the guard, and 12¼ in. over the saddle with the guard removed. The spindle runs in plain and roller bearings, with a centre bearing, and is bored 2⅝ in. diameter to take work up to 2½ in. in diameter. In common with the other six lathes on the Dean, Smith and Grace stand, it is fitted with a totally-enclosed feed box with dial change, giving 48 sliding feeds from 14 to 800 cuts per inch, 48 surfacing feeds from 28 to 1,600 cuts per inch, and 48 pitches of thread from 2 to 112 threads per inch. The spindle speeds are 36 in number in the forward direction, from 3·9 r.p.m. to 720 r.p.m., and 12 reverse speeds from 6·9 r.p.m. to 720 r.p.m. The lathe can be fitted for relieving and taper-turning, and can be supplied with two different lengths of bed, for admitting either 36 in. or 48 in. between centres. A wide range of extra equipment is available.

16-in. Swing Combination Turret Lathe.

Messrs. H. W. Ward and Company, Limited, Dale-road, Selly Oak, Birmingham, 29, are showing some representative examples of their capstan and turret lathes, including the No. 7 combination turret lathe illustrated in Fig. 55, on Plate XXII, and described below. The smallest—and the most popular—of the range is the No. 2A capstan lathe, which will take 1¼-in. bars and has a swing over the cross-slide of 6½ in. and over the bed of 11¼ in. The chuck can be either pneumatically or manually operated. The No. 2C capstan lathe, with stainless-steel covers to the bed shears, also takes 1¼-in. bars, but has a maximum swing of 13¼ in. The No. 3A takes 1½-in. bars and has a swing of 13½ in., and the No. 7 takes 2-in. bars and has a swing of 16¼ in. The combination turret lathes being shown include the No. 8 (3½-in. bars and 19½-in. swing), the No. 10 (4-in. bars and 23-in. swing), and the No. 16 (8-in. bars and 35-in. swing); all have covered beds.

The No. 7 combination turret lathe with covered bed (Fig. 55) has been designed to meet the demand for a rigid high-speed machine which will allow the full use of tungsten-carbide cutting tools. It will accommodate bars up to 2½ in. in diameter, through an air-operated chuck, and has a maximum swing of 9½ in. over the cross-slide and 16-in. swing over the bed covers. A machine of similar size—the "Prelector" No. 7 combination turret lathe—which is also on view, is provided with a pre-selecting speed change, which is hydraulically operated and permits a change of speed and direction of rotation simultaneously. The operator rotates the dials in advance, and when the moment comes for the change he simply moves a single lever.

To return to the lathe illustrated: the spindle is carried on roller-journal and combined journal and ball-thrust bearings of large diameter. The ranges of spindle speeds, forward and reverse, are as follow: pulley at 600 r.p.m., 26, 40, 64, 95, 151, 223, 362 and 530; pulley at 840 r.p.m., 37, 55, 90, 133, 310, 312, 506 and 750; pulley at 1,120 r.p.m., 50, 74, 119, 177, 280, 416, 675 and 1,000. The overhead pilot bar is bridged across the headstock, and being clamped at both ends is particularly rigid. Eight stop positions are provided for the surfacing feeds (four in each direction), and six stops mounted on a rotatable shaft provide for tripping the longitudinal motions of the saddle. The taper-turning attachment, which can be fitted if required, is used in conjunction with the cross-slide; any taper up to an included angle of 20 deg. can be turned. Automatic sliding, surfacing and screwcutting are available. The screwcutting motion is obtained from a detachable leader screw and nut, the leader being driven from the gearbox. The bed covers are made of stainless steel, and as they are fixed to the bed they never overhang the bed and are not subject to abuse or accidental breakage. No part of the bed is ever exposed to cuttings. A steel rule is fitted to the front cover, and the turret saddle is provided with an adjustable pointer—features which help the operator when setting-up and making single pieces.

Gear changes cannot be made until the driving clutch is disengaged. As every lever withdraws the clutch and applies a brake before the gears can be moved, speed changes are effected under no-load conditions. Conflicting gears cannot be engaged. The brake, of bonded-asbestos fabric, is incorporated in the guard for the driving pulley, and the machine can be decelerated or stopped from any speed. The spindle, gears and shafts are lubricated automatically by a pump, and as the lower gears revolve in oil, both positive lubrication and splash lubrication are obtained, irrespective of spindle speed. Sight dials are provided to check the oil level and the pump outlet. The sliding and surfacing feeds are operated by the same lever, and it is therefore impossible to engage both simultaneously, opposite motions of the lever being required. An interlocking device prevents the use of the screwcutting motion when either of the other feeds is engaged. The wide and rigid cross-slide is of high-tensile steel and carries a square turret giving four tool positions on the front and one tool post on the rear. A 7½-h.p. motor is recommended when the machine has independent drive.

Portable Hardness Tester.

The exhibits on the stand of Messrs. Firth Brown Tools, Limited, Carlisle-street East, Sheffield, 4, include a machine for sharpening twist-drill points, a sharpening machine for circular saws with Mitia carbide-tipped teeth, an electric metal band-sawing machine, and a very wide range of engineer's cutting tools.

The firm's Hardometer hardness-testing machines comprise a fixed-load type, a variable-load type, and a new double-pillar design which is illustrated in Fig. 56, on Plate XXII. This machine has been designed to meet the need for a machine capable of testing large and bulky specimens. It acts on the principle of the Brinell test, in which the size of the impression provides the measure of hardness and the actual value is obtained from tables supplied with the machine. The load is applied through a calibrated spring and the impression is measured by means of a microscope. The impression may be read without removing the specimen, the indenter head being swung away from the specimen and the microscope automatically taking its place immediately over the impression. The machine can be provided with a baseplate and built-up anvil, and in this form is capable of testing small parts, with the additional advantage of testing wider specimens, the distance from the base casting to the indenter point having been extended to 7 in. As the built-up anvil is fitted with a top plate which is reversible, for flat and V sides, rounds can be tested. The machine is also intended to work suspended over the edge of a bench or table, as shown in Fig. 56, on Plate XXII, two pillars being incorporated for added strength and rigidity. By this means the range of the larger components which can be tested is almost unlimited, as they can be built up from the floor or from a suitable jig or fixture. A further advantage is that the whole apparatus could be made portable by the addition of wheels to the bench. The machine illustrated is fitted with a 30-kg load cylinder which has a range of from 36 to about 800 Brinell; the latter figure is equivalent to 1,150 diamond hardness number. The makers also have a similar machine fitted with a 10-kg load cylinder, which is intended for use on specimens with relatively thin carburised or nitrided surfaces and has a hardness range of from 74 to 1,533 diamond hardness. This machine embraces all the features of the 30-kg model, but, owing to the lighter load employed, a double column is not necessary.

24-in. Diameter Universal Hobbing Machine.

Machine tools for generating, hobbing and shaving gears are being shown on the stand of Messrs. W. E. Sykes, Limited, Manor Works, Staines, Middlesex. Apart from the hobbing machine shown in Fig. 57, on Plate XXII, and described below, there are also the V4 vertical gear generator, for external and internal spur and helical gears, and, if fitted with the appropriate attachment, for racks with straight or helical teeth; the V10A vertical gear generator, which produces a similar range of external and internal gears to that produced on the V4; the 3C horizontal multi-cutter gear generator, one of a range of machines with capacities up to 66 in. in diameter and 18 in. face; the HV14 universal hobbing machine, with a capacity of 14 in. diameter, 9 in. face and 6 diametral pitch, for producing spur and helical gears, worms, wormwheels and splines; and the VS8 gear-shaving machine, one of a range of three sizes designed for accurately finishing spur and helical gears up to 18 in. in diameter by 5 in. face. The stand also displays a wide range of precision gear-shaper cutters, hobs and shaving tools.

The HV24 universal hobbing machine (Fig. 57) has a capacity of 24 in. diameter, 15 in. face and 3½ diametral pitch. There is also a model HV40 with a capacity of 40 in. diameter, 19-in. face and 3 diametral pitch. Both machines are new designs and produce spur and helical gears, splines, sprockets worms and wormwheels. The hob head is mounted on a moving column, the work-table axis remaining stationery. Rapid power traverse, which is provided with both directions of the column and hob-slide movement, is operated by a single lever, with the controls interlocked. Vernier scales are provided for accurate angular setting of the hob head, a micrometer device being fitted for centring the hob, and a large micrometer drum is fitted to regulate the depth of cut. All normal operating controls are conveniently grouped. Lubrication is automatic, a separate motor driving the coolant pump. Optional equipment includes differential feed gear and an interchangeable axial-feed hob head.

(To be continued.)

Lecture Course on Road Safety and Traffic.—We gave, on page 807 of the previous volume of Engineering (June 27, 1952), particulars of lecture courses on road materials and construction to be held at the Road Research Laboratory at various dates from October 14 until February 12, 1953. In addition to these, a course on "Road Safety and Traffic," of seven days' duration, has also been arranged. It will be held from February 24 until March 4, 1953, at the Laboratory's Safety and Traffic Division, Langley Hall, near Slough. The course will include the most recent results of research and thought on factors relevant to road safety and traffic engineering. The fee for the course is 7*l*. 7*s*. Application forms may be obtained from the Director, Road Research Laboratory, Harmondsworth, West Drayton, Middlesex.

Northampton Polytechnic, London.—As stated on page 319, *ante*, leaflets of special courses of lectures of advanced or post-graduate character, to be held during the coming autumn and winter at the Northampton Polytechnic, St. John-street, London, E.C.1, have now been issued. These include a course of evening lectures on "Refractories, their Manufacture, Properties and Uses," to be delivered in the Department of Applied Chemistry by Mr. L. R. Barrett on Tuesday evenings at 7 p.m., commencing on September 30. The fee for the course is 30*s*. The prospectus of the Northampton Polytechnic part-time, day and evening, courses in pure and applied chemistry for 1952-53, is also available. These courses lead to examinations for the associateship of the Royal Institute of Chemistry and the licentiateship and associateship of the Institution of Metallurgists and to other examinations. Courses in fuel technology, metal finishing and chemical engineering are also provided. The autumn term opens on Monday, September 22.

EXHIBITS AT THE INTERNATIONAL MACHINE TOOL EXHIBITION.

(*For Description, see Page* 367.)

FIG. 51.

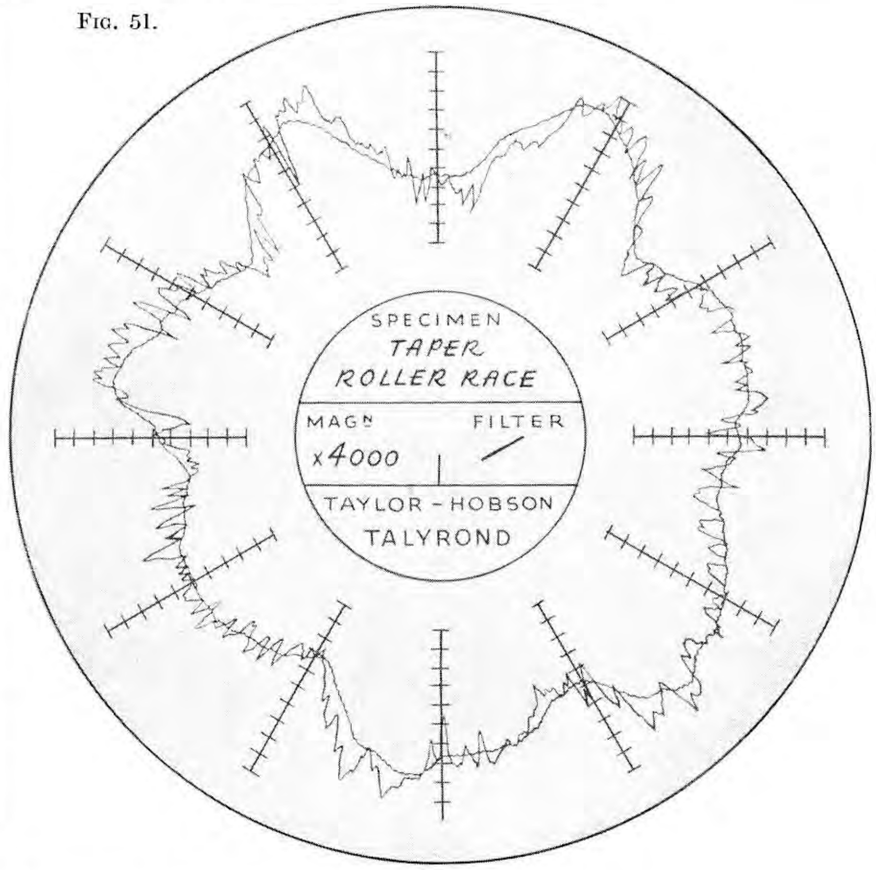

FIG. 50.

FIGS. 50 AND 51. ROUNDNESS-MEASURING INSTRUMENT; TAYLOR, TAYLOR AND HOBSON, LTD.

FIG. 52. KODAK CONTOUR PROJECTOR; GASTON E. MARBAIX, LTD.

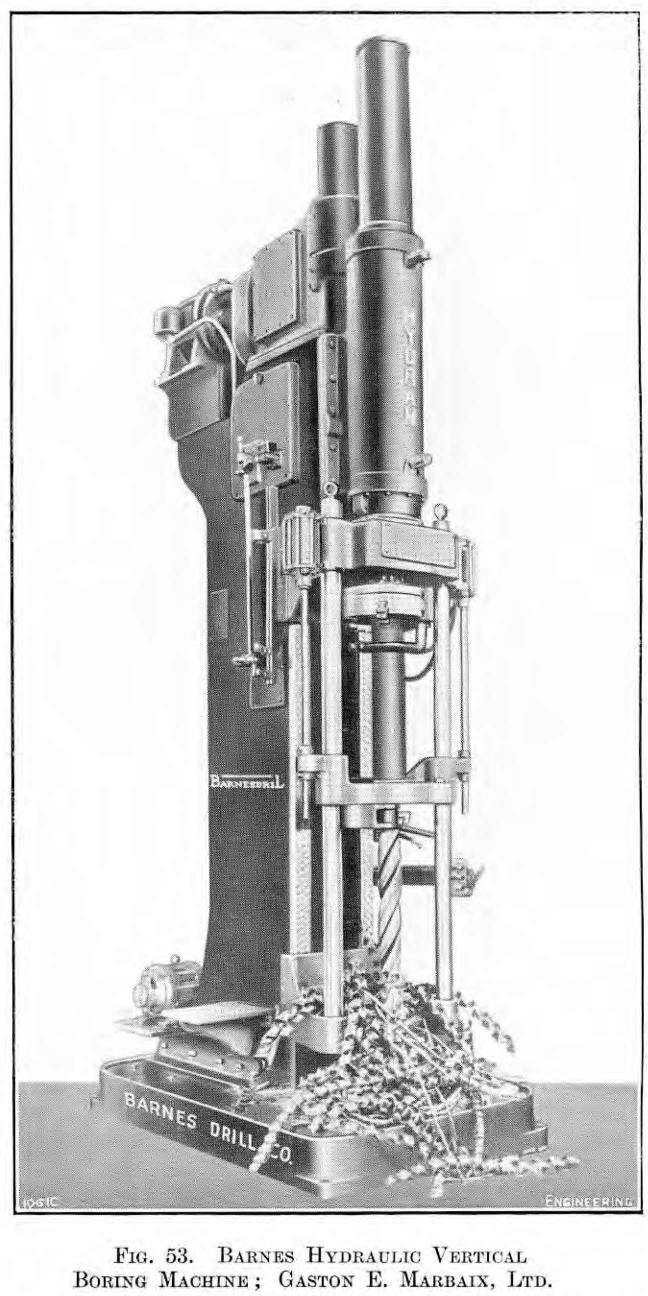

FIG. 53. BARNES HYDRAULIC VERTICAL BORING MACHINE; GASTON E. MARBAIX, LTD.

(To face page 368.)

EXHIBITS AT THE INTERNATIONAL MACHINE TOOL EXHIBITION.

(*For Description, see Page* 368.)

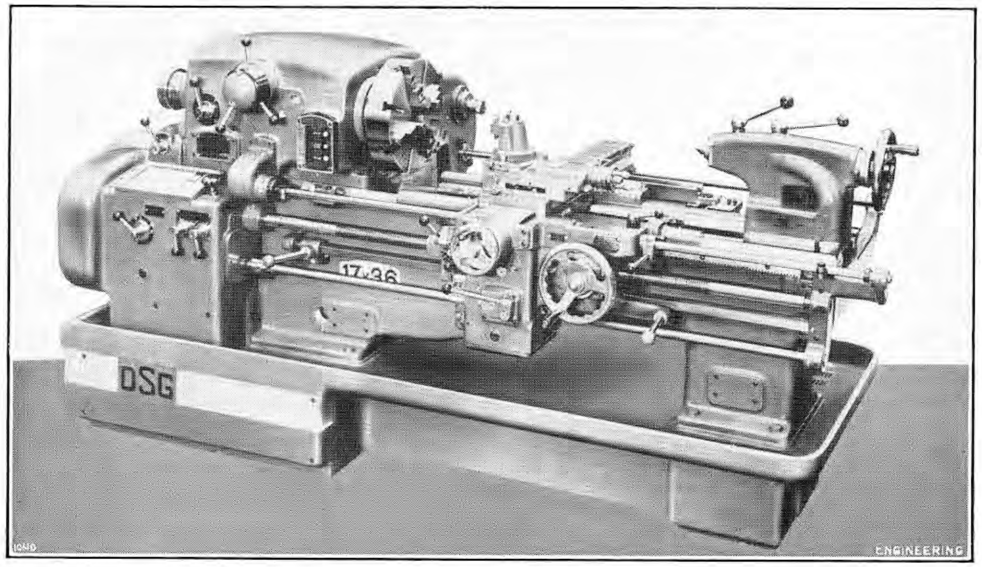

Fig. 54. 17-in. Swing Precision Tool-Room Lathe; Dean, Smith & Grace, Ltd.

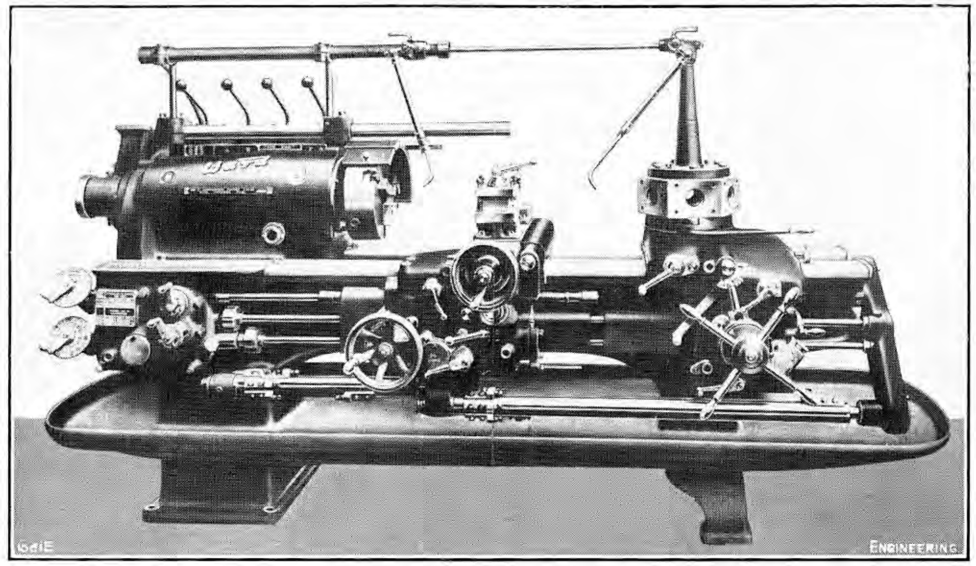

Fig. 55. 16-in. Swing Combination Turret Lathe; H. W. Ward & Co., Ltd.

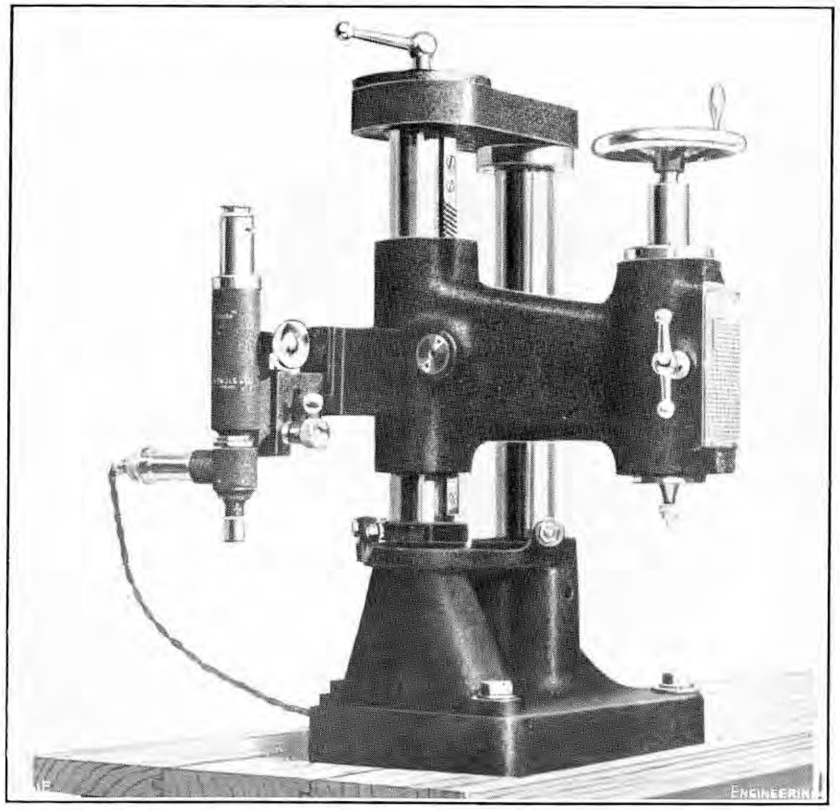

Fig. 56. Portable Hardness Tester; Firth Brown Tools, Ltd.

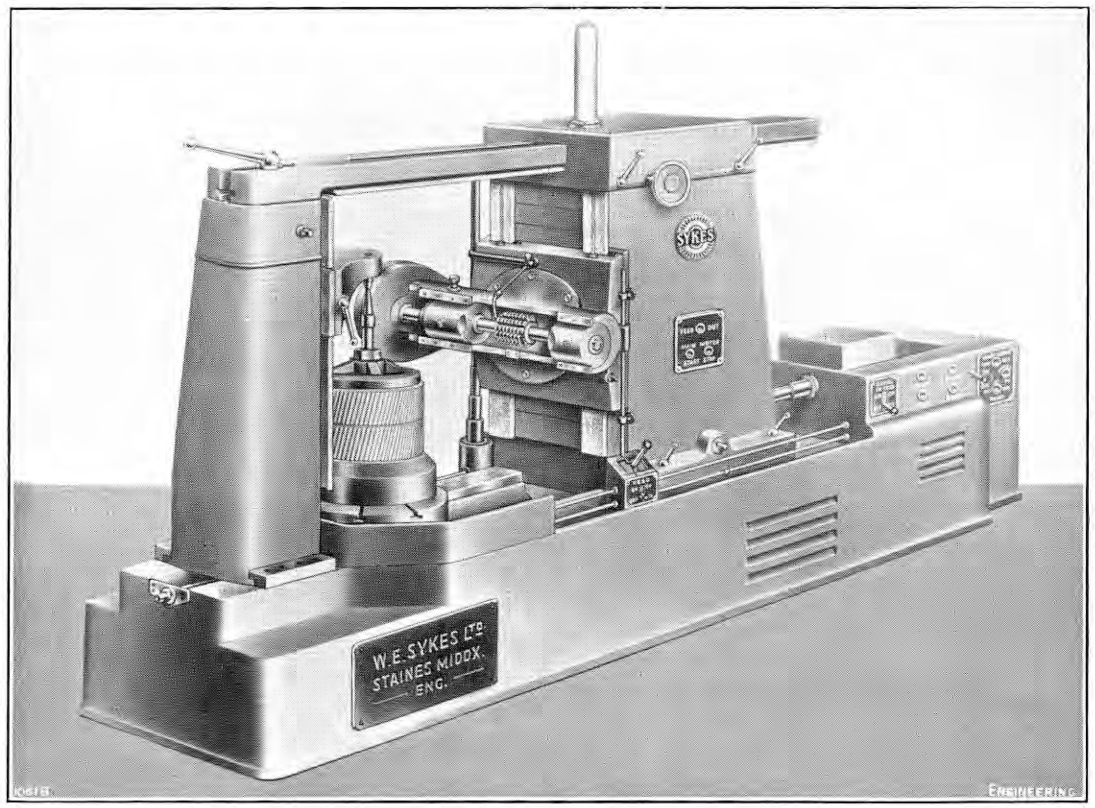

Fig. 57. 24-in. Diameter Universal Hobbing Machine; W. E. Sykes, Ltd.

CENTENNIAL OF AMERICAN ENGINEERING.

(*Continued from page* 346.)

As was mentioned previously, the programme of discussions at the Centennial of Engineering, held in Chicago from September 3 to 13 to mark the centenary of the American Society of Civil Engineers, consisted of two parts. The first of these was a series of public addresses forming a symposium on engineering subjects of broad general interest, the object of which was to stimulate public interest in the achievements of engineers and awareness of the rôle played by them in modern society. The second, and much greater, part of the programme was composed of meetings of over 60 leading American engineering societies each of which had arranged a series of addresses and discussions on subjects of a more specialised character. These meetings were held in various Chicago hotels.

The symposium comprised 12 main sessions and lasted for seven days. On the opening day, September 3, the subject selected was "The Role of the Organised Profession." Seven speakers gave accounts of the development of the main American professional engineering associations, and of their present-day collaboration. The part played by American military, as opposed to civil, engineers was also discussed. The history of the American Society of Civil Engineers was traced by Professor J. K. Finch, Dean Emeritus of the School of Engineering, Columbia University, New York, who extended the scope of his address to include an outline of the evolution of the engineering profession as a whole and also dealt briefly with the founding of the British Institution of Civil Engineers and the Institution of Mechanical Engineers. The history of the American counterpart of the latter, the American Society of Mechanical Engineers, was traced by Dr. George A. Stetson, editor of the Society's publication *Mechanical Engineering.* The major incentive to the foundation of engineering societies, said Professor Finch, had been the desire among professional men for an opportunity to meet others of their own profession, to form friendships and further knowledge by an exchange of views and ideas derived from varied experience. The engineering societies, however, had accomplished much more than this. By insisting on high technical qualifications as a pre-requisite of membership, and by adopting codes of ethics and practice, they had helped to protect the public from charlatans and incompetent persons.

The second day of the symposium was devoted to "Education and Training" and the proceedings included accounts of the history of engineering education and of present-day achievements in this field. The value of technical institutes, as distinct from universities and technical colleges, as a means of ensuring a supply of trained technicians was stressed and the differences between pure and applied research and between the problems of the research laboratory and those of industry were discussed and exemplified. In the final address, probable trends in engineering education were indicated.

On the third day, the symposium was conducted in two parts and visitors had a choice of attending one or other of these. The subjects of discussion were "Food" and "Engineering Tools." In the case of food, the discussion ranged over the world problems presented by the needs of a growing population and the national problem of maintaining the proper balance in the use of land for all purposes. The role of the farmer in the national economy and developments in mechanised farming were the subjects of other addresses. Food processing and distribution, industries of particular importance in Chicago, were also discussed, as was the science of nutrition. The session on engineering tools covered the development and design of small tools and machine tools, and included a discussion of the standards of accuracy required in engineering work and of the methods employed to measure and maintain accuracy.

When the symposium was resumed on Monday, September 8, there were three distinct series of papers which were given in parallel. Moreover, two of the sessions occupied two whole days, so the number of papers was considerable. "Transportation" was the general theme of one of these extended sessions and "Mineral Industries" that of the other. In the third series, "Engineering Structures and Construction" was the topic on Monday, September 8, and "Chemical Industries" that on the following day. There was no discussion on Wednesday, September 10, this day being designated "International Day" and devoted to special functions. Three separate series of papers devoted to the broad subjects of "Communications," "Energy" and "Health and Human Engineering" began on the morning of Thursday, September 11, when the symposium was resumed. The first two of these continued for a further day, but the third gave place to a discussion on "Urbanisation" which was the twelfth and final section of the symposium and occupied the whole of Friday, September 12. In all, 93 main addresses and a number of supplementary papers were delivered at the symposium.

Nearly 1,000 papers were presented during the meetings of the 64 specialist societies who participated in the Centennial celebrations. These meetings took place during the period of the symposium and were supplemented by daily breakfasts, luncheons and dinners at which, also, discussions and, occasionally, special ceremonies took place. The American Society of Civil Engineers held an "Honorary Membership" dinner in the Conrad Hilton Hotel on Saturday, September 6, at which Mr. C. S. Proctor, President of the Society, presided, and the principal guest was Mr. A. S. Quartermaine, President of the Institution of Civil Engineers in Great Britain. At this function, which was the Society's private celebration of its centenary, five distinguished engineers, all of whom were present, were admitted to honorary membership of the Society, and all those seated at the high table were introduced to the company.

Mr. Quartermaine, speaking on behalf of the foreign visitors and delegations, offered congratulations to the American Society of Civil Engineers on attaining its centenary and thanked Mr. Proctor for a previous reference to the valued advice and assistance received by the American Society from its British counterpart at the time of its foundation. He recalled, also, that the first president of the American Society had been James Laurie, a Scotsman, born at Bell's Quarry, in Midlothian, in 1811. He also congratulated the Society on having successfully established itself as the single body representing civil engineers in the United States. An excellent feature of the Society's organisation, he thought, was the large number of student chapters, which stimulated interest in the Society's work among young engineers and provided a link between the Society and the universities and technical colleges. He would like to see similar organisations established in Britain. He also noted with approval the inclusion of courses on the arts and humanities in the curricula of many engineering schools in America. A past-President of the American Society of Civil Engineers, Mr. J. F. Wallace, had remarked in London, in 1900, that the technical schools were actively studyihg the strength of materials, but not the moral constitution of man. He thought that there was a tendency to over-indulge in technology, which should be resisted.

Mr. Quartermaine, continuing, said that engineers were inclined to be reticent about their achievements. One of the objects of the Centennial of Engineering had been to stimulate public interest in engineering and he thought this aim was a worthy and important one. The Centennial had also demonstrated the unity of the engineering profession not only on the American continent but also the world over. Means for maintaining contact between engineers throughout the free world were now firmly established. In Great Britain, there had been joint consultation between the engineering societies of the mother country and the Commonwealth; in America, there was the pan-American union of engineering societies; and now contact between engineers in the Old World and the New was well established. He regarded the present visit of representatives of the Institution of Civil Engineers to America as a happy and historic event. The last occasion on which representatives of the Institution had visited the United States officially was in 1904, and this visit had followed one paid by the American Society to London in 1900, when the delegates had journeyed to Windsor and been received by Queen Victoria. When the American Society of Civil Engineers was founded in 1852, Britain was the leading industrial power and the world's banker; yet *The Economist* had predicted, in 1851, that the industrial expansion of the United States would ultimately eclipse that of Great Britain. This had now become a fact, but it did not mean that Britain's day as a great industrial nation was over. The country which had produced Parsons, Whittle, Watson Watt, and the designers and builders of the Comet and the Canberra was far from finished, and he would like to assure all present that Britain would continue to compete with the other nations of the world as hard as possible, though always in a friendly spirit.

(*To be continued.*)

THE BRITISH ASSOCIATION MEETING IN BELFAST.

(*Continued from page* 335.)

THE BIOLOGY OF FLYING.

THE sectional proceedings commenced on the morning of Thursday, September 4, and the first matter dealt with in Section G, to which we must confine our attention, was a joint session with Section I (Physiology) on the subject of the Biology of Flying. Four papers were read on this subject. They were as follows: "The Biology of Flying," by Dr. K. G. Bergin; "Physiological Problems of High-Performance Military Aircraft," by Group Captain W. K. Stewart; "Skill and the Airman," by Dr. W. E. Hick; and "Engineering Problems of Conditioning Aircraft for Human Occupation and Control," by Mr. D. G. A. Rendel. The chair was occupied by Sir Ben Lockspeiser, K.C.B., F.R.S., President of Section G. The papers, which we summarise below, were not discussed.

Dr. K. G. Bergin, Medical Superintendent of London Airport, first referred to the commonly held misconception of the similarity between military and civil flying, but pointed out that the only common factor was the aeroplane. In military flying, danger was an incentive and economics were of minor importance; in civil flying, safety came first, followed by economy, reliability and comfort and the satisfaction of the fare-paying public. Obviously, many of the problems were closely allied, although the emphasis was different. One of the major problems of civil aviation was the transfer of communicable disease from one country to another. To prevent this, strict precautions had to be taken on an internationally-agreed basis and the World Health Organisation was handling the problem successfully. An allied problem was the transport of invalids and of casualties, but the provision of pressurised cabins and the lesser vibration of jet-engined aircraft enabled the difficulties to be overcome.

One of the problems for the aircrew was that of aviation deafness, which was an irreversible and progressive condition brought about by continual bombardment of the ear by noise. This decline in hearing was experienced by those who flew over long periods, but it was now possible more easily to measure auditory acuity and to learn more about the problem. The deterioration commenced in the higher frequencies on a gradually descending scale, and the first symptom noticed was inability to distinguish consonants and sounds of high pitch. A clear association had been shown to exist between number of hours flown, age and a decrease in auditory acuity. The condition could not be cured, but its onset could be prevented or greatly minimised by the proper noise insulation of the fuselages or the provision of suitable ear protectors. Air sickness was a well-known but not serious problem in air travel; its incidence was 1 per cent. of those travelling by air, and of those who were air sick, 7 per cent. had a psychological background.

The preservation of a high standard of health and physical fitness among the aircrew, he continued, was vital to the safe and efficient operation of an airline. The methods adopted were strict pre-employment medical examinations, followed by regular medical checks; strict attention to the living and feeding conditions, particularly in the tropics; constant supervision of flying duties, flying times, prevention of fatigue, cockpit lay-out, seating, ventilation, humidity, lighting and other factors which affect a man's general state of well-being. It was vital to reduce the load on the pilot as far as possible; there was a multiplicity of controls and instruments which had to be watched and it was incumbent upon engineers to try to simplify the problems with which the pilot had to deal. In conclusion, Dr. Bergin said there was a wide variety of problems of medical interest which demanded attention in the operation of a civil airline.

Physiological Problems of High-Performance Military Aircraft.

In his paper Group Captain Stewart said the problem was the application of the basic medical sciences to flying personnel, to safety and to survival in emergencies during flight. The medical practitioners concerned had established an intimate liaison with engineers and this process of mutual education had played a valuable part in the design of modern aircraft. High-performance military aircraft imposed stresses vastly greater than the powers of adaptation of the human body. In the next decade it might be essential to solve some of the physiological problems before solving the design problems. The physiologist could best aid the engineer by deriving the information required on the useful limits the body could withstand if exposed to a situation which endangered the completion of any skilled task or life itself.

An important problem was created by the physiological and anatomical limitations of the seated body in response to loads imposed by acceleration and deceleration. The body responded to the load at a natural frequency of 12 to 13 cycles per second. That was of the utmost importance when the seat was accelerated upwards, but was of little importance when the aft-facing seat was decelerated so that the load was taken by the back. Where a man was on a seat which was accelerated suddenly upwards, a limit of $20g$ was taken as being a tolerable limit; where an aircraft was decelerated and the man was sitting facing forwards, the original limit was $25g$, but recently the Americans had extended this to over $40g$ in a series of courageous experiments. Where the man was facing aft and the seat was decelerated, and the load was taken on the back, there was virtually no practical limit, for the body was much stronger than the structure of any aircraft. Where the man was pulled downwards and the strain taken on the safety harness, the limit was about $11g$.

Referring to the problems of respiration and gas exchange, he said they were largely concerned with pressurised aircraft, but in the R.A.F. the occupants of pressurised military aircraft had still to be provided with oxygen equipment. This involved many problems, one of them being that related to the mechanics of respiration. The oxygen equipment must be carefully designed, for any feeling of oppression or discomfort could not be tolerated by the pilot. The ventilation volume required for the pilot was about 12 to 14 litres per minute measured at body temperature and pressure, but under conditions of excitement, fear or anoxia both the rate and the volume might increase. The oxygen equipment provided by the engineer must be capable of passing a gas flow of up to 200 litres per minute at back pressures not greater than 2 in. of water, and for normal breathing about 12 to 14 litres were required and the back pressure should be about 0·1 in. of water.

The next problem was that of the ordinary gas exchange in pressure cabins. If pilots flew with cabin conditions equivalent to an altitude of 10,000 ft., undue fatigue, intolerable from the military point of view, was experienced. Without additional oxygen, the crew should not be exposed to cabin altitudes greater than 8,000 ft., and about 5,000 ft. was preferable. At high altitudes, even breathing pure oxygen did not prevent unconsciousness developing if pressure in the cabin was lost. Following explosive decompression at 52,000 ft., consciousness was lost in 10 to 15 seconds, and this was probably the most dangerous limitation to high-altitude flying. If the designer could not guarantee absolute integrity of the cabin—and under military conditions he could not—engineers must provide either a method of escape from the aircraft which could be used within the time reserve before unconsciousness developed, or an artificial atmosphere around the pilot to replace the pressure in some degree. The physiological requirements for escape indicated that the method used must be automatic, imposing the least expenditure of muscular energy either in releasing escape hatches or in clearing the aircraft. It must be in the form of an ejection seat, which must be automatic in function after the pilot had carried out the initial drill.

The possible range of cabin temperatures, the author said, was greater than in any other occupation and could be more than $\pm$ 60 deg. C. The relative humidity of the cabin might vary from 80 per cent. to 5 per cent., according to circumstances. The design of the aircraft might tend to form abnormal temperature gradients so that the pilot might be very warm at his head and very cold at his feet. At different altitudes there might be different levels of heat loss. The designer of the aircraft must be given the details of temperatures a man could withstand.

Inherently, jet aircraft did not demand a much higher skill in pilots than was required a decade ago, but there was a far smaller time latitude in an emergency. The average response time to an ordinary visual stimulus was 0·5 sec., but the average response time to a situation which was anticipated but which required analysis—for which the pilot had been trained—was about two seconds. It was the engineers' task, therefore, to attempt to design the cockpit with those factors in mind. The important switches must be placed where they could be reached with the minimum delay; they must be visible and it must be possible to feel and identify them with a gloved hand.

Skill and the Airman.

Dr. W. E. Hick explained in his paper that the study of piloting skill was a special branch of a wider subject, namely, the properties of the human operation in machine control of all kinds. It was only in the last 12 years that engineers, physiologists and psychologists had come together to try to illustrate the nature of skill in this context. The solution would assist the designer to fit the machine to the man, although it would also affect personnel selection in fitting the man to the machine. The author described the pilot as a kind of computing box, with information being fed into one end, the output being a series of muscular forces applied to various controls. The effects of these forces passed through the aircraft's system and instruments back to the pilot's sense organs. The multiplicity of channels within both aircraft and pilot made the system extremely complex, and it was made even more so by time lags. Nevertheless, it was possible to evolve a differential equation for the human operator performing a task. He emphasised, however, that the brain did not work in a continuous manner; it worked in steps, and the collection of information alternated with its discharge into actions, whether mental or physical.

Flying controls had a large aerodynamic restoring force and the range of movement in accurate control at high speed might be almost imperceptible. With the velocity control it was best to use a lever which had no appreciable movement but to which the operator merely applied force. It did not require skill to press a button, but skill was required in not forgetting to press it.

There was now available a useable definition of a quantity of information; the criterion was not merely accuracy, but accuracy per second. The theories of information and communication dealt with the amount of information which could be transmitted per second through any channel, human or otherwise, but it was too soon to say how far the new theories could be extended. In his own experiments, it had been possible to vary the information, and the average reaction time turned out to be proportional to the amount of information supplied. To react quickly was not merely a matter of speed but of skill, which had to be learned. Reaction time was, in fact, only a particular case of the rate of handling of information by the human organs, and experiments were useless unless there was some means of discovering the rate of error. Danger arose when something abnormal demanded immediate attention, expanding the stream of information beyond the capacity of the human channel to carry it. In those circumstances, some information was delayed, if not lost. The training of pilots to be prepared for all reasonable emergencies could be enhanced by the use of flight simulators on the ground.

Consideration must be given to the least confusing form and arrangement of the necessary controls and to the provision of an automatic device to do something which the pilot might forget to do or might do incorrectly, bearing in mind the expense and weight factor and also the probability of failure of the device itself. The engineer might be able to test the reliability of the device, but he could not normally test the reliability of the pilot in doing the same job. What was required was a method of defining it, and in fact reasonable inferences could be made about human fallibility.

Conditioning Aircraft for Human Occupation and Control.

In his paper, Mr. Rendel said the physiological and psychological difficulties involved in flying at high speeds and altitudes presented the engineer with some unusual problems to which there was no complete or precise solution. Under the atmospheric conditions in which flights were frequently made, life could not be sustained because of the physiological limitations of the human body. The best the engineer could do was to devise systems of control requiring the minimum of acquired skill and to produce an artificial atmosphere in the cabin similar to that encountered near the ground. To condition the cabin adequately, air must be supplied to it at a pressure equivalent to some comfortable altitude, in sufficient quantities to provide the necessary oxygen and at a temperature which would ensure that the heat balance in the cabin was obtained when the air in it was uniformly comfortably warm. For a civil aircraft, the numerical values usually given in this country for those variables were 8,000 ft. equivalent altitude or $10\frac{1}{2}$ lb. per square inch absolute, 2 lb. per minute of air per person and a temperature of between 60 and 75 deg. F. The distribution of air within the cabin was also critical since transparent areas required large quantities of heat to prevent mist and ice formation, while radar and radio sets needed cooling. The control of humidity was important in some cases, particularly where refrigeration was required. The effects of solar radiation at high altitudes and those of air speed and high Mach numbers were considerable and difficult to predict accurately.

For a maximum operating altitude of 25,000 ft. and air speeds less than 400 knots, the problem was mainly that of compressing the air to twice the atmospheric pressure at the cruising altitude, and heating it. This was relatively easy and with turbine-engined aircraft the air supply was at hand. Moreover, life could be sustained for a long time at altitudes below 25,000 ft., so that a failure of the system was not likely to be serious. At higher speeds and altitudes, however, the requirements were more difficult to meet. Increased speed led to large temperature increases necessitating refrigeration. Increasing altitude above 25,000 ft. meant an increase in the pressure ratio across the cabin walls and led to design difficulties. It involved also lower outside air temperatures, increased solar radiation, reduced humidity levels and more serious results of failure. At extreme altitudes, it was possible that the compression of the atmosphere would not itself be enough to maintain life, because the oxygen content would be inadequate. Dealing with noise and vibration, the author said there was little fundamental difference between suppression problems for aircraft and for other vehicles. This might not be so at higher speeds, when noise due solely to passage through the air might predominate. There was no satisfactory way of measuring discomfort due to noise and vibration, which could not be separated.

With regard to the "feel" of controls, he said it was necessary to distinguish between strategic decisions and tactical considerations, the latter concerning the maintenance of control during a manœuvre. Tactical control, in the sense of the completion of a manœuvre, concerned the engineer, whose function it was to design the controls so that the strategic decision could be put into effect as easily and accurately as possible. A more important consideration was the lag between the control movement and its effect. Mishandling of the controls could lead to break-up of the aircraft and the pilot must have some warning indication, which he could not overlook, that this was about to happen. External visual indications were of limited value and as there was no fixed visual datum, rates of change of position could be assessed only instrumentally or through "feel." At high speeds, instrumental indication increased the time delay in the pilot's response, and in high-performance aircraft the number of observations required was too large. For all those reasons, "feel" must be provided to enable the pilot to control the aircraft with the minimum of acquired skill. Control "feel" could be made to vary with control movement, aircraft speed, normal acceleration, or a combination of all three. For large and high-speed aircraft, servo-controls were often necessary and there was no way of assessing whether the "feel" provided was adequate, because the merits of any system could be judged only subjectively.

In a high-speed fighter, capable of withstanding large pressures, the normal accelerations imposed on the pilot could render him unconscious before the strength limit of the airframe was reached, so he must be protected from these effects. If the orthodox seated position was retained, some protection could be given by the application of greater pressure to the lower half of the body than to the upper part. Better protection against high normal accelerations could be given, however, by designing the cockpit so that the pilot was in a lying or kneeling position, where he was much less sensitive to the effects of acceleration. Although the design of such a cockpit presented no fundamental engineering difficulties, consideration had to be given to the pilot's reactions against unorthodox controls and body attitudes.

On the subject of vision, the author said a pilot must be able to see clearly and quickly over the widest possible field; but there were two sets of conflicting requirements. For the maximum field of view, the line of sight must everywhere be perpendicular to the transparencies, which must be extended as far round the cabin as possible; this, however, was in direct conflict with the requirements for optimum aerodynamic shape. There was also the problem of maintaining clear vision through extreme changes in atmospheric conditions, for in a modern fighter the atmospheric temperature could change by over 100 deg. C. in a minute or two, and with the high fuel consumption of the turbine engine, there was little margin for cruising round at the end of a flight while the aircraft temperatures stabilised. There was frequently a large temperature difference between the surfaces of the transparency and the air in its immediate vicinity, leading to misting or frosting, which could be effectively removed only by heat. The methods available for heating transparencies without worsening their properties were complicated and not satisfactory and presented design problems.

Referring to safety equipment, including the design of seats and safety harness, the author said the major objective for the designer of seat harness, and a subsidiary objective for the seat designer, was to protect the occupant in a crash landing from the high accelerations imposed. In 95 per cent. of aircraft crashes in which there had been fatalities, the cause of death was due to head injuries. In high-speed crashes—flying into hills—the accelerations would probably be great enough to cause break-up of the structure. In these cases, accelerations of less than $40g$ were unlikely and structural break-up would lead to injuries to the occupants. In the more controlled type of crash landing it seemed that accelerations were not likely to exceed $25g$, and some aircraft structures could stand more than that. There was, therefore, no object in increasing the strength—and the weight—of seats and attachments above that necessary to withstand $25g$. With the simple lap-strap harness and a forward-facing seat, the human body was not adequately supported to withstand accelerations much in excess of $6g$, but military aircraft were fitted either with rearward-facing seats, in which the body could be supported to withstand $25g$, or with shoulder harness, which improved matters in the forward-facing seat, taking the maximum tolerable acceleration to about $16g$. In existing civil aircraft there was no object in increasing the seat-attachment strength above $6g$ unless either shoulder harnesses or rearward-facing seats were provided, and there was similarly no object in providing those facilities unless the seat attachment was simultaneously increased—with extra weight—because, unless that were done, although the body would be supported, the seats would come adrift. The policy adopted for military aircraft appeared to be paying dividends in saving life in transport operations.

Turning to escape problems from aircraft in flight, as they affected military aircraft, the author pointed out that until 10 years ago a man could climb out of the cockpit, drop over the side and pull his parachute rip cord with confidence. The problem to-day was more difficult. Modern high-performance aircraft had pressure cabins and some part of the cabin structure must be detached before an escape could be made. The man must be able to survive under the reduced pressure and temperature, climb out into the atmosphere, fly through it for a brief period at a speed high enough to tear off his clothing and break his bones, and then descend by parachute. It was difficult to provide a structurally sound canopy in a pressure chamber and at the same time make it so that it could be jettisoned in flight without damaging another part of the aircraft. The man must also be able to pass through the exit at very high speeds and with imposed accelerations without damaging his oxygen supply. It was not physically possible to get out of an exit flush with the fuselage at speeds above 180 knots, nor to reach the exit at all if the normal acceleration was much above $2g$. Having emerged, the man must avoid all other parts of the aircraft and open his parachute at a safe altitude. Above 20,000 ft. the initial opening loads on the parachute were very high and failure was likely if the rip-cord was pulled above that height. At the same time, during a prolonged free fall a man's body performed violent manœuvres, and there was danger of his losing consciousness from this alone, apart from the risks associated with lack of oxygen and low temperature.

The author pointed out, in conclusion, that to meet these risks such developments as ejection seats, shielded doors and hatches, personal emergency oxygen equipment and automatic barometric parachute releases had been introduced. They were of special interest and significance because of their possibilities in the direction of saving life and giving some measure of peace of mind to the sorely strained pilots of military aircraft.

(*To be continued*.)

COMBINED MERCURY-ARC AND TUNGSTEN LAMP FITTINGS.—The General Electric Co., Ltd., Kingsway, London, W.C.2, has designed a combined mercury-arc and tungsten lamp fitting to give a light distribution with almost perfect colour blending. It consists of a housing of No. 20 s.w.g. sheet steel finished in grey stove enamel. This contains reflectors of anodised aluminium and is fitted with skirted lamp holders to which asbestos covered cable is led. The lamp holders are arranged so that either 250 or 400-watt mercury and 500, 750 or 1,000-watt tungsten lamps can be used.

WIND TUNNEL FOR BRITISH RAILWAYS.—A new 100-m.p.h. wind-tunnel testing plant is to be built by British Railways at Derby to provide data for the design of locomotives, carriages, wagons, and railway structures. Among the great variety of subjects to be studied will be improved train ventilation, dispersal of smoke and steam, wind resistance of wagons used in high-speed freight trains, design of draught-proof signal lamps, extraction of smoke from engine sheds, and cooling of Diesel locomotives. The tunnel will be housed in a separate building close to the Railway Research Laboratory. It will be operated by an airscrew driven by a 50-h.p. motor. The tunnel will be of the return-flow type, which enables use to be made of the unexpended velocity of the air as it returns. The new tunnel is expected to be in use by the end of the year.

THE "PRINCESS" FLYING BOAT.

(*Continued from page 293.*)

IN the first of these articles on the "Princess" flying boat, on page 289 of our issue of September 5, reference was made to the "faired" step, a development resulting in considerable aerodynamic and hydrodynamic improvements. The photograph reproduced in Fig. 18, on page 372, which has since become available, shows this feature clearly.

POWERED FLYING CONTROLS.

Because of the size and speed of the aircraft, Saunders-Roe, Limited, decided that manual operation of the flying controls, even as an emergency measure, was not feasible. It was, therefore, decided to provide a duplicated fully power-operated control system (which is tab-assisted to give a maximum hinge moment of 5,000 lb.-ft.) and to take advantage of its irreversibility by eliminating mass- and surface-balancing of the elevator, ailerons and rudder, thereby saving considerably in weight and also in drag. Since, however, pilots are not yet accustomed to the lack of "feel" associated with irreversible control, the system is arranged to feed back artificial feel proportional to the angular displacement of each control surface and to the speed of the aircraft. Extensive precautions have been taken to guard against possible sources of failure, by duplication of the electrical system, power packs, control runs and surfaces, and by automatic safeguards to avoid overloading the structure, to disconnect faulty power packs from the control circuit, and to centralise failed control surfaces. The power for operating the control surfaces is supplied by six identical Boulton Paul hydraulic power packs, each driven by a B.T.H. electric motor. Fig. 20, on Plate XXIII, shows the layout of the duplicated control system. Each half of the elevator is divided into two sections, the two outer sections being driven by one power pack and the two inner sections by another. Thus, should one of the elevator power packs fail, there is still sufficient elevator control available for safe flight and landing. Similarly, the rudder is divided into three sections, the two lower sections driven by one power pack and the upper section by another. The way in which the control surfaces are divided has been dictated by the maximum torque output, 5,000 lb.-ft., of the power packs.

In the case of the ailerons, each aileron is driven by one power pack. This arrangement has been adopted because there is still adequate lateral control on one aileron only, should the power pack of the other aileron fail, and the installation is simpler and lighter than would be the case if the power outputs were divided between the two ailerons, necessitating an additional line of torque shafting in each wing. It will be observed from Fig. 20 that the power packs are all located within the pressure cabin, the rudder and elevator packs in a compartment just forward of the rear pressure bulkhead, and the aileron packs on the forward face of the rear spar. They are, therefore, operating under normal temperature and pressure conditions, and are accessible for examination during flight.

To transmit the pilot's control movements to the power packs, a mechanical signalling system is used. Normal duplicated control columns and rudder pedals are fitted; the lateral, fore-and-aft and directional control movements are communicated to one of three transmitter units (serving respectively the aileron, elevator and rudder systems) through suitable linkages, bevel-gear boxes and torque tubes. From the transmitter unit, the functions of which is described later, the pilot's signal is sent through a cable system, by way of an "input gearbox" and automatic clutches, to the two appropriate power packs, bringing into action the power-pack hydraulic generators and motors. The output of each hydraulic motor is taken through an automatic isolating box, which serves to isolate a run-away power unit from its associated control surface, by declutching and locking the torque shafting which drives the screw-jack actuators operating the control surfaces.

The transmitter unit has three functions. In addition to transmitting the pilot's signals to the power packs, it serves to feed back "feel" to the pilot, and to trim out the loads on the control column and rudder pedals. The transmitter units also provide for cutting out the automatic-pilot servo-motor in the event of the latter "running away." A drawing of the elevator transmitter unit, cut away to show the mechanism, is reproduced in Fig. 19, on Plate XXIII. The pilot's signal at the input shaft is transmitted through bevel gearing to the cable-drum coupling. To provide "feel" or "hardening" of the pilot's controls in response to the angular movement of the control surface, a torsion spring opposes the pilot's signal: the input-shaft movement is transmitted through a quadrant gear to a shaft carrying a crank, the end of which carries a roller engaging in a long slot in a "hardener" lever. The slotted lever is splined to one end of a torsion bar, the other end of which is anchored to a cantilever torsion tube which also forms part of the torsion-spring system. The torsion tube is attached at its forward end to a movable carriage. The effect of the forward speed on the pilot's control loads is reproduced by an aneroid capsule, the inside of which is connected to the airspeed indicator and the outside to the atmosphere. Responding to changes in airspeed, the aneroid capsule operates a switch controlling an electric motor which drives, through an epicyclic gear train, a vertical screw jack which raises or lowers the carriage on which the torsion spring assembly is mounted, and thereby alters the leverage between the input and the torsion bar. A follow-up gear switches off the motor when the leverage has been adjusted to correspond to the airspeed.

Trimming out the loads on the pilot's controls is carried out by taking the load off the torsion bar. The normal type of trimmer wheels are provided in the pilot's cockpit, but instead of operating trimming tabs, as in conventional aeroplanes, each trimmer wheel operates a switch controlling a second electric motor in the transmitter unit. The trimmer motor drives, through a reduction-gear train, twin screw jacks connected to a second slotted lever linked to the tube of the torsion-spring assembly. As the lever is shifted by the action of the trimmer screw jacks, the torsion tube is rotated until a point is reached at which the pilot feels no load on his controls and, therefore, he releases the trimmer wheel, switching off the electric motor.

The Smith S.E.P.I. automatic-pilot servo-motors drive through the input gearboxes before the power packs, so that they feed back to the transmitter unit. If the servo-motor gets out of control and passes signals into the power pack which are more than a specified amount in advance of the control-surface movement, the unit switches off the servo-motor. The mechanism which operates the servo-motor cut-out is mounted on the slotted hardener lever on the torsion bar, so that it is unaffected by the trimming-out of the pilot's loads. It consists of a cam clamped to a spindle mounted in ball bearings; on one end of the spindle is a forked lever engaging with a roller on the hardener lever. When the servo-motor output is more than 2 deg. out of phase with the input, the angular deflection of the forked lever rotates the cam and brings it into contact with a follower arm, thus operating a micro-switch cutting the servo-motor out. It also operates a position transmitter which indicates to the pilot that the cam is displaced from the central position; it is essential that, before the automatic pilot is engaged, the cam roller should be in the central position, i.e., the instrument indicating zero trim.

THE "PRINCESS" FLYING BOAT.

MESSRS. SAUNDERS-ROE, LIMITED, COWES.

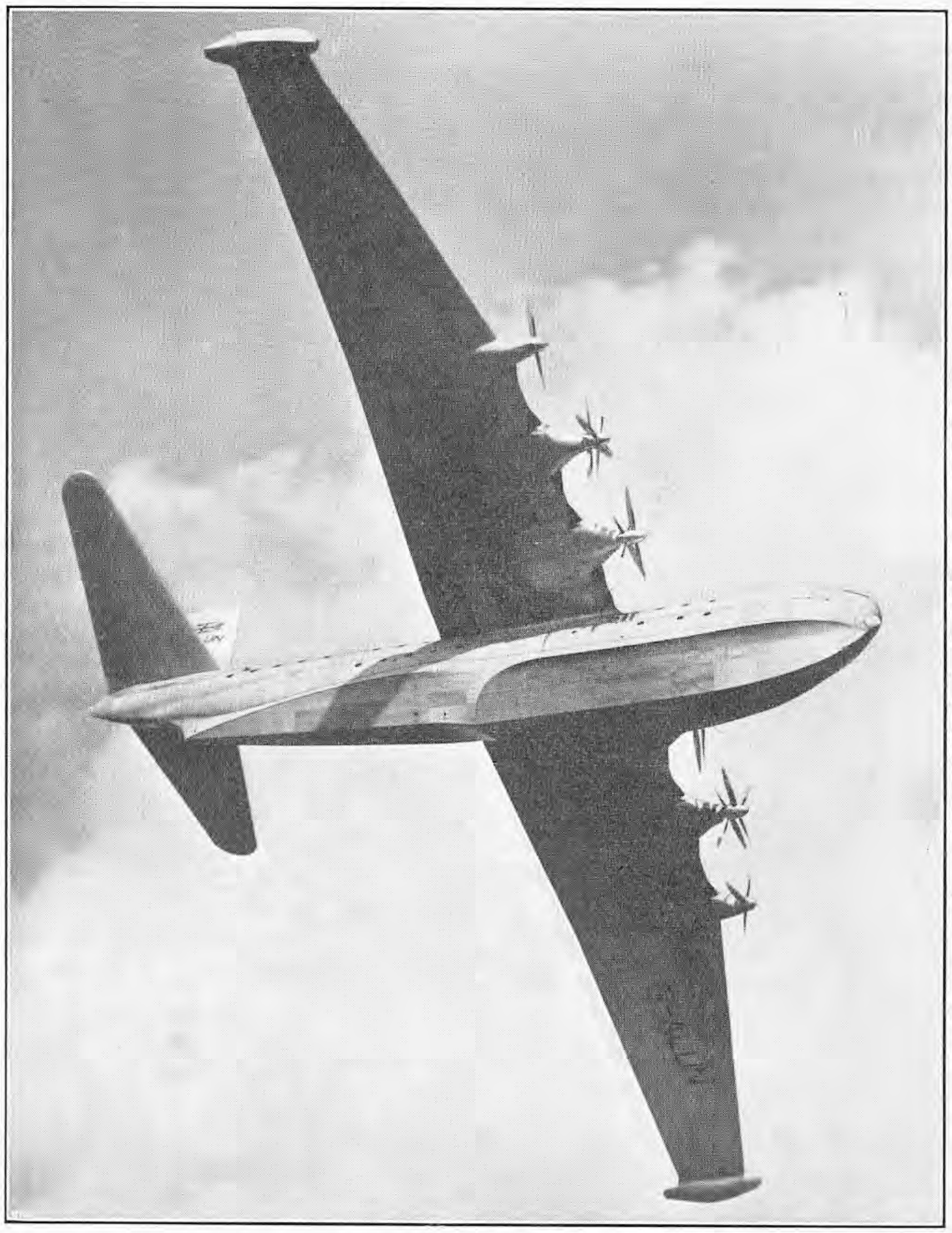

FIG. 18. AIRCRAFT IN FLIGHT.

In each control circuit, two 10-cwt. load cables, preloaded to 30 lb., are anchored at their forward end to a cable drum coupled to the transmitter unit, and at the far end to a cable drum driving the input gearbox. To ensure that both cables share the load equally, a cable tensioner, illustrated in Fig. 21, on Plate XXIII, is incorporated. In the elevator and rudder input gearboxes, the cable drum drives a cross-shaft in two sections connected by a bevel gearbox to which the automatic-pilot servo-motor drive is coupled, through a shear quill, which can be broken by the pilot's manual controls in the event of any jamming of the servo-motor units. Right-angle bevel gearing in each section of the cross-shaft conveys the drive to the input shaft of the power pack. The aileron input gearbox is illustrated in Fig. 22, on Plate XXIII. In this case, the cable drum drives, through bevel gearing, a dividing input gearbox from which cross shafts and further bevel gearing drive the port and starboard power packs. The aileron servo-motor drive is also connected through a shear quill to the driving bevel of the dividing gearbox. In all the power-pack input shafts, a clutch is incorporated, which will slip in the event of the power-pack servo valve becoming jammed, so that the drive to the other power pack can continue.

The input shaft is coupled to a control unit in the hydraulic power pack, which operates a servo valve regulating the strokes of the pistons of a variable-delivery radial piston-pump assembly, constituting the hydraulic generator. The latter, driven by an electric motor, runs continuously, but its output to the hydraulic motor is regulated, in accordance with the pilot's signals, by the servo valve. A relief valve operates when the surface hinge moment exceeds 5,000 lb.-ft. The control unit is driven through a worm and wormwheel, and comprises a cam wheel operating the servo-valve piston through a linkage. A feed-back coupling to the output of the hydraulic motor returns the servo valve to the neutral position when the hydraulic motor has obeyed the input signal, the input coupling remaining in the position determined by that signal. The control-unit cam wheel has two stages of lift, one for normal operation, and one which comes into operation only in the event of "run-away" of the power unit, when it operates a micro-switch cutting out the faulty power-pack electric motor. The hydraulic motor is a reversible

THE "PRINCESS

SAUNDERS-ROE,

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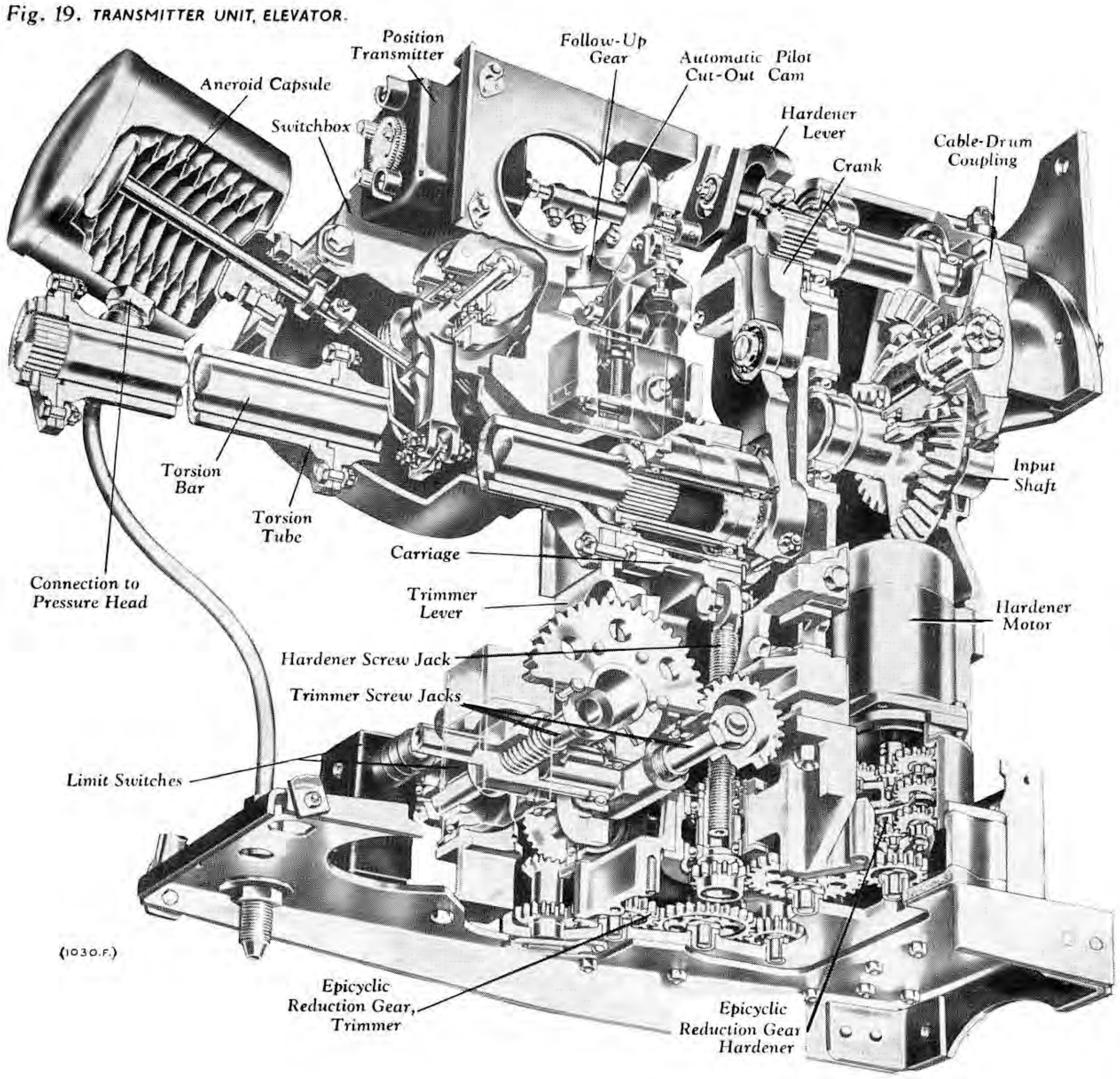
Fig. 19. TRANSMITTER UNIT, ELEVATOR.



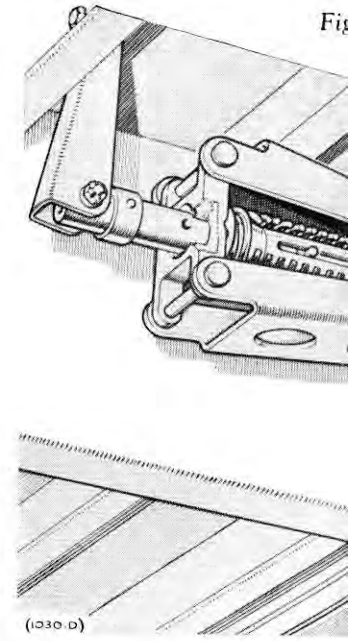
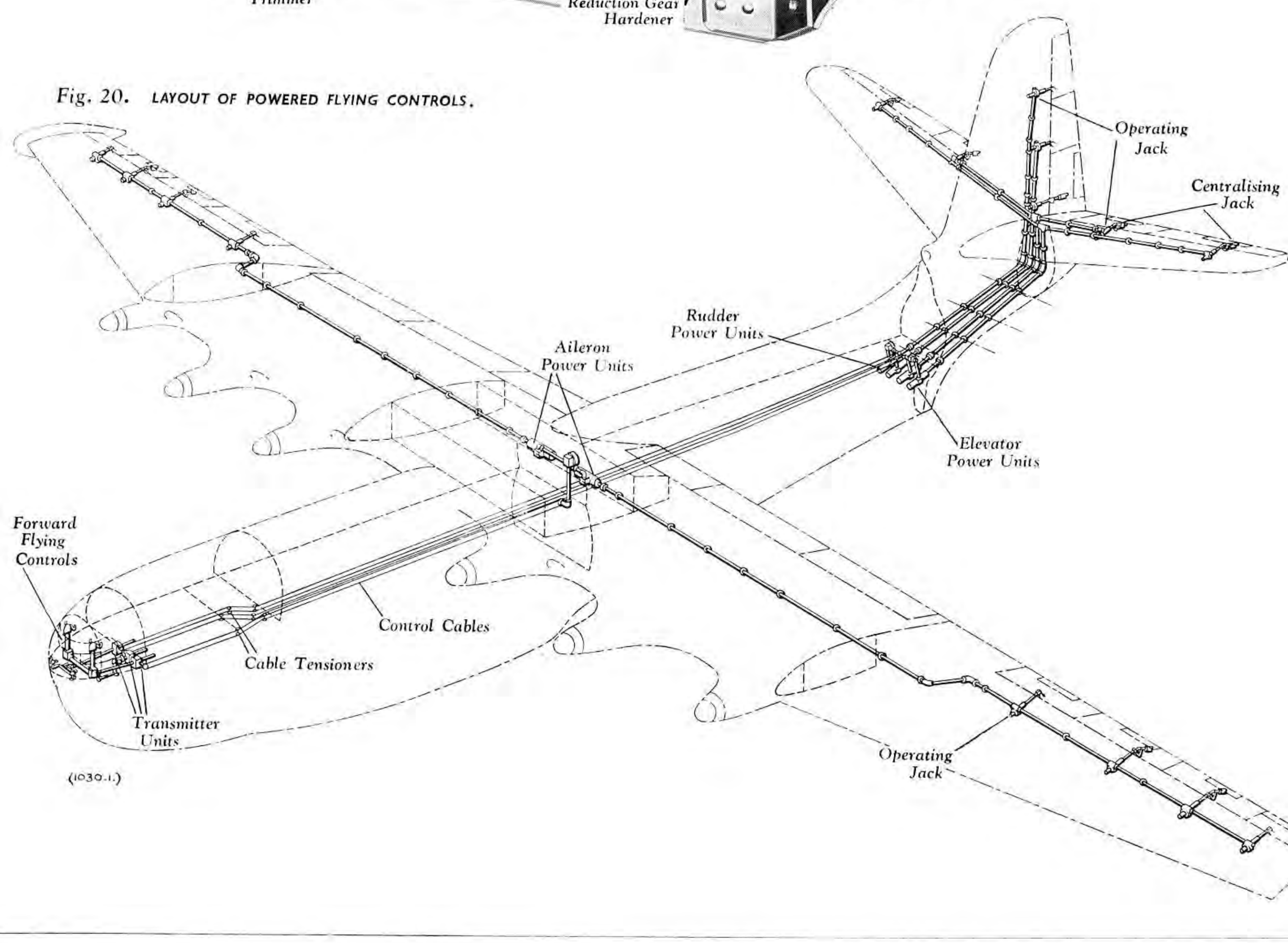


Fig. 20. LAYOUT OF POWERED FLYING CONTROLS.



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FLYING BOAT

MITED, COWES.

(See Page 371.)

. CABLE TENSIONER, AILERON.

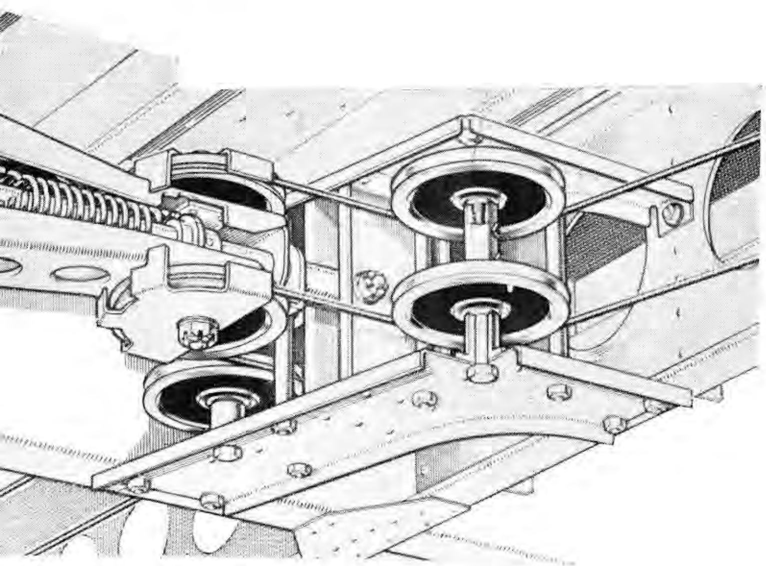


Fig. 22. INPUT GEARBOXES, AILERON POWER UNIT.

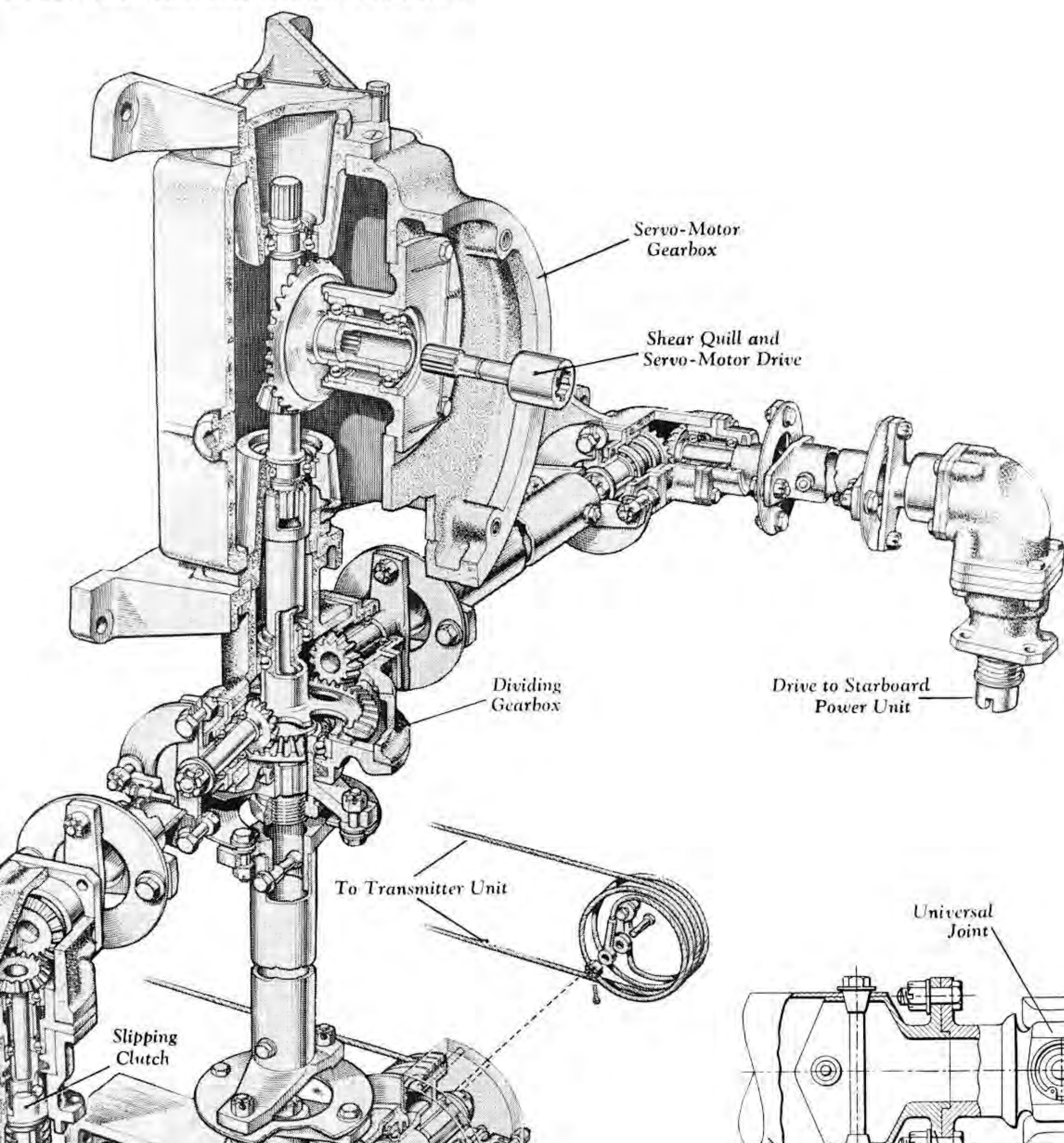


Fig. 23. AUTOMATIC ISOLATING BOX, AILERON.

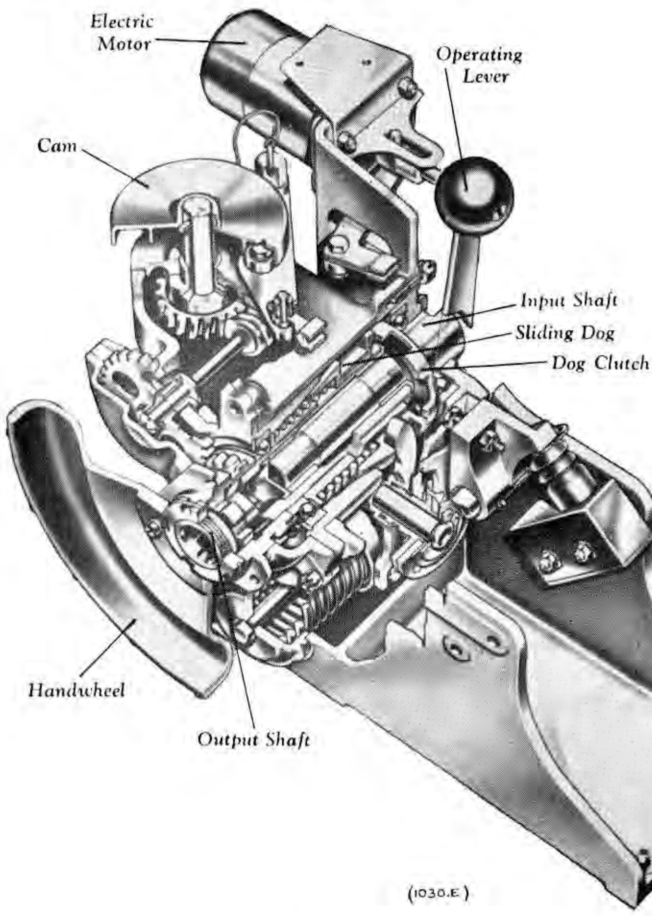
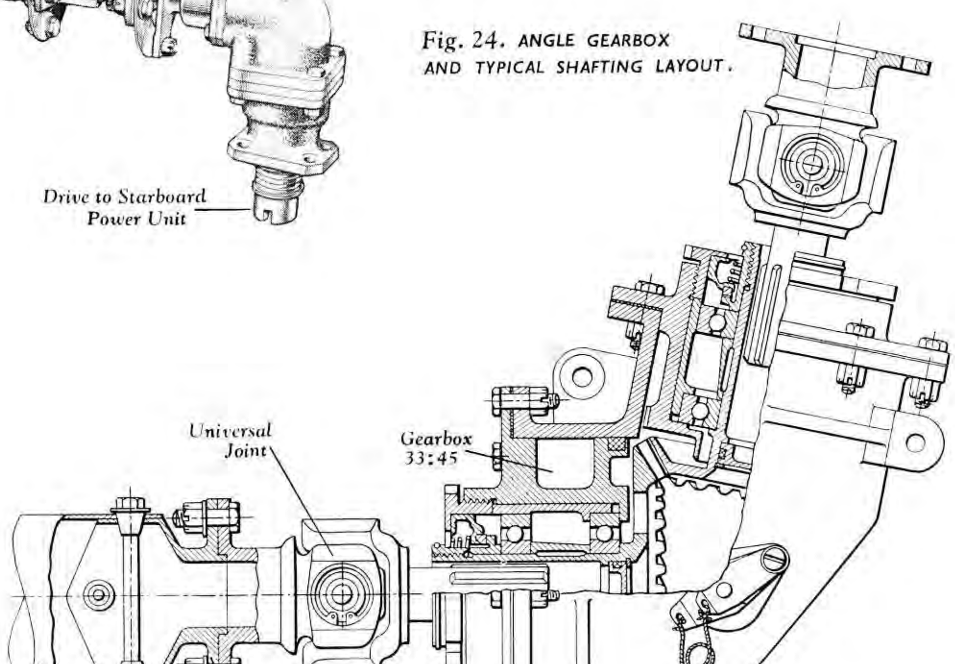


Fig. 24. ANGLE GEARBOX
AND TYPICAL SHAFTING LAYOUT.

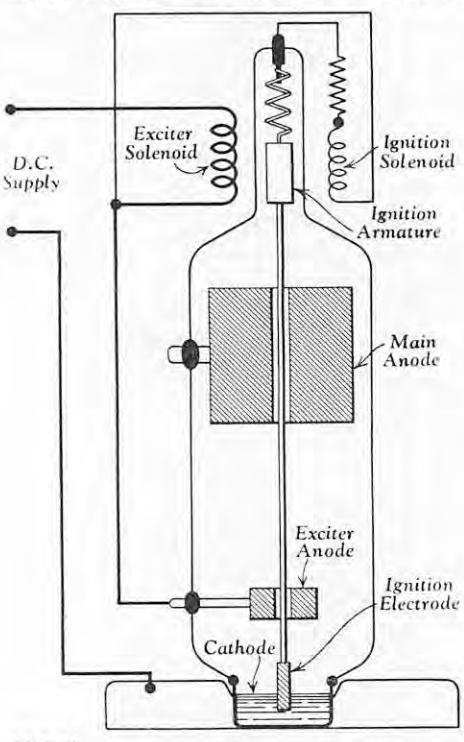


es 372 and 373.)

THE "NEVITRON" MERCURY-ARC RECTIFIER.

Fig. 1.

DIAGRAM OF IGNITION AND EXCITATION SYSTEMS.



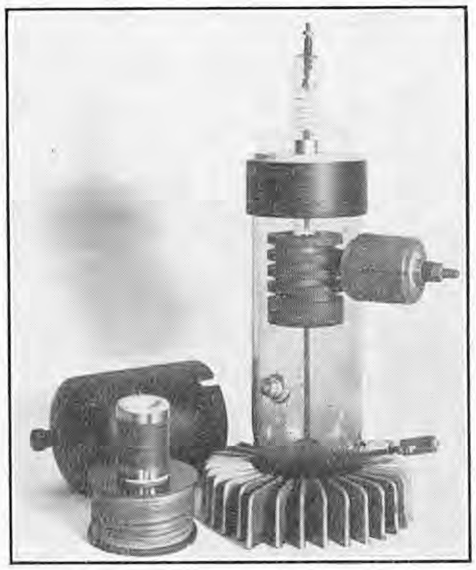


FIG. 2.

radial-piston pump, with automatic locking in the event of failure of pressure.

The output shaft of the hydraulic motor is coupled, through a Saunders-Roe reduction gearbox, to an isolating clutch box. A follow-up mechanism in the gearbox is connected with the feed-back coupling of the power-pack control unit. The isolating clutch box serves to isolate a run-away power unit from the torque shafting driving the control surfaces; the way in which this is carried out can be followed by referring to Fig. 23, which shows the aileron isolating box. The input shaft of the isolating box is coupled through a dog clutch to the output shaft to which the torque transmission shafting is connected. The output shaft drives a cam through a gear train. If, under the action of a run-away motor, the output shaft moves beyond its normal maximum angular position, the cam operates a linkage which withdraws a retaining catch holding a spring-loaded cocking lever. When released, the cocking lever springs back, withdrawing the driven member of the dog clutch and engaging a cone brake. Thus, the drive to the surfaces is disengaged and immediately locked against rotation. Desynn transmitters indicate to the pilot when this occurs by revealing a phase difference between the surface and shaft of the "sound" and "failed" units on the instrument panel. It may happen that the isolating mechanism locks the control surfaces at a high angular setting. Centralising gear, therefore, is provided at certain control surfaces to return them to the neutral position after they have been isolated.

From the isolating clutch box, torque is transmitted to the operating screw jacks at the control surfaces through 6-ft. lengths of 2-in. diameter 20-s.w.g. light-alloy torque tube, supported in self-aligning ball races, and connected together through universal and telescopic joints to allow for structural deflection and thermal expansion. Pressure-tight glands are provided where the shafting passes out of the pressure cabin. Angle-bevel gearboxes (Fig. 24) are provided at stations where the direction of the shafting is changed, i.e., the fin rear-spar frame in the hull, and rib 33 in the wing; and dividing gearboxes take the drive to the various control-surface sections operated by each pack. Standard operating screw jacks, comprising a worm and wormwheel driving screw, are fitted throughout. Variations in the angular movements of the different control surfaces are obtained by suitable transmission gearing and by varying the length of the actuating levers attached to the control surfaces.

Centralising gear is provided on all the elevator sections, but, in order to save weight, only on the lower section of the rudder and the two intermediate sections of each aileron. It is still possible to make turns, even if the sections of rudder and ailerons not fitted with centralising gear are locked hard over. The centralising gear comprises electrically-driven screw jacks, mounted between two subsidiary ribs on the control surfaces concerned, and arranged so as to overcome the normal operating jacks when they are brought into action. The operating-jack lever is mounted on a pivot attached to the control surface, and during normal operation the centralising jack forms a rigid bracing member. When the centralising motor is switched on, the extension of the centralising jack ram [illegible]es the operating jack about the pivot an[illegible]tralises the surface, the main operating jack being "dead" and therefore acting as a strut. The control surfaces are fitted with drum switches which determine the direction of operation of the centralising motors and switch them off when the surface is central.

In the case of the elevator and the two lower rudder sections, the centralising motor is automatically switched on if there is a phase difference greater than 27 deg. between the pilot's control setting and the actual setting of the control surface. This is carried out by a switch in the control unit of the power pack which is actuated when the follow-up mechanism from the output gearbox is out of step with the input valve gear. If, however, the phase difference is a result of a failure between the power pack and the control surface, and not in the power pack, the hydraulic-motor output will still be in phase with the pilot's signal, and the automatic switch will not operate. In that case, it is still possible for the pilot to centralise the surfaces by switches in the cockpit.

The problem of centralising the ailerons is complicated by the fact that one power pack drives all four sections of the aileron. If, therefore, the pilot were to switch on the centralising motors before the automatic isolating box had cut out a run-away power pack, the sections not provided with centralising jacks would be seriously overloaded. To prevent this, as soon as the centralising motor is switched on, the isolating clutch is tripped by an electric motor mounted on the isolating box, which is set in motion by a switch on the power-pack control unit. The motor is switched off automatically by a micro-switch when declutching is complete.

For ground servicing, and in flight if desired, it is possible to centralise all the control surfaces by a handwheel fitted to the output shaft of the isolating box.

(To be continued.)

THE "NEVITRON" MERCURY-ARC RECTIFIER.

THE Nevelin Electric Company, Limited, Purley Way, Croydon, Surrey, have produced an air-cooled single-anode mercury-arc rectifier, known as the Nevitron, in which the losses are lower and the space occupied is less than that of the multi-anode bulbs which are generally available.

The conventional multi-anode rectifier, although highly reliable and possessing a long life, suffers from the disadvantage of requiring a large inactive space for condensing the vapour evaporated from the cathode. The high temperature of the cathode, the long and tortuous arc path from the cathode to the anode, and an arc voltage drop of from 18 to 22 volts, as well as variations in mercury pressure with different load currents, are other drawbacks. It seemed likely, however, that if the cathode spot could be anchored and its temperature controlled the amount of vapour emitted from the cathode pool, and thus the condensation, could be reduced. At the same time, the vapour conditions would be stabilised so that anode shields or long and distorted paths would no longer be necessary to ensure reliable operation, so the arc loss would, therefore, be reduced and the efficiency improved.

To establish the correctness of this theory, the cathode pool was contained in a molybdenum cup, which was sealed to the glass envelope of the rectifier and was surrounded by aluminium cooling fins. As a result, the cathode spot was anchored to the periphery of the mercury pool, provided the molybdenum was satisfactorily wetted by the mercury and formed a concave meniscus. If these conditions are fulfilled, the cathode spot then runs in a continuous line round the edge of the pool, while the cooling system ensures that there is no excessive emission of vapour. A rectifier of this type is illustrated in Fig. 2.

At the same time, a new ignition system was devised to enable the continuous excitation employed in the conventional multi-anode rectifier to be retained and to avoid the use of an ignitor, which might have a short life. A diagram of the system is given in Fig. 1, from which it will be seen that when the circuit is closed a small current flows from the cathode, through the electrode to the solenoid. The electrode is thus lifted from the mercury, causing an arc to be struck between it and the exciter electrode. The ignition current also flows through a second winding which holds the electrode clear of the mercury so long as the excitation current remains at its normal value.

Tests have shown that the performance of the tube is steady and that, owing to the shortness of, and absence of obstruction in, the arc path, the arc-voltage drop is only 12·5 volts, compared with 18 to 22 volts for the conventional type of rectifier. The continuous and overload ratings were also found to approximate closely to the values expected when the Nevitron was designed and it is capable of operating under conditions of considerable vibration and movement and is resistant to damage from accidental shock. The weight of a 50-ampere 500-volt Nevitron is only $2\frac{1}{2}$ lb., excluding the ignition coil. It is stated that, besides replacing multi-anode rectifiers of the conventional type, Nevitrons can be connected in single-phase or three-phase bridge, so that on many motor drives the main rectifier transformer can be eliminated. Grid control tubes with controlled cathode evaporation and a short arc path have also been tested and have exhibited many of the characteristics of the thyratron with much higher continuous loading. In particular, the power required in the grid circuit for full control is only one-thousandth of that for a multi-anode rectifier, thus simplifying the circuits when electronic units are used for grid control.

NOTES FROM THE INDUSTRIAL CENTRES.

SCOTLAND.

THE MECHANICAL ENGINEERING RESEARCH STATION AT EAST KILBRIDE.—The sum of 165,000*l*., equal to one-half of the total building expenditure allocated this year to the Department of Scientific and Industrial Research, is to be spent on new buildings for the Mechanical Engineering Research Establishment at East Kilbride. This was announced by Lord Woolton, Lord President of the Council and chairman of the Department, after his first visit to the establishment on September 10.

TOLLCROSS COKE-OVEN PLANT.—A new coke-oven and by-product plant, designed to make the three blast furnaces at Messrs. Colville's Clyde Iron Works, Tollcross, independent of outside sources for any part of their coke needs, is coming into production this week. The new plant has 67 new ovens in three batteries, making a total of 135 ovens. Production will amount to about 12,000 tons of blast-furnace coke and 1,200 tons of domestic coke a week. The coal-blending plant, in conjunction with the service bunkers, will have a total capacity of 30,000 tons of coal. The new plant has cost 2,300,000*l*.

WICK RADIO STATION.—Wick radio station, enlarged and re-equipped with the most modern apparatus, was officially opened on September 10 by Mr. David Gammans, Assistant Postmaster-General. The station has facilities for communicating on medium frequencies, either by radio or radio-telephony, with ships at sea. It is the most northerly of eleven stations in a link. The station deals primarily with fishing and coastal vessels, and its range extends to Iceland, the White Sea, and Bear Island.

FUTURE OF FIFE COALFIELDS.—The potential wealth of the Fife coalfields was such that Kirkaldy and district would one day at least equal in importance the industrial value of Glasgow in Scotland, stated Mr. F. M. T. Bunney, area general manager of the National Coal Board for East Fife, at Buckhaven Technical College annual prizegiving on September 5. Production, he added, was as yet small, compared with what it would be, but the advance of mining must inevitably mean also the growth of other heavy industries in the neighbourhood.

ROTHES COLLIERY, FIFE.—Members of the Mining Institute of Scotland paid a visit on September 5 to the new Rothes Colliery, being sunk at Thornton, Fife, and descended the No. 1 shaft, which has reached a depth of 1,524 ft. The final planned depth to the lowest working level is 2,820 ft. Heavily-watered strata have been encountered during most of the sinking, and concreting has been adopted. Difficulties have arisen owing to the nature of the strata, which are mostly of white sandstone, peculiarly devoid of fissures into which to inject cement.

TARIFFS OF HYDRO-ELECTRIC BOARD.—The North of Scotland Hydro-Electric Board announced on September 12 that on account of recent increases in the rate of interest, local-authority rates and the cost of coal, materials and labour, they were compelled to increase their charges for electricity by nearly 10 per cent. The prices would apply to electricity consumed from the first meter reading after September 13, 1952.

KINTYRE NAVAL AIR STATION.—H.M.S. Landrail, the Royal Naval air station in Kintyre, closed down as an operation naval station on September 10 and the flying control was taken over by the Ministry of Civil Aviation. It was announced last month that it was closing down as a naval station temporarily for runway construction, but it is now learned that there is little prospect that it will be reopened for naval flying and that the Admiralty have decided not to proceed with the runway construction at present.

CLEVELAND AND THE NORTHERN COUNTIES.

GREENWELL'S DRY DOCK, SUNDERLAND.—The first ship to enter the newly-reconstructed and enlarged dry dock of T. W. Greenwell & Co., Sunderland, is the 15,000-ton tanker, Merchant Knight. The dock will take ships of 32,000 tons deadweight capacity and will be officially opened on October 3. The Merchant Knight is being built by Sir James Laing & Sons, Sunderland, for Messrs. Lydiardopulo & Co., and was launched on June 11. The largest ship yet docked on the Wear was the 16,750-ton Charlton Venus, which entered Greenwell's No. 2 dock.

COUNTY DURHAM DEVELOPMENT EXHIBITION.—At the opening of an exhibition in Durham Town Hall dealing with the 324,000,000*l*. development plan for County Durham drawn up by the County Council, it was suggested that new industries for about 43,000 people might have to be established in the county if the present population were to be maintained. The exhibition was opened by Lord Lawson, the Lord Lieutenant.

NEWBIGGIN COLLIERY.—The proposed closing of Newbiggin Colliery, Northumberland, is to be postponed. It was originally decided that the colliery should close by 1956, the miners to be transferred mainly to the expanding colliery at Lynemouth. About 400 miners have so far been transferred to Lynemouth, but the Coal Board have informed the miners that the closing of Newbiggin will be deferred for at least six years. This step, it is understood, is due to the placing of about 100 miners at Lynemouth from Woodhorn Colliery. It is reported that the Coal Board are to drive two drifts into a 5-ft. seam at Newbiggin. The miners at Newbiggin Colliery have actively campaigned against the closing of the pit, since the plan was announced three years ago, though the closing had the support of the Northumberland Area of the National Union of Mineworkers.

PLASTIC CONVEYOR BELT IN COLLIERY.—Experiments are being made at Horden Colliery, County Durham, with a plastic conveyor belt which, it is believed, will considerably reduce the possibility of underground fires caused by friction on conveyors. Devices have been fitted to conveyors at the colliery which cut off the electric power if a conveyor is slowed down for any reason.

THE LATE MR. J. M. MANSON.—Mr. James McDonald Manson, former general manager and secretary of the Tyne Improvement Commission, died on September 11 at Worthing, Sussex, at the age of 86. He joined the Commission in 1900, having been previously on the staff of the Mersey Docks and Harbour Board, and, from 1911 until his retirement in 1922, was general manager and secretary.

LANCASHIRE AND SOUTH YORKSHIRE.

POST-ADVANCED LECTURES IN ENGINEERING.—The Manchester and District Advisory Council for Further Education, Education Offices, Deansgate, Manchester, 3, have now issued their brochure relating to "Post-Advanced Lectures in Electrical and Mechanical Engineering," covering the session 1952-53. This contains details of courses of an advanced or special character available at the College of Technology, Manchester; the Royal Technical College, Salford; the Bolton, Crewe, Horwich, Oldham, and Warrington Technical Colleges; the Stockport College for Further Education; and the Wigan and District Mining and Technical College. Copies of the brochure are obtainable on application to the honorary secretary of the Council at the address given above.

OPEN DAY AT HUDDERSFIELD FACTORY.—Approximately 1,000 people attended on "open day" at the Lee Mills, Scholes, Huddersfield, factory of David Brown & Sons (Huddersfield), Ltd., on September 6. Purchased in July, 1951, the works have been adapted to provide various service facilities for the factories within the David Brown organisation, including the reconditioning of machine tools, the reconditioning of electrical equipment and the re-winding of electric motors, and the servicing and rebuilding of typewriters. A section for the service and overhaul of vehicles is scheduled to open early in 1953. Formerly a textile factory, Lee Mills has now 120 employees. Among the features which attracted most interest was an old but still efficient beam engine, which now drives a 230-kVA generator to supply power for the works.

LIGHTER INDUSTRIES WANTED IN CHESTERFIELD.—Chesterfield is anxious to have established light industries which would provide employment for elderly people who can no longer work in heavy industries. The matter has been taken up by the Chesterfield and District Committee of the East Midlands Board of Industry, who have asked the Board of Trade to assist in the matter.

INCREASE IN UNEMPLOYMENT.—During August the number of unemployed in Sheffield increased by 130 to 2,151, due, it is believed, to many works being closed for the annual holidays and applicants for employment having to wait for their re-opening. The total included 1,040 men and 836 women. Sheffield's percentage of the working population unemployed, at 0·9 per cent, however, is well below the East and West Ridings' average of 1·7 per cent., and the national average of 1·9 per cent.

METAL MACHINING LECTURES.—A series of lectures on the machining of metals has been arranged by the Sheffield University Department of Mechanical Engineering for advanced students and industrial technologists. Every aspect of metal machining will be dealt with in weekly lectures which are to commence on October 2, and the lecturers will include Mr. J. Woolman of the Firth-Brown Research Laboratories, Mr. F. C. Turner and Mr. B. Wilcock of Sheffield University, and authorities from the Production Engineering Research Association, the Royal Technical College, and other establishments and firms.

PATENTS LIBRARY.—The Manchester Public Libraries have issued a brief guide to the patents collection in the technical library, compiled by Mr. J. E. Wild, to assist readers in finding patents. The Technical Library Patents Collection is at Central Library, St. Peter's-square, Manchester, 2.

THE MIDLANDS.

FUEL ECONOMY SCHEME.—An advisory panel of fuel experts is to assist industrialists in the Derby area, through a fuel-economy mutual-aid group, to achieve an overall economy of five per cent. a year in the consumption of all forms of fuel and power. Trade unionists are included in the panel. It is computed that a saving of 25,000 tons of coal is probable. Letters are being sent to 125 firms whose consumption of fuel was from 100 to 250 tons a year, and it is hoped that they will take advantage of the opportunities afforded to endeavour to save fuel.

MINES INSPECTION IN THE MIDLANDS.—The 1951 report of Mr. H. S. S. Scott, H.M. Inspector of Mines, West Midland and Southern Division, published on September 8, shows that the number of fatal accidents in the area decreased by eight compared with the previous year's total. The overall reduction in the fatal accident rate since 1949 has been nearly 40 per cent., but, the report adds, this improvement has been offset by an increase in the number of serious non-fatal accidents. Of mining methods and equipment, Mr. Scott reports that several developments have taken place, including the installation of an Anderson Boyes dirt-stower on a longwall face in the Cannock Chase coalfield. The future working of that coalfield will be facilitated by the work which is being done on mapping the extent of the glacial drift and unconsolidated deposits, and the report records considerable progress in this direction. Drainage of methane gas by means of boreholes has been tried at Stafford Pit, Stoke-on-Trent, where it has made possible the working of at least one panel of coal which otherwise might have had to be abandoned.

POSTPONEMENT OF RAILWAY CLOSING.—The Railway Executive have postponed the closing of the branch railway between Malvern and Upton-on Severn, Worcestershire, which was due to take place on September 15. A meeting of the West Midlands Area Transport Users' Consultative Committee is to be held on September 23, and deputations from Malvern will put their case for retention of the train services. The Midland branch of the Railway Development Association recently made a special study of the branch line, and reported that, though the traffic is light and a steam train service would be expensive to operate, the use of a Diesel car would be justified.

DIRECTORY OF FURTHER EDUCATION.—To provide easily accessible information about the many facilities for further education available in the West Midlands, a directory has been prepared, giving a list of all senior institutions in the area, with details of the full-time and part-time day and evening classes conducted. The directory is issued by Mr. J. Lord, secretary of the West Midlands Advisory Council for Technical, Commercial and Art Education, 141, Great Charles-street, Birmingham, 3.

THE B.R.M. COMPANY.—At a meeting held at Stratford-upon-Avon on September 4, it was decided by representatives of the firms which supported British Racing Motors, Ltd., that the company should be offered for sale as a going concern. After the meeting, Mr. A. G. B. Owen, chairman and managing director of Rubery Owen & Co., Ltd., Darlaston, who is chairman of the B.R.M. Trust, would neither confirm nor deny rumours that he would take over the firm.

THE LATE MR. G. STEVENS.—The death occurred on September 11 of Mr. George Stevens, of Wolverhampton. Mr. Stevens, who was 73 years of age, was one of the founders of the former firm of A. J. Stevens, makers of the A.J.S. motor cycle. After that company ceased to exist, he became a member of the firm of Stevens Brothers (Wolverhampton), Ltd.

SOUTH-WEST ENGLAND AND SOUTH WALES.

WELSH PIG-IRON PRODUCTION.—A new record was established for pig-iron production in South Wales during August, when the weekly average output was 32,530 tons. The previous best was 31,210 tons weekly in July last, while the comparative figure for August, 1951, was 25,700 tons. The weekly average production of steel ingots and castings in August, however, totalled only 63,200 tons, against 72,570 tons in July.

WELSH INDUSTRIES FAIR.—The Welsh Industries Fair, organised by the National Industrial Development Council of Wales and Monmouthshire, was opened by Sir David Maxwell Fyfe, Home Secretary and Minister for Welsh Affairs, at Cardiff, on September 10, and remains open until September 20. Sir David said that more than 250,000 people in Wales were working in manufacturing industries, an increase of 80 per cent. over 1939, but, he pointed out, this change in the industrial structure did not minimise the importance of the basic industries. Products of 49 firms, from all parts of the Principality, are on view at 65 stands.

OPERATIONS AT SWANSEA DOCKS.—Swansea Docks recently handled its largest weekly tonnage of general cargo since the war. For the week ended September 6, 33,380 tons were dealt with from 33 vessels—24,698 tons inwards and 8,682 tons outwards. The new motorship Kowhai, owned by the Union Steamship Co., Ltd., New Zealand, left Swansea Docks on September 10 on her maiden voyage to Napier, New Zealand. She took tin-plates and general cargo.

SOUTH-WESTERN DIVISION OF COAL BOARD.—The financial results of the South-Western Division of the National Coal Board for the second quarter of this year show a loss of 178,438*l*., or 6·8*d*. per ton. The main coalfield in the division, however, that of South Wales and Monmouthshire, made a profit of 80,235*l*., equivalent to 3·2*d*. per ton, but this was offset by losses in the Forest of Dean coalfield of 100,417*l*. or 11*s*. 0·9*d*. per ton and in the Somerset coalfield of 158,256*l*., or 23*s*. 5·9*d*. per ton. The total production for the division was 6,308,596 tons, of which 5,992,490 tons were brought up in the South Wales and Monmouthshire district, 181,353 tons in the Forest of Dean, and 134,753 tons in Somerset.

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 MINING AND METALLURGY.—Monday, September 22, 5 p.m., Royal Institution, 21, Albemarle-street, W.1. Third Sir Julius Wernher Memorial Lecture on "Radioactivity in Mineral Dressing," by Professor A. M. Gaudin.

INSTITUTION OF WORKS MANAGERS.—*Northampton Branch:* Monday, September 22, 7 p.m., Franklins Gardens Hotel, Northampton. Discussion on "Computing Overheads or Costings." *Glasgow Branch:* Monday, September 22, 7.15 p.m., 39, Elmbank-crescent, Glasgow, C.2. Annual Meeting. "Impressions of American Industry," by Mr. J. C. Campbell.

INSTITUTION OF PRODUCTION ENGINEERS.—*Derby Section:* Monday, September 22, 7 p.m., College of Art, Green-lane, Derby. "Starting a New Factory," by Mr. A. R. Northover. *Manchester Section:* Monday, September 22, 7.15 p.m., College of Technology, Sackville-street, Manchester, 1. "Measurement of Productivity," by Mr. B. H. Dyson. *Sheffield Graduate Section:* Tuesday, September 23, 6.30 p.m., Royal Victoria Station Hotel, Sheffield. "Preventive Maintenance," by Mr. J. R. Widdowson. *Coventry Section:* Tuesday, September 23, 7 p.m., Geisha Café, Hertford-street, Coventry, "Applications of Operational Research to Production Engineering Problems," by Mr. M. J. Moroney. *South Essex Section:* Wednesday, September 24, 7.30 p.m., South-East Essex Technical College, Barkingside. "The Urgency of Simplification," by Mr. T. H. Windibank. *South Wales and Monmouthshire Section:* Thursday, September 25, 6.45 p.m., South Wales Institute of Engineers, Park-place, Cardiff. "Recent Developments in the Use of Materials," by Mr. M. H. Le Vie. *Regional Meeting:* Wednesday, October 1, 7.15 p.m., Wolverhampton and Staffordshire Technical College, Wolverhampton. 1952 Sir Alfred Herbert paper on "The Development of Engineering Metrology," by Mr. F. H. Rolt.

ENGINEERS' GUILD.—*West Midland Branch:* Tuesday, September 23, 6.45 p.m., Imperial Hotel, Temple-street, Birmingham. Annual Meeting. Sound Films on "Floods in the North" and "Main-Line Diesel."

INSTITUTE OF ROAD TRANSPORT ENGINEERS.—*North-East Centre:* Tuesday, September 23, 7 p.m., King's Head Hotel, Darlington. "Some Factors Influencing the Choice of a Crankcase Lubricating Oil," by Mr. A. Towle. *Western Group:* Thursday, September 25, 7.30 p.m., Grand Hotel, Bristol. "Dieselisation," by Mr. D. Poole.

BRITISH INSTITUTION OF RADIO ENGINEERS.—*West Midlands Section:* Tuesday, September 23, 7.15 p.m., Wolverhampton and Staffordshire Technical College, Wulfruna-street, Wolverhampton. "A Pulse Tester for Coaxial Cables," by Mr. N. S. Dean and Mr. E. Carey.

ASSOCIATION OF SUPERVISING ELECTRICAL ENGINEERS. *York Branch:* Tuesday, September 23, 7.30 p.m., Creamery Restaurant, Pavement, York. Film on "A Concrete Proposition."

INSTITUTION OF LOCOMOTIVE ENGINEERS.—Wednesday, September 24, 5.30 p.m., Institution of Mechanical Engineers, Storey's-gate, St. James's Park, S.W.1. Presidential Address, by Mr. C. M. Cock.

INSTITUTION OF HEATING AND VENTILATING ENGINEERS.—*Birmingham Branch:* Wednesday, September 24, 6.30 p.m., Imperial Hotel, Birmingham. "Radiant Heating," by Mr. F. R. L. White. *Yorkshire Branch:* Wednesday, September 24, 7.30 p.m., Hotel Metropole, Leeds. Film Evening. *Scottish Branch:* Tuesday, September 30, 6.30 p.m., Engineering Centre, 351, Sauchiehall-street, Glasgow, C.2. Annual Meeting.

INSTITUTE OF WELDING.—*North London Branch:* Thursday, September 25, 7.30 p.m., The Polytechnic, Regent-street, W.1. "Welding in America," by Mr. F. Clark, Mr. H. E. Lardge and Mr. S. M. Reisser.

INCORPORATED PLANT ENGINEERS.—*South Yorkshire Branch:* Thursday, September 25, 7.30 p.m., Grand Hotel, Sheffield. Discussion on "Hazards and Regulations in Steelworks." *Birmingham Branch:* Friday, September 26, 7.30 p.m., Imperial Hotel, Birmingham. "Modern Factory Lighting," by Mr. F. Jamieson.

INSTITUTION OF MECHANICAL ENGINEERS.—*North-Western Industrial Administration and Engineering Production Group:* Thursday, September 25, 6.45 p.m., Engineers' Club, Manchester. "Basic Engineering Standards and Their Place in Design," by Captain G. C. Adams. *East Midlands Branch:* Thursday, September 25, 7.30 p.m., Grand Hotel, Leicester. Address by the branch chairman, Mr. W. N. Bray.

ILLUMINATING ENGINEERING SOCIETY.—*Leicester Centre:* Monday, September 29, 6.30 p.m., Offices of East Midlands Electricity Board, Charles-street, Leicester. "Horticultural Lighting," by Mr. J. J. French. *Cardiff Centre:* Tuesday, September 30, 5.45 p.m., Offices of South Wales Electricity Board, Cardiff. Centre chairman's address by Mr. A. J. Dalton.

INSTITUTION OF ELECTRICAL ENGINEERS.—Thursday, October 9, 5.30 p.m., Savoy-place, Victoria-embankment, W.C.2. Inaugural Address by the President, Colonel B. H. Leeson.

BIBLIOGRAPHY ON LABOUR.—The American Library, 41, Grosvenor-square, London, W.1, has issued a bibliography, entitled "A List for Labour," of books and pamphlets held by them dealing with various phases of labour and employment. The library is open to the public from 9 a.m. to 6 p.m. from Monday to Friday. Books may be borrowed free of charge either by post or by calling in person.

"FAWLEY ACHIEVEMENT."—The oil refinery of the Esso Petroleum Company was formally opened on Friday, September 14, 1951, and was fully described on page 385 of our 172nd volume (1951). The construction of this plant, which is the largest oil refinery in Europe, has now been admirably portrayed in a film with the title of "Fawley Achievement," which was written and produced by members of the company's staff. The film depicts the stage-by-stage erection of the main refinery units, including the catalytic cracking plant, which is 265 ft. high, and is an excellent factual record of a great achievement. It is available in 35-mm. and 16-mm. versions and can be obtained on loan from the Public Relations Department of the Company.

COURSES IN PHOTO-ELASTICITY.—A course of 15 lectures and demonstrations on the practical application of photo-elastic methods to the investigation of two-dimensional stress distributions will be held in the Faculty of Engineering at University College London, from 5 to 6 p.m., on Mondays, commencing on October 13. The fee for the course is $8\frac{1}{2}$ guineas. A second course of ten lectures and demonstrations, on recent developments in the photo-elastic investigation of three-dimensional stress problems, will be held from 5 to 6 p.m., on Mondays, commencing on February 16, 1953. The fee for this course is 6 guineas. For students taking both courses the fee is $13\frac{1}{2}$ guineas, but they are available, without extra fee, to students of University College who have paid composition fees. Students wishing to attend should communicate with the secretary, University College London, Gower-street, W.C.1.

PERSONAL.

SIR HAROLD WEST, managing director of Newton Chambers and Co. Ltd., Thorncliffe, Sheffield has been elected Master of the Cutlers' Company in Hallamshire for 1952-53, in succession to MR. G. M. FLATHER. MR. R. L. WALSH has been elected Senior Warden and MR. W. G. IBBERSON Junior Warden. The Master Cutler-elect will be installed and the other officers will take up their duties on October 7.

DR. C. SYKES, F.Inst.P., F.I.M., F.R.S., managing director of Thos. Firth and John Brown Ltd., Sheffield, has been elected President of the Institute of Physics. He will take office in October.

The President of the Lincolnshire Iron and Steel Institute for 1952-53 is MR. W. L. JAMES, J.P.

MR. G. R. MORTON, F.I.M., has left Coventry Technical College to take up the position of senior lecturer in metallurgy on the staff of the County Technical College, Wednesbury, Staffordshire.

MR. H. N. BOWEN has been elected President of the Swansea and District Metallurgical Society for the session 1952-53.

MR. L. J. W. BAILEY, general manager of Dunlop Plantations, Ltd., since 1947, has taken up his duties as chief purchasing agent of the Dunlop Rubber Co. Ltd., in succession to MR. J. P. ANDERSON who is leaving for Toronto as vice-president and general manager of the Dunlop Tire and Rubber Goods Co. Ltd., Canada.

MAJOR J. W. BANSALL, education officer to Imperial Chemical Industries, Ltd., Billingham-on-Tees, since 1945, and the former deputy labour manager, is retiring on September 30.

MR. J. D. LAST, B.Sc., of London, N.21; MR. A. W. WATERFIELD, B.Sc., of Harrow, Middlesex; MR. T. F. J. HAWKINS, B.Sc., of Wanstead, London, E.12; MR. J. D. GWYNNE, B.Sc., of Bude, Cornwall; and MR. P. R. OLLIVER, B.Sc., A.M.I.C.E., of Harlow, Essex, have been appointed to the Colonial Engineering Service. Mr. Last goes to the Gold Coast, Mr. Waterfield to Malaya, Mr. Hawkins to Northern Rhodesia, and Mr. Gwynne and Mr. Olliver to the East Africa High Commission.

MR. GEORGE M. DUNBAR, who joined the staff of John Fowler and Co. (Leeds) Ltd., Hunslet, Leeds, 10, in 1950, as commercial manager, has been elected to the board.

MR. G. A. T. BURDETT, A.M.I.I.A., has joined the staff of Holophane Ltd., as publicity manager, at Elverton-street, London, S.W.1, in succession to MR. R. J. W. BRIDDON, who now represents the company in the South-Western area.

The Ministry of Materials, Horse Guards-avenue, Whitehall, London, S.W.1, has announced that MR. PHILIP G. SMITH, of Bassett Smith & Co. Ltd., will be appointed Government broker from October 1, for all sales of lead, on the London Metal Exchange, from Ministry stocks.

MR. F. C. GOLDSMITH, previously on the home sales staff of the Morgan Crucible Co. Ltd., has joined the staff of Foundry Services Ltd., Long Acre, Nechells, Birmingham, 7, to become their resident technical representative in India and Pakistan.

RADIOVISOR PARENT LTD., 1, Stanhope-street, London, N.W.1, have appointed J. Broughton and Son (Engineers) Ltd., Security Works, 234, Pershore-road South, King's Norton Factory Centre, Birmingham, 30, to be sole selling agents for their photo-electric press brake guard.

The accounts division of the BOARD OF TRADE has moved to Lacon House, Theobald's-road, London, W.C.1. (Telephone: CHAncery 4411.)

PUBLICATIONS ON INDUSTRIAL DIAMONDS.—A "Bibliography of Industrial Diamond Applications," now in its ninth year of publication, has been incorporated, from July, 1952, in the trade journal *Industrial Diamond Review*, which is in its twelfth year of issue. Both publications are henceforth to be supplied under one and the same cover, but, for the convenience of some, the bibliography will also continue to be issued separately. The offices of the publishers are at St. Andrew's House, 33-34, Holborn Viaduct, London, E.C.1.

UNITED KINGDOM IRON AND STEEL PRODUCTION.—The output of steel ingots and castings in this country in August is shown by figures issued by the British Iron and Steel Federation, Steel House, Tothill-street, London, S.W.1, to have been at an annual rate of 14,535,000 tons. This compares with a rate of 14,236,000 tons in the previous month and of 13,855,000 tons in August, 1951. The pig-iron production in August was at an annual rate of 10,498,000 tons, against a rate of 10,482,000 tons in July and of 9,409,000 tons in August, 1951.

SHIPS BUILT BY MESSRS. HARLAND AND WOLFF, LIMITED, AT BELFAST.

(*For Description, see Page* 385.)

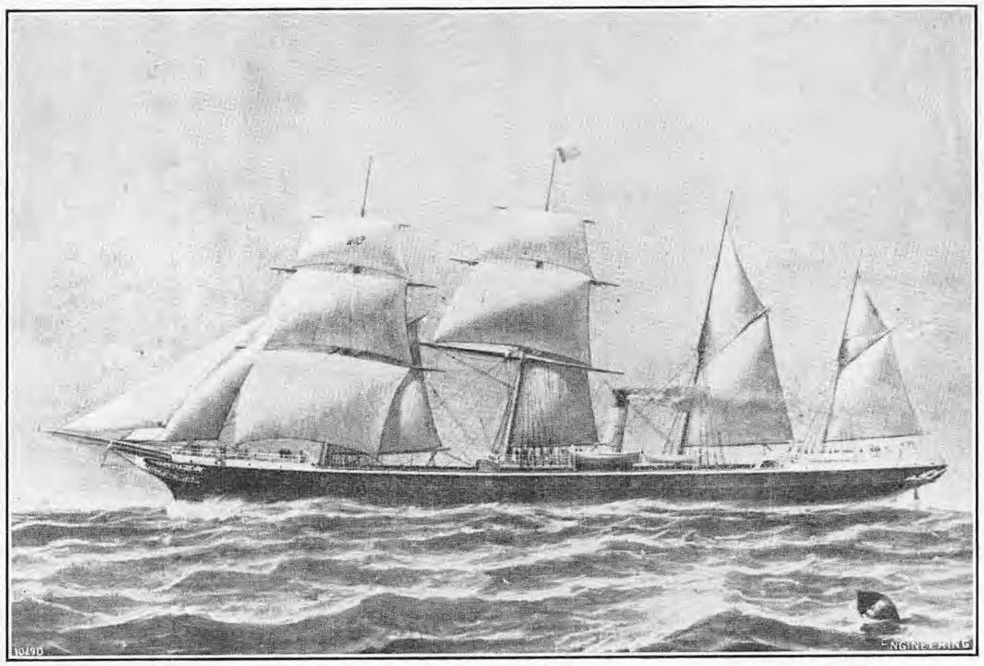


FIG. 7. BIBBY LINER "VENETIAN," 1859.

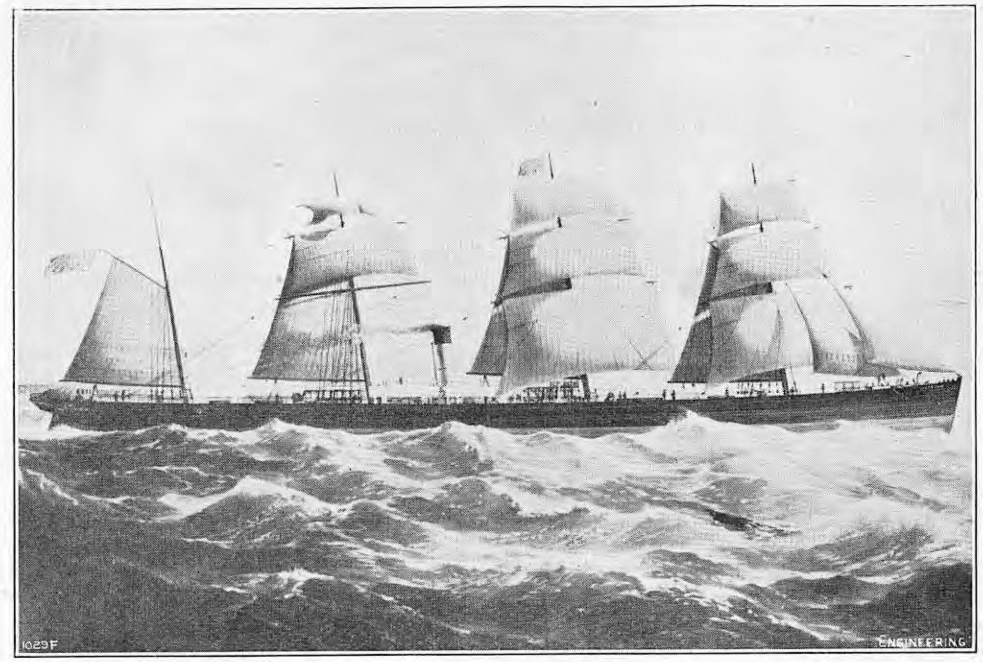


FIG. 8. BIBBY LINER "ISTRIAN," 1867.

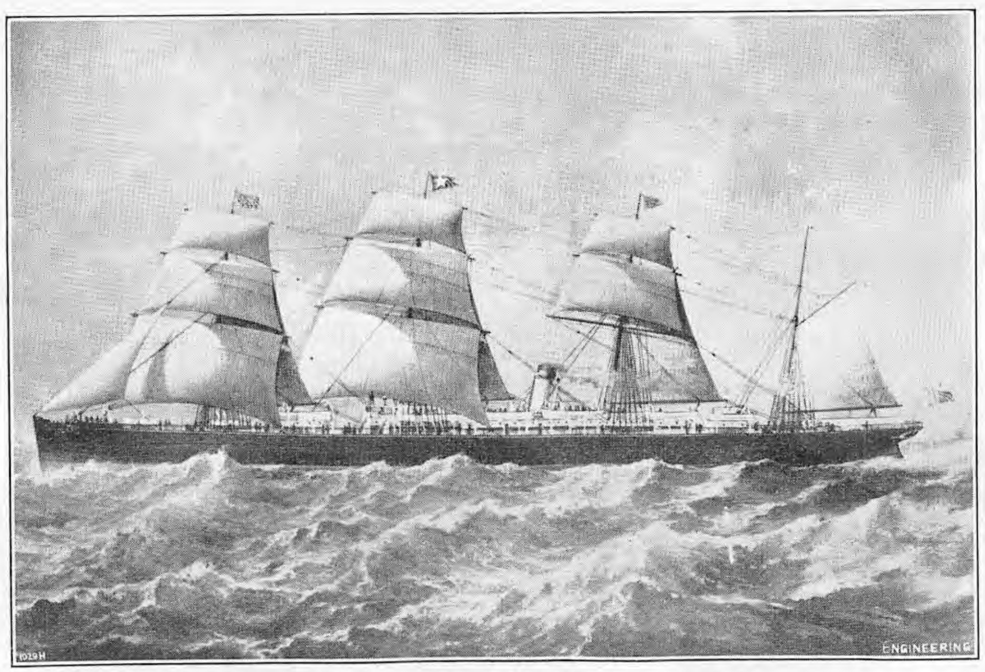


FIG. 9. WHITE STAR LINER "OCEANIC," 1870.

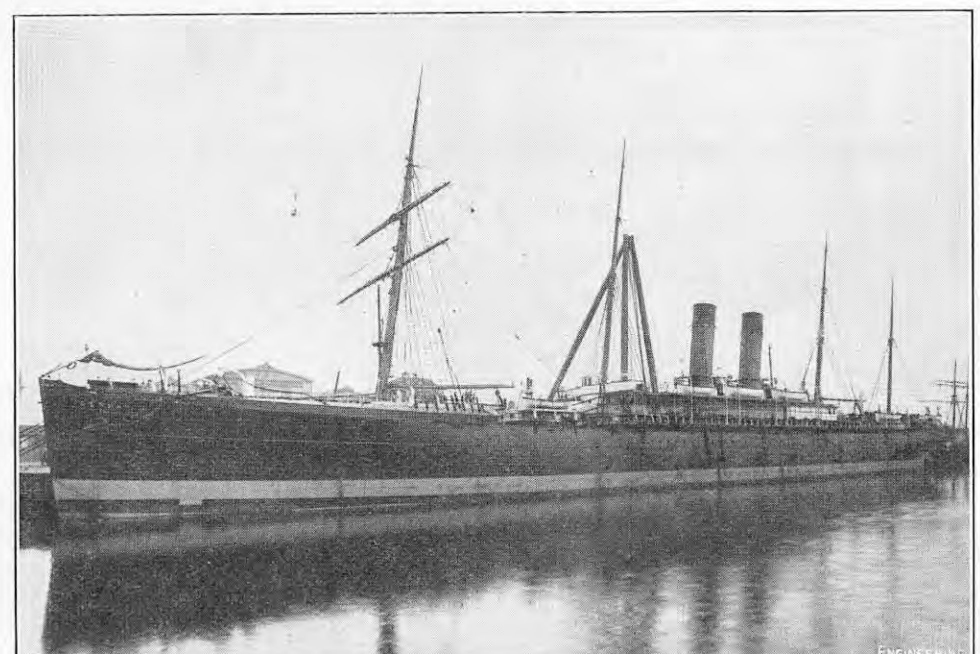


FIG. 10. WHITE-STAR LINER "GERMANIC," 1874.

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

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Telegraphic Address:

ENGINEERING, LESQUARE, LONDON.

Telephone Numbers:

TEMPLE BAR 3663 and 3664.

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

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

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ENGINEERING may be ordered from any newsagent in town or country and from railway bookstalls, or it can be supplied by the Publisher, post free, at the following rates, for twelve months, payable in advance:—

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Subscriptions for periods less than twelve months are based on the price of a single copy, namely, 2*s.* 3*d.* post free.

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ENGINEERING

FRIDAY, SEPTEMBER 19, 1952.

VOL. 174. No. 4521.

FULL EMPLOYMENT.

UNDER the Charter of the United Nations, member nations undertake to promote higher standards of living and full employment. Great Britain has accepted these responsibilities and has undertaken to apply a policy of full employment. The word "policy" may be variously defined. It may mean a definite course of action or may merely indicate in a general way that those adopting it are in favour of certain objectives. To be in favour of full employment, and to devise and operate methods of attaining it, are different things. The full employment which this country has experienced since the end of the war has not been entirely due to the application of methods of attaining it and when the circumstances which have caused it show a tendency to change there does not appear to be any method by which the undesirable effects of that change can be counteracted.

In recent months, there has been a serious fall in the demand for textile products, with resulting considerable unemployment in the North-Western part of England and in Northern Ireland. The causes of the recession in demand are to be sought both at home and abroad, but explanation of the reasons for the unemployment does not eliminate it. The "policy" of full employment under which the country operates does not seem to be able to do anything about it. To be fair, a policy of full employment cannot be expected to mean 100 per cent. employment; a reasonable margin must be allowed. This consideration, however, is not likely to carry much satisfaction to textile workers, who will not unnaturally expect that the policy of full employment should apply to them as much as to anyone else. A question which has not yet arisen, but may in the future, when the heavy pressure on the shipyards, mainly due to the great expansion in the world's oil industry, has exhausted itself, is what method the full-employment policy has for dealing with unemployed shipyard workers.

As, however, full employment cannot fairly be held to mean that no one will ever be out of a job, there must be a working margin of unemployment and, presumably, certain classes, say, textile and shipyard workers, must be satisfied to represent that margin. What that margin will be or should be, appears to be nothing more than a guess, but Lord Beveridge, in *Full Employment in a Free Society,* did not hesitate to guess; he defined full employment as employment of 97 per cent. of the working population. The matter was later pursued by the Economic and Social Council of the United Nations, who asked each Government to define the meaning they attached to "full employment." The British reply, presumably based on Lord Beveridge's estimate, was that unemployment might be allowed to rise to 3 per cent. of the total number of employees. The Belgian Government gave 2·9 per cent. of the total civilian labour force or 3·7 per cent. of the labour force available for hire. With every respect, it may be suggested that these decimal points are representative of the activities of a statistical bureau, rather than of any practically applicable standard. Moscow replied that there was no unemployment in the Soviet Union, so that the question did not arise. This may be true, but, as the title of Lord Beveridge's book indicated, the discussion is concerned with "a free society."

This somewhat thorny topic was the subject of the Presidential address to Section F of the British Association, delivered by Professor D. T. Jack at Belfast on September 5. The title he adopted was "Full Employment in Retrospect." We suggested above that there is a difference between vague promises that full employment will be ensured and the devising of a sound policy to ensure it. It would not be correct to say that this country has not adopted a policy; it has, and whether that policy is sound, the future will show. Professor Jack stated that the measures adopted "consist basically in operating on the flow of money incomes." The long-term effect of this policy is that, as employment increases, prices and wages also increase, home demand results in larger volumes of imports, and the price of the exports which should pay for them rises. The policy which, at bottom, means that most people in the country shall have more money to spend, has not been the sole cause of the high level of employment enjoyed since the end of the war. It has been helped by the world demand for goods created by the most destructive war in history, and the gift of large sums of money from America, which have been expended somewhat recklessly.

At the risk of appearing very elementary, it may be pointed out that the total amount of goods available in the country is equal to the total amount produced. The more there are produced, the more there are for everybody. The direct application of this simple statement is complicated by questions of overseas trade, but in broad terms the statement is correct. The process of "operating on the flow of money incomes" results in the major proportion of the population being in a position to buy more goods and to demand more services. If the total amount of goods produced remains constant, this demand will result in a minority of the population getting less. That has happened, but as the minority is so much smaller than the majority there would not have been enough goods to satisfy the latter, had production not increased. It has increased and the increase has been responsible for the phenomenon of full employment. It is not overlooked that this simple process has been complicated by a proportion of the goods produced being exported, but when something is exported something else is imported to balance it, and the overall statement that "operating on the flow of money incomes" has resulted in most people getting more goods is correct.

This elementary dissertation might call for an apology were it not that there does not appear to be a general realisation of the situation into which this policy of full employment has led the country. Professor Jack pointed out that, as prices and wages move upward, strains and stresses appear within the economy. The maintenance of full employment has owed much to the export trade, but the immediate demands of a devastated world have now been met and many countries cannot, or will not, continue to purchase goods irrespective of price. The upward movement of wages and prices will also affect the home market and sales will tend to decrease. The trade union remedy for keeping up sales is still higher wages—for instance, the current demand of the engineering trades for a rise of 2*l*. a week—but that leads to what the economists call inflation, with ultimate bankruptcy or, at least, a further depreciation of the value of money.

"Operating on the flow of money incomes" has gone as far as it safely can, and probably farther. One of its effects is that manufacturing industry has been starved of capital; capital, indeed, has been spent as income. The only way to maintain a high level of employment in this country is to ensure that its industry operates at high efficiency. It cannot do this if the sums which should be spent on the modernisation and replacement of plant, and which are, in effect, part of its working capital, are withdrawn in the form of taxation and used in operations "on the flow of money incomes." It is doubtful if the maintenance of "full" employment is possible in this imperfect world but a better approximation to it will be achieved as the efficiency of industry rises and the output of the average employee increases.

To some, this statement may appear absurd. Much has been heard in the past of such expressions as "making the job last," and "working one's self out of a job." The point of view which those expressions represent is still widely held, and instructions are issued that no piecework or overtime is to be worked because some employees have been found to be redundant. In more than one case strikes have been called with the idea of forcing employers to retain workpeople for whom there are no jobs. This kind of activity is not only inimical to the economic interest of the country as a whole; it is unsound from the point of view of the workpeople immediately concerned. The prospects of employment are not improved by hampering and frustrating the operations of the organisation by which it is provided.

It was said earlier that the amount of goods available is equal to the amount produced. Since the war, the proportion enjoyed by the majority has increased; naturally, the beneficiaries will wish to retain that proportion, and to increase it further, but they cannot do so unless the goods are produced. That is one reason why it is to the interest of labour that the industry of the country should operate at high efficiency. There is another reason, however. Export trade, which has had much to do with the maintenance of a high level of employment, is becoming more difficult, and if that high level is to be maintained, efforts must be made to reduce prices, which can best be done by working more efficiently. This procedure will also increase the home demand. The majority will buy more if it can afford more. So far from labour increasing unemployment by working hard and efficiently, and so producing more goods, the effect will be the opposite; the history of the Ford motor-car is an outstanding demonstration of that thesis, and there are many others. The country will absorb all the goods it can get if it can afford them. The more efficiently labour operates, and the more it is prepared to take advantage of labour-saving appliances, the cheaper will goods become and the larger their sales. Restrictive practices will not increase employment; "full" employment depends on their abandonment.

FUEL AND POWER.

In last week's issue of ENGINEERING, on page 343, *ante*, we summarised very briefly the main recommendations of the committee set up in 1951 by the Minister of Fuel and Power, under the chairmanship of Lord Ridley, to examine the whole question of the use of fuel and the production of power. The questions referred to the committee, however, and the conclusions reached, are of sufficient technical interest to warrant a more extended notice; especially as the recommendations, if adopted, would appear to presage the application of incentives and, perhaps, of "sanctions" (to use a familiar word in the purely political sense that has acquired so much prominence in recent years) that threaten to interfere materially with the freedom of choice and action of both industrial and domestic users of fuel in selecting the type of heating and power-producing equipment that they may wish to adopt.

Lord Ridley, in the covering letter with which he submitted the report to the Minister of Fuel and Power (the Rt. Hon. Geoffrey Lloyd, M.P.), explained that the committee had taken their terms of reference to include "all use of fuel and power resources, both by the ultimate consumers—householders, manufacturers, traders and others—and by the industries which convert primary fuels (chiefly coal and oil) into secondary forms (mainly gas, coke and electricity); and that they had studied "how, on what scale, and in what patterns the different consumers use and may in future use fuel and power." That is, by any standards, a very comprehensive interpretation, amounting indeed to the assumption, if the recommendations are adopted, of practically dictatorial powers to control the choice of every form of prime mover or heating appliance in the country and the activities—even the very existence—of a number of supply, equipment and maintenance trades which depend largely on catering for needs arising out of the consumer's judgment of his own requirements.

The question of fuel and power selection has been complicated greatly in recent years by a number of factors which have little or nothing to do with the comparative suitability of different fuels or forms of power for specific uses. By rights, each such problem should be examined on its individual merits, but in practice, in many cases, expediency —coloured, perhaps, by circumstances that are or may prove to be merely temporary—has dictated a policy that should have been decided on purely technical considerations and which, in the light of those considerations alone, might have developed along totally different lines. It cannot be denied that, in some instances, the selection has been made on grounds of personal preference or prejudice, influenced only in minor degree by technical and economic factors, but such examples are relatively few. Most users, before committing themselves to the capital outlay on new plant, weigh the pros and cons of alternative systems with as much care, and often with as much technical knowledge, as the Ridley Committee were able to bring to their investigations.

Where the qualifications of the individual user might be inferior to those of the committee is more likely to be in the field of "background" information; the reserves of statistical data, the expert appraisal of its significance, and, to some extent, a knowledge of the higher economic policies and wider political issues that is not commonly available to the ordinary commercial or industrial executive, though it may be to a few of those in the forefront of industry. In such respects as these, the committee's report is frequently illuminating, and it is certainly interesting. Only by the aid of the overall statistics that a Government can command, for example, could the committee have arrived at their estimate of this country's fuel and power requirements in ten years' time. By the period 1959-63, according to their computation, the inland coal consumption of the United Kingdom should rise to an annual total of 232 million tons, as compared with 210 millions in 1951, leaving an exportable surplus of 25 to 35 millions, including coal shipped as bunker fuel; and the inland oil consumption is expected to rise from 8 million tons in 1951 to 14 million tons, in terms of its coal equivalent. Concurrently, the coal equivalent of the hydro-electric power generated should rise from one million to two million tons. These figures are based on the assumption that "there will be an annual increase of 4 per cent. in the production of iron and steel and the main sectors of industry, and that fuel efficiency increases at 1 per cent. a year."

The fuel costs of transport by road and rail, which form the subject of Appendix IX to the report, provide some comparisons of particular interest, though it will be realised that these alone do not provide all the evidence necessary to decide in favour of one kind of transport or another. The fuel consumption for passenger services, reduced to pounds of coal or coal equivalent, are 0·16 lb. per passenger seat-mile for express steam trains, 0·48 lb. for steam branch-line trains, and an average of 0·21 lb. Unfortunately, the corresponding figures for electric passenger-train services are not available, but those for road services are given; the average for all the petrol-engined and Diesel 'bus and coach services of London Transport, Tilling and the Scottish Groups is 0·025 lb. per passenger seat per mile. This is a notable difference. On freight services, however, it is much less marked, being 0·21 lb. per capacity ton per mile as an average of steam railway services and about 0·21 lb. for the vehicles of the Road Haulage Executive.

Another appendix to the report consists of a memorandum by the British Electricity Authority. An accompanying diagram shows that, since 1900, the total annual inland consumption of coal has increased by only 30 million tons, though, in the same period, the amount of coal carbonised in gasworks and coke ovens has increased from 35 to 48 million tons, the amount consumed in the generation of electricity from 3 to 35 million tons, the population has risen from 37 to 49 millions, and the volume of the national production of goods and services has been "approximately trebled." How the "volume" of a "service" is calculated is not stated, but that is by the way; it is evident that there have been immense improvements in the efficiency of fuel utilisation. It is mentioned that the specific consumption has been reduced from over $3\frac{1}{2}$ lb. of fuel in 1920, per kilowatt-hour sent out, to less than $1\frac{1}{2}$ lb. in 1950.

The figures quoted above are merely a few typical items from the many that are contained in the ten chapters of the report and its 15 appendices, but there is space to refer to only one more memorandum, namely, that of the Federation of British Industries. It is of especial importance because of the emphasis with which it argues that industrial expansion is being frustrated by the inadequacy of the present supplies of fuel and power. The National Coal Board, adding together the various separate estimates of consumers' requirements, calculate that they would represent an increase from 210 million tons of coal in 1951 to over 230 million tons in 1956, and state that this "would not be possible . . . even if all coal exports and bunkers ceased." The F.B.I., however, estimate that the true demand by 1961-65 would be no less than 293 million tons (allowing for 30 million tons of export coal and bunkers) if British industry is to receive all that it requires, the biggest single item being 63 million tons for the generation of electricity. Evidently, therefore, the likelihood of any real alleviation of present stringencies is somewhat remote.

NOTES.

SYMPOSIUM ON THE CHEMISTRY OF CEMENT.

SPEAKING at the 3rd International Symposium on the Chemistry of Cement in London this week, Sir Ben Lockspeiser, F.R.S., Secretary of the Department of Scientific and Industrial Research, compared the organisation of research with the running of a business. There was, he said, a trading account and a capital account, and no sensible business man would undermine his capital position to promote sales. Similarly, scientists must not sacrifice the capital of their business to immediate needs, and it was of first importance that a due proportion of effort be devoted to fundamental inquiry. This provided, by the accumulation of knowledge, not only the surest basis for the solution of future problems, but also the intellectual climate which promoted discovery and the growth of new ideas. Revolutionary advances in science were often unexpected, and if we were wise we would allow something for scientific adventure which might be priceless. Sir Ben quoted a recent significant case of an unforeseeable connection between one branch of science and another. Tobermorite, he said, was a very rare natural mineral first described in 1880 by Professor Heddle, who recognised it as a hydrated calcium silicate. Its true nature remained unsolved until this year, when the first detailed X-ray data on the principal silicate constituent of hydrated cement were published. At the same time, a collection at the British Museum was being rearranged and an X-ray powder diagram of Tobermorite was taken. It was identical with this calcium silicate hydrate. Thus, it transpired that Heddle's rare mineral was synthesised daily throughout the civilised world, and to such an extent that millions of tons of it were produced annually in Great Britain alone. The total effort devoted to cement and concrete research was substantial, but he doubted if it was large enough. In this country, it was probably less than one-fifth of 1 per cent. of the total value of the products made from cement —a total of 180,000,000*l*. The delegates to the symposium were welcomed at the Royal Institution on Monday, September 15, by Sir Francis Meynell, R.D.I., director of the Cement and Concrete Association, which, in conjunction with the Building Research Station, has organised the symposium. Sir Francis said that the Association was supported wholly by the cement makers, and since it was founded 16 years ago the annual cement production had increased from 5,793,000 tons to 10,086,000 tons. The symposium ends to-morrow (Saturday); its programme was given on page 243 of our issue of August 22.

THE GAUGE AND TOOL MAKERS' ASSOCIATION.

Since the Gauge and Tool Makers' Association was founded ten years ago, in August, 1942, the number of member firms has increased from 16 to over 250. The tenth report, which is to be presented at the annual general meeting on September 29, reviews the work which has enhanced the usefulness and status of the Association during the past year. Co-operation in the interests of the members has been maintained with Government departments and other trade associations. A conference was held in June, at the request of the Ministry of Supply, between representatives of a large number of member firms and technical officers of the companies in the "Avon Engine Group" with the object of finding additional capacity, during the remaining months of 1952, particularly for the production of jigs and fixtures urgently required by the aero-engine makers. A "very satisfactory" total of 400,000 extra man-hours was obtained and allocated to the members of the group. Overseas, the Association's Canadian office, at 39, Walmer-road, Toronto, continued to function under the direction of Mr. F. E. Weaver, and the Association received the support of the members of its overseas section situated in Australia and New Zealand. The export committee issued a revised edition of an 80-page memorandum summarising the customs duties and taxes levied by the principal world markets on the import of tools and gauges. The education and apprenticeship committee are considering, in conjunction with the mould and die manufacturers' section, the preparation of a booklet to interest boys in a gauge and tool making career. Attention has also been given to the issue of a syllabus which would serve as a guide to members of the Association in the training of apprentices. The competition in craftsmanship and draughtsmanship has gained in popularity and is to be held again in 1953. Similarly, it is hoped to repeat the arrangement, first tried this year, of having a composite stand at the British Industries Fair.

THE INSTITUTE OF METALS.

The 44th annual autumn meeting of the Institute of Metals opened in the Sheldonian Theatre, Broad-street, Oxford, under the Presidency of Dr. C. J. Smithells, M.C., on the evening of Monday, September 15, when the 23rd annual autumn lecture was delivered by Professor H. W. Swift, M.A., D.Sc., M.I.Mech.E., who occupies the Chair of Engineering in the University of Sheffield. Before the delivery of the lecture a brief business meeting was held, during which the secretary announced that, as required by the Articles of Association, the following members would retire from the Council at the annual general meeting in 1953. These comprised, as President, Dr. C. J. Smithells, M.C.; as past-president, Sir Arthur Smout; as vice-presidents, Professor H. O'Neill and Professor F. C. Thompson; and as ordinary members of the Council, Mr. E. A. Bolton, Mr. C. H. Davy, Professor A. G. Quarrell and Professor G. V. Raynor. In accordance with the Articles, Dr. C. J. Smithells would fill the vacancy on the Council as past-president, and the Council had nominated the following members to fill the other vacancies, namely, as President, Professor F. C. Thompson; as vice-presidents, Major C. J. P. Ball, D.S.O., M.C., and Professor G. V. Raynor; and as members of Council, Mr. W. A. Baker, Mr. J. C. Colquhoun, M.B.E., Mr. E. R. Gadd, and the Hon. John Grimston. The Council had further elected Dr. S. F. Dorey, C.B.E., F.R.S., to serve as senior vice-president for 1953-54, and he would be the Council's nominee for the Presidency in 1954-55. In the course of his lecture, which was entitled "On the Foot-hills of the Plastic Range," Professor Swift gave a survey of the activities of the several classes of pure and applied scientists engaged in the general field of metal plasticity. He outlined the extent to which research was at present able to make its contribution to the various technological processes involving plastic deformation and suggested a classification of the most profitable directions of inquiry appropriate to the mathematician, the metal physicist, and the engineering scientist. The methods of mathematical plasticity were illustrated by simple examples of shear-line fields and flow grids, and the limited success of more elementary methods of analysis by engineering investigators, by results obtained in the process of deep-drawing a cylindrical shell. In conclusion, Professor Swift appealed for the co-ordination of research programmes and for the presentation of reports and results in a form intelligible to all scientific investigators and to those more directly concerned with plastic processes in industry. He also appealed to the metal physicist for a more realistic model of lattice structure and for a systematic study of stress/strain relations on a wider front than heretofore. We commence a reprint, in abridged form, of Professor Swift's address on page 383.

SAFETY FOOTWEAR IN INDUSTRY.

Speaking at a Press conference on protective footwear, held in London on September 9, under the chairmanship of Mr. J. B. Steadman, President, Boot and Shoe Manufacturers' Federation, Mr. Harold Watkinson, M.P., Parliamentary Secretary, Ministry of Labour, stated that operatives in all industries, but especially in heavy engineering, shipbuilding and dockside work, as well as in mines and quarries, and in railway transport, which did not come under the Factories Acts, were always liable to foot injuries. They were most frequently incurred by the employee being trapped by loads moving over the work-place floor, or being struck by falling articles dropped from the hands, the bench or the machine. A solution to the problem was for the feet of the workpeople to be protected by specially-built boots having internal toe-caps of spring steel. In 1941, the British Standards Institution had issued a specification requiring a drop test for ascertaining the resistance to impact of the safety toe-caps. During the war, however, and for some time afterwards, manufacturers had had difficulty in procuring sheet steel of sufficient strength to meet these test conditions. These difficulties had now been overcome and a revised British Standard Specification, B.S. No. 1870 : 1952, was now available (price 2*s*. 6*d*., post free), in which minimum standards of construction for safety boots and shoes were laid down. Another speaker at the conference, Sir George Barnett, Chief Inspector of Factories, stated that two of the causation groups into which accidents notifiable to the Inspectorate were divided were those relating to the handling of goods or articles and those due to persons being struck by falling bodies. Most of the foot injuries arose in these two categories, and, in 1950, they accounted for 71,264 accidents of the total of 193,059 notified. Mr. Gordon Weston, technical director of the British Standards Institution, who also spoke at the conference, emphasised that B.S. No. 1870 covered safety footwear for men only and governed the construction of the complete boot or shoe. For women operatives, it was the usual practice to limit the protection to the special toe-cap, and these were covered by B.S. No. 953 : 1945, which dealt with strength tests for the protective toe caps of boots and shoes used for industrial purposes.

AMERICAN SOCIETY FOR ENGINEERING EDUCATION.

At the 60th annual meeting of the American Society for Engineering Education, held at Dartmouth College, Hanover, New Hampshire, U.S.A., in June, there was a discussion on the difficulty of preserving proper educational aims and standards at the many American universities and institutes of technology which receive financial aid from the Federal Government for the prosecution of research on defence, agricultural and other national projects. It was stated that the magnitude of such tasks often tended to distort the educational structure of the teaching institution. As a corrective, balanced courses with "a strong liberalising content" were advocated, though it was not clear how this content was to be incorporated in the curriculum. Some complimentary references were made to the English practice of demanding a high level in physics and chemistry as a preliminary to specialisation in degree subjects, and of carrying mathematics through to the final year of the degree course. Where courses were arranged primarily to enable a student to gain "credits" in specific subjects, there was often a lack of co-ordination between the basic sciences and their applications. To avoid the cramping influence of periodical examinations there was strong support for the project method, in which a practical problem is posed, the student searches for the principles involved, chooses the analytical methods and tools, tests the results, evaluates the process and draws conclusions. Such a method, it was argued, corresponded most closely to ordinary engineering practice. Even if only one project could be included in the undergraduate course, its educational value far outweighed the time involved. The importance of a good command of the English language was stressed, and it was clear that already in many American institutes a serious effort is being made to achieve effective co-operation between the language and engineering faculties. The meeting attracted representatives from most of the universities and technical institutions of the United States and a number of guests from overseas. This country was represented by Mr. John Woolston, of the United Kingdom Scientific Mission at Washington, and Dr. H. Lowery, of the South West Essex Technical College, London, E.17.

ROBERT WARNER FELLOWSHIPS OF THE WORSHIPFUL COMPANY OF FOUNDERS.

The first award of a Robert Warner Fellowship, established by the Worshipful Company of Founders of the City of London, in accordance with the will of a past-master of that name, is due to be made by the Company prior to March, 1953. In this instance, the Fellowship will commence in October, 1953, and there will be no stipulation as to the age, training or qualifications of candidates, or as to where the successful applicant shall conduct his research, which need not necessarily be regarded as a full-time occupation. He may engage in any branch of research that has specific relation to foundry practice. In view of this, the Company does not indicate the sum available for the Fellowship, otherwise than to state that in no circumstances is it likely to exceed 600*l*. for a period equivalent to one year. The Company also has a scheme for the award of Fellowships which are primarily intended to provide facilities for advanced education to men who have already completed their normal training. As it is considered that the two types of award serve different purposes, both cannot be held at the same time, but the possibility of one candidate receiving the two awards at different times is not excluded. Only natural-born British subjects of British parents are eligible and the proposed research must be of sufficient value to the industry to justify an award. The Company will require to be satisfied as to the character of the applicant, his capacity for the work he proposes to undertake, his facilities for its execution, and that adequate supervision of its progress can be provided. Periodical reports of progress must be furnished, in person if required, and, at the end of the period for which an award is made, a full report must be prepared, the results of which may be made available by the Company to the foundry industry. Applications should be sent to the Clerk of the Worshipful Company of Founders, Founders' Hall, 13, St. Swithin's-lane, London, E.C.4, before the end of this year.

THE SUPPLY OF BRANDED PETROL.

On the conclusion of a recent exhibition of the film "Fawley Achievement," to which reference is made on page 375 of this issue, Mr. R. B. Sawrey-Cookson of the Esso Petroleum Company said it might be difficult to appreciate why, as the result of all these developments, it was still impossible to obtain premium-grade petrol. The primary source of this petrol was the fluid catalytic-cracking plants now in operation or under construction. Of these, the largest in this country was that at Fawley, which since November, 1951, had produced over 100 million gallons of high-octane petrol. Accordingly, the Esso Company had applied to the Government for permission to market premium-grade petrol, but had been refused on the grounds that the balance of payments throughout the sterling area would be adversely affected, because some increased expenditure on imported crude oil and tetra-ethyl lead would be necessary. In the view of the company, however, these increased financial commitments would be relatively small and would progressively diminish. Moreover, they would be largely offset by the introduction of high-octane fuels, owing to the greater mileage, improved engine performance and general availability of petrols of guaranteed uniform quality which would result. In fact, such petrol would be a major contribution to greater transportation efficiency. Another important aspect of the matter was that the continued use of low-octane petrols was not helping the British motor industry to design engines for high-quality fuels and thus to meet competition in overseas markets. Discussions with the Government on this subject were still proceeding, and the company were hopeful that there would be a successful outcome. They wished motorists to know that they were ready at short notice to meet their needs.

CALCULATION OF TRANSMISSION-LINE CONSTANTS: ERRATA.—We regret that in printing Professor R. O. Kapp's paper on the above subject, read at the recent British Association meeting in Belfast, a few errors escaped attention. In the two expressions for α and β near the centre of the third column on page 315, the small brackets after $\omega^2 R^2 C^2$ should be omitted; and in the substitution for f, about $3\frac{1}{2}$ in. from the bottom of the first column on page 316, η is printed in place of π. The three simplified formulæ for line constants, with which the paper concludes, were wrongly numbered (10) instead of (11). Fortunately, none of these errors is likely to cause confusion.

LETTERS TO THE EDITOR.

PRODUCTION OF COMBUSTIBLE AND FERTILISING SLUDGE AT MAPLE LODGE SEWAGE WORKS.

TO THE EDITOR OF ENGINEERING.

SIR,—In his letter on page 308, of your issue of September 5, Mr. Willans asks why the sludge from these works could not be sprayed on fields without any preliminary drying.

There are a very few sewage works in this country where a part of the sludge is applied directly to surrounding farm land by pumping. The very small number of such works is an indication of the difficulties involved, the principal of which are: the grease, weed seeds and disease germs present, together with the low fertiliser value of the mixed, raw and activated sludge, make it unattractive to farmers and the smell to everyone else, unless it is digested; farmers cannot take the sludge all the year round, consequently alternative means of disposal or storage must be provided for about six months of the year; the amount which can be disposed of in any particular area will vary considerably from year to year, depending upon the way in which the land is being worked and the wetness of the season; and sludge, even when mechanically thickened, will contain not less than 12 tons of water to every ton of solid matter. For these reasons, the area of distribution required for even small works is very large indeed, requiring many miles of sludge piping and heavy pumping and administration costs. In the case of an authority such as the Colne Valley Sewerage Board, producing 300,000 tons of wet sludge per year, it would be quite prohibitive.

At the Maple Lodge Works, the aim has been to provide a means of reducing the sludge to a form in which it can be stored, handled and applied to the land in a safe, clean, convenient and controlled manner, and to do this in a way which is as flexible as possible both in the quantity and quality of the product to meet varying demands. By these means, the fertilising value of the sewage is made available to the land (both farms and gardens) more fully and rapidly than would be possible by direct application, even were this feasible in the quantity which has to be disposed of.

Yours faithfully,
SANDFORD FAWCETT & PARTNERS.

53, Victoria-street,
Westminster, S.W.1.
September 12, 1952.

APPLIED PSYCHOLOGY AND MACHINE DESIGN.

TO THE EDITOR OF ENGINEERING.

SIR,—Mr. S. C. McKenzie has drawn attention, on page 308 of the September 5 issue of ENGINEERING, to the difficulty of applying in industry the results of research in psychological and physiological laboratories of the British and American universities, which is largely due to a lack of published information. Unfortunately, this is only too true and such publications that are available are, on the whole, not of a form which can readily be used by design engineers. The general field is fairly adequately covered in *Applied Experimental Psychology*, by A. Chapanis, W. R. Garner and C. T. Morgan (John Wiley and Sons, New York, and Chapman and Hall, London, 1949), *The Handbook of Human Engineering Data for Design Engineers*, published by the U.S. Office of Naval Research, and *Human Factors in Underseas Warfare*, published by the U.S. National Research Council. These books are, however, now two to three years out of date and are more suitable for research workers and students than for engineers. The Ministry of Supply have published a monograph by W. E. Hick and J. A. V. Bates, called *The Human Operator of Control Mechanisms*, and other information on control design has been published by L. E. Davis in the *Mechanical World*, vol. 129, pages 601 to 607 (1951), under the title "Human Factors in the Design of Manual Machine Controls."

The Ergonomics Research Society, one of whose objects is the dissemination of laboratory information to those who can use it, held a symposium last year on "The Human Factor in Equipment Design," the proceedings of which will be published before the end of the year. I am myself preparing a summary of published work which will be of value to engineers, which I hope will also be completed before the end of the year. A part of it, on the design of dials and the layout of panels, has already been published in *Instrument Practice* for February and July of this year.

It will be seen, therefore, that although the publication of results of research in usable form is at present in an unsatisfactory position, there are some of us who are well aware of this, and who are trying to improve the position.

Yours faithfully,
H. MURRELL,
Secretary, Ergonomics Research Society.

T.I. (Group Services), Limited,
Sampson Works,
Oldbury, Worcestershire.
September 9, 1952.

WATER HAMMER IN PIPE-LINES.

TO THE EDITOR OF ENGINEERING.

SIR,—The letter from Mr. P. Linton, on page 212 of your issue of August 15, discussing the contents of my letter which appeared in your issue of August 1, only came to my notice on August 29, when I returned from holiday. Experiments on water-hammer effects under the usual conditions, i.e., when the control valve is closed in a short (but finite) time, show that the maximum intensity of pressure depends on the mean velocity of flow in the pipe and on the time taken to close the valve. The fixed details of the pipe-line, such as diameter and wall thickness, do, of course, enter into the picture but are constant for a given case. Now, the velocity of flow depends on the pressure difference between inlet and control valve. If the pressure at inlet be fixed—as it may be—the velocity of flow must depend on the pressure intensity at the valve. Thus, I cannot accept that my equation (1) is in error on this account. Mr. Linton's proposed correction to a rational formula, to make it agree with another theoretical result, is quite indefensible.

But I am obliged to Mr. Linton, since he has caused me to look over my own application of energy conservation. I find that the terms involving pressure energy on each side were omitted. When these are included, the expression for maximum fluid stress due to water-hammer becomes:—

$$p = c_1 + \sqrt{(p_1 + c_1)^2 + \rho c_1 v^2 - \frac{2 g \rho c_1}{W} (U^1 - U_1)} \quad . \quad . \quad . \quad (3)$$

where

$$c_1 = \frac{K}{1 + \frac{K}{E}\left(\frac{k r_m}{c d}\right)} \quad . \quad . \quad (4)$$

The symbols denote the same quantities as on page 148, *ante*, with the following additions: W is the total weight of water in the pipe; U^1 is the external work done on the pipe and its fixings; U_1 is the energy supplied to the water by operating the quick-action valve. The equations are numbered in succession from those in my first letter. The quantities U^1 and U_1 are unknown and may be small and so will be ignored.

It is essential to bear in mind that equation (3) holds only for a very short interval of time for valve closure, since it is assumed that the kinetic energy given up per unit mass is $\frac{1}{2} v^2$. For the purpose of engineering science it is suggested that instantaneous valve closure may be represented by 0·0001 sec. In practice, a hand-operated quick-action valve cannot be closed in less than 0·1 sec. against a flow of water. Since, by Newton's Second Law, force (and thus also pressure intensity) is inversely proportional to time, it becomes necessary to include a coefficient (C_p) to permit equation (3) to represent practical conditions. We then have:—

$$p = C_p \left[c_1 + \sqrt{(p_1 + c_1)^2 + \rho c_1 v^2}\right] \quad . \quad (3a)$$

where C_p is a function of time and also, possibly, of U^1 and U_1. As a first approximation it is suggested that

$$C_p = \frac{\text{time for instantaneous closure (say } 0\cdot0001 \text{ sec.)}}{\text{actual time for rapid closure, say T secs.}}$$

$$= \frac{0\cdot0001}{T} = 0\cdot001, \text{ when } T = 0\cdot1 \text{ sec.}$$

I am aware that this suggestion conflicts with the usual view that p is independent of time, provided T be less than a certain critical value. In most cases, it will be found that p_1 is negligible compared with c_1, and also that $\rho c_1 v^2$ is very small compared with c_1^2. Equation (3a) thus reduces to

$$p = C_p \times 2 c_1 = \frac{0\cdot0001}{T} \left\{ \frac{2 K}{1 + \frac{K}{E}\left(\frac{k r_m}{c d}\right)} \right\} \quad (5)$$

The value of k is given correctly by equation (2) of my first letter to you on this subject.

In conclusion, I would add that if Mr. Linton can refer me to more recent experiments on water hammer in simple pipe-lines, covering the range $v = 0\cdot5$ to 20 ft. per second, I should be very glad to know of them.

Yours faithfully,
L. E. ADAMS.

11, Milner-road,
Kingston-on-Thames,
Surrey.
September 2, 1952.

FIXED END MOMENTS IN BEAMS WITH LINEAR HAUNCHES

TO THE EDITOR OF ENGINEERING.

SIR,—I read with interest the above article by Mr. B. Mayfield and Mr. R. C. Coates, which appeared on page 68 of your July 18 issue. The method given for obtaining the fixed end moments and carry-over factors of tapered beams necessitates a rather laborious mathematical integration of the "Column Analogy" functions, and suffers from the disadvantage of needing greater than slide-rule accuracy in the evaluation of the results. The method is also restricted to linear haunches in which the moment of inertia at any section can be simply expressed as a function of its co-ordinates. The method given here is not restricted to prismatic members or beams with linear haunches. The varying functions are summed in parts by a system of multipliers, which is equivalent to considering the area to be summated as a number of parabolic sections.

If $a, b, c, d, e \ldots x, y, z$, are the ordinates of an area divided into an even number of parts, each of width δs, then the area is

$$\frac{\delta s}{3}(1a + 4b + 2c + 4d + 2e \ldots 2x + 4y + 1z)$$

Using the same symbols and expressions as appeared in the original article, Table I is given for the case where the haunches extended 0·4L. The method is here applied to linear haunches in order to compare the results by the two methods. For convenience in the table, E I, the flexural rigidity at any section, is taken as $\frac{\text{depth}^3}{10}$, and L, the total length, is taken as 12 units. $\frac{\delta s}{3}$ is common to all summations and is omitted. The positions of the points are shown in Fig. 1.

The values for $a = 0\cdot2$ are obtained in a similar fashion, and a final summary is given in Table II.

TABLE II. *Fixed End Moments*

a	Carry-Over Factor.	$\frac{M_A}{L}$ Position of Load.			$\frac{M_B}{L}$ Position of Load.		
		7	5	3	7	5	3
0·4	0·724	0·171	0·205	0·139	0·171	0·081	0·014
0·2	0·662	0·154	0·198	0·146	0·154	0·070	0·013

These values are shown, in Fig. 2, plotted on the original graphs, and, as can be seen, are in good agreement with the results obtained by the more rigid calculation.

Yours faithfully,
D. E. JONES, B.Sc.

Constructional Design Department,
The Quasi-Arc Company, Limited,
Bilston, Staffs.
August 26, 1952.

Fig. 1.

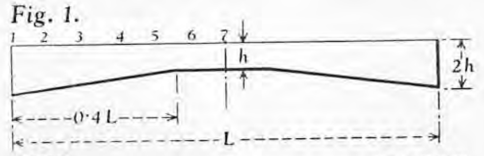


Fig. 2. INFLUENCE LINES FOR FIXING MOMENT.

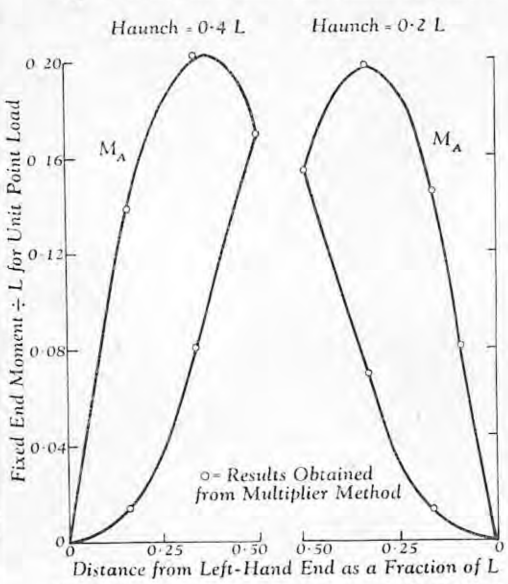


TABLE I.

Pt.	I.	$m.$	$\frac{m}{I}$.	$x.$	$x^2.$	$\frac{x^2 m}{I}$.	Unit Load at 7.			Unit Load at 5.			Unit Load at 3.		
							M_F.	$\frac{m}{I} M_F$.	$\frac{mx}{I} M_F$.	M_F	$\frac{m}{I} M_F$.	$\frac{mx}{I} M_F$.	M_F.	$\frac{m}{I} M_F$.	$\frac{mx}{I} M_F$.
1	0·8	1	1·25	6	36	45	6	7·5	4·5	4	5	30	2	2·5	15
2	0·577	4	6·93	5	25	173·2	5	34·65	173·2	3	20·79	103·95	1	6·93	34·65
3	0·397	2	5·04	4	16	80·7	4	20·16	80·7	2	10·08	40·32	0	0	
4	0·260	4	15·37	3	9	138·3	3	46·11	138·3	1	15·37	46·11			
5	0·159	2	12·57	2	4	50·3	2	25·14	50·3	0	0	0			
6	0·1	4	40·0	1	1	40	1	40·0	4·0						
7	0·1	1	10·0	0	0		0								
			91·16			527·5		173·56	527·5		51·24	220·38		9·43	49·65

$$A = 2 \times 91\cdot16 = 182\cdot32$$
$$I_{yy} = 2 \times 527\cdot5 = 1{,}055$$

$$\text{Carry-over factor} = \frac{I_{yy} - \frac{A L^2}{4}}{I_{yy} + \frac{A L^2}{4}}$$

$$= \frac{1055 - 182\cdot3 \times 36}{1055 + 182\cdot3 \times 36}$$

$$= \frac{1055 - 6560}{1055 + 6560} = 0\cdot724$$

$W = 173\cdot56$
$\frac{W}{A} = 0\cdot95$
$M_{yy} = 527\cdot5$
$\frac{M_{yy}}{I_{yy}} \frac{L}{2} = 3$
$M_A = 6 - 3 - 0\cdot95 = 2\cdot05$
$M_B = 3 - 0\cdot95 = 2\cdot05$

$W = 51\cdot24$
$\frac{W}{A} = 0\cdot281$
$M_{yy} = 220\cdot38$
$\frac{M_{yy}}{I_{yy}} \frac{L}{2} = 1\cdot253$
$M_A = 4 - 1\cdot253 - 0\cdot281 = 2\cdot466$
$M_B = 1\cdot253 - 0\cdot281 = 0\cdot972$

$W = 9\cdot43$
$\frac{W}{A} = 0\cdot052$
$M_{yy} = 49\cdot65$
$\frac{M_{yy}}{I_{yy}} \frac{L}{2} = 0\cdot283$
$M_A = 2 - 0\cdot283 - 0\cdot052 = 1\cdot665$
$M_B = 0\cdot283 - 0\cdot052 = 0\cdot231$

INELASTIC DEFORMATION OF REINFORCED CONCRETE IN RELATION TO ULTIMATE STRENGTH.

TO THE EDITOR OF ENGINEERING.

SIR,—One feature in the otherwise excellent review by Dr. Henry J. Cowan on page 276 of your issue for August 29, might alarm those engineers who have no intimate knowledge of the properties of concrete. The rheological model in Fig. 5 and the relevant equations imply that, even at working stresses, the creep of concrete continues indefinitely and therefore reaches an infinite value after an infinite time because of the series dashpot and the deformation $y = P b_1 t$. This is contrary to practical experience and to the results of investigations which indicate that creep reaches a definite limiting magnitude. It is realised that the series dashpot is introduced in order to satisfy the condition of a relatively small creep recovery on release from stress, but, if such a dashpot is included in the model, it must necessarily have a non-linear characteristic such that its resistance is progressively increased and its velocity decreased for increasing deformations.

A similar model, which does not suffer from this defect, was described by the writer in the *Jl. Inst. Civ.Eng.*, vol. 21 (1), page 38 (1943).

Yours faithfully,
A. D. ROSS.

King's College,
Strand,
London, W.C.2.
September 4, 1952.

OBITUARY.

SIR RICHARD GREGORY, BT., F.R.S.

A PROMINENT figure has passed from the scientific world by the death of Sir Richard Gregory, Bt., F.R.S., which, we regret to record, occurred on Monday last, at his home in Middleton-on-Sea, near Bognor Regis. Richard Arman Gregory was born at Bristol on January 29, 1864, so that he had reached the ripe age of 88 years. His early education was obtained in an elementary school in Bristol and he also attended evening classes. His first employment was as an assistant in the physical laboratory of Clifton College, a position he occupied for three years from 1882 to 1885. He then became a teacher in training at the Royal College of Science and afterwards acted as science demonstrator in H.M. Dockyard School at Portsmouth. His connection with astronomy commenced in 1889, when he was engaged as a computor to the Solar Physics Committee and also acted as an assistant to Sir Norman Lockyer.

It is probable, however, that he will best be remembered as a very capable editor of our contemporary *Nature*, having been connected with that journal for 46 years, first as assistant editor and later as editor, retiring in 1939. Members of the British Association will also remember him for his regular attendance at the meetings of the Association for many years. He had the distinction of remaining President of the Association from 1940 to 1946, as the meetings had to be abandoned during the war, although the Association itself was by no means inactive during that period. He was an acknowledged authority on educational matters and held many important official positions related to this subject. His publications included several text-books on physical geography, physics, chemistry and experimental science, as well as works on astronomy and other branches of science, all of which showed a notable breadth and depth of knowledge. This is also indicated by the fact that he was a Fellow of the Royal Astronomical Society, of the Royal Meteorological Society and of the Institute of Physics, as well as of the Royal Society, to which he was elected in 1933. Among the academic honours he received may be mentioned the Hon. D.Sc. degrees of Leeds and Bristol Universities and the Hon. LL.D. of St. Andrews. He was also Emeritus Professor of Astronomy in Queen's College, London. He received a knighthood in 1919 and a baronetcy in 1931.

THE TROSTRE TIN-PLATE WORKS OF THE STEEL COMPANY OF WALES.

THE Trostre tin-plate works of the Steel Company of Wales, near Llanelly, which are to be visited by members of the Iron and Steel Institute on Tuesday, October 7, form part of a large reconstruction project for the South Wales sheet-steel and tin-plate industry, which was inaugurated after the war. They are situated on 420 acres of low-lying ground, upon which an ash carpet has been laid to an average depth of 2 ft., bringing the elevation up to 16·00 above Ordnance Datum. Some 26,000 concrete piles, 17½ in. in diameter, were then driven to an average depth of 24 ft. to form the foundation, although use was also made of the rock on the site to support the five-stand cold-reduction and temper mills and certain other plant. To ensure safety from flooding and to provide natural drainage, the mill floor was raised to 28 ft. O.D., and the underlying space used for cellars, etc.

The raw material for Trostre consists of hot-rolled steel coils of various qualities, which are normally transported by rail in special 42-ton wagons from the Abbey works, Port Talbot. These wagons are hauled into a reception bay where the coils are unloaded by Heppenstall-type tongs on to a conveyor, which takes them to an uncoiler at the entry end of the continuous pickling line. A view of this pickling line appears in Fig. 1. As the strip is uncoiled, the scale is broken up and it is then levelled and trimmed. To enable the pickling operation to be continuous, the trailing end of one coil is welded and stitched to the leading end of the following coil, and the combined length is fed by pinch rolls into a looping pit, whence it is withdrawn into the first of five 80-ft. acid tanks. It passes through these tanks, which contain sulphuric acid of different strengths, at a maximum speed of 500 ft. per minute and is then washed and dried before passing into a looping pit. The stitched ends are cut out, after which the strip is side-trimmed and recoiled into 30,000-lb. coils and coated with hot palm oil. The coils are then ejected on to an automatic weigher and rolled to a storage ramp.

The coils are next loaded on to the entry conveyor of a five-stand cold-reduction mill, which is equipped with work rolls 21 in. in diameter by 48 in. body length and back-up rolls 53 in. in diameter by 47 in. body length. The first stand is driven by a 1,750-h.p. direct-current motor, the second and third stands by 3,500-h.p. motors, the fourth stand by a 4,000-h.p. motor, and the fifth stand by a 5,500-h.p. motor. All these motors and the motor-generators from which they are supplied are housed in a separate air-conditioned room, as will be seen in Fig. 2. The five stands of this mill reduce the strip to the required gauge, after which it is rewound into 30,000-lb. coils by an electrically-driven reel. All traces of oil are next removed by passing the strip through a caustic washer, scrubber, electrolytic cleaning tank and a second scrubber, and washing and drying it. The maximum speed of this cleaning line is 2,000 ft. per minute and its operation is continuous.

To ensure that the plate is sufficiently ductile, the coils after cleaning are stacked to form a charge weighing about 200 tons, and are covered with a heat-resisting cylindrical steel cover. They are then passed into one of five oil-fired annealing furnaces through which inert gas is circulated during the heating and soaking cycle. The annealed strip is cold-rolled to the required temper in one of two cold temper mills. Each of these mills consists of two stands, which are equipped with four-high rolls, the work rolls being 18 in. in diameter and 48 in. long and the back-up rolls 53 in. in diameter and 47 in. long. The mills operate at a maximum speed of 4,000 ft. per minute.

The strip from these mills is taken either to hot-dip or to electrolytic tinning plant. Nine Poole Davis machines are being installed for the former process. At present, however, the hot-dipping of sheets produced at Trostre is carried out at other of the company's plants in the area. Coils which are destined for electrolytic tinning are passed through preparatory lines incorporating side trimmers and shears at a maximum speed of 1,800 ft. per minute, to an electrolytic continuous-tinning unit. This consists of two acid "Ferrostan" lines which have been designed to handle 30,000-lb. coils and to tin ½ lb. coatings at a speed of 800 ft. per minute. The plant includes electrolytic de-greasing equipment, cold-water rinses, electrolytic sulphuric-acid picklers and water sprays and brushes. The tinning zone is made up of five plating tanks, the current through which is controlled to give a constant coating at varying speeds, and one drag-out tank, in which the strip is washed and the electrolyte recovered for future use. The strip then enters the flow melt unit where it is heated so that the tin flows and gives the product a bright surface, after which it is treated in an electro-chemical chromic-acid unit to prevent discolouration on lacquering and during stocking. Finally, the strip is covered with an emulsion of cotton-seed oil to provide the necessary lubrication during fabricating operations and it is sheared into plates of the required width for stock.

Electric power is used extensively throughout the works and is supplied mainly from the grid at 132 kV. It is stepped down from this voltage in local substations and distributed through 40 transformers with a total capacity of 12·5 MVA into networks operating at 11 kV, 3·3 kV, and 415 volts. There is also a 230-volt direct-current supply. These networks are designed to provide alternative supplies at the principle distribution points so as to reduce the risk of stoppage. It is estimated that the annual electricity consumption will exceed 200 million kWh.

Mr. H. Leighton Davies described the Trostre works in his presidential address to the Iron and Steel Institute, a part of which we reprinted on page 629 of our issue of May 16, 1952.

TROSTRE TIN-PLATE WORKS.

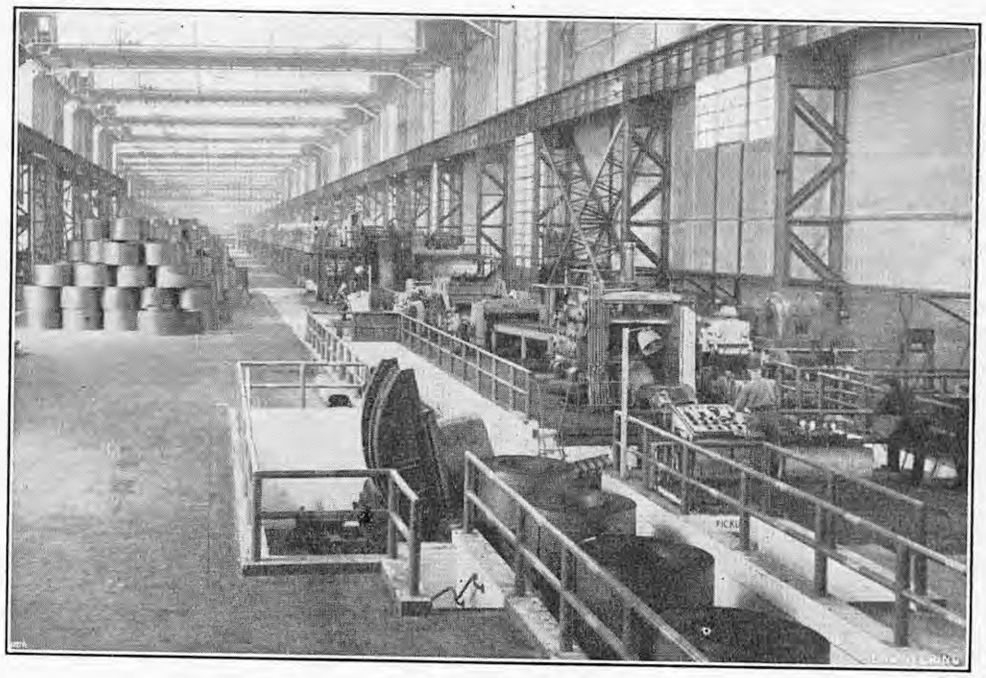


FIG. 1. ENTRY END OF PICKLE LINE.

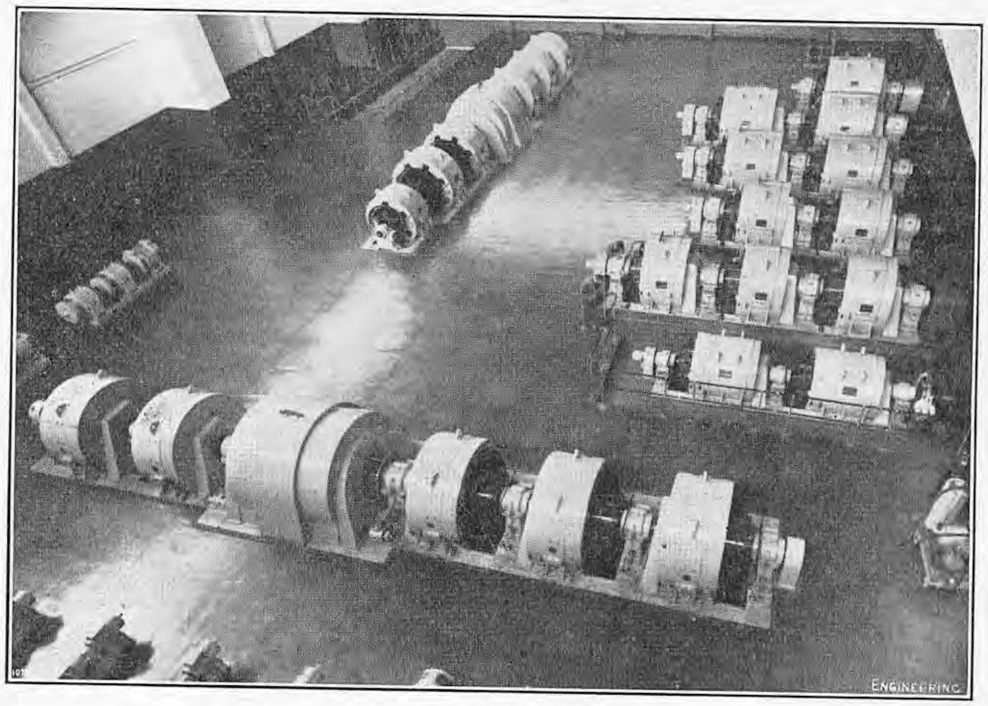


FIG. 2. MOTOR ROOM.

ROYAL AERONAUTICAL SOCIETY: BRITISH COMMONWEALTH AND EMPIRE LECTURE.—The 8th British Commonwealth and Empire Lecture of the Royal Aeronautical Society is to be given by Mr. R. E. Hardingham, O.B.E., F.R.Ae.S., on Thursday, October 2, at 6 p.m., at the Institution of Mechanical Engineers, Storey's Gate, London, S.W.1. The subject of the lecture is "Maintaining Airworthiness in Operation."

LAYING PIPE-LINES BY LOCOMOTIVE.

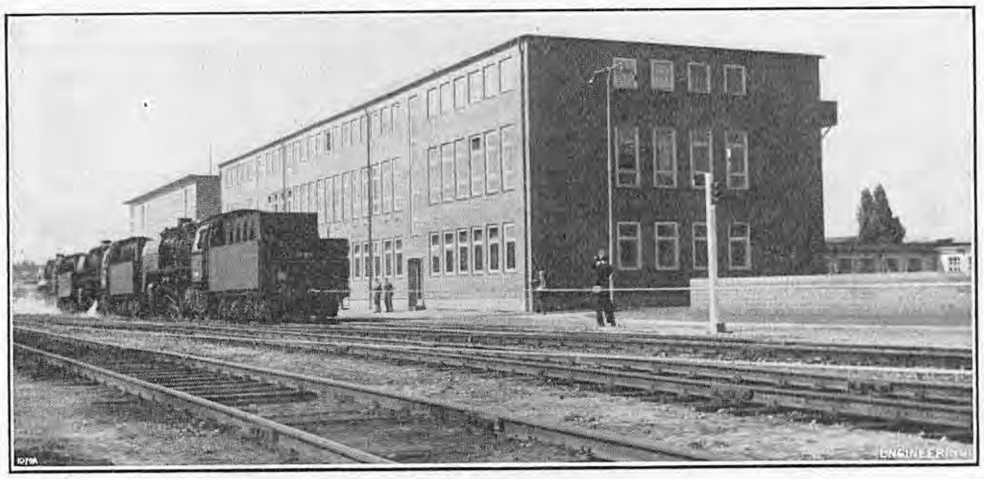


FIG. 1. THREE FREIGHT LOCOMOTIVES HAULING PIPE-LINES.

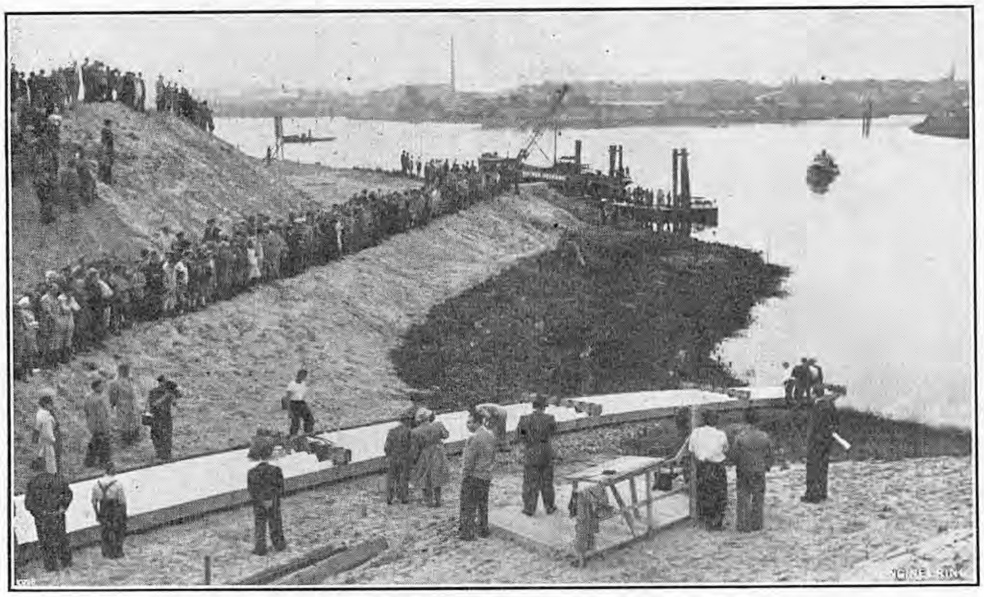


FIG. 2. EIGHT PIPE-LINES ON LAUNCHING SIDE OF RIVER.

PIPE-LINES HAULED ON TO RIVER BED BY LOCOMOTIVES.

To connect a refinery on a river bank with a storage-tank site on the opposite bank, eight pipe-lines have recently been laid on the bed of the river by coupling them, with a steel cable, to three locomotives. The work was carried out, in one hour, between the Shell Harburg Refinery on the south side of the ½-mile wide Süder Elbe River at Hamburg, Germany, and a new site for storage tanks on the north side. Owing to the density of river traffic and to the rise and fall of the tide, it was not possible to lay the pipes (four 10 in. in diameter, two 8 in., and two 4 in.) by floating them into position on pontoons and then lowering them on to the river bed.

The pipes were therefore laid side by side on a continuous steel plate, on which they were held in correct alignment by U-bolts secured through wooden cross-members spaced at frequent intervals, as shown in Fig. 2, above. The pipes were protected against corrosion by thick coatings of bitumen and a glass-fibre wrapping. The complete assembly was laid out on a launching way consisting of railway lines arranged at right-angles to the river and smeared with graphite grease. The approaches, on both the launching and landing sides, were cut back to ensure an easy contour down to the river bed, as shown in Fig. 2. A launching nose with an upswept bow was fixed to the leading end of the pipe-line assembly to prevent it catching in the bed of the river during the operation. The whole assembly, weighing 160 tons, was connected through a 2-in. steel cable across the river to three German Railways steam locomotives, each of which, it is stated, was capable of exerting a pull of between 50 and 70 tons. The engines operated on sidings in the Harburg Refinery, as shown in Fig. 1, and it appears from another photograph (not reproduced) that at least one large sheave, mounted on a rail trolley, was introduced between the pipes and the locomotives.

At a signal, and with careful co-ordination by telephones on each side of the river, by five sets of traffic lights and by "walkie-talkie" radio, the pipes were drawn at a speed of 2 to 3 miles an hour, along the launching way and across the river, and laid in a 6-ft. channel that had been dredged in the bed. The Harburg Refinery is thus connected by under-water pipe-lines to the new site, recently acquired by Shell on the north side of the river, where it is planned to begin construction immediately on a number of new storage tanks, pump houses and boiler houses. Because of the position of the refinery, bounded on three sides by harbour basins, it was not possible to expand the existing storage facilities there.

PNEUMATIC COMPACTORS.—Compactors Engineering Ltd., 1A, Brailsford-road, London, S.W.2, have recently introduced a pneumatic internal vibrator designed for mass concrete and heavy reinforced-concrete construction work. The vibrating head is 4 in. in diameter and 20 in. long, and is vibrated by an eccentric, mounted on high-speed bearings and driven by a four-vane air motor consuming 60 cub. ft. per minute of free air at a pressure of 90 lb. per square inch. The frequency can be adjusted up to a maximum of 9,000 cycles.

ON THE FOOT-HILLS OF THE PLASTIC RANGE.*

By PROFESSOR H. W. SWIFT, M.A., D.Sc., M.I.Mech.E.

PLASTIC deformation forms the basis of one of the oldest of the industrial arts and one of the youngest of the applied sciences. From the earliest historical times man has applied to malleable metals the group of compressive operations which include forging, coining, and hammering; for over a thousand years he has been drawing wire, and for over a century he has been drawing tubes and sheet metal. Yet little attempt had been made before the present century to formulate the principles of plastic deformation or to correlate them with the properties of metals. It is true that the basic equations of theoretical plasticity were laid down by Levy in 1871, but so little attention did they attract that they are generally credited to von Mises, who re-enunciated them over 40 years later; and although Tresca introduced the shear-stress criterion for plastic flow in 1868, this is still commonly attributed to Guest in 1900, though he subsequently did his best to live it down.

Von Mises, of course, made other notable contributions to the theory of plasticity, and was one of the leaders of the German school which was mainly responsible for experimental and theoretical developments up to the beginning of the last war. The transfer of Continental workers to America—by cold extrusion before the war and by wire-pulling since—carried the initiative across the Atlantic for a time, but the emergence of a theoretical group at Fort Halstead during the war and the development of experimental groups under the energetic leadership of certain of the British industrial research organisations have done much to restore the balance, and in so far as results are to be judged by weight rather than volume, there is probably at the present time a greater potential of applicable theory and experiment in this country than anywhere else. Whether the appetite of British industry as a whole is as keen, or its digestible organs as efficient, as elsewhere, is perhaps another question.

But this question must not be held to imply any doubt as to the technological skill of those engaged in the metal-forming industries in this country. There can be no doubt on this score in the mind of anyone who has visited an automobile press shop and witnessed the transformation of a flat sheet into a motor-car wing in a single stroke. In fact, of course, much expense is involved in processes of trial and error and in the use of materials capable of withstanding plastic maltreatment, and there are still many products which have to be produced by slower operations or more expensive machinery than would be necessary if the plastic properties of materials were fully understood. There is, therefore, still much scope for development in technical plasticity, and this involves on the one hand the study of plastic deformation in its physical and mechanical aspects, and on the other the application of the results of this study to industrial problems. Between these there is the need for an important link; scientific results only become useful when they are interpreted in such a way that they can be understood and applied by those concerned with industrial production.

In this broad field of development there is work for many hands: for the pure scientist and the applied scientist, for the mathematician, the metallurgist, and the engineer. Indeed, since he is directly concerned with the finished product, the engineer is probably most conscious of the need for further knowledge over a wide front.

He realises that almost every manufacturing operation from the ingot to the finished product is essentially related to the plastic properties of the material: rolling, forging, pressing, drawing, extrusion, and even machining. He realises, moreover, that the plastic properties of materials are becoming increasingly significant in modern engineering design. Apart from such established processes as shrinking, over-speeding, and auto-frettage, he is

* Twenty-third Autumn Lecture delivered before the Institute of Metals at Oxford on Monday, September 15, 1952. Abridged.

beginning to take advantage of the economies made possible by considerations of plastic strain in the limit design of structures. And he is just beginning to realise that in his innocence he has, in fact, for many years been basing his designs on the plastic properties of ductile metals, for the "ultimate tensile strength," to which he has traditionally applied his factor of safety, is itself nothing but a function of the plastic stress/strain curve.

For his own purposes the engineer needs to be able to assess the possibilities of various processes of formation and fabrication in relation to materials which are economically available. He needs to devise these processes so as to produce results with the minimum demand on these materials and the minimum expense; he needs to design machines and equipment to carry out these processes; and he needs to be able to specify and therefore to test material suitable for these processes. And at all stages he is concerned as far as possible to eliminate the expense and delay involved in trial-and-error methods.

In this field, if in no other, and however reluctantly, the metallurgist has to accept a rôle complementary to the engineer. It is his concern to provide material with properties suitable for the engineer to fabricate and process, and to advise him on the specification and treatment of this material. For this purpose he needs to know—and preferably to understand—how suitable plastic properties can be obtained, and he is continually seeking to develop new materials to circumvent the engineer's ingenuity in maltreatment. He also needs to have at his disposal means for the testing of materials, which shall be relevant to their application and acceptable to the engineer.

If they were left to their own devices, the metallurgist and the engineer would be compelled in the main to have recourse to empirical or trial-and-error methods, methods which are tedious and uneconomical, and uncongenial to the scientific mind. They are therefore gratified to realise that applied mathematicians and such physicists as are prepared to regard the atom as a unit rather than a universe, have been increasingly finding in the field of plasticity material worthy of fundamental inquiry.

The metal physicist is concerned to understand the nature and mechanism of plastic deformation in relation to atomic and crystal structure, and so to be able to correlate physical and mechanical properties with the structure and treatment of metals. In this way he should be in a position to point directions in which desirable plastic properties are likely to be found, and to guide the metallurgist in the development of materials possessing these properties.

The mathematician's interest in plasticity can cover a considerable range. He can apply his techniques in the field of metal physics to explain plastic deformation at the atomic level and seek correlation between single-crystal and polycrystalline properties. Or, closer to the field of the engineer, he can study the distribution of stresses and strains in a material of specified properties under a given type of deformation, and he can seek to prescribe the limiting range of this deformation in relation to the intrinsic strength of the material.

So we have four distinct parties each concerned from its own point of approach, by its own route, with its own resources, and its own objective, to explore the secrets and exploit the resources of the plastic range. The engineer is all too conscious that his own equipment is quite unequal to the task of scaling the real heights, so he must limit his pedestrian efforts to the foot-hills of the range. Here he can watch and admire the skill of those whose special scientific equipment enables them to climb to greater heights and perhaps even to aspire to the peaks of the range.

(*To be continued.*)

JET-RESISTANT ASPHALT CARPET.—The Shell Petroleum Company, Limited, St. Helen's-court, Great St. Helen's, London, E.C.3, have developed a jet-resistant asphalt carpet for airfield runways and aprons. It is applied on normal bituminous or tar-surfaced runway areas where jet-exhaust heat is likely to cause disintegration. The carpet has successfully undergone extensive trials and has been proved to withstand heat and blast effects.

LABOUR NOTES.

THE restriction of piecework and a ban on overtime, to be applied throughout the engineering, shipbuilding and allied industries, were approved, by a majority of 113 to 75, at a meeting of executive officials of the 38 unions affiliated to the Confederation of Shipbuilding and Engineering Unions at a conference in York on September 10. The delegates decided to instruct the members of their unions to impose such bans as from a date to be decided upon later by the executive council of the Confederation. Recommendations for the enforcement of these restrictions on industrial output were first made at a meeting of the Confederation's executive council at a meeting in Margate on August 31, as a means of protesting against the rejection by the Engineering and Allied Employers' National Federation of a demand from the Confederation for an increase of 40*s*. a week for all male manual employees in the engineering group of industries.

Engineering employees engaged on piecework, the executive council suggested, should not be permitted to work longer than would be required to bring their earnings up to the equivalent of 44 hours' wages at day-work rates. Considerable differences of opinion appear to have been shown at the full delegate meeting at York. The main opponents to the executive council's recommendations were delegates from unions catering for unskilled employees in the engineering and shipbuilding industries. Officials of the Transport and General Workers' Union and of the National Union of General and Municipal Workers are reported to have brought forward proposals for the wage claim to be referred to arbitration, but their proposition was defeated by a substantial majority.

Suggestions by the Amalgamated Engineering Union, that a national ballot should be taken on whether there should be a ban on overtime and piecework or a strike, and by the Electrical Trades Union, that the men should be free to take any action they thought fit and that if a strike resulted it should be supported, were defeated by even larger majorities. Mr. H. G. Brotherton, the President of the Confederation, stated after the meeting that the resolution imposing the bans was an instruction to the Confederation's affiliated unions, but that it would be left to each union to decide on the way in which its members would implement the decision.

Apart from the serious consequences which a ban on overtime and the limiting of piecework would have on Britain's export trade and on the re-armament programme, there can be no doubt that individual employees would suffer considerable financial losses by the enforcement of these restrictions on earnings. Recent official figures indicate that rather more than half of all employees in the engineering and allied industries are engaged on a payment-by-results basis, in some form. In the shipbuilding and ship-repairing industries, the proportion of workpeople on piecework is estimated to be as high as 80 per cent. About a third of the two-and-a-half million persons engaged on engineering work were recently reported to be performing an average of eight hours' overtime each week. The great majority of all these employees would be affected immediately restrictions were put into force. Altogether, about three million workpeople are concerned in the dispute.

The executive council were to have met on September 11 to decide on the date from which the restrictions were to be enforced, but, immediately after the delegate meeting on the previous day, the Confederation's general secretary had informed the Ministry of Labour of the decisions which had been taken at that meeting, and Sir Robert Gould, the chief industrial commissioner to the Ministry, suggested a meeting between himself and officials of the Confederation to discuss the situation. This meeting took place in London on Monday last, and it was announced afterwards that a decision on the date for bringing the restrictions into effect would be postponed.

It is understood that any possibility of the Confederation revising its wage claims was not among the many aspects of the dispute discussed at Monday's meeting. As previously reported, these claims were for an all-round increase of 40*s*. a week in the engineering industry and for a "substantial" increase in the shipbuilding and ship-repairing industries. It seems not unlikely that the 40*s*.-a-week claim may be allowed to lapse. As a first step towards settling the dispute, the Confederation officials appear to have concentrated on proposals for joint meetings with the employers' Federations to discuss, on their merits, the present levels of wages in the industries concerned and without being handicapped by any formal claims.

An official announcement issued after Monday's meeting stated that the situation that had developed had been discussed in "a full exploratory talk," in which the Confederation's executive council had explained its existing attitude in the light of its discussion with the engineering and shipbuilding employers. Although the decision to impose the restrictions on overtime and piecework was directed against employers in both groups of industries, the problems of the two groups were distinct and would need to be considered separately. As a result of the meeting, representatives of the Engineering and Allied Employers' National Federation and of the Shipbuilding Employers' Federation were invited to hold separate meetings with Ministry of Labour officials, to enable the Minister of Labour to obtain their respective points of view. The meeting with the former took place yesterday and that with the latter will be held on Tuesday.

Claims that members of the Amalgamated Union of Foundry Workers are not afraid of a strike in support of the wage claim for the engineering and cognate industries, are contained in the union's *Monthly Journal and Report* for September. Mr. J. Gardner, the general secretary, discussing the rejection of the demand for an all-round increase of 40*s*. a week for employees in these industries and writing before the meeting with the employers on August 22, states that if it should happen that no offer is made by the employers, or if one is made which is unsatisfactory, the question of deciding the union's attitude will be faced. He affirms that the union does not want a strike. On the other hand, he continues, the union is not afraid of a strike and if that be the only alternative, it is not the responsibility of the union's members, but of the employers and "their" Government.

Mr. Gardner considers that employees are faced with a serious deterioration in their living standards and writes that if it is to be that there is no other way to win a wage increase commensurate with the needs of the union's members, there will be no shirking of the issue. At a special delegate conference of the union in Manchester on Tuesday last, a resolution was approved affirming the union's support for the Confederation's wage policy. The delegates congratulated the Confederation on the stand it had taken respecting the claims.

The lowest accident rate on record for the North-Eastern Division of the National Coal Board was reached in 1951. In his report for the twelve months ended December 31 last, published in Doncaster on September 12, Mr. C. W. Scott, the divisional inspector of mines, states that the 185 collieries in the division employed about 137,000 men in 1951, and that there were 51 fatal and 333 serious non-fatal accidents during the year. He records that these low accident figures, to be fully appreciated, must be viewed against the background of an increase in the number of men employed in the mines, and of a substantial advance in the ouput of coal during the period. Over the past ten years, there had been a steady decline in the number of accidents from falls of ground. Belt conveyors, now more numerous as a result of increased mechanisation, provided the greatest fire hazard underground, but fireproof belting had been installed up to the limits of supply. Mr. Scott considers that many accidents could have been avoided and that quite a number were due to sheer neglect.

SHIPS AND SHIPBUILDING IN BELFAST.

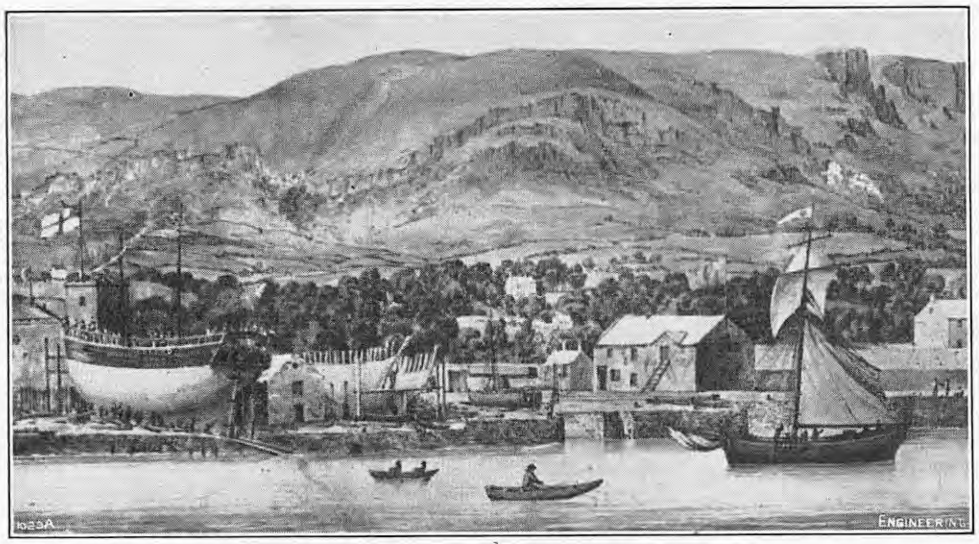


FIG. 1. BELFAST SHIPYARD, 1812.

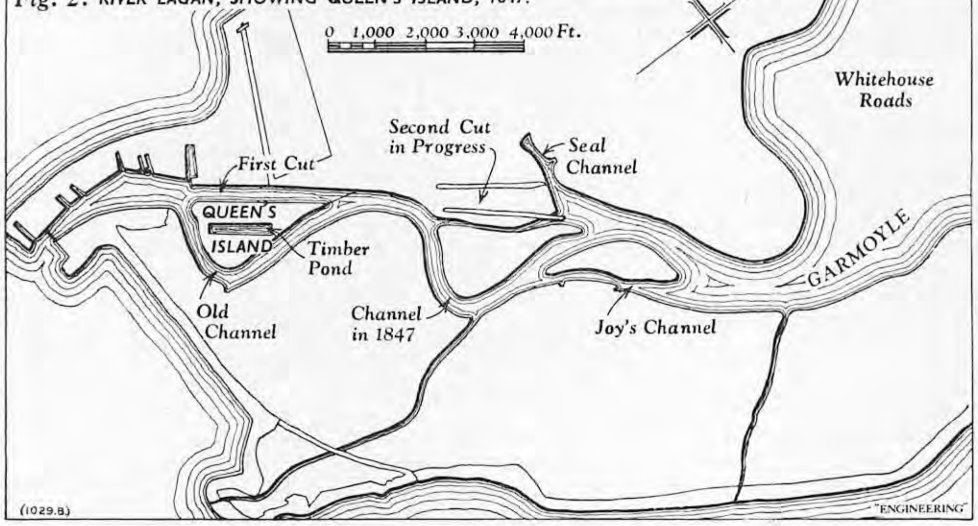
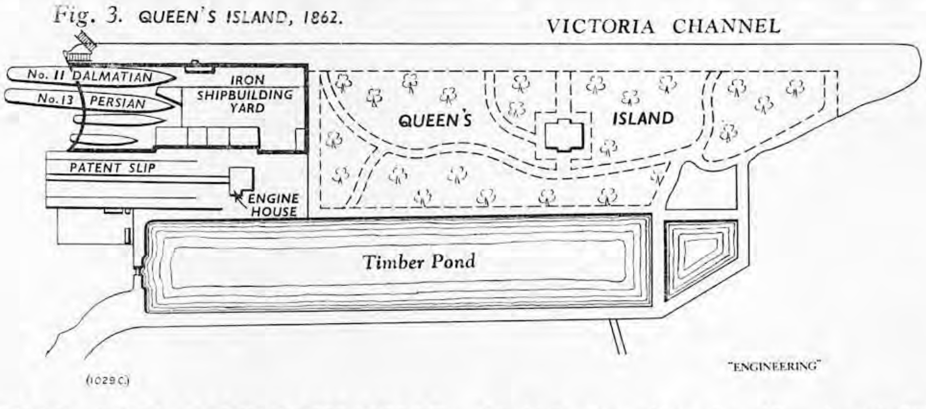


Fig. 2. RIVER LAGAN, SHOWING QUEEN'S ISLAND, 1847.

Fig. 3. QUEEN'S ISLAND, 1862.



SHIPS AND SHIPBUILDING IN BELFAST*.

By DR. DENIS REBBECK†, C.B.E., M.A., M.Sc., B.Litt., J.P., M.I.C.E., M.I.Mech.E.

EVIDENCE of shipbuilding on the Lagan before the Eighteenth Century is very meagre, and it is generally accepted that the industry did not assume substantial proportions until 1791, when a Scot named William Ritchie paid a visit to Belfast with a view to transferring his shipyard from Saltcoats in Ayrshire to the banks of the Lagan. Having been impressed with the possibilities of Belfast as a shipbuilding centre, Ritchie started a small yard the same year, with ten men and a quantity of shipbuilding apparatus and materials. Ritchie's first ship, the Hibernia, of 300 tons burthen, was launched on July 7, 1792, and the largest vessel built by his yard was the James, of 400 tons, which at the date of her launching—October 16, 1810—was also the largest vessel to be built at Belfast. Fig. 1 shows the appearance of the yard in 1812.

The next stage in the development of the Belfast shipyards commenced with the formation of the world-famous Queen's Island. The progress of Belfast trade and commerce had long been impeded by the lack of a port authority with sufficient power to carry out the various engineering works which were absolutely essential if vessels of more than 200 to 300 tons burthen were to navigate the slob-lined and winding channel of the River Lagan. The old Ballast Corporation, dating from an Act of 1785, was superseded in the year 1837 by a new body with larger powers; and this again was displaced in 1847 by Harbour Commissioners, vested with the full unified control of the Port. Belfast is indebted to the wise, far-sighted and extremely able men of that period who planned the many harbour improvements to which the prosperity of Belfast as a port is largely due.

The most important improvement was the straightening of the river. The material excavated from the new channel was deposited on the eastern side of the cut so as to form an island which would act as a training bank for the Lagan. This 17-acre island became known as "Dargan's Island," after William Dargan, the contractor who carried out the work. It was used as a pleasure park, and was the only public park which Belfast then possessed. In 1849, the name of the island was changed to "Queen's Island," shown in the plan, Fig. 2, in honour of Queen Victoria, who visited the city of Belfast in that year (just three years before the first visit of the British Association) to open the "New Cut." At a later date, the old channel of the river on the east side of the island was filled in, but the name "Queen's Island" remained, and became world-famous as the birthplace of ocean liners.

The iron shipbuilding yard on the Queen's Island was laid out in 1853. The Belfast Harbour Commissioners' Annual Report for that year states that: "The shipyard formed for Mr. Hickson, on Queen's Island, with the object of encouraging Iron Shipbuilding on a more extensive scale than previously, affords a striking proof of the advancement of the shipping interest. The business has been commenced in a spirit that augurs well for its future success and importance, the vessels contracted for being of a very large tonnage, and the Proprietor already finding it necessary to ask for additional space. It is also proper to observe that the other yards, for Timber-built Ships, are extending their business and laying down vessels of a much larger burthen than formerly." Mr. Hickson was a partner in the firm of Robert Hickson and Company, the proprietors of an ironworks in Eliza-street, Belfast. The ironworks had been started with the intention of supplying iron plates for ships and boilers, but, as there was an insufficient demand, Hickson decided to start a shipbuilding yard of his own, and so use the products of his ironworks. Hickson was unfortunate in the choice of his first shipyard manager, and inside twelve months the latter had been dismissed. An advertisement for a new manager was duly circulated, and Robert Hickson waited impatiently for replies to reach him.

One man who applied for the position and was, in due course, appointed was Edward James Harland. His dominant personality was destined to increase considerably this new industry in a locality which, though offering certain advantages, must at the same time have presented very many problems. As Harland was destined to play such a very great part in the development of the shipbuilding industry on the Lagan, and as he turned out to be a man of remarkable ability, of great courage and of resolute determination, it would not appear inappropriate to touch on his training and his early history.

Edward James Harland, later Sir Edward Harland, Bt., was born at Scarborough in May, 1831, being the sixth of a family of eight. He was the son of a medical practitioner who appears to have been at the same time an inventor of some note in the sphere of steam-propelled road vehicles. Young Harland spent many of his boyhood days in observing the construction of 1,000-ton East Indiamen which were being built near his home at Scarborough, and to quote his own words: "Scarcely a timber was moulded, a plank bent, a spar lined off, or launching slipways laid, without my being present to witness them." When schooldays were over, Harland, through his father's early acquaintance with George Stephenson, entered the engineering works of Robert Stephenson and Company at Newcastle-upon-Tyne, as a pupil, on his 15th birthday. It is worth noting that the hours of working were from 6 a.m. to 8.15 p.m. five days a week, and the stopping time on Saturdays was 4 p.m. The young man's apprenticeship was completed in May, 1851, on his 20th birthday, whereupon he was engaged as a journeyman with the same firm, at the princely wage of 20s. a week. A short while afterwards, Harland proceeded to Glasgow, where he gained further experience with a

* Paper read before Section G of the British Association at Belfast on Friday, September 5, 1952.

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firm of marine-engine builders, Messrs. J. and G. Thomson. In the autumn of the year 1853, the young man accepted the position of yard manager with a shipbuilder on the Tyne, a Mr. Thomas Toward, whose yard at St. Peter's was about two and a half miles below Newcastle. Harland was not satisfied with the quality of the work at Toward's yard, and he contrived to raise the standard without a corresponding increase in production costs. He had learnt another very important lesson, a lesson which was to make, in later years, the Queen's Island famous for quality in ship construction. Harland once said that quality is " a very important element in all commercial success," and on that statement he built much of his successful business.

Harland had not been at Toward's for very long before he realised that the yard was capable of only limited development. Mr. Toward was a very sick man and could pay but scant attention to his work, and, although this tended to throw nearly all the responsibility on Harland's young shoulders, the latter was not happy about the future prospects of the undertaking. In consequence, Harland answered Hickson's advertisement for a yard manager for the Belfast shipyard, and in due course travelled over to Northern Ireland towards the end of 1854 to take up his new position at the Queen's Island.

The author has purposely given a fairly detailed description of Sir Edward Harland's career up to the time when he came to Belfast, because there is no doubt that Harland was the man to whom all the credit is due for the competent and far-sighted way in which the foundations of Messrs. Harland and Wolff were laid, thus making possible the development of the firm into the great concern which we know to-day. It was also most fortunate that one of his first pupils, W. J. Pirrie, who later became Lord Pirrie, developed into such an outstanding shipbuilder that he was able to carry on the work which Harland had so ably started. The great developments that have taken place in the establishment since the death of Lord Pirrie are modern history, but, in view of the author's close relationship to the present chairman and managing director, he hesitates to express his views on the further considerable progress achieved since the death of Lord Pirrie in 1924. It is generally agreed, however, that the example of energetic and active men invariably attracts similar capable and forceful personalities in a very pronounced manner. Edward Harland started in his new position as manager of Hickson's yard on the Queen's Island at Christmas, 1854. He was evidently much impressed by the fact that the yard was capable of great expansion, also that it was well placed, alongside a fine patent slip, shown in Fig. 3, on page 385, with clear frontage, thus allowing the largest ships to be launched with ease.

At this time, Robert Hickson had just launched and completed his first ship, the Mary Stenhouse, an iron sailing ship of 1,289 tons, and the firm had an order for two large iron sailing ships, one of which was partly framed. This, then, was Edward Harland's first job at Belfast, and as Hickson was not a practical shipbuilder, the new manager found that the responsibility for the construction of the new vessels fell on his broad young shoulders. After going through various " teething " troubles with men, material and wages, Harland got the establishment going to his satisfaction, and the two large sailing ships were duly completed to the owners' requirements. Orders were obtained for several more large iron sailing ships and steamers, wrecked ships were lifted and repaired, and all went well " to the material advantage of Mr. Hickson." Harland soon became dissatisfied with being virtual head of the yard without the privileges and satisfaction of ownership. Thus, after being with Hickson for a period of three years, he decided to start elsewhere on his own account. He made inquiries at Garston, Birkenhead and other places. It was during these searchings for an opening elsewhere that Harland's employer, Hickson, heard of the young man's intentions, and, saying that he had no desire to carry on the concern after Harland had left, Hickson made a satisfactory proposal for the sale of the yard to Harland.

The author had before him as he wrote this paper the letter of transfer from Hickson to Harland, dated September 21, 1858. This valuable document consists of a sheet of faded notepaper on which, in Hickson's legible hand, are written the terms of the transfer of ownership of the yard; offering ". . . my interest and goodwill in the shipyard at the Queen's Island, Belfast, together with steam engine, boiler plant, tools, machinery, and other appliances for shipbuilding, as now in use by me for the sum of five thousand pounds." At the bottom of the letter, in a bold, firm hand, is written, " I accept the above offer," signed E. J. Harland. The transfer and purchase were soon completed, through the assistance of Harland's old and esteemed friend, a Mr. G. C. Schwabe, of Liverpool, an uncle of Harland's private assistant, Mr. G. W. Wolff.

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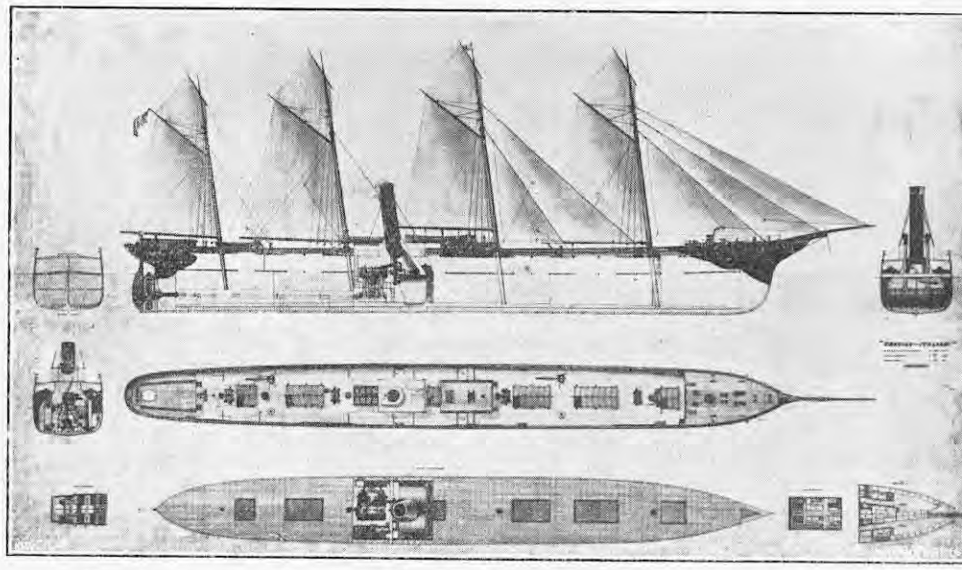

FIG. 4. RIGGING PLAN OF BIBBY STEAMERS BUILT AT QUEEN'S ISLAND, 1861.

Harland's first order came from Messrs. J. Bibby, Sons and Company, of Liverpool, and was for three screw steamers—four-masted iron barques—the Venetian (Fig. 7, page 376), Sicilian and Syrian, each of 290 ft. overall length, 34 ft. beam, and 22 ft. 9 in. depth, intended to trade between Liverpool and ports in the Mediterranean. These vessels are Nos. 1, 2 and 3, respectively, in the list of ships ordered from Messrs. Harland and Wolff, Limited—a list which now, in 1952, has almost reached the figure of 1,550. The Bibby order was considered a large one, in the middle of the Nineteenth Century, and it required many additions to the plant and machinery at the Queen's Island. Harland invited Mr. Gustav Wilhelm Wolff, who was at that time sailing as an engineer in the Mediterranean, to return and take charge of the drawing office. Wolff was a very able engineer with considerable practical experience. Born in Hamburg on November 10, 1834, he was educated both in Hamburg and at the Liverpool College, subsequently serving his time with Messrs. Joseph Whitworth and Company, of Manchester. The Venetian was launched on July 30, 1859, being christened by Mrs. Robert Hickson, the wife of Harland's previous employer. The Sicilian, launched on November 12, 1859, was christened by a Mrs. Wann (Harland's mother-in-law to be), while the Syrian, which entered the water on March 26, 1860, was christened by Mrs. E. J. Harland.

These three vessels could not be engined by Harland, as the Queen's Island was a shipyard pure and simple, so the vessels were towed to Greenock, where the boilers and engines were installed by the makers, Messrs. MacNab and Company. The steam machinery consisted of two simple cylinders, each 54 in. bore and 3 ft. 3 in. stroke, developing about 450 indicated horse-power at 46 r.p.m., with steam at 18 lb. per square inch pressure. The order for these three ships was of greater importance to Harland than he realised at the time it was placed, because it forged a commercial link between the Queen's Island shipyard and the Bibby Line which held fast for over six decades. A perusal of the ships built at the Queen's Island in the first ten years of the establishment's existence reveals a remarkable preponderance of Bibby steamers.

More orders followed, and, as Harland found that he was frequently away from home in connection with the new contracts, he decided to take Wolff in as a partner, so that the latter could attend to any business, and look after the shipyard, during Harland's absence. The partnership agreement, dated April 11, 1861, was before the author when he wrote this paper. The document contains much of interest, not least a statement to the effect that the business of the partnership should be carried on as heretofore, under the name and style of " Edward James Harland," until the said Gustav Wilhelm Wolff should desire to have his name added, when the style of the partnership would be changed to " Harland & Wolff "—a euphonious name which has become synonymous with good shipbuilding. The capital of the new company was 2,416*l*., of which E. J. Harland contributed 1,916*l*. and G. W. Wolff 500*l*. An amusing note is struck by the paragraph which stipulates that " the said Gustav Wilhelm Wolff may, in the event of his being married, or of his requiring to furnish a house, draw out of the partnership funds the sum of 800*l*." It is well known that Wolff remained a bachelor to the end of his days, but the author is not at all certain whether the funds of the Queen's Island shipbuilding firm had to stand the strain of disgorging the sum of 800*l*. towards furnishing a residence for the young German partner. At all events, Wolff was possessed of a keen sense of humour and named his house—most appropriately—" The Den " !

Harland increased the length of his later Bibby ships without increasing the beam (Fig. 4), so as to obtain greater carrying capacity without a sacrifice in speed. He made the upper deck entirely of iron, so that the hull became, in fact, a box girder of immensely increased strength compared to the more orthodox design. The rig, too, was unique. The four iron masts were made in one continuous length, with fore and aft sails, but no yards—thereby reducing the number of hands necessary to work them. The steam winches were arranged so as to be serviceable for all the heavy hauls, as well as for the rapid handling of cargo. The successful re-introduction of sea-water condensers, by introducing india-rubber rings at each end of the tubes, was advised for the main engines and found to be perfectly satisfactory. A fuel saving of some 20 per cent. was effected, and the method was adopted in the whole Bibby fleet.

More orders flowed in, more " Bibby coffins " (as the Merseyside cynics referred to Harland's vessels) set forth from the Queen's Island, and Harland's future was assured by the successful operation of these long narrow ships. To a young firm, a repetition of orders like these was a great advantage, and the novel and successful design attracted new customers from many quarters, as the firm's records of ships built at that period clearly shows. Harland

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Fig. 5. QUEEN'S ISLAND SHIPYARD AND ENGINE WORKS, 1886.

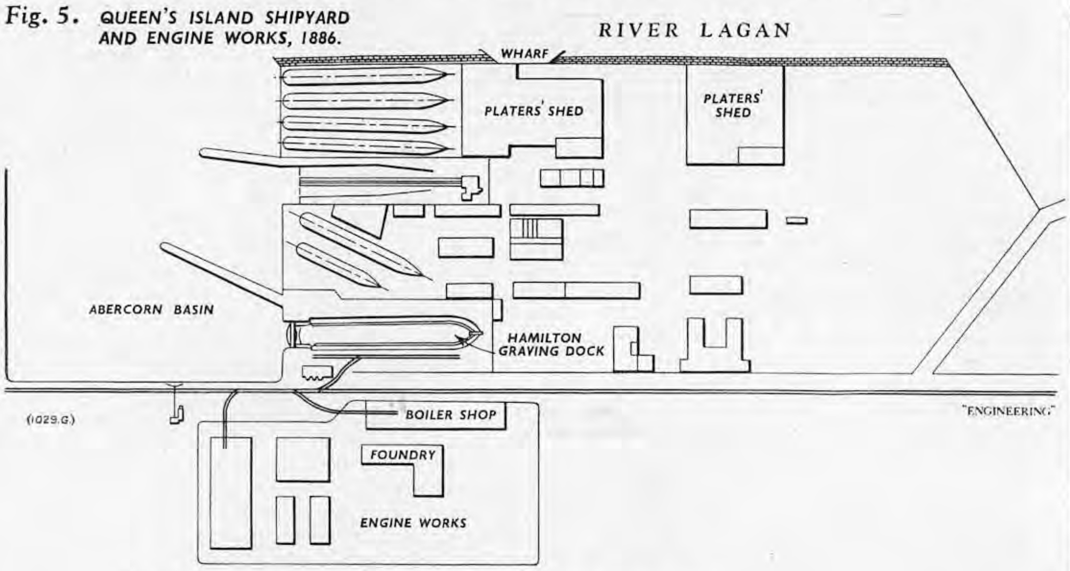
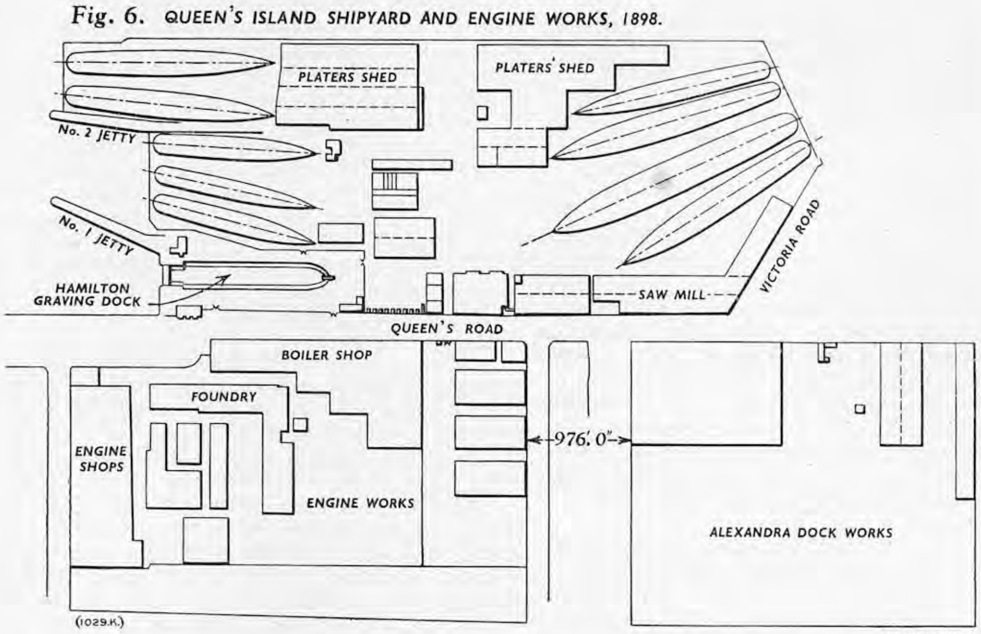


Fig. 6. QUEEN'S ISLAND SHIPYARD AND ENGINE WORKS, 1898.



had hit upon a happy medium between velocity and stability; he had gone a long way towards solving what he called "the art and mystery of shipbuilding." In order to obtain large carrying capacity, he had arranged for flatness of bottom and squareness of bilge—the "Belfast bottom," as it became known in Liverpool—and these features in turn provided stability without lessening speed.

The Bibby Line continued to order further vessels from the Queen's Island, and a notable example in the 1860's was the Istrian. In this ship, Fig. 8, page 376, the perpendicular stem was introduced in place of the picturesque bowsprit and figurehead (shown in Fig. 4). This enabled a longer vessel to be swung in comparatively small and crowded docks. The Press of the day stated that the ship was "beautiful, but in some respects peculiar—almost unique. The form of the bow verges little from the wedge-shape, and gives the forward section of the vessel, as seen from the ground, an appearance such as would be presented by a vast Indian canoe." The vessel was provided with a "patent elevator which could raise the screw out of the water in case of accident or under any other circumstances." This particular feature was necessitated by the high coal consumption of the low-pressure simple-cylinder steam engines and the limited bunker capacity of those days. A special coupling was therefore provided, by means of which the propeller, built in a guided iron frame, could be disconnected and the frame then raised above the water-line and into a recess in the hull by a winch on deck. When these vessels were sailing along with canvas alone and a fair wind, the engine was shut down and the propeller raised out of the water so as not to retard the speed of the ship. Indeed, the ship might well go 50 per cent. to 75 per cent. faster under sail than under steam power, apart altogether from the saving in fuel. The Persian—another Bibby ship—was launched on January 21, 1863, and the *Belfast News-Letter* of the following day stated that: "These are certainly wholesome and encouraging indications of spirit, perseverance, and progress in a branch of industrial enterprise for which Belfast has now become widely famed."

As time went on, many acres of ground were added to the works. The Belfast Harbour Commissioners had, in 1867, made a fine new graving dock—the Hamilton dock (Fig. 5)—and connected the Queen's Island with the mainland. The yard, thus improved and extended, was surveyed by the Admiralty, and placed on the first-class list. As a result, the firm was entrusted, in 1868, with the building of H.M. gun vessel Lynx, and later the Algerine, and the store and torpedo ship Hecla, of 3,360 tons. This is of particular interest to-day, in view of the many Press references to the latest Queen's Island-built naval ship, H.M.S. Eagle. This truly gigantic aircraft carrier—she is over 800 ft. in length, and is the largest carrier in the Royal Navy—was accepted into Naval service on March 1 this year.

It has been said that Harland and Wolff won their laurels by building the many celebrated vessels which formed the White Star fleet. Undoubtedly, when that great company placed their first order with the Queen's Island for six large transatlantic steamers in the year 1870, there began a long and a happy association which was to remain constant until the 1930's, when, due to the severe economic blizzard, the White Star Line ceased to exist as a separate entity. The first vessel built for the Oceanic Steam Navigation Company (to give the White Star Line its full official title) was the Oceanic (Fig. 9, page 376), a single-screw four-masted iron barque, 420 ft. long, 41 ft. beam, 31 ft. 6 in. depth, and almost 8,000 tons displacement, loaded. This ship and her sisters were to be as fast, if not faster, than the Cunard and Inman liners, and the Queen's Island men eagerly embraced this great opportunity. The Oceanic was launched on August 27, 1870, and sailed on her maiden voyage early the following year. In her hull, in her machinery, and in her internal arrangements she excelled any vessel built. The first-class accommodation was placed amidships, where it was well away from the noise and vibrations of the propeller. The saloon extended the full width of the vessel, and thus had natural light on each side. A large smoking room amidships, contrasted most favourably with the scanty accommodation provided in other vessels. Electric bells were fitted for the first time, and the accommodation was lit by gas. The main propelling machinery consisted of inverted vertical direct-acting compound steam engines. There was a pair of high-pressure cylinders, 41 in. bore, arranged in tandem with two low-pressure cylinders, 78 in. bore, and the stroke was 5 ft. Steam was provided by 12 oval boilers with a working pressure of 65 lb. per square inch. The indicated horse-power was 2,000, with a daily coal consumption of 65 tons, and the ship had a speed of $13\frac{1}{2}$ knots.

The Oceanic crossed the Atlantic at a speed of one knot faster than any ship had done before, and proved to be a great success It was not unnatural that the successful operation of the Oceanic and her sister ships should lead to additional orders, but it would be too tedious to enumerate all the splendid vessels built at the Queen's Island for the White Star Line. Mention must be made, nevertheless, of one more notable early vessel built for the White Star fleet. The Germanic (Fig. 10, page 376), a single-screw four-masted iron barque, built in 1874, had an overall length of 468 ft., and an engine of 5,000 indicated horse-power. She is noteworthy not only because she had a long and useful life, being 60 years old when wrecked in the Sea of Marmora as the Turkish-owned Gulcemal, but also because she was the last of the White Star liners to be built of iron, all subsequent vessels built at the Queen's Island for this company being constructed of steel.

The year 1880 was an important one for Harland and Wolff because it saw the building of an engine works at Belfast. Another piece of the land which had been reclaimed by the Belfast Harbour Commissioners was rented by the firm and there, in close proximity to the shipyard (Fig. 5), the manufacture of all the machinery required for the many and varied vessels building at "the Island" was commenced. The first metal was melted in the foundry on September 24, and the first engines built in the new engine works were single-screw compounds, 27 in. and 52 in. diameter with 3 ft. stroke. These were for the Winnebah and the Akassa, to the order of the African Steamship Company. Each ship had a single boiler delivering steam at 90 lb. per square inch—a modest figure judged by to-day's standards. Another important item associated with the year 1880 was the building of the Rosetta—a three-masted screw-propelled iron schooner, 390 ft. long, launched on May 27 of that year. This vessel was ordered by the Peninsular and Oriental Steam Navigation Company, and marked the beginning of another long connection between Harland and Wolff and a great shipowning company. It is pleasing to record that at the present time a large passenger vessel is building at the Queen's Island for this same company. A comparison between to-day's vessel and the little Rosetta would provide some intriguing figures.

The same year, 1880, witnessed the establishment of the firm of Workman, Clark and Company. Their original shipyard covered some four acres of ground, which had been leased from the Belfast Harbour Commissioners on the north side of the River Lagan. The output for the first year amounted to two steamers of 800 tons. Two years later, however, the owners of the yard had the satisfaction of seeing vessels 400 ft. in length being constructed on their slips. It may be mentioned in passing that on slips Nos. 1 and 2 the masts of the famous Great Eastern were used as crane and derrick posts. The site chosen for the yard was good from the point of view of shipbuilding as, like the Harland and Wolff yard, there was ample room and depth of water for launching, as well as ground available for extension. By 1891, the small yard had increased in size until it covered 14 acres, and the firm were building screw and paddle steamers as well as sailing ships, the engines and boilers for the steamers being supplied from engineering shops on the Clyde. In that year, 1891, Workman, Clark and Company decided to add the construction of marine engines and boilers to their shipbuilding business; ground was secured alongside the south yard (close to the Queen's Island) and there engine and boiler works were erected. The south yard was immediately opposite the parent yard on the other side of the river, the ships all being launched into the same stretch of water.

Two years later, in 1893, the yard took over the business of Messrs. McIlwaine and MacColl, who had been shipbuilders and engineers in a comparatively small way in Belfast since 1863. This move increased the area of the Workman, Clark works to 40 acres, and the firm was further extended at the end of the Nineteenth Century. By 1902, it covered 50 acres, and headed the tonnage returns of the world's shipbuilders with an output of 75,800 tons. The yard achieved this distinction again, seven years later, with an output of 88,200 tons gross. Prominent among the vessels turned out by the firm may be mentioned the Allan Line triple-screw steamer Victorian, which was the first transatlantic turbine-propelled mail steamer. The year 1920 saw the ownership of the firm pass into new hands, and the subsequent post-war industrial depression struck the business a heavy blow. The company's affairs were reorganised again in March, 1928, when the firm became Workman, Clark (1928) Limited. The continued depression, however, completely undermined the company and seven years later, in 1935, the whole establishment was taken over and dismantled by National Shipbuilders Securities, Limited. The south yard was subsequently purchased, together with the extensive engine works, by Messrs. Harland and Wolff, Limited, and used to good advantage in supplying the needs of Great Britain's mercantile marine in the second World War.

But we must return to the 1880's and 1890's and to the expansion of the Harland and Wolff Engine Works (Fig. 6, page 387). In the year 1885, the engine works built its first triple-expansion engine, installed in a vessel named the Iran, of 3,500 gross tons, for Bates and Sons. This installation is also of interest in that the boiler pressure was no less than 160 lb. per square inch. Mention must be made of two White Star liners built shortly after the Iran, the Teutonic and the Majestic—notable because they were the first ocean-going vessels built by Harland and Wolff to have twin-screw machinery. In addition, they were the longest vessels afloat, being 582 ft. overall and 565 ft. between perpendiculars, with a gross tonnage of 10,000, and having main engines with a total of 17,000 indicated horse-power. The vessels had no yards, though fore and aft sails were fitted, and reference to old photographs of these vessels reveals that the port propeller was located some distance behind the starboard propeller because the propellers overlapped by a few feet. An almost modern note was struck in their design in that they were the first merchant vessels built to comply with the Admiralty's requirements for cruisers: seatings for 12 guns were built into each hull. The year 1897 saw the first quadruple-expansion engine built at the Queen's Island. This unit was for the Hamburg-America Line Pennsylvania, a 560-ft. vessel of 13,700 tons gross.

(To be continued.)

RECOMMENDED DOMESTIC SOLID-FUEL APPLIANCES.—The Coal Utilisation Council have issued recently List No. 5 of "Recommended Domestic Solid Fuel Appliances." It cancels List No. 4, issued in December, 1951. Copies of the list may be obtained, price 6*d*., from the offices of the Council, 3, Upper Belgrave-street, London, S.W.1.

THE TRAINING OF CHEMICAL ENGINEERS.*

By D. M. NEWITT, D.Sc., F.R.S.

THE rise of chemical engineering as a primary technology is one of the direct consequences of industrial and economic developments which are still taking place. It may be said to owe its origin to the big expansion in the heavy chemical industry and to the simultaneous growth of new industries, resulting from intensive scientific research during the latter half of the Nineteenth Century. There was at that time a growing conviction that empirical methods of plant design, based largely upon trial and error, could no longer meet the needs for better process control and for higher operating efficiencies and would have to give place to more scientific procedures. George E. Davis, one of the pioneers of chemical engineering, first began to lecture on the subject in 1887, and his well-known "Handbook of Chemical Engineering" was published in 1901. The introductory chapters of this book deserve to be studied by anyone in doubt as to the true functions of a chemical engineer.

The new branch of engineering, however, made slow progress in this country and, as has so often happened, it was left to Germany and America to build up those renowned schools of chemical technology and chemical engineering which, during the inter-war years, gave them such an outstanding lead in the international race for higher industrial productivity. There is a great deal of evidence to suggest that our industries have, over the course of years, lost the initiative in the development of new processes and products; and numerous examples might be quoted in which inventions and discoveries made by our scientists have been left for exploitation abroad.

To meet this situation requires combined action by industry and the schools. The objective of a chemical engineering training is, in the words of Professor W. K. Lewis, "The development of the capacity of the student when faced with a new and unfamiliar situation, to handle it with a competence, involving skill, initiative and leadership." Industry must ensure that, when such men are available, opportunities are offered for the exercise of their talents.

It may be well, at this stage, to dispose of certain misconceptions which exist in regard to the nature and scope of a chemical engineering curriculum. In the first place, it must be recognised that the subject constitutes a distinctive discipline which embraces the whole of that body of applied science utilised in transferring a process from the laboratory stage to large-scale production; it is, in addition, concerned directly or indirectly with the economics of production and with the social implications of new scientific discoveries. The range of subjects to be covered is, therefore, extensive and any endeavour to insist upon a high degree of proficiency in all the sciences included in the definition would be impracticable. A thorough grounding in the fundamental principles of the physical sciences is essential but attention should, thereafter, be directed towards those special applications which constitute what are now generally known as the unit operations and unit processes of chemical engineering.

It will be clear from these considerations that endeavours to base a first degree course in chemical engineering upon any synthesis of existing courses in chemistry, physics and mechanical engineering are unlikely to be successful. The only feasible compromise is that by which chemical engineering may be taken as a post-graduate subject following upon a first degree in chemistry or mechanical engineering; this method, however, involves an additional one or two years of study and carries with it no very tangible compensating advantages.

From the educational point of view, one of the important problems common to all categories of technology is the emphasis which should be given to works experience as an integral part of a university training. The purpose of introducing a student to industrial life during his university career is to impress upon him at an early stage that this work has to form part of a complex structure, other component parts of which are labour and management. Up to a point, this can be done by instruction in the principles of industrial management and in the economics of production, but nothing can replace the first-hand experience gained by direct contact with men and things.

Two alternative methods have been adopted to this end in this country, the one based upon vacation work and the other upon sandwich courses; in the former, the student is expected to devote some eight weeks of at least two long vacations to employment in a works; in the latter, more extended periods of employment are sandwiched between attendance at the university. There is not much to choose between the two and both depend for their success upon the student's being able to identify himself with the routine and life of the works and being given definite duties and responsibilities. In all circumstances, he will pick up something of value from such industrial contacts and, when the courses are carefully planned, the benefit he obtains is important and far-reaching.

In general, first degree courses in chemical engineering extend over three post-intermediate years, the first two of which are devoted to the physical sciences and to certain branches of mechanical engineering and mathematics and the final year to unit operations and processes. It cannot be held that such a short period is sufficient to enable any comprehensive syllabus to be covered in its entirety, and it is particularly important to guard against the dangers of introducing so much detail that the student fails to obtain a broad perspective of his subject. For this reason, an extension of the course to a fourth year, with all the formal apparatus of lectures, tutorials and examinations, is not altogether desirable. The atmosphere of impending examinations is not conducive to independent thought and inquiry; and, if we wish to foster and develop initiative and enterprise, there must be a period during which the student can, under direction, begin to apply his knowledge. In some respects, this end is attained by one or two post-graduate years devoted to original work. In the case of selected students the time so spent is undoubtedly of great value. The planning of a systematic piece of research, the devising of new experimental methods and techniques, and the critical appraisal and discussion of results bring out qualities in a student which no system of examinations can hope to reveal. But it must be recognised that all students are not temperamentally or intellectually fitted for research work.

If we remember, however, that the technologies aim at the application of fundamental principles to practical problems and at the introduction of new methods and techniques into industrial practice, it becomes possible to devise a post-graduate course which will entail investigations of a more practical character than those generally included under the heading of fundamental research. There is no reason why such investigations should not, in suitable circumstances, be undertaken by teams of students rather than by individuals and in co-operation with industry rather than in the isolation of a university laboratory.

As the result of such a system of training, the graduate should enter industry with a background of fundamental science, with some knowledge of industrial organisation and with a sound understanding of the basic operations of chemical engineering. He will not be familiar with the practice of any one industry nor with those technical details of plant operation which can only be acquired by works experience; and it must be recognised that some time will elapse before he can be expected to make his full contribution as a technical specialist. He should, however, be competent, at the outset, to undertake design and development work and to bring to it initiative, originality and adaptability.

Finally, it will be evident that chemical engineering differs essentially from those technologies which are confined to the principles and practices of particular industries or of groups of related industries and that chemical engineers can, by the generality of their training, be regarded as a mobile force of technologists able to move from industry to industry as economic conditions dictate.

* Paper read before Section G of the British Association at Belfast, on Monday, September 8, 1952. Abridged.

ANALYSIS OF STATICALLY-INDETERMINATE STRUCTURES BY THE COMPLEMENTARY-ENERGY METHOD.*

By T. M. CHARLTON.

COMPLEMENTARY energy is a fictitious quantity represented graphically by the area to the left of the force-extension diagram for a system. The method of complementary energy was first proposed by Engesser in 1889† and depends upon the fact that, subject to certain important reservations, the complementary energy of an initially unstrained linear or non-linear elastic structure is stationary. Castigliano's least-work principle is really a particular case of stationary complementary energy for linear structures, as will be seen later, and a similar course of reasoning to that adopted by Castigliano can be employed to establish Engesser's principle.

In a previous paper,‡ the author has reviewed briefly the classical energy methods and indicated their dependence upon the conservation of mechanical energy. It was shown that the complementary-energy principle depends upon "conservation" of complementary-energy and the suggestion was made that energy methods may be regarded as mathematical artifices. Unlike the principle of stationary total potential energy, the complementary-energy principle is not fundamental and has no obvious physical significance. It can be deduced, however, from a form of the total potential energy principle, namely, the principle of virtual work, which can also be derived directly from considerations of equilibrium and conservation of mechanical energy. That the complementary-energy principle is employed to ensure the fulfilment of the compatibility conditions, having previously taken the conditions of equilibrium into account, might, therefore, seem strange at first.

Consideration of the complementary-energy principle clearly indicates the fortuitous nature of Castigliano's theorem which might otherwise appear to have a really fundamental physical basis. The complementary-energy method can be applied, (without advantage) to certain dynamical problems as shown by Westergaard,* but if it is used indiscriminately the limitations upon its validity tend to be disregarded and incorrect results obtained in consequence.

For simplicity, it will be assumed that supports are rigid, but it is not difficult to take elastic supports into account where necessary.

Complementary Energy.—Mathematically, complementary energy is represented by $C = \int_0^F y\,dF$, where y represents the displacement in its line of action produced by the force F. Reference to Figs. 1 (*a*) and 1 (*b*) will show that it is complementary to the strain energy $U = \int_0^y F dy$ having regard to the quantity Fy which might be called the total energy. It is clear that $\frac{dC}{dF} = y$ in contrast with $\frac{dU}{dy} = F$ for all cases, linear or non-linear.

Fig. 1.(*a*) ENERGY DIAGRAM FOR EXTERNAL FORCE.

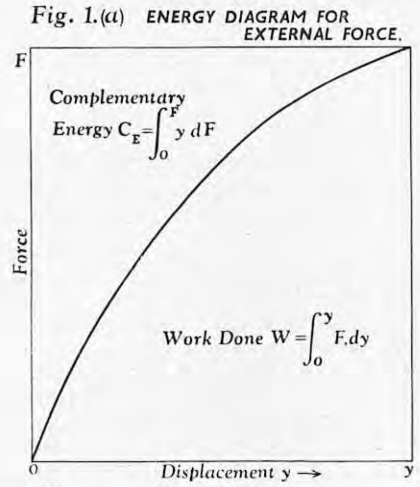


Fig. 1.(*b*) ENERGY DIAGRAM FOR SINGLE MEMBER.

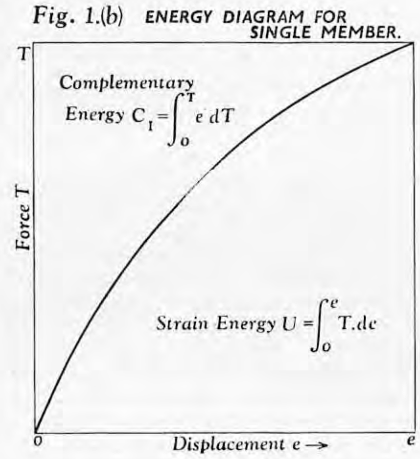


Fig. 2.

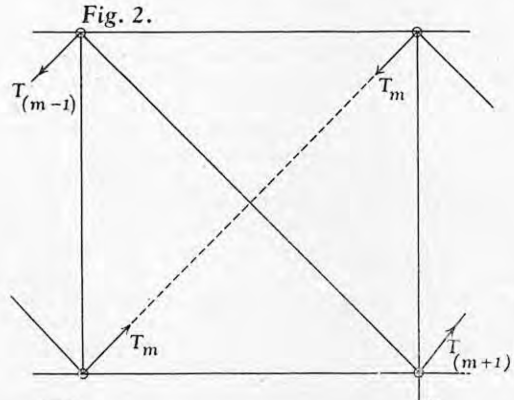
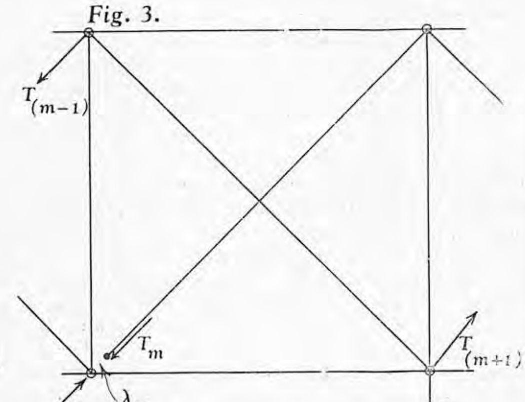


Fig. 3.



Before complementary energy can be of value for structural analysis it must be the same whether it is computed as the sum of the complementary energies of the individual members or the sum of the complementary energies of the external forces. This is equivalent to the necessity for the law of conservation of energy (i.e., the equality of strain energy and external work) for the validity of the various well-known energy methods.

Thus, if the structure consists of N pin-jointed members, its complementary energy

$$C_I = \sum_{i=1}^{i=N} \int_0^{T_i} e_i\,dT_i, \qquad (1)$$

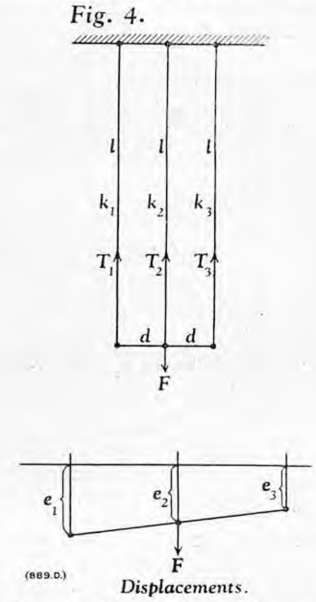
must be equal to the complementary energy of the n external forces :—

$$C_E = \sum_{j=1}^{j=n} \int_0^{F_j} y_j\,dF_j, \qquad (2)$$

where e represents an internal displacement, y an external displacement, T an internal force, and F an external impressed force. The conditions for the conservation of complementary energy will be considered below. It is important to note that, while $\frac{dU}{dF} = y$ for linear elastic systems (which is the basis of Castigliano's least-work theorem) the first differential of external complementary energy with respect to a force always gives the movement in the line of action of the force, irrespective of the force-deflection characteristics of the system. To this extent, the complementary-energy concept is fundamental and may be compared with the fact that the first differential of strain energy with respect to displacement gives the external force associated with the displacement in all cases, linear or otherwise.

Stationary Complementary Energy.—Provided that conservation of complementary energy is applicable, it is easy to prove, by using an approach similar to that of Castigliano, that the complementary energy of an elastic system (linear or otherwise) which is initially unstrained, is stationary. Thus, if, say, a pin-jointed frame has r redundant members and if any one of them is considered as being removed and replaced by the equivalent (external) forces T_m at the joints which it previously connected, as shown in Fig. 2, then the complementary energy of the modified system is

Fig. 4.



$$C_I' = C_E' = \sum_{j=i}^{j=n} \int_0^{F_j} y_j\,dF_j + \int_0^{T_m} e_m'\,dT_m + \int_0^{T_m} e_m''\,dT_m. \qquad (3)$$

Since the T_m's are being considered as external forces for the moment, the respective displacements of the two joints e_m' and e_m'' which they produce, are also strictly external displacements. Clearly now

$$\frac{\partial C_I'}{\partial T_m} = \frac{\partial C_E'}{\partial T_m} = e_m' + e_m'', \qquad (4)$$

and if the mth redundant member were present in the structure, these displacements would obviously be internal quantities. Furthermore, their sum would then also represent the amount of the axial deformation of the member and be given alternatively by

$$\frac{dC_m}{dT_m} = -(e_m' + e_m''), \qquad (5)$$

the first differential coefficient of the complementary energy of the mth redundant member with respect to the force T_m induced in it. (The minus sign must be applied because the deformation of the member will be opposite in sense to that of the structure between the two joints concerned.) Equating expressions (4) and (5)

$$\frac{\partial C'}{\partial T_m} = -\frac{dC_m}{dT_m}$$

or

$$\frac{\partial C'}{\partial T_m} + \frac{dC_m}{dT_m} = 0. \qquad (6)$$

Equation (6) can be rewritten as :—

$$\frac{\partial}{\partial T_m}(C' + C_m) = \frac{\partial C}{\partial T_m} = 0, \ (m = 1, 2, \ldots, r) \qquad (7)$$

* Paper read before Section G of the British Association at Belfast on Tuesday, September 9, 1952.

† Fr. Engesser, *Zeitschrift des Architekten-und Ingenieur Vereins zu Hannover*, vol. 35, No. 8, 1889, cols. 733-744.

‡ T. M. Charlton, *Jl. Franklin Inst.*, No. 6, vol. 250, pages 543-551. December, 1950.

* H.M. Westergaard, *Proc. Amer. Soc. C. E.*, vol. 67, pages 199–227, 1941.

where $C = C_I = C_E$ is the total complementary energy of the structure given by

$$C = \sum_{i=1}^{i=N} \int_0^{T_i} e_i \, dT_i = \sum_{j=1}^{j=n} \int_0^{F_j} y_j \, dF_j . \quad . \quad (8)$$

It should be noted that, as well as equation (7),

$$\frac{\partial C}{\partial F_j} = y_j \qquad (j = 1, 2, \ldots, n). \quad . \quad (9)$$

Equation (7) indicates that the complementary energy is stationary with respect to variation of the forces in the redundant members. It is not possible to state generally that a minimum is implied, but this is unimportant and does not impair the value of the method.

In the case of linear systems $C = U$, clearly, so that

$$\frac{\partial U}{\partial T_m} = 0 \qquad (m = 1, 2, \ldots, r), \quad . \quad (10)$$

which is Castigliano's least-work principle, and since the complementary and strain energies of this type of system are represented by positive definite functions it can further be stated that equation (10) represents a minimum in the mathematical sense. Southwell* has given an ingenious explanation of the physical significance of Castigliano's minimum, but since the same reasoning might be applied to stationary complementary energy it seems doubtful whether there is any really fundamental physical basis for Castigliano's principle.

If the structure considered above is self-strained due, for example, to the redundant members being initially lacking in fit by an arbitrary amount λ_m $(m = 1, 2, \ldots, r)$ and being forced into place by suitably deforming the structure and the members (Fig. 3, page 389), the above reasoning is applicable with slight modification. It can be shown that

$$\frac{\partial C'}{\partial T_m} = e'_m + e''_m,$$

and if the mth redundant member is originally too short by an amount λ_m

$$\frac{dC_m}{dT_m} = \lambda_m - (e'_m + e''_m), \quad . \quad . \quad (11)$$

or

$$\frac{dC_m}{dT_m} - \lambda_m = -(e'_m + e''_m).$$

Adding equations (4) and (11)

$$\frac{\partial}{\partial T_m}(C' + C_m) = \frac{\partial C}{\partial T_m} = \lambda_m \; (m = 1, 2, \ldots r), \quad . \quad (12)$$

whereas in the case of linear systems

$$\frac{\partial C}{\partial T_m} = \frac{\partial U}{\partial T_m} = \lambda_m \qquad (m = 1, 2, \ldots r) \quad . \quad (13)$$

Although pin-jointed systems only have been used for illustration the deductions are of general application, subject to overall limitations which will be dealt with later.

Conservation of Complementary Energy. The Principle of Virtual Work.—In order to appreciate the limitations of the stationary complementary-energy principle it is necessary to consider its basis in relation to the fundamental principle of virtual work. The principle of virtual work follows from considerations of conservation of energy; thus for an elastic structure (linear or otherwise) an increment of strain energy is given by

$$\delta U = \sum_{i=1}^{i=N} T_i \, \delta e_i, \quad . \quad . \quad . \quad (14)$$

which is equal, by conservation of energy, to the corresponding increment of work done by the external forces

$$\delta W = \sum_{j=1}^{j=n} F_j \, \delta y_j \quad . \quad . \quad . \quad (15)$$

(If the supports of the structure are elastic, corresponding terms representing the increment of their strain energy can be included in (14).)

For equilibrium, therefore, $\delta(U - W) = 0$,

$$\text{i.e.} \quad \sum_{i=1}^{i=N} T_i \, \delta e_i - \sum_{j=1}^{j=n} F_j \, \delta y_j = 0, \quad . \quad . \quad (16)$$

which is a form of the principle of virtual work, and this work equation is applicable to a small displacement of a structure in its finally loaded state. It will be observed that the actual magnitudes of the small displacements δe and δy are unimportant provided that they are compatible with the geometry of the loaded structure. In many cases, therefore, it is quite legitimate to substitute finite displacements which conform to this requirement, in which case equation (16) can be rewritten :—

$$\sum_{i=1}^{i=N} T_i \, e_i' - \sum_{j=1}^{j=n} F_j \, y_j' = 0 \; . \quad . \quad (17)$$

If, in addition, the quantities e'_i and y'_j can be of the same magnitude as those actually associated with the forces T_i and F_j, namely e_i and y_j, respectively, without violating the geometrical conditions to which reference has been made, then

$$\sum_{i=1}^{i=N} T_i \, e_i - \sum_{j=1}^{j=n} F_j \, y_j = 0. \quad . \quad . \quad (18)$$

Reference to Figs. 1 (*a*) and 1 (*b*) will show that equation (18) expresses conservation of the total energy quantities, i.e.

$$(C_I + U) = (C_E + W) \; . \quad . \quad . \quad (19)$$

Now by the fundamental principle of conservation of energy $U = W$; therefore it follows immediately from equation (19) that

$$C_I = C_E \quad . \quad . \quad . \quad . \quad (20)$$

which is the principle of "conservation of complementary energy." The same process of reasoning can be extended to take account of self-straining, as will be shown.

It is interesting to note that equation (18) can be used to ensure either equilibrium or compatibility as desired, without further development, but its direct use in this way is not advantageous.

From the above analysis it appears that it is applicable to all cases in which solution is possible by the well-known direct approach using the equilibrium and compatibility conditions referred to the geometry of the structure in the unloaded state, and the actual displacements produced by the forces. Thus, it is immediately clear that the principle will be valid for pin-jointed frames having non-linear members provided that the loading does not produce gross distortion. It is worth noting that for those cases of pin-jointed frames to which the principle is not applicable, Castigliano's least-work principle would break down also, even if the individual members had linear characteristics.

Portal structures constitute continua and it is more difficult to generalise the limitations of the complementary-energy principle for this kind of system with non-linear characteristics, although Engesser asserted that the principle was applicable to continuous structures generally. It is safe to say, however, that good approximations can be expected in many cases. The principle does not seem to have been used for the study of the plastic behaviour of steel structures, although, as the author has indicated elsewhere,* it is the basis of the Haar-Karman principle for pin-jointed frames.

A simple non-linear structure is analysed in Appendix I by means of the principle of virtual work using finite displacements and the stationary complementary-energy principle. It will be seen that the use of finite displacements would only be impossible if they were such as to produce gross distortion of the system.

Self-Strained Structures.—The case of self-strained structures has already been considered above, assuming the validity of "conservation" of complementary energy. Further reference to the principle of virtual work indicates that this assumption is justifiable, as will now be shown, remembering the case of a pin-jointed frame, the redundant members of which lack fit initially to the extent of $\lambda_1, \lambda_2, \ldots \lambda_r$, respectively (e.g., due to temperature differences or imperfection of construction).

It is assumed that the frame has been constructed initially without the redundant members and that suitable external forces T_m are applied to enable the extra members to be connected at the same time as the loading which the frame must withstand is applied. On this basis the principle of virtual work gives the following equation :—

$$\sum_{i=1}^{i=N} T_i \, e_i = \sum_{m=1}^{m=r} T_m \, \lambda_m + \sum_{j=1}^{j=n} F_j \, y_j, \quad . \quad (21)$$

provided that the use of finite displacements is valid. The forces T_m actually appear both as external forces and internal forces as shown in Fig. 3 and virtual displacement of the "unconnected" system is considered such that connection of the redundant members is possible when the external displacements y (see Appendix II) have reached their final values due to the forces F.

The total strain energy U of the structure due to self straining and the external forces F is

$$U = \sum_{i=1}^{i=N} \int_0^{e_i} T_i \, de_i \, . \quad . \quad . \quad (22)$$

The corresponding external work done is

$$W = \sum_{j=1}^{j=n} \int_0^{y_j} F_j \, dy_j + \sum_{m=1}^{m=r} \int_0^{\lambda_m} T_m \, d\lambda_m . \quad . \quad (23)$$

Now if the strain energy and external work quantities are subtracted from the "total energies" in equation (21) the conservation of complementary energy equation,

$$\sum_{i=1}^{i=N} \int_0^{T_i} e_i \, dT_i = \sum_{j=1}^{j=n} \int_0^{F_j} y_j \, dF_j + \sum_{m=1}^{m=r} \int_0^{T_m} \lambda_m \, dT_m, \quad (24)$$

is obtained, i.e., $C_I = C_E + C_0$, where C_0 represents the external complementary energy for self straining. Thus,

$$\left.\begin{aligned} \frac{\partial C_I}{\partial T_m} &= \frac{\partial C_0}{\partial T_m} = \lambda_m \qquad (m = 1, 2, \ldots, r) \\ \frac{\partial C_I}{\partial F_j} &= \frac{\partial C_E}{\partial F_j} = y_j \qquad (j = 1, 2, \ldots, n) \end{aligned}\right\} \quad (25)$$

Conclusion.—Owing to neglect of the complementary-energy method much confusion has arisen over the classical-energy methods, especially with regard to the significance of Castigliano's least-work principle. It is essential to remember that variation of either the strain energy or the total potential energy of a system can only be achieved by varying displacements in their own terms or in terms of generalised co-ordinates. Such variation can be used to obtain equilibrium conditions as, for example, when the principle of stationary total potential energy is applied (or stationary total potential and kinetic energy in dynamical problems). Variation of forces is only permissible in so far as they represent displacements unless the complementary energy is varied; thus Castigliano's principle for linear systems is fortuitous but has every appearance of fundamental physical significance. Since systems having approximately linear characteristics are common in engineering practice, it is not surprising that Castigliano's ingenious work has been widely received without further question. It is important, however, that the implications of variation of real energy, as opposed to complementary energy, should be appreciated. The complementary-energy method is applicable to many non-linear systems for which the loading does not cause gross distortion.

The author is indebted to the partners of Messrs. Merz and McLellan for permission to present this paper.

APPENDIX I.

Example of the Application of the Complementary-Energy Principle.—The statically indeterminate structure shown in Fig. 4, page 389, will be analysed by both the principle of virtual work using finite displacements and the related principle of stationary complementary energy assuming that the flexibility coefficient $k_1 = \alpha_1 T_1$, while k_2 and k_3 are constant. By the principle of virtual work, therefore,

$$F e_2 = T_1 e_1 + T_2 e_2 + T_3 e_3 \quad . \quad . \quad . \quad (1)$$

The compatibility conditions are clearly:

$$e_1 - e_2 = e_2 - e_3;$$

that is

$$e_1 = 2 e_2 - e_3 . \quad . \quad . \quad . \quad (2)$$

Substituting this in equation (1)

$$F e_2 = T_1 (2 e_2 - e_3) + T_2 e_2 + T_3 e_3.$$

* *Phil. Mag.* vol. 45, Sixth Series, pages 193-212 (1923).

* T. M. Charlton. Discussion of paper by P. S. Symonds and W. Prager. *Jl. App. Mech.*, vol. 18, No. 1, page 118, March, 1951. See also authors' reply, page 119.

Therefore

$$F = 2T_1 + T_2 \quad . \quad . \quad . \quad . \quad . \quad (3i)$$
$$T_1 = T_3, \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (3ii)$$

which are the equilibrium conditions.

Now, by equation (2), putting $e_1 = \alpha_1 \int_0^{T_1} T_1 dT_1 = \frac{\alpha_1}{2} T_1^2$, $e_2 = k_2 T_2$ and $e_3 = k_3 T_3$,

$$\frac{\alpha_1 T_1^2}{2} = 2k_2 T_2 - k_3 T_3. \quad . \quad . \quad (4)$$

Substituting equation (3i) in (4):

$$\frac{\alpha_1}{2} T_1^2 + (4k_2 + k_3) T_1 - 2k_2 F = 0, \quad . \quad (5)$$

whence

$$T_1 = T_3 = -\frac{1}{\alpha_1}\left\{(4k_2 + k_3) \pm \sqrt{[(4k_2 + k_3)^2 + 4\alpha_1 k_2 F]}\right\} \quad (6)$$

and

$$T_2 = \frac{1}{\alpha_1}\left\{\alpha_1 F + 2(4k_2 + k_3) \pm 2\sqrt{[(4k_2 + k_3)^2 + 4\alpha_1 k_2 F]}\right\} \quad (7)$$

Alternatively, the complementary energy of the system is given by

$$C = \int_0^{T_1} e_1 dT_1 + \tfrac{1}{2}(e_2 T_2 + e_3 T_3). \quad . \quad (8)$$

Expressing the displacements in terms of the forces, equation (8) can be rewritten:

$$C = \frac{\alpha_1}{6} T_1^3 + \frac{k_2}{2} T_2^2 + \frac{k_3}{2} T_3^2,$$

and application of the equilibrium conditions gives finally:

$$C = \frac{\alpha_1}{6} T_1^3 + \frac{k_2}{2}(F - 2T_1)^2 + \frac{k_3}{2} T_1^2. \quad (9)$$

For the complementary energy to be stationary

$$\frac{\partial C}{\partial T_1} = \frac{\alpha_1}{2} T_1 - 2k_2(F - 2T_1) + k_3 T_1 = 0 \quad . \quad . \quad (10)$$

or

$$\frac{\alpha_1}{2} T_1^2 + (4k_2 + k_3) T_1 - 2k_2 F = 0. \quad . \quad (11)$$

This is identical with equation (5), the solution of which is equation (6), from which follows equation (7).

It is worth noting that equation (10) is obtainable directly from a form of the virtual work equation; that is:

$$e_1 \delta T_1 + e_2 \delta T_2 + e_3 \delta T_3 - e_2 \delta F = 0, \quad . \quad (12)$$

by expressing the e's in terms of the T's and applying the equilibrium conditions with $\delta F = 0$.

APPENDIX II.

Self Straining.—An alternative approach to that previously given for obtaining the complementary energy for self straining is possible. Instead of supposing that the redundant members are connected simultaneously with the application of the loading F it is clearly legitimate to take the more practically realistic case of the loading applied to the complete self-strained structure. In order to pursue this approach it is necessary to apply the principle of virtual work twice, once for the connection of the redundant members in the unloaded simply stiff structure and again for the loading of the redundant self-strained structure. Thus, for the connection of the redundant members, assuming that the necessary external forces T_{mo} ($m = 1, 2, \ldots, r$) are applied and that virtual displacements of magnitude equal to the initial amounts of lack of fit λ_m ($m = 1, 2 \ldots, r$) of the redundant members are permissible, the virtual work principle gives

$$\sum_{i=1}^{i=N} T_{io} e_{io} - \sum_{m=1}^{m=r} T_{mo} \lambda_m = 0. \quad . \quad (1)$$

where the suffix zero indicates absence of loads F.

Again, when the loads F have been applied so that their points of application move distances y' in their lines of action while the consequent changes in length of the structural members are e', and if sets of virtual displacements y' and e' are permissible, the second virtual-work equation is

$$\sum_{i=1}^{i=N} T_i e'_i - \sum_{j=1}^{i=n} F_j y'_j = 0. \quad . \quad . \quad (2)$$

The y's in equation (2) are different from those employed in equation (21) above, because the latter are measured from the initial positions of the load points of the simply stiff system, whereas the former are measured from the initial positions of the load points of the redundant system. During connection of the redundant members the positions of the load points will generally be modified, but by the law of conservation of energy, the final positions of the loads in space must be the same in both cases.

The work done W_0 in straining the frame before loading to connect the redundant members is clearly

$$W_0 = \sum_{m=1}^{m=r} \int_0^{\lambda_m} T_m \, d\lambda_m \quad . \quad . \quad (3)$$

while the corresponding strain energy U_0 is given by

$$U_0 = \sum_{i=1}^{i=N} \int_0^{e_{io}} T_i \, de_i. \quad . \quad . \quad . \quad (4)$$

Subtracting $U_0 - W_0 = 0$ from equation (1) yields the conservation of complementary-energy equation

$$\sum_{i=1}^{i=N} \int_0^{T_{io}} e_i \, dT_i - \sum_{m=1}^{m=r} \int_0^{T_{mo}} \lambda_m \, dT_m = 0, \quad (5)$$

i.e.,

$$C_{Io} - C'_o = 0,$$

whence, by differentiation,

$$\frac{\partial C_{Io}}{\partial T_{mo}} = \frac{\partial C'_o}{\partial T_{mo}} = \lambda_m \quad (m = 1, 2, \ldots, r). \quad (6)$$

Again, the work done W_F by the external forces is:

$$W_F = \sum_{j=1}^{j=n} \int_0^{y'_j} F_j \, dy'_j \quad . \quad . \quad (7)$$

and the corresponding strain—strain energy U_F is given by:

$$U_F = \sum_{i=1}^{i=N} \int_{e_{io}}^{e_i} T_i \, de_i. \quad . \quad . \quad (8)$$

Subtracting $U_F - W_F = 0$ from equation (2) gives the second conservation of complementary-energy equation:

$$\sum_{i=1}^{i=N} \int_{T_{io}}^{T_i} e_i - e_{io} \, dT_i - \sum_{j=1}^{j=n} \int_0^{F_j} y' \, dF_j = 0 \quad . \quad (9)$$

i.e.,

$$C_{IF} - C'_E = 0,$$

from which, by differentiation,

$$\frac{\partial C_{IF}}{\partial T_m} = 0 \quad (m = 1, 2, \ldots, r), \quad . \quad (10)$$

and

$$\frac{\partial C_{IF}}{\partial F_j} = \frac{\partial C'_E}{\partial F_j} = y'_j \quad (j = 1, 2, \ldots, n). \quad (11)$$

It is the deflection y' which is of practical interest as the amount by which the redundant structure deflects under load.

This alternative self-straining theory offers no advantages over that given above for the analysis of a given structure. It is, however, of value for calculating external deflections, as demonstrated.

"ELECTRICAL INSTALLATION MATERIAL."—Since 1888, the General Electric Co., Ltd., Magnet House, Kingsway, London, W.C.2, have issued a series of catalogues covering the products manufactured by them and illustrating, indirectly, the progress made in this branch of the electrical industry. To cover the entire range of manufacture in more recent years would have required a cumbersome volume and to avoid this it was decided to make certain omissions from the edition issued in 1936, and to make the remainder as complete as possible. This policy has also been followed in the latest volume, which is entitled "Electrical Installation Material" and covers conduit, wires, cables, bells, torches, batteries, lighting fittings, lamps and measuring instruments, as well as small switchgear, circuit-breakers, motors and motor starters, fans, and water, space and industrial heating equipment. The textual matter, which is fully illustrated, amounts to some 800 pages and is carefully indexed, so that the volume should prove most useful. Those responsible for its compilation may be congratulated on the result.

TRADE PUBLICATIONS.

Research Engineers.—We have received from Tiltman Langley Laboratories, Limited, Redhill Aerodrome, Surrey, an illustrated brochure describing their research activities, which cover the solution of design problems in aeronautical and mechanical engineering, and testing equipment, materials and processes. They are equipped with machine shops, fabrication and fitting shops, and undertake the production and development of prototype equipment.

Gas Turbines and Rocket Motors.—Armstrong Siddeley Motors, Ltd., Coventry, have issued an illustrated booklet describing their 8,300-lb.-thrust Sapphire jet engine, Mamba and Double Mamba propeller turbines, Python propeller turbine, Viper and Adder jet engines for research projects, and the Snarler rocket motor.

Spray Nozzles.—We have received from Ascog Ltd., Ascog House, 44, Theobalds-road, London, W.C.1, a leaflet describing their wide range of spray nozzles, most of which work under liquid pressure. Compressed-air nozzles are, however, also available.

Vacuum Equipment.—Five illustrated leaflets have been issued by W. Edwards & Co. (London), Ltd., Worsley Bridge-road, Lower Sydenham, London, S.E.26, giving (i) specifications of a combined rotary-piston compressor and vacuum pump, developing a pressure of 70 lb. per square inch under continuous running, and a vacuum of 28 in. of mercury; (ii) pumping units for vacuum pipelines; (iii) self-contained vacuum pump units; (iv) ground-glass cone joints for high vacua, with new sealing and locking arrangements; and (v) educational equipment for schools.

Trucks and Ladders.—H. H. Stark, Ltd., 193, White-chapel-road, London, E.1, have issued an illustrated catalogue of their hand trucks and ladders.

Electric Lamps and Tubes.—Full particulars of the various Osram lamps and tubes manufactured by them are contained in a pamphlet recently issued by the General Electric Co., Ltd., Magnet House, Kingsway, London, W.C.2. Technical data on the employment of these lighting units and details of a number of accessories are also given.

Electric Conductor Accessories.—A publication received from Aluminium Wire and Cable Co., Ltd., 37, Thurloe-street, South Kensington, London, S.W.7, contains particulars of the accessories they supply for use with steel-cored aluminium, all aluminium and Silmalec overhead conductors. Methods of erecting and jointing these materials are also described.

LAUNCHES AND TRIAL TRIPS.

M.S. "CALTEX DELHI."—Single-screw oil tanker, built and engined by William Doxford and Sons, Ltd., Sunderland, for the Overseas Tankship (U.K.), Ltd., London, W.1. Third vessel of a series of four for these owners. Main dimensions: 490 ft. overall by 61 ft. 9 in. by 36 ft. 3 in.; deadweight capacity, 12,300 tons on a draught of 28 ft. 2½ in. Doxford five-cylinder opposed-piston balanced oil engine, developing 5,150 b.h.p. at 108 r.p.m., and giving a speed of 13¾ knots in service. Trial trip, August 25.

H.M.S. "EDDYCLIFF."—Single-screw vessel for carrying oil in bulk, built by the Blythswood Shipbuilding Co., Ltd., Scotstoun, Glasgow, for the Naval Stores Department, Admiralty, London, S.W.1. Main dimensions: 270 ft. between perpendiculars by 44 ft. by 18 ft. 6 in.; deadweight capacity, 2,000 tons on a draught of about 17 ft. 2 in. Triple-expansion steam engine, developing 1,750 i.h.p. at 227 r.p.m., constructed by Lobnitz and Co., Ltd., Renfrew. Service speed, 12 knots. Launch, August 25.

M.S. "BOSTON JAVELIN."—Single-screw trawler, built by Cook, Welton and Gemmell, Ltd., Beverley, Yorkshire, for the Boston Deep Sea Fishing and Ice Co., Ltd., Fleetwood. Main dimensions: 169 ft. overall by 29 ft. by 14 ft. 9 in.; fishroom capacity, about 11,500 cub. ft. Eight-cylinder super-charged oil engine, constructed by Mirrlees, Bickerton and Day, Ltd., Stockport, Cheshire. Launch, August 26.

M.S. "DUCHESS OF ATHENS."—Single-screw oil tanker, built by the Furness Shipbuilding Co., Ltd., Haverton Hill, County Durham, for the Trent Maritime Co., Ltd., London, E.C.3. First vessel of an order for two. Main dimensions: 525 ft. between perpendiculars by 71 ft. by 39 ft. 3 in.; deadweight capacity, 18,175 tons on a summer draught of 30 ft. 5½ in.; oil-carrying capacity, 17,283 tons. Vickers-Doxford six-cylinder two-stroke single-acting oil engine, developing 6,600 b.h.p., constructed by Vickers-Armstrongs Ltd., Barrow-in-Furness. Speed, 15 knots. Trial trip, August 27.

M.S. "IRISH HEATHER."—Single-screw cargo vessel, built by the Goole Shipbuilding and Repairing Co., Ltd., Goole, for Irish Shipping, Ltd., Dublin. Main dimensions: 204 ft. between perpendiculars by 35 ft. by 14 ft. 6 in.; deadweight capacity, 1,397 tons on a mean draught of about 13 ft. 10 in. British Polar six-cylinder marine Diesel engine, developing 960 b.h.p. at 250 r.p.m., constructed by British Polar Engines, Ltd., Glasgow. Speed, 11 knots. Trial trip, August 28.

NOTES ON NEW BOOKS.

Plastics in Building.

By JOSEPH B. SINGER, B.Sc. (Arch), A.R.I.B.A. The Architectural Press, 9-13, Queen Anne's Gate, London, S.W.1. [Price 18*s*. net.]

PLASTICS are defined by the author of this book as organic materials, mainly synthetic, which, at some stage of their manufacture, are capable of flow when the necessary heat and pressure are applied, though in their finished form and at atmospheric temperatures they are stable and rigid. The introduction includes a brief historical outline of plastics applied to building, their production, merits and limitations. Some of the comparisons drawn might have been made with greater care; on page 14, for instance, the tensile strength of Gordon Aerolite, given as 45,000 lb. per square inch—almost certainly an ultimate strength—is placed alongside the strength of steel, given as 18,000 lb. per square inch, which is a safe working stress for a mild structural steel of which the ultimate strength is about 70,000 lb. per square inch. Structural uses described include the Vinylite house, made almost entirely of plastics; the Jicwood house, sheeted with resin-bonded plywood; the Holoplast system of building with pressed boards of paper impregnated with phenolic resin and made up into panel units between light aluminium framing; laminated wood; and structural sections. The all-plastics house, and the use of plastics for structural members of large section (other than laminated wood) must, at present prices, be regarded as "stunts" rather than positive contributions to contemporary building; but there are many useful purposes which plastics, in one or other of their many varieties, can fulfil. Descriptions are given of their applications to external covering, glazing (such as with Perspex), interior linings and fittings, floor coverings, piping and plumbing. The information collected from many sources into this volume makes it a handy work of reference, particularly to architects and builders. The book closes with a glossary of trade names, a short bibliography and an index.

Problems of Power Transmission at Voltages above 225 kV.

By FRANÇOIS CAHEN. British Electrical and Allied Manufacturers Association, 36, Kingsway, London, W.C.2 [Price 5*s*. net.]

THIS book contains a reprint of four lectures on power transmission at voltages exceeding 225 kV, which were delivered by Professor Cahen before the University of London last year. The author bears the titles of Directeur-Adjoint des Etudes et Recherches à l'Electricité de France and of Professeur à l'Ecole Supérieure d'Electricité. He is therefore fully qualified to deal with a branch of electrical engineering which is receiving increasing theoretical and practical attention. The first lecture begins with a general survey of the problems of electric power transmission at extra-high voltages, the factors governing the choice of voltages up to 400 kV being detailed and the nature of the technical difficulties that await economic solution being analysed. The next two lectures are devoted to problems of corona, including power losses, the use of multiple conductors and radio interference, the space allotted being a true indication of the importance of these questions. These two lectures are, in fact, of particular value, since they include an account of the experimental research on this subject and of the practical results that have arisen therefrom. The influence of conductor diameter, surface condition and weather on the generation of corona is studied for both single-phase and three-phase lines, while the relative advantages of using a single large-diameter conductor or multiple conductors are considered and then compared with the results of tests carried out both in France and elsewhere. In the fourth lecture, Professor Cahen studies the effect of over-voltages and surveys the latest theories on protection and the co-ordination of insulation. The treatment throughout is not so mathematical as is often the case in a French book; and while theory has its place, much practical information of value is included. In fact, the lectures form an excellent basic introduction to a subject which is becoming of increasing importance now that the possibility of an inter-European network may be assumed to be entering the sphere of practical politics. The publishers are to be congratulated on the excellence of the presentation of what is a useful work of reference.

Materials Handling in Industry.

British Electrical Development Association, 2, Savoy-hill, London, W.C.2. [Price 8*s*. 6*d*.]

THIS book is the fourth of a series of eight dealing with specialised industrial applications of electricity. It has been written specifically to show how better handling of materials can increase productivity and at the same time improve working conditions. Although the treatment is not exhaustive and is, in fact, confined to the handling of materials in and around buildings, a good deal of ground is covered and concise descriptions of the construction and use of several appliances are accompanied by informative illustrations. In particular, overhead runways and lifting equipment; cranes; and elevators and conveyors of different types are dealt with. There is also a section on floor transport and storage in which stillage and pallet systems and trucks of various types are described. Details are also given of other equipment, including vibrators and electronic metal detectors. In a final chapter old and new methods of handling heavy tools and fractional horse-power motors are compared. It will be seen that, in spite of its source, the book, is something more than mere electrical propaganda, although, of course, an inherent feature of most of the equipment described is that it is electrically driven. Neither are the descriptions excessively technical; in fact, appendices might well be added giving the output of the motors required for the various types of drive and details of the possible systems of control. A useful feature is a list of British Standard specifications dealing with mechanical-handling equipment from which, of course, much additional information can be obtained. The book is well worth study by all those who have reason to believe that their present methods of handling materials might be improved.

BOOKS RECEIVED.

Reviews of Petroleum Technology. Vol. 12 (covering 1950). Edited by DR. F. H. GARNER, DR. E. B. EVANS, and GEORGE SELL. The Institute of Petroleum, Manson House, 26, Portland-place, London, W.1. [Price 50*s*., post free.]

The Practical Electrician's Pocket Book, 1953. Edited by ROY C. NORRIS. "Electrical and Radio Trading," 189, High Holborn, London, W.C.1. [Price 5*s*., post free.]

The Journal of the Institute of Metals. Vol. LXXIX. 1951. Edited by N. B. VAUGHAN. The Institute of Metals, 4, Grosvenor-gardens, London, S.W.1. [Price 30*s*.]

Metallurgical Abstracts (General and Non-Ferrous). Vol. 18, 1950-51. Edited by N. B. VAUGHAN. The Institute of Metals, 4, Grosvenor-gardens, London, S.W.1. [Price 60*s*.]

The Stratford-upon-Avon and Midland Junction Railway. By J. M. DUNN. The Oakwood Press, Tanglewood, South Godstone, Surrey. [Price 5*s*. net.]

Industrial Leadership and Joint Consultation. By DR. W. H. SCOTT. The University Press of Liverpool, Liverpool, 3. [Price 12*s*. 6*d*.]

Engineering Drawing. By H. T. DAVEY and R. J. WILKINS. Macdonald and Company (Publishers), Limited, 16, Maddox-street, London, W.1. [Price 45*s*. net.]

Direct Current Machines for Control Systems. By A. TUSTIN. E. and F. N. Spon, Limited, 22, Henrietta-street, London, W.C.2. [Price 50*s*. net.]

Rewinding and Repair of Electric Motors. By KARL WILKINSON. E. and F. N. Spon, Limited, 22, Henrietta-street, London, W.C.2. [Price 20*s*.]

Surveying and Field Work. By JAMES WILLIAMSON. Third revised and enlarged edition. Constable and Company, Limited, 10, Orange-street, London, W.C.2. [Price 40*s*. net.]

South Africa. Electricity Supply Commission. Twenty-Ninth Annual Report, Year Ended 31st December, 1951, with a Brief Review of Activities to 30th April, 1952. Offices of the Commission, Escom House, Rissik-street, P.O. Box 1091, Johannesburg, South Africa.

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.

Vulcanised-Rubber Compounds.—A revision of B.S. No. 1154, covering vulcanised-rubber compounds, has now been issued. It replaces the war-emergency specification, published in 1944, and the earlier Government department specification T.G.25A on which that publication was based. The new edition covers four white compounds and six black compounds, the former being produced from natural rubber and zinc oxide, and the latter from natural rubber, zinc oxide and lamp-black. The various compounds are classified according to their hardness. Skeleton compositions, as well as testing requirements, are included, while mixes giving compounds (or "vulcanizates" as they are termed) complying with the requirements of the specification are set out in tabular form in an appendix. [Price 2*s*. 6*d*., postage included.]

Flanged-Steel Globe Valves for the Petroleum Industry.—Another specification in the series being prepared for the petroleum industry has been published. This, B.S. No. 1873, covers cast-steel or forged-steel outside-screw-and-yoke globe valves with integral flanges for the petroleum industry. The valves may be fitted with either ball-type or plug-type discs, the seat rings being renewable and either shoulder-seated or bottom-seated. The globe valves dealt with are of classes 150, 300, 400, 600, 900 and 1,500, which represent their respective primary service pressure ratings, in lb. per square inch, at certain stipulated temperatures. The normal sizes of the valves range from ¾ in. to 8 in. The specification contains provisions relating to design and manufacture, materials, workmanship, marking, tests, inspection, dispatch and guarantee. Two detailed drawings illustrating the valves covered by the specification and on which all the component parts are identified by numbers, and appendixes of tables of dimensions, materials specifications, pressure-temperature ratings and other matters, are included. [Price 10*s*., postage included.]

Code of Practice on Mechanical Refrigeration.—The Council for Codes of Practice for Buildings, Construction and Engineering Services, Lambeth Bridge House, London, S.E.1, have issued, in final form, Code No. 406, covering mechanical refrigeration. The Code opens with general notes on specifications and on performance tests of plant, and then follow two main sections dealing with safety and with thermal insulation. Safety is considered from the point of view of safeguarding life, health and property. The physical, toxic and explosive properties of the commoner refrigerants are set out in an appendix. In the section on thermal insulation, guidance on design considerations, inspection and testing, and maintenance are given. Attention is drawn to points on which consultation between interested parties is necessary in the early design stages. The Code carries the usual warning that, in the present abnormal conditions, it may not be practicable to carry out all the recommendations made. [Price 5*s*., postage included.]

CONTRACTS.

BLACKBURN AND GENERAL AIRCRAFT, LTD., Brough, East Yorkshire, have received a production order from the Ministry of Supply for the universal freighter for use by the Royal Air Force.

BARTRAM & SONS, LTD., Sunderland, have received an order for a 10,900-ton cargo vessel from the United British Steamship Co., Ltd., London. The engines, which will give the vessel a speed of 12½ knots, are to be built by J. G. KINCAID & CO., LTD., Greenock.

HOLLAND & HANNEN AND CUBITTS, LTD., Howdon-on-Tyne, Northumberland, have obtained the contract for the construction of two new building berths, capable of handling ships of more than 30,000 tons deadweight capacity, at the Wallsend shipyard of Swan, Hunter, and Wigham Richardson, Ltd. The piling work will be carried out by HOLMPRESS PILES, LTD., Hull. It is also proposed to build a crane gantry and a jetty extension 135 ft. in length.

G. AND J. WEIR, LTD., Cathcart, Glasgow, S.4, have been given an order by Ewbank and Partners, Ltd., 15, Grosvenor-place, London, S.W.1, for sea-water distillation plant capable of supplying one million gallons of fresh water daily. The plant is destined for His Highness the Ruler of Kuwait, Persian Gulf, and will comprise ten sets of triple-effect horizontal evaporators, each set having a distilling condenser and pre-heater. The installation will be located at Shuwaikh and the fresh water produced will be used locally for domestic purposes.