THE "PRINCESS" FLYING BOAT.

THE first of the three 140-ton Princess flying boats, Britain's largest aircraft, has recently made her maiden flight. Those who have had the opportunity of seeing this graceful machine at close quarters can well appreciate the ingenuity and skilled workmanship that have gone into her construction, which renders the uncertainty of her future role greatly to be regretted. The Princess project has had setbacks largely resulting from difficulties in developing suitable power plants. Proposed in 1944 by Messrs. Saunders-Roe, Limited, East Cowes, Isle of Wight, as a transatlantic air-liner capable of carrying 100 passengers on the direct London-to-New York route throughout the year, at a high cruising speed, the design was originally based on the assumption that Rolls-Royce Tweed propeller turbines would be available. In 1946, three aircraft were ordered for British Overseas Airways Corporation. The development of the Tweed, however, was abandoned by Rolls Royce, and a considerable amount of re-design was involved in accommodating the alternative power plants, Bristol Proteus propeller turbines. As is well known, there has been, and still is, delay in the development and production of the Proteus engines, resulting in mounting costs. An account of the way in which the development costs have risen was given in the *Civil Appropriation Accounts*, 1950-51, and was summarised on page 435 of our 173rd volume (1952). Briefly, it may be said that by March, 1951, British Overseas Airways Corporation had decided that the Comet air-liner was more suited to their needs and it was decided, therefore, that they would not adopt the Princess. The Air Ministry then agreed to adopt the Princess flying boats for the Royal Air Force, but in December, 1951, they withdrew their request. It appears at the moment, therefore, that the first Princess, which is fitted with Proteus II propeller turbines, will probably be an experimental aircraft. Construction of the remaining two Princesses is, for the time being, postponed, owing to the delay in the production of the more powerful Bristol Proteus III engines with which they are to be equipped.

A photograph of the Princess on the water is reproduced in Fig. 1, and outline drawings are shown in Figs. 4, 5 and 6, on page 290. Ten Bristol Proteus II propeller-turbine engines, each developing 2,500 shaft horse-power plus 800 lb. thrust under static sea-level conditions at maximum r.p.m., provide power for the first aircraft, arranged as two single outboard units and four coupled inboard units. De Havilland Hydromatic propellers are fitted, the coupled engines being provided with contra-rotating propellers and the outboard engines with single propellers. To provide ample clearance for the propellers when manœuvring in rough water, a high-wing layout and a two-deck hull has been adopted. The cross-section is formed by segments of two intersecting circles, the upper-deck floor level being the intersection of the two circles and the lower-deck level the intersection of the lower circle with the planing bottom. Above the lower-deck level, the hull is pressurised throughout, with the exception of a nose compartment below the flight deck. The space between the lower deck and the planing bottom is not under pressure; it is divided into 14 watertight compartments. In adopting this layout, Saunders-Roe considered that the two-deck arrangement gave a more efficient utilisation of space than the cabin of circular cross-section, the necessary floor space for 100 passengers being provided without excessive cabin height which cannot be usefully employed; this, it was considered, offset the lower structural efficiency inherent in the "double-bubble" pressure cabin as compared with the circular-section cabin.

FIG. 1. "PRINCESS" FLYING BOAT ON THE WATER.

GENERAL PARTICULARS AND PERFORMANCE.

The span of the aircraft is 219 ft. 6 in., the length 148 ft., the height 55 ft. 9 in., and the beam 16 ft. 8in. At an all-up weight of 147 tons, the wing loading is 65 lb. per square foot, and the take-off power loading, with the Proteus III engines for which the aircraft was designed, is 8·7 lb. per horse-power. These low loadings have been chosen to give the flying boat an exceptionally good take-off and climb performance. It is, of course, too early in the flying career of the aircraft for any actual performance figures to be available; it is estimated, however, that the aircraft will take off, fully loaded in still air in 1,300 yards with all engines (Proteus III) operating, and will climb away at 1,900 ft. per minute; with one coupled engine out of action, the initial rate of climb is 1,350 ft. per minute. The aircraft is designed to cruise at a speed of 380 m.p.h., at altitudes between 30,000 ft. and 40,000 ft., giving a still-air range, with no allowances, of 5,500 miles. After making allowance for head winds, diversion to an alternative base, fuel consumed while awaiting permission to alight, and other contingencies, this corresponds to an actual stage distance of about 3,500 miles. The London to New York route, it may be recalled, is 3,450 miles.

A hydro-dynamic innovation is the shallow front step of the planing bottom. It is the result of extensive research carried out in the testing tank at the Saunders-Roe works. The Princess is the first aircraft to be fitted with the new "faired step," which is elliptical in planform and only ½ in. deep. The chine at the step is rounded and faired into the step. It is claimed that excellent hydrodynamic and aerodynamic characteristics are thus obtained.

The laminar wing section is to Saunders-Roe's own design, to give the required lift-drag characteristics. The maximum thickness is 40 per cent. back from the leading edge, and ranges from 18 per cent. of the root chord to 12 per cent. of the chord at the wing tip. Electrically-operated slotted flaps are fitted. Retractable stabilising floats are arranged to lie along the wing tips, when retracted, and are electro-hydraulically operated. In an aircraft of this size, some form of power operation for the flying controls is essential; in the Princess, a duplicated system of electro-hydraulically-operated flying controls has been installed, manual control being completely eliminated. It has therefore been possible to use unbalanced control surfaces, which results in a saving of weight and drag. The operation of the flaps, floats and the power controls has been extensively tested on ground rigs while the aircraft was under construction. The control system power-packs have also been tested thoroughly in flight on a Short Sunderland flying boat.

The pressure cabin is designed for a maximum differential pressure of 8 lb. per square inch, giving an equivalent cabin altitude of 8,000 ft. when the aircraft is flying at 40,000 ft. The cabin superchargers and the pressure-ducting arrangements have been designed by the Bristol Aeroplane Company, Limited, Filton, Bristol, the valves and controls being supplied by Messrs. Normalair, Limited, Yeovil. Representative sections of the hull, including windows and a freight door, the pilots' transparent canopy, and the front and rear pressure bulkheads, have been submitted to tests under a pressure of 25 lb. per square inch; the section under test was mounted between concrete blocks, within a water-filled pressure tank of circular cross-section designed to prevent damage to personnel, etc., in the event of the hull-specimen exploding under pressure. Deformations were recorded by means of strain gauges.

ACCOMMODATION.

Aft of the crew compartment, on the top deck, there is cabin space extending as far back as the

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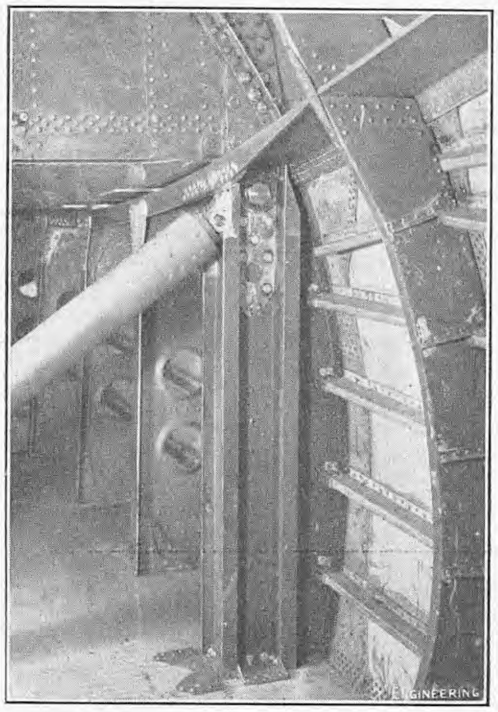


FIG. 2. FRONT SPAR PICK-UP, PORT SIDE, SHOWING GUNWALE MEMBER.

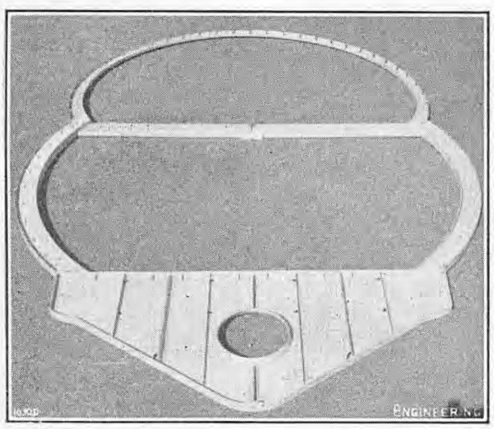


FIG. 3. TYPICAL HULL FRAME.

Fig. 4.

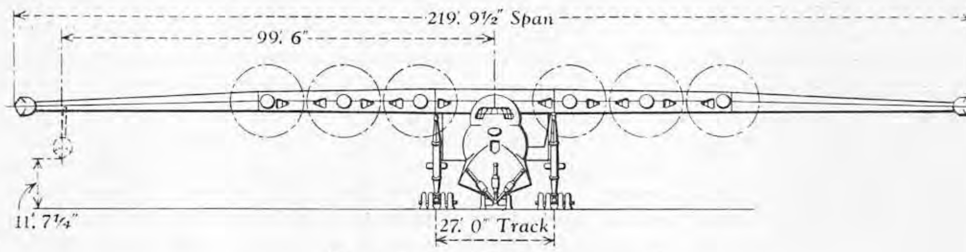


Fig. 5.

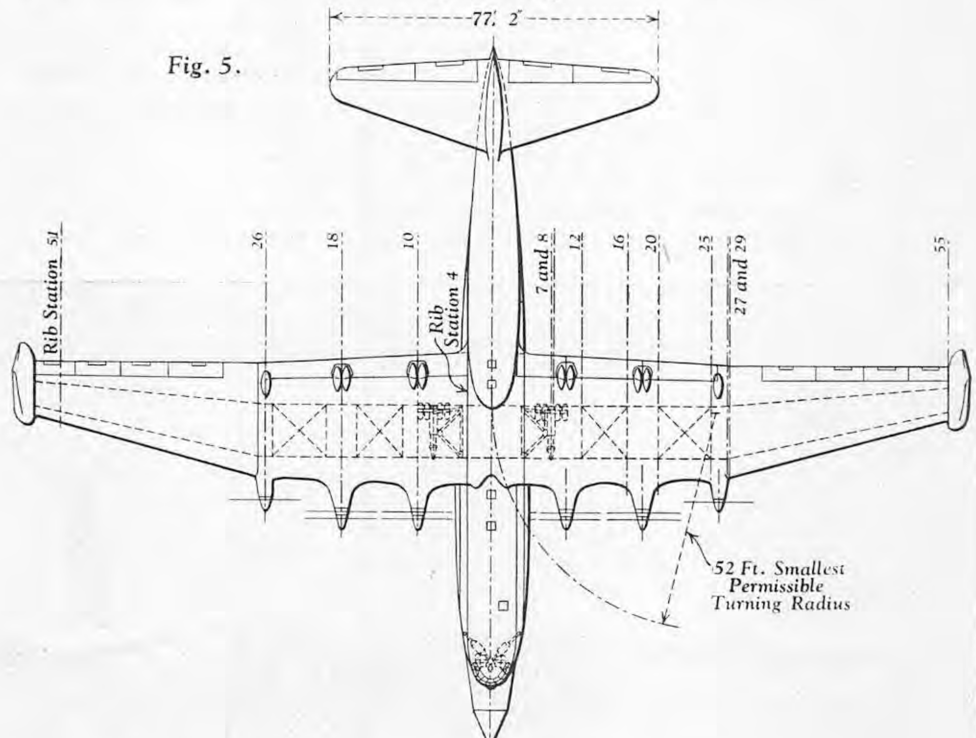
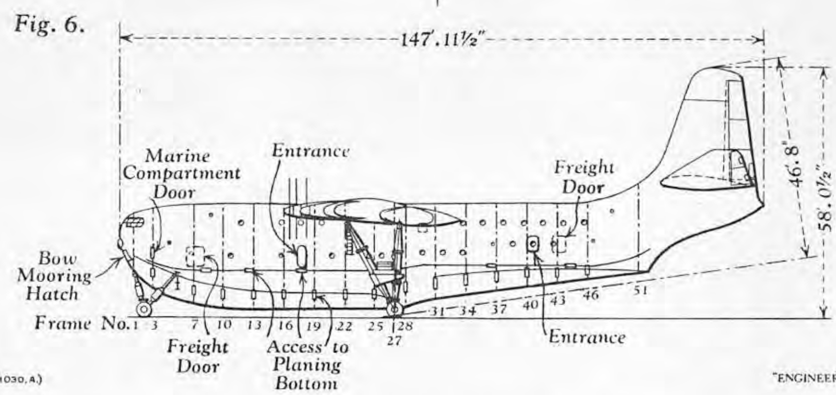


Fig. 6.



centre-section wing; at the rear a curved stairway leads down to the lower deck. Aft of the top-deck cabin, there is no direct through-way in flight; at this point the centre-section wing is carried across the hull; the plating of the upper-deck front and rear spar frames and the lower wing plating form pressure-tight bulkheads. The space below the wing accommodates batteries, humidifiers, water tanks, etc. For ground servicing, access panels are provided to give a passage-way through the centre-section wing. At the forward end of the lower-deck cabin space there is a freight and luggage compartment, with a door on the starboard side which is large enough to allow a spare double Proteus power plant to be loaded. The freight door can be opened from inside or outside, is self-sealing, and forms part of the load-carrying structure. The forward wall of the freight compartment is of heavy construction and forms a pressure-tight bulkhead; the unpressurised nose compartment, below the flight deck, houses the mooring gear. There is free access along the whole of the lower deck, at the rear end of which is a second stairway leading to the upper-deck cabin space aft of the centre section. It is bounded by the lower part of the rear pressure bulkhead.

For ease of loading, passengers enter the aircraft through a door on the port side at the rear of the lower-deck tourist saloon, whereas freight-loading, refuelling and other servicing operations are carried out on the starboard side of the aircraft.

Roomy crew accommodation is provided for two pilots and, in a compartment behind the pilots' cockpit, two flight engineers, a navigator and a radio operator. The senior flight engineer has control of all the engine instruments and controls and will normally operate the engine controls according to the pilot's orders. The other flight engineer deals with the remaining equipment, such as fuel system control, wing-tip float and flaps operation, air-conditioning equipment, de-icing equipment, etc. All the instruments and controls for the flight engineers are grouped on the starboard wall. The radio operator and navigator are provided with swivel chairs so that they can either face the radar screens, which are located on the port wall, or their desks, situated, respectively, at the aft and forward ends of the crew compartment. A rest bunk is provided for the crew on the starboard side of the forward galley.

HULL.

The hull, wings and tail surfaces of the Princess are of orthodox stressed-skin construction. High-strength aluminium-alloy sheet, to specification DTD546, and extrusions to specification DTD683 are used throughout the structure. It was found that the sheet, which had to be softened for forming and then artificially age-hardened, expanded approximately 0·01 in. per ft. during ageing; it was therefore necessary to form and age-harden all the hull plates before any drilling was done. Many of the extrusions and formed-sheet sections employed in the hull, including the keel, had to be formed to complex curvatures, and for this purpose special tools were developed which were used in conjunction with hand presses, power-presses, rolling and pipe-bending machines. A Mills Oilaulic power press was installed for forming the larger sections, and a heavy-duty rolling machine was designed and constructed by Saunders-Roe, Limited.

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(*For Description, see Page* 289.)

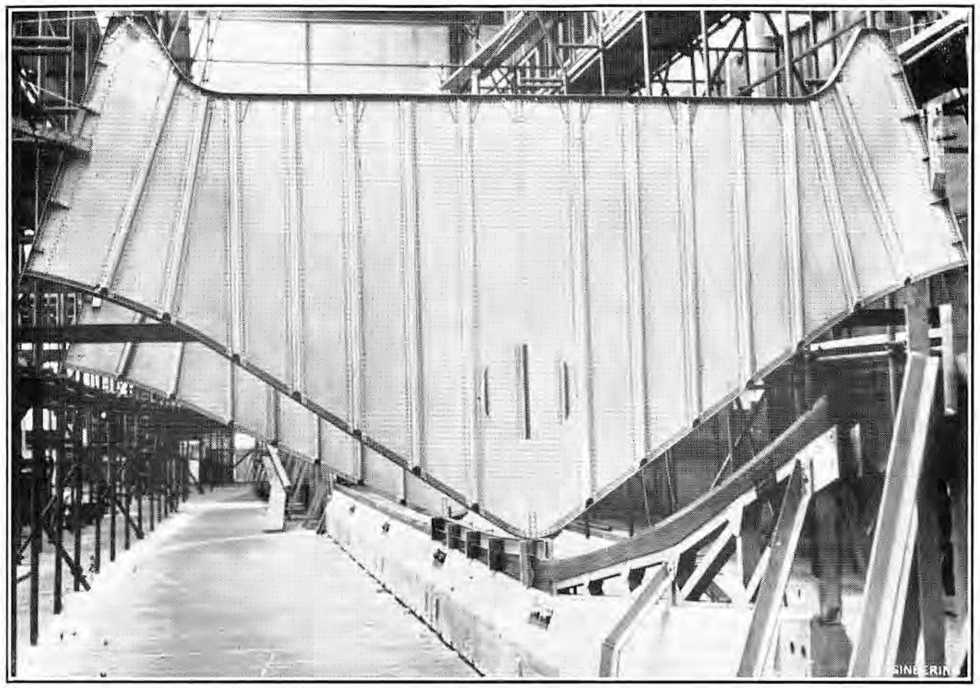

FIG. 7. EARLY STAGE IN HULL ASSEMBLY, SHOWING ANCHOR-SECTION KEEL.

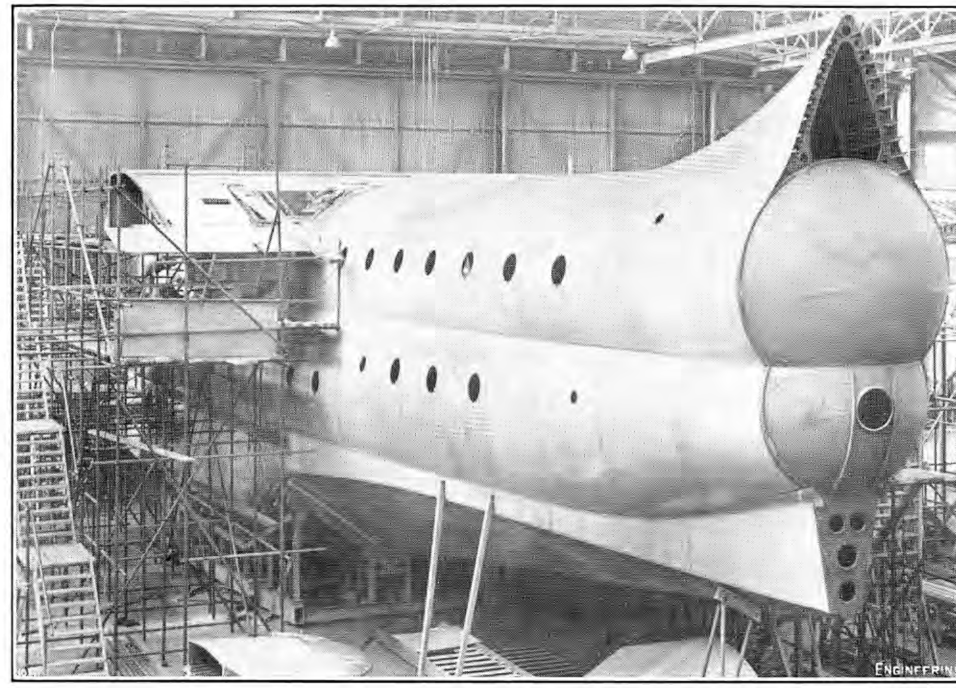

FIG. 8. REAR PRESSURE BULKHEAD.

FIG. 9. HULL STRINGERS, SHOWING DISCONTINUITY AT STEP.

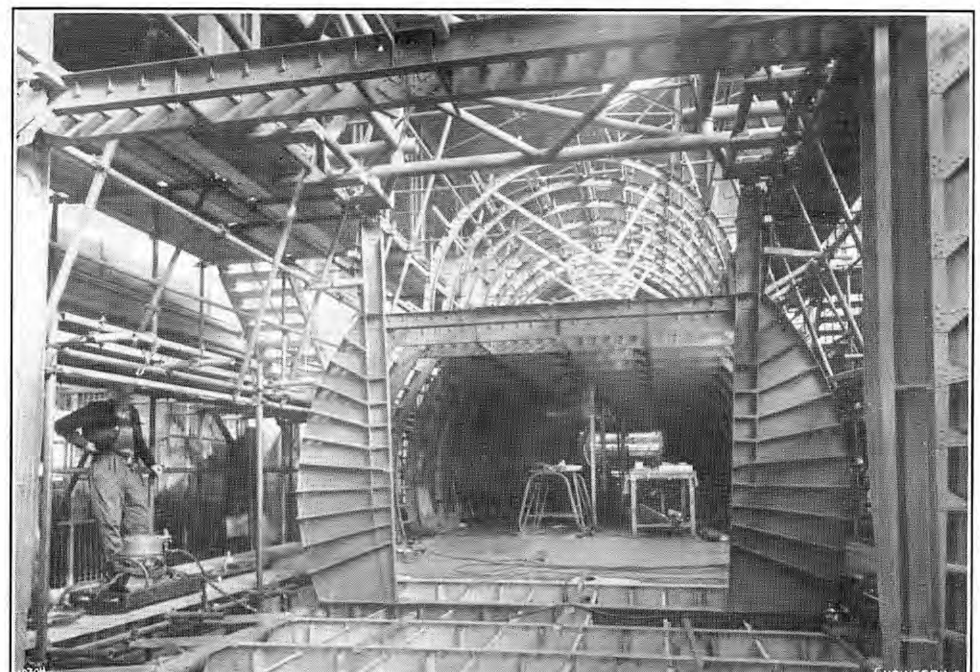

FIG. 10. ERECTION OF SPAR FRAME.

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(*For Description, see Page* 289.)

FIG. 11. ERECTING MAIN PART OF FIN ON HULL.

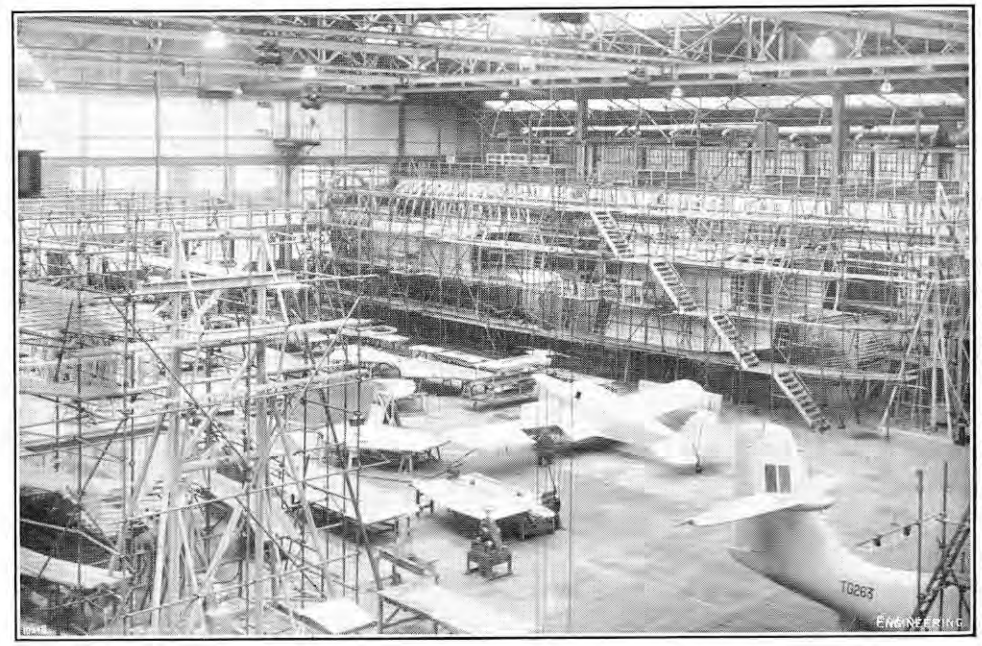

FIG. 12. GENERAL VIEW OF "PRINCESS" DURING CONSTRUCTION.

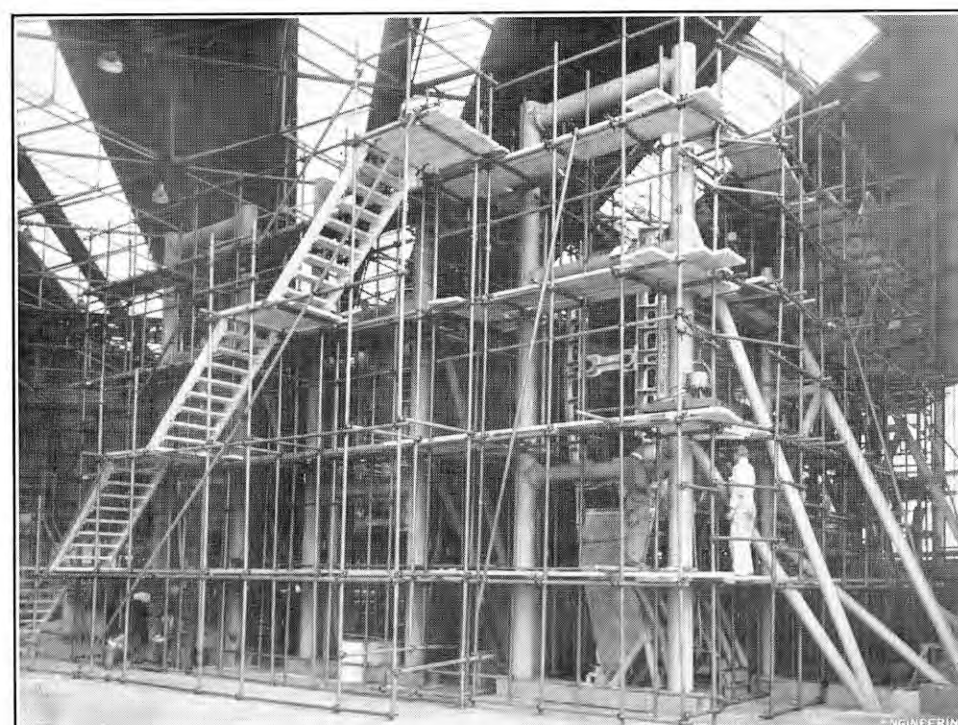

FIG. 13. TRIPLE ASSEMBLY FIXTURE FOR WINGS.

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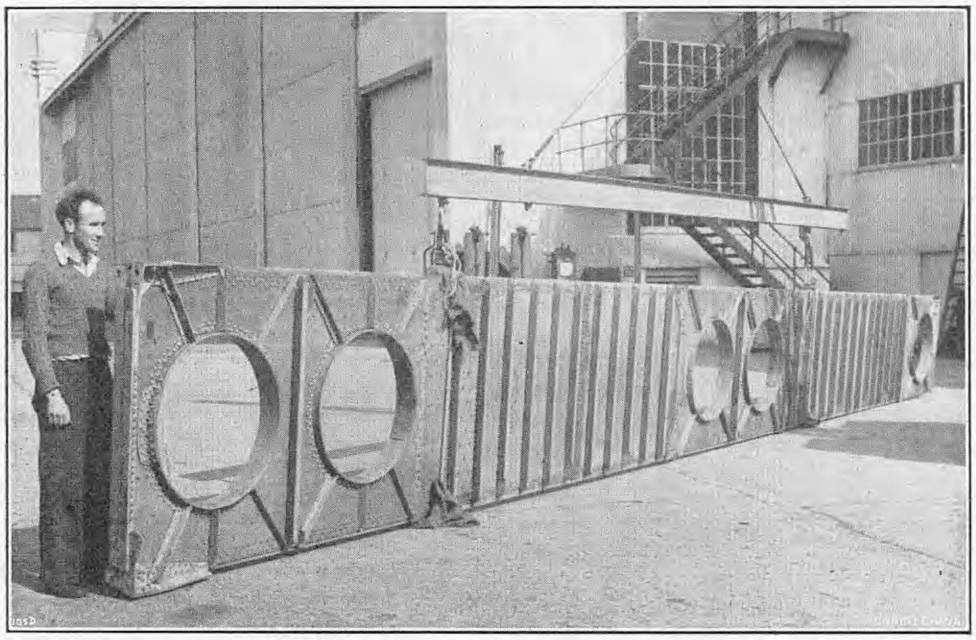

FIG. 14. INNER-WING FRONT SPAR.

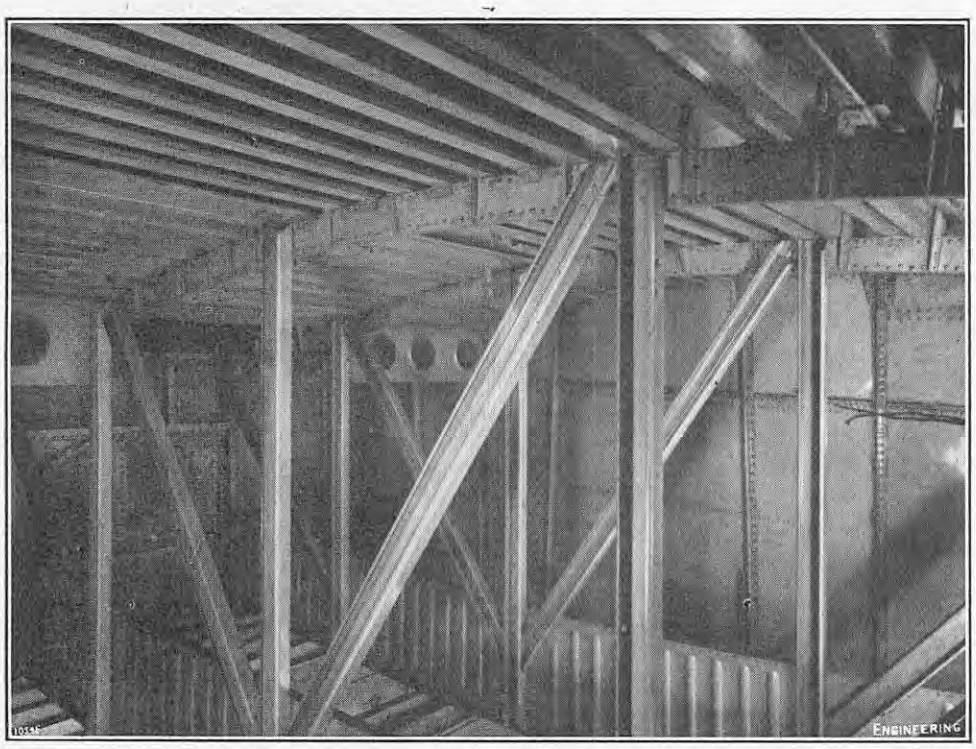

FIG. 15. INTERIOR OF FUEL TANK.

Over the whole length of the boat there are 63 frames, spaced at 2 ft. 4 in. centres; some of the frame stations are indicated in Fig. 6, opposite. The keel, a substantial anchor-section extrusion, extends from the nose to the rear pressure bulkhead, frame 51. Aft of frame 51, the tail end and lower part of the fin were assembled as a separate unit and attached subsequently to the main hull structure, shown in Fig. 8, on Plate XIII, and Fig. 11, on Plate XIV. Excepting the front and rear-spar frames, Nos. 22 and 27, and frame 51, the frames are in general of the type shown in Fig. 3, in which frame 43 is shown lying on the ground. The upper "bubble" frames, consisting of a channel-section circular arc, mostly in 16-s.w.g. sheet, are built in four sections. The outer flange of the channel is cut to receive the longitudinal Z-section stringers, which are continuous over the upper bubble portion of the hull. Between frames 22 and 27, however, the upper frames are not complete but consist of two circular arcs, one on each side of the hull, the top of each frame being joined to a longitudinal gunwale member, conforming to the lower profile of the centre-section wing, and bolted to it. One of the gunwale members can be seen in Fig. 2, which shows the wing front-spar joint with the hull. The gunwale members, which are inverted channel-section extrusions, extend from frame 19 to frame 30. Frames 19 to 21 and 28 to 30 are cut away to receive them and are attached to them by forged angle brackets on the aft side of the frame webs. The section of the gunwale members is progressively reduced forward and aft of the front-spar and rear-spar frames.

The lower-bubble frames consist of two circular arcs connected, at top-deck level, by a 14-s.w.g. channel-section transverse member, made in two pieces; when finally erected on the hull, each of these transverse channels was connected to a central longitudinal deck beam. In the centre part of the boat, between frames 15 and 32, the lower-bubble frames are of heavier construction than the rest and comprise a built-up I-section with T-section flanges and a 16-s.w.g. sheet web. The remaining lower frames comprise a 16-s.w.g. channel section, to the inner flange of which is riveted another shallow channel section to form a T-flange. The Z-section stringers are intercostal along the lower bubble of the hull; their inner flanges are, however, joined by butt-straps, through slots cut in the frames.

Below lower-deck level, the frames are all of the stiffened diaphragm type, as illustrated in Fig. 7, on Plate XIII, every third frame forming a watertight bulkhead. From frames 19 to 25, which are of considerable depth, the top boundary flanges of the bulkheads are cut down, except at the front spar frame 22, in order to save weight. Over the planing bottom proper, the longitudinal stringers are continuous, except at the step, where they are joined by gusset plates, as shown in Fig. 9, on Plate XIII. Along the upper sides of the planing bottom the stringers have intercostal webs and butt-jointed inner flanges passing through slots in the bulkhead webs.

Fig. 10, on Plate XIII, shows frame 27 which carries the rear-spar attachment points; frame 22 to which the front spar is attached, is of similar but heavier construction. It will be seen that, above the bulkhead, which is similar to those of the other frames but is more heavily reinforced by vertical stiffeners, the spar frame comprises two stiffened diaphragms; the inner boundary members of the diaphgrams consist of extruded uprights, spaced 8 ft. 9 in. apart at lower-deck level, extending from the spar-attachment points to the bulkhead flange. A transverse beam, comprising two channel-section extrusions back to back, spans between the pillars at upper-deck level.

As already noted, the top of each spar frame is bounded by the longitudinal gunwale member to which the centre-section wing is bolted; on either side of the hull, the fork-end attachment fittings on each spar protrude through rectangular holes in the gunwale flanges, and are bolted through plate fittings on either side of the pillar and diaphragm webs, as shown in Fig. 2. The upper part of each spar frame is reinforced by diagonal tubular bracing members between the spar-attachment point and the centre of the transverse top-deck beam.

The rear pressure-cabin bulkhead, frame 51, consists of two intersecting part-domes of 18 s.w.g. sheeting, joined at their intersection through an extruded Y-section transverse member. It is well shown in Fig. 8, on Plate XIII. The boundary member is a skew Z-section member. The shell plating of the hull is attached to the outer flange of the boundary member. The hull plating ranges in thickness from 18 s.w.g. at the forward end of the top deck to 12 s.w.g. adjacent to the wing. The shell plating of the upper and lower "bubbles" is joined at top-deck level through an extruded Y-section member secured to the deck sheeting; the lower-deck shell and the side panels of the planing bottom are similarly joined, and the plating at the chine is attached through a 12-s.w.g. angle. The top-deck plating, of 18 s.w.g., is carried on a series of longitudinal intercostals extending between the transverse channels, together with the continuous longitudinal girder. The main bearers of the lower deck comprise six longitudinal I-section beams. Superimposed on these are transverse I-section extrusions and Z-section intercostals forming a floor grid to which the 18-sw.g. deck sheeting is riveted.

TAIL STRUCTURE.

The tail end of the hull and the lower part of the fin were constructed in one unit, shown in Fig. 11, on Plate XIV, during erection. Hull frames 55 and 59 are extended upwards to form the fin front and rear spars respectively; these frames have sheet webs and extruded angle booms. Aft from frame 51, a shear deck extends back, forming a continuation of the top of the hull, back to frame 55. On this deck are mounted combustion heaters which provide for de-icing the fin and tailplane leading edge. In the nose the products of combustion are led through a pipe which passes through circular holes in the nose ribs; diaphragms spanning between the nose ribs form a de-icing duct along the fin leading edge.

The aft tip portion of the fin is insulated from the leading edge and acts as a surface aerial. For access to the radio equipment housed in the tail surfaces, and to the de-icing equipment, a manhole in frame 51 leads by way of a catwalk to ladders, one extending up the fin just forward of the fin rear spar, and another leading to the shear deck. A second manhole in the fin skin leads to the tailplane interior.

A continuation of the tailplane front and rear spars and skin is carried across the centre-line of the aircraft. The rear spar carries the elevator hinge brackets. The attachment of the tailplane to the hull is by two bolts at each spar pick-up point—i.e., eight bolts on each side of the hull—and by bolted joints all round the profile. The tailplane leading edge has a de-icing duct along the nose similar to that of the fin. The tailplane trailing-edge root also forms a surface aerial. The rudder, a single-spar structure, is constructed in three sections; the lower section only is provided with a balance tab.

Erecting the Hull.

One of the most notable features in the building of the Saunders-Roe Princess flying boat was that no special assembly sheds had to be built. The firm were fortunate in possessing a large erection hangar, known as the Colombine shop, built on strong foundations, and in having available a pool of skilled craftsmen, experienced in shipbuilding techniques. The stocks of the three hulls were all laid in the Colombine shop. The wings and the fin and tail portion of the hull were built in a separate hangar nearby.

The assembly of the hull has followed shipyard practice, the hull structure being built up from the saddle, a shaped mahogany former supported on concrete blocks and steel girders. At the forward end of the saddle, a light steel structure was erected to carry Taylor-Hobson alignment telescopes which were used, in conjunction with portable optical targets, for establishing the hull centre-line and stations and setting up the hull components accurately. At the aft end of the saddle a heavier framework was erected, also carrying alignment telescopes, which served as a locating and drilling jig for the hull rear-pressure bulkhead and the after-body. No other fixed jigs were used in erecting the hull. After setting up the keel anchor-section extrusion and marking out on the floor a plan of the hull and frame stations, a four-stage scaffolding was erected from which to carry out the assembly work. This may be seen in Fig. 12, on Plate XIV. Erection commenced at the forward and aft end of the hull, the centre-section assembly being delayed until a considerable portion of the rest of the hull was well advanced. The forward and aft planing-bottom bulkheads were lowered into position by an overhead crane for erection, followed by the longitudinal floor beams and the partly-plated floor-grid sub-assemblies. The planing-bottom stringers were then attached to the frames and the shell plating was drilled and riveted in position. The assembly of the lower-bubble frames, the longitudinal deck beams, the top decking, the lower-bubble plating and the upper-bubble frames followed. The stairways between the upper and lower decks were assembled separately and installed as complete units.

The next operation was the erection of the spar frames, which were assembled as complete units before being erected, as were all the centre-section frames. After these frames had been temporarily shored in position, the gunwale members were lowered on to them; in order to ensure that the frames were accurately aligned for receiving the wing-spar attachments, a special removable reference jig was built, which also served for the assembly of the wing centre-section and for drilling the bolt-holes in the gunwale members. This jig can be seen in Fig. 10, on Plate XIII, which shows the spar frame being erected on the hull.

The centre-section wing was moved into position on the hull by two 4-ton mobile cranes braced together. When the hull plating was completed, the hull was moved from its position at the side of the hangar to the centre, for erecting the inner wings. An account of this operation on the first hull, which took place in July, 1949, was given on page 139 of our 168th volume. The tail-end and lower-fin assembly were erected on the hull while it was in the centre of the hangar (Fig. 11, on Plate XIV). In order to erect the top part of the fin, which extends to a height of 31 ft. 6 in. above the top of the hull, and the outer wings, it was necessary to move the hull, complete with the inner wings, out on to the tarmac in front of the hangar, since the latter could not accommodate the full wing and vertical fin spread. This movement was carried out on October 30, 1951, and was described on page 563 of our 172nd volume.

Wings.

The wings of the Princess, of two-spar torsion-box construction, are built up from five main units—the centre section which is carried across the hull and extends slightly beyond it on each side, two inner-wing units which house the power plants and the integral fuel tanks, and the two outer wings, at the outboard ends of which the float-retracting mechanisms are housed. The floats themselves, when retracted, form the wing tips. The assembly of the main centre-section and inner-wing units—i.e., the portion between the spars—was carried out in the large triple-assembly fixture illustrated in Fig. 13, on Plate XIV. The main outer-wing units with the leading and trailing edges were constructed in vertical jigs. The spars comprise deep extruded angle booms and stiffened sheet webs; Fig. 14, on page 291, shows the front spar of the inner wing, the tail-pipe apertures being reinforced by extruded T-section stiffening rings and angle stiffeners. The skin is reinforced by spanwise stringers, mainly Z-section extrusions, except at span-wise skin butt joints, where wide top-hat section stringers are used.

In the rectangular centre-section wing there are 13 rib stations, No. 1 being on the centre line and Nos. 7—8 at the junctions between the inner and centre-section wings. Some of the key rib stations are indicated in Fig. 5, on page 290. Ribs No. 4, at the hull boundaries, comprise extruded T-section booms and reinforced sheet webs provided with a manhole which gives access to the control runs for ground servicing. The lower boom of No. 4 rib conforms to the profile of the hull gunwale member, to which it is bolted. To carry the pressure loads from the hull, spanwise trusses built up from tubular and channel-section members are fitted between ribs No. 4. Ribs Nos. 1, 2 and 3 are deep I-section girders interlaced between the spanwise trusses. The spars are each attached to the hull spar-frames at two points by fork-end fittings bolted to the spars, and protruding through slots in the gunwale members. At the wing-hull junction, the hull plating is secured to an extruded T-section boundary member shaped to the contour of the hull and riveted to the spar web; the hull stringers are also attached to this member by angle cleats. Sealing is provided at all intersections of the pressurised hull with the unpressurised wing by strips and cornerpieces of Rubazote. Outside the hull, ribs Nos. 5 and 6 are of Warren girder form.

The inner-wing to centre-section wing joint is through the mating booms of the boundary ribs at station 7-8. At rib station No. 7, in the centre wing, are two unbraced heavy extruded angle-section booms forming an open "rib." The centre-section stringers are connected to the boundary-member booms by slotted T-section cleats which embrace the stringer webs, and are bolted through the mating booms of ribs 7 and 8 to corresponding fittings attached to the inner-wing stringers. The boundary-member booms in each unit and the spar booms are bolted together through corner castings, through which the main-spar joints at the inner and centre-wing junction are also effected. On the centre-wing unit, the lower corner castings also provide attachment points for the main beaching chassis, and special bolts have had to be adopted for the lower inner-wing and centre-wing main-spar joints in order to clear the projecting beaching-chassis pick-up bolts. The flanges of the spars of the centre-section and inner-wing units are connected by multi-bolt attachments.

The end rib No. 8 of the inner-wing units is a heavy tubular braced girder with large extruded angle-section booms. The outer end rib, No. 27, has a plate web with large extruded angle booms. A manhole in the web gives a passage into the outer wing. In each inner wing, there are two integral fuel tanks between ribs 12 and 16, and ribs 20 and 25, respectively, the tank walls being formed by the spars, the wing skin, and these ribs, which are bulkheads extending over the full depth of the wing and reinforced on the outside by horizontal stiffeners. No rivets are used in the joints in the tank bays, all connections being bolts. Fig. 15, on page 291, shows the interior of one of the tank bays. The lower booms of the intermediate ribs in the tank bays form anti-surge baffles. Secondary spanwise baffles are provided between the rib booms. The spaces between ribs 8 and 12, ribs 16 and 20, and ribs 25 and 27 enclose the engine exhaust ducts which emerge through the trailing-edge skin. Fig. 16, opposite, shows the interior of the port outer coupled-engine bay. The wing stringers in the engine bays are connected to those in the fuel-tank bays through special fork-ended fuel-tight cleats, seen clearly in Fig. 16, bolted on each side of the bulkhead rib booms.

At stations 9, 11, 17, 19 and 26, through which pass the centre-lines of the engine tail pipes, open "ribs" are employed, comprising upper and lower I-section girders, stabilised by triangular and diagonal bracing members in the spanwise direction. At the centre-line of each coupled-engine bay, stations 10 and 18, is a Warren-girder rib. Large hatches and removable panels are provided in the leading edge for access to the engine services. For the tank ends and jet pipes between the spars, there is access through manholes in the top plating. There are also access panels in the trailing edge, for various controls, etc., and for entering the fuel tanks by way of removable covers in the rear spar.

The joint between the inner-wing and outer-wing units, at station No. 27-29, is carried out through stringer-cleat connections and corner castings in the same manner as in the centre-section to inner-wing junction. From rib stations 30 to 49, Warren-girder ribs are used. Diaphragm ribs are employed at stations 50 and 51, the latter being of heavier construction with extruded booms. Outboard of station No. 51, the spars are parallel, and the space between them houses the wing-tip float-retracting gear. Rib No. 51 carries the float-chassis support brackets. To make room for the float chassis, rib

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SAUNDERS-ROE, LIMITED, COWES.

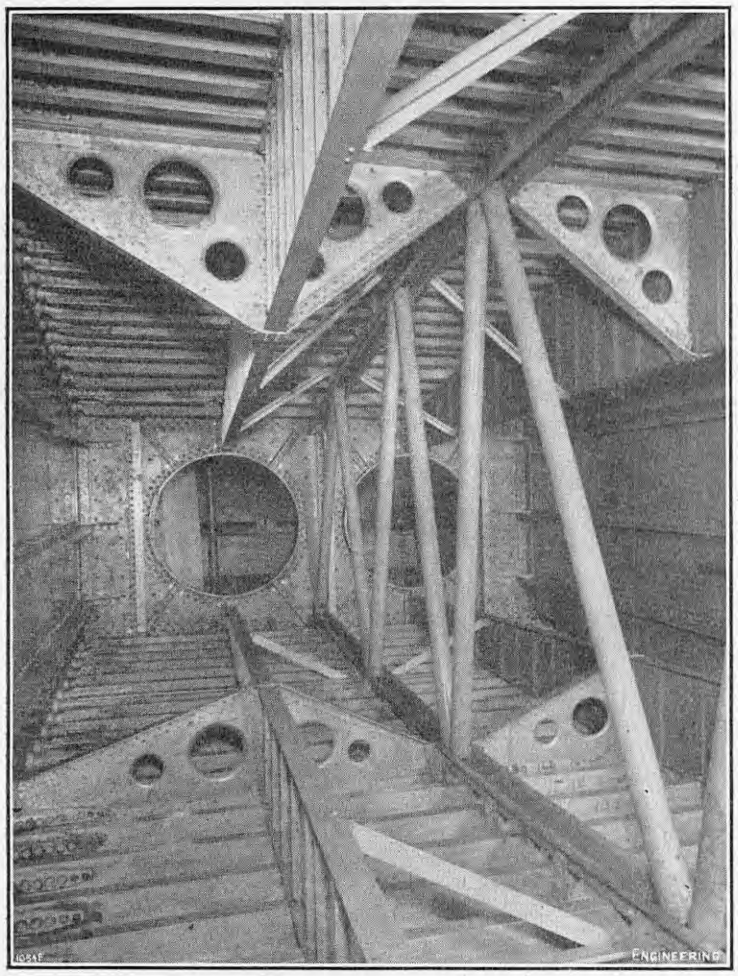


FIG. 16. INTERIOR OF PORT CENTRE COUPLED-ENGINE BAY.

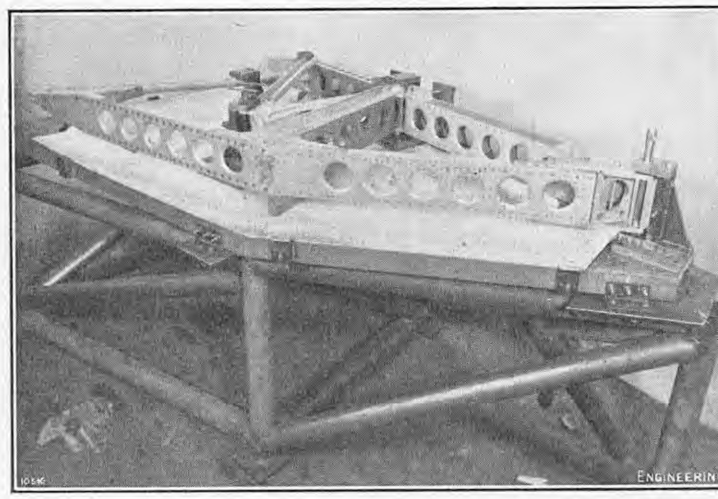


FIG. 17. FLAP HINGE OUTRIGGER.

Nos. 52, 53 and 54 extend only to about half the depth of the spar. From station 51 to station 55, the entire lower-wing skin panel can be detached to give access to the float chassis for dismantling or special servicing. The hydraulic power pack for float retraction and lowering is carried on rib 54.

In the inboard leading edge are the air intakes for the engines, engine auxiliaries, and the cabin supercharger. The cabin air intake is between nose ribs 4 and 5; these ribs, of open construction with tubular bracing, carry the brackets supporting the cabin supercharger. The air trunking is secured by quick-release pins so that the whole blower unit may be quickly removed for servicing. Stainless-steel fireproof ribs are provided at the engine-bay bulkheads. The intakes for the coupled power units are on each side of the power unit bays, that for the single engine being on its inboard side. Each intake contains three ducts—the oil-cooler air duct passing straight back to the oil cooler; the engine air duct, which is provided with toroidal guide vanes, turns through 90 deg. and passes through the fire-wall into the plenum chamber; and the exhaust-cooling duct, built integrally with the engine duct, but with its outlet between the fire-wall and the front spar. This duct supplies cooling air to the space enclosed between the exhaust pipe and its shroud, in order to avoid overheating the wing structure. The engine fire-extinguisher system and certain of the oil tanks are also housed in the inner leading edge.

The outboard leading-edge unit encloses the thermal de-icing duct, which extends outboard to station 50. The heater pipe passes through a circular hole in the sheet webs of the nose ribs; a vertical diaphragm spans between each rib to form a de-icing compartment in the forward part of the leading edge. Inner corrugated skin panels form fore-and-aft heat conducting channels to the wing surface, extending to about 8 in. aft of the spanwise diaphragms.

Aft of the rear spar, the trailing edge comprises an assembly of open and diaphragm ribs with a skeleton spar which carries the aileron hinge brackets. The ailerons, which extend over a span of 42 ft. 3 in., in the outer wing, are divided into four units, each of which has a single tab. Structurally, all the flying control surfaces are similar, and comprise a single spar and trailing-edge member with pierced sheet ribs. The inboard and two centre aileron sections are supported on three hinges, the centre one of which is linked to the screw-jack actuator. The outermost aileron section has two hinges only, the inner one forming the operating hinge.

FLAPS.

Slotted flaps span over the whole length and about half the chord of the trailing edge of the inner and centre-section wings. They are divided into three separate sections by the engine tail pipes, each section being actuated by two electrically-operated screw jacks carried on outriggers, as illustrated in Fig. 17, which are attached to the rear wing spar.

In order to provide the desired backward and downward movement of the flaps, each section is carried on a system of links hinged on the outrigger which carries the screw jack. All pivot points on the linkage are provided with roller bearings. The screw jacks are operated through a worm drive by a common torque shaft driving all the flap jacks on one side of the aircraft. The torque shaft is universally jointed and splined, and runs in ball bearings mounted on the trailing edge ribs at a number of points between the screw jacks, in order to avoid whip. Two 3-h.p. variable-speed reversible electric motors on the forward face of the rear spar in the centre-section drive, through epicyclic reduction gearboxes, to each side of a 1-to-1 differential gearbox. If one motor should fail, an electric brake is automatically applied to stop that motor, and the other motor continues to drive, through the differential gearbox, both port and starboard flap systems at half the normal speed. From the differential gearbox, the drive is transmitted through a pair of shafts, running along the forward face of the rear spar out to each hull boundary rib, thence through two bevel gearboxes to the flap torque shaft in the wing trailing edge.

The operation of the flaps is controlled by a fairly complex electrical circuit. The pilot's switch has three marked positions—"raise," "take-off" and "lower," and five intermediate positions, two between "raise" and "take-off," and three between "take-off" and "lower." When the pilot selects a flap setting, a control relay in a 24-volt circuit is energised through a drum switch. The latter is mechanically linked to the flaps so that when the desired flap position has been attained, the control circuit is broken. There are two of these control relays, one for raising and one for lowering the flaps, which determine the direction of rotation of the motors. When a control relay is closed, a series of relays are set in action, which bring in a 120-volt direct-current supply to release the motor brake, which is normally held on by a spring, and to close one of the main contactors ("raise" or "lower") of the motor. Polarised relays cut out the starting resistance when the motor has built up speed, and introduce a "brake economy" resistance to reduce the large current required to operate the brake to a small holding current. When the flap reaches the selected position, the drum switch breaks the 24-volt control circuit and thereby breaks the 120-volt supply to the motor and brake. The polarised relays, in addition to timing the sequence of actions, also provide for rapid reversals of current flow through the motor, should the pilot change his mind during the flap operation. The operating coils of the "raise" and "lower" main contactors are interlocked so that they cannot be closed at the same time. Two limit switches are provided to break the appropriate control circuit, in the event of faults in the system, when the flaps reach the extremes of travel.

(To be continued.)

INSTITUTION OF CIVIL ENGINEERS STUDENTS PRIZES.—Among the awards made for students' papers read in the 1951-52 session before the Institution of Civil Engineers is that of the James Forrest Medal and a Miller Prize to Mr. F. G. Johnson, M.Eng., for his paper, "The River Dee as a Source of Water Supply for the Wirral Peninsula." Miller Prizes have also been awarded to Mr. A. D. Anderson, Mr. H. A. Hope, Mr. E. T. Haws, M.A., Mr. George Diggle, B.Sc., Mr. W. H. J. Dobson, Mr. D. F. Watson, Mr. Arthur Marsland, M.Sc., Mr. E. W. Parkinson, B.Sc.(Eng.), Mr. A. C. Allen, B.Sc.(Eng.), and Mr. J. R. Kemp.

THE APPLICATION OF STATISTICS TO ENGINEERING PROBLEMS.

Fig. 1. TERMINAL TIME AND STANDAGE CHARGES.

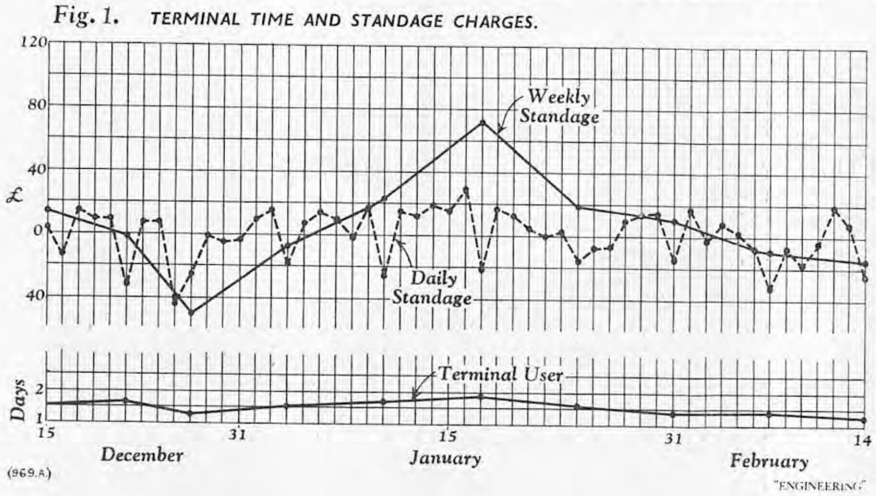


Fig. 2. DISTRIBUTION OF NUMBERS OF WAGONS IN WORKS ACCORDING TO PERIODS.

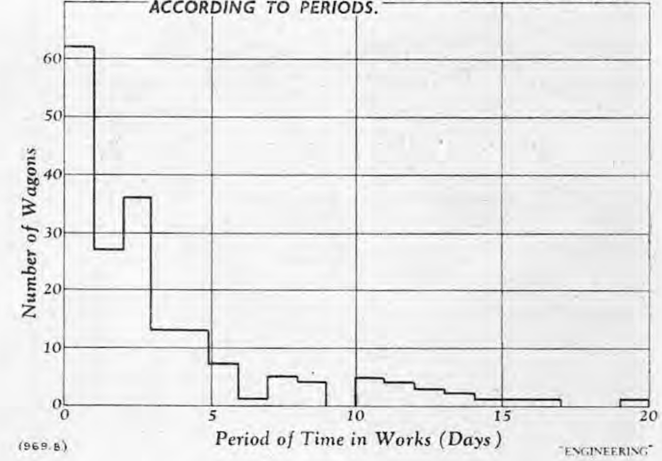


Fig. 3.

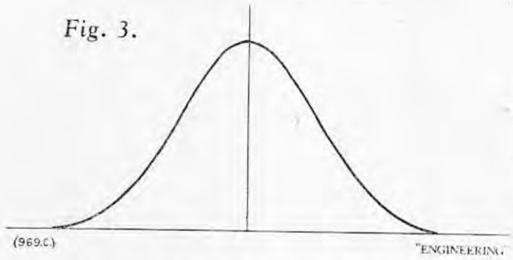


Fig. 4.

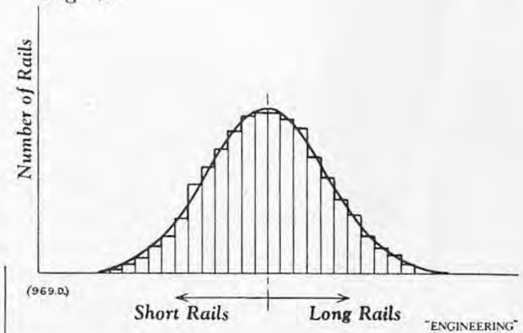
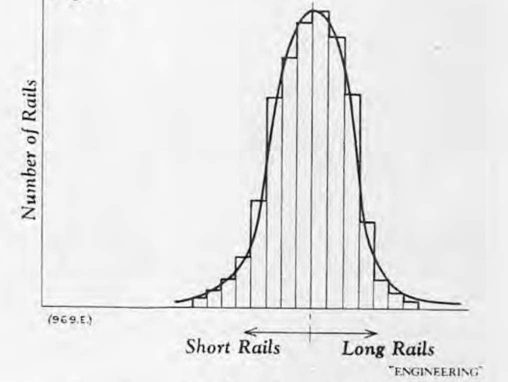


Fig. 5.



THE APPLICATION OF STATISTICS TO ENGINEERING PROBLEMS.

By M. D. J. Brisby.

The difference between applied and fundamental engineering research is that, with applied research, the variables are usually known, while with fundamental research they are generally unknown. The corollary to this is that, if variables are known, it is usually possible to foresee the form of the answer, or, at least, to get a reasonably good idea of the lines along which research will progress. This means that, with a certain amount of experience in applied research, the investigator will be able to assess the chances of success and also the probable time it will take to complete the investigation.

In this, applied research is usually more positive than fundamental research. Applied research should not be started unless the goal is in sight, or at least the chances of success are good. Because of this, applied research has positive economic value and is the best method of promoting advancement in industry. With few exceptions, industrial research is, in fact, applied research. The time lag between fundamental discovery and industrial application is usually a matter of years, conditioned by the risk factor in adopting new techniques, the cost of re-equipping works, and the problems of reorganising production. By the time that managements have weighed the pros and cons of a new discovery, it is already well established and its final adoption in the works becomes purely a matter of application.

Because of the positive quality of applied research the method is admirably suited to productivity and efficiency studies. This positive or "directional" aspect of applied engineering research may be illustrated as follows. Firstly, there must be a motive, which is usually a suspicion of lack of efficiency. This in itself, however, does not justify research; there must, in addition, be confidence that the research will yield significant results, i.e., that, when the work is completed, the investigator will be in a position to express a definite opinion on how to improve the efficiency of the plant. In other words, the chances of success must be reasonably high. Lastly, the research must be really useful; the data collected and the evidence must serve to raise materially the efficiency of the plant.

The variables are all available for the research engineer to examine: power consumption, fuel efficiency, power input and output, operating rates, tonnage throughputs, manpower, labour efficiency, bonus rates; and, if these do not suffice, he can make time and motion studies of all operations. The problem is to measure them quantitatively and then to interpret the results.

The quantitative measurement of these variables may be difficult but more often it is simple, though it may be a lengthy process. Generally, however, modern industry is so well equipped with automatic counters and recording devices that many of these variables may be read directly from records. The real problem of the applied research engineer is to know how to analyse these records, interpret the results, and then recommend action on the evidence obtained in order to increase productivity.

The Use of Records.

A vast number of records are kept in modern industrial organisations; mostly, it is true, for accounting purposes, either to keep a check on the costing of various processes or to keep track of the consumption of commodities, or possibly to assist rate fixing. These records, if suitably interpreted, can form a substantial part of "investigator's evidence" in applied engineering research. Consider, for example, the numerous records dealing with the deliveries and consumption of raw materials, stock records of individual departments, power-consumption records, and maintenance and breakdown records.

Much has been said of statistics and statisticians in the last few years—and not all has been complimentary. This is not so much the fault of statistics and statisticians, as of those who interpret the results. In applied research, statistical methods are a most powerful tool; they can be used to help to plan experiments so as to cancel out errors, and to determine the minimum number of tests required to get results of given accuracy. If experimental errors are unavoidable, at least they can be compensated or evenly distributed. Statistics may be used to find absolute and relative errors in experiments or to calculate the probable error even before the experiments are made. The very existence of quality specifications, tolerances and factors of safety—the essence of engineering—is intimately connected with statistics.

To all but the trained mathematician, statistical methods may seem complex. Sometimes this is, in fact, the case, but often it is not. The value of statistics to an engineer resides not so much in the technicalities as in the general frame of mind which even a limited knowledge of the science develops in him. Statistical methods, for example, will have rendered a great service to engineering, and particularly to engineering research, even if they do no more than help to make engineers more critical of the evidence on which to control their day-to-day work. Intuition can be very misleading and the word "obvious" is often brought into arguments to conceal the fact that the truth is not known. Examples will now be given of actual engineering problems which can be analysed with the help of information largely obtained from records.

Congestion Studies.

As a first example of how records can be used to give information ultimately leading to better utilisation of space, materials and men, consider the problem of deliveries of raw materials to works. In heavy industry, these may be delivered by sea, canal or rail, according to geographical location. Since much of Britain's industry has grown up in the proximity of the large Midland and Scottish coalfields or near the iron-ore deposits, the greater part of the raw materials delivered to industry is carried by rail.

The growth in rail traffic to meet the increases in production over the last few years has shown up cases of considerable congestion in works railway systems.* On simple inspection, it is clear that

* "Traffic of Iron and Steel Works: A Method of Traffic Analysis," by H. H. Mardon and M. D. J. Brisby. *Jl. Iron and Steel Inst.*, December, 1949.

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Fig. 6.

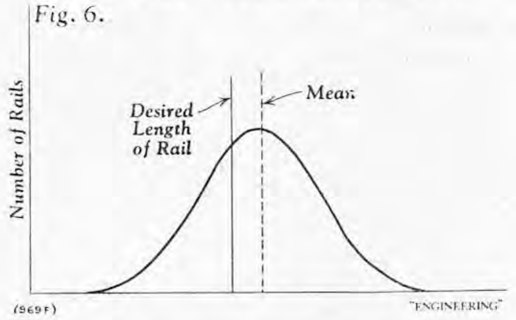


Fig. 7.

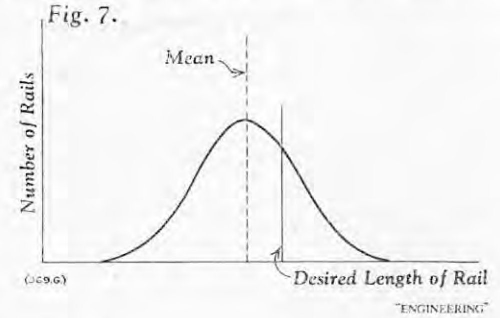


Fig. 8. DISTRIBUTION OF WAGON LOADS.

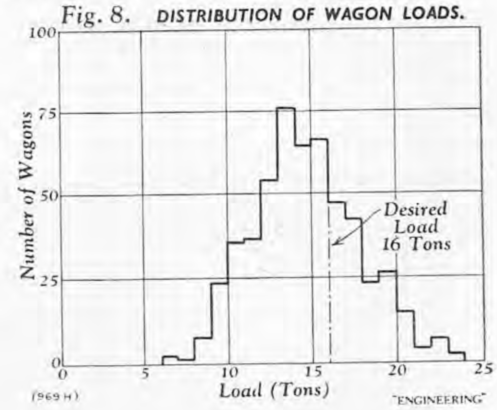


Fig. 9. DISTRIBUTION OF WAGON LOADS.

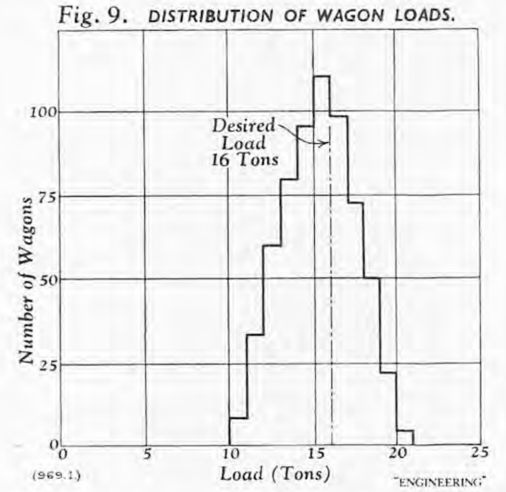


Fig. 10.

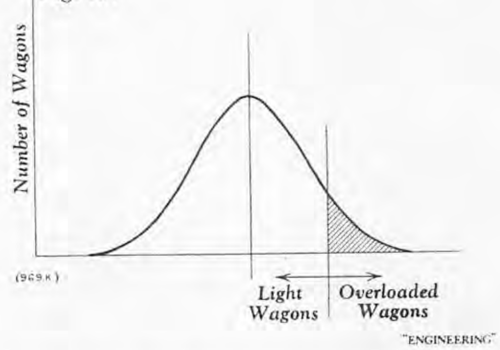
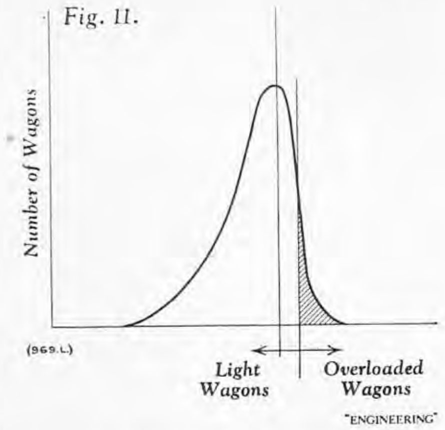


Fig. 11.



this is because more wagons are standing in the works than there is room for. This means that wagons are left standing on running lines, in " shunting necks " and loop lines, with the result that it becomes extremely difficult to operate works locomotives efficiently and far more shunting is needed to marshall wagons into the order required by the consuming departments.

The reason for this congestion is simple—wagons at times enter the works faster than they can be discharged. To determine how long individual wagons remain in the works involves taking counts of them at regular intervals. This would require a number of investigators working three shifts a day for several weeks.

A simple expedient was devised* to determine the average time that wagons remained in the works by consulting the records kept by the works' traffic departments for accounting purposes. By dividing the total number of wagons on hand by the total number discharged during the previous 24 hours, the " terminal user time," or the time that wagons remained in the works, was obtained. It was found at different works that this figure ranged from about one and a half days to well over four days. In addition to applying this expedient to works transport systems, it was applied to individual departments within the works and also to particular commodities. By this means, the departments with slow wagon turn-round were immediately identified, as well as the particular commodities which were held in wagons for long periods.

This analysis was made at different works in a matter of days and, in some cases, without so much as walking over the railway system. From the information obtained, it was then possible to relate the time that wagons stood in the works to the standage charges paid out to the railways (Fig. 1, opposite), to make recommendations for speeding up wagon turn-round, for better unloading equipment and better layout of track, leading ultimately to better wagon and locomotive utilisation. It will be seen from Fig. 1 that no payment is made for wagons held in the works up to one and a half days—a very real incentive for speeding wagon turn-round.

* *Loc. cit.*

A simple statistical anaylsis will show the likelihood of wagons staying in works for more than a given number of days (Fig. 2, opposite). While the first analysis (Fig. 1) gives general information on the overall efficiency of a works transport system and the average speed of wagon turn-round, the second analysis (Fig. 2) gives detailed information on how this average is made up. For example, for an average time of two days spent in the works for all incoming wagons, some may be discharged in the first day, some after three days and a few after 20 days. Fig. 2 gives the actual distribution of times spent in a works for some 200 wagons remaining in the works an average time of 3·3 days.

USE OF THE GAUSSIAN CURVE.

A great many day-to-day operations, involving an element of uncertainty, can be plotted in such a manner as to lie on the Gaussian or " bell-shaped " curve as shown in Fig. 3, opposite. From tossing coins to the probability of making measurement errors of specified magnitude, from gambling chances to the most learned scientific forecasts, all problems involving natural selection and human limitations follow this bell-shaped or " normal distribution " curve. In other words, this curve represents the amount of scatter that is experienced if a large number of samples or readings are taken. Much useful information can be obtained from the curve as the following examples show.

If a mill is set up to roll rails, these will not all be exactly the same length because of imperfections in the mill, differences in ingot, bloom and billet sizes, and human factors. One would expect (and this is, in fact, the case) that a fairly large number of rails would be very nearly the right length; some shorter and some longer. If these are plotted so as to show the number of rails of given lengths, the result will be a diagram of the form shown in Fig. 4, opposite, the envelope of which is similar to the curve given in Fig. 3. The diagram shows the scatter in rail lengths obtained under certain specific conditions. If the same number of rails were rolled under a different set of conditions, these might have the distribution shown in Fig. 5, opposite, which is drawn to the same scale as in the previous case. It will be seen that a greater proportion of the rails are of almost correct length. This may be due to a variety of reasons, the most important of which is probably consistency in ingot, bloom and billet weights.

Obviously, it is preferable to roll rails with a distribution as shown in Fig. 5, as this means that " crop-end " scrap will be greatly reduced. Re-circulated home scrap represents a loss in mill output and additional melting and processing costs. Passano has shown* how, by careful analysis, the lengths of rolled products can be related to ingot weights and to bloom and billet sizes, pointing to the need for closer control of ingot, bloom and billet dimensions. This greater control in the initial stages of production might reduce the tonnage of home scrap by as much as 25 per cent.

A point of interest in this type of analysis is that if, for instance, rails rolled from batches of billets show consistently distributions as in Fig. 6, this means that the billets are on the heavy side for rolling this length of rail. If, on the other hand, the distributions are consistently as shown in Fig. 7, this indicates that the billets are on the light side. It appears, therefore, that, if the mean values deviate consistently from the desired value, with no outside influences such as penalties or bonuses, this must be due to a systematic fault—in this case, heavy or light billets. The advantage of spotting a systematic error or fault is that effective measures can be taken to put it right.

A similar investigation was made on the loading of wagons. A preliminary analysis showed these to be loaded as in Fig. 8. Though the wagons were all of the same capacity (16 tons), the loads ranged from six to 24 tons, with about as many overloaded wagons as underloaded wagons. This, as in the case of the rail lengths just mentioned, is what would be expected.

A second analysis of wagons of similar size was made and these showed a distribution as in Fig. 9, on page 295, showing less scatter and a greater number of wagons loaded to the correct capacity. In other words, the second operator working on the second batch of wagons was more skilful than the

* " Finished Steel Production: Possible Increase from Existing Equipment," by R. F. Passano. Paper read before Amer. Iron and Steel Inst., May 25, 1949.

THE APPLICATION OF STATISTICS TO ENGINEERING PROBLEMS.

Fig. 12. DISTRIBUTION OF TIME INTERVALS BETWEEN TRAIN ARRIVALS.

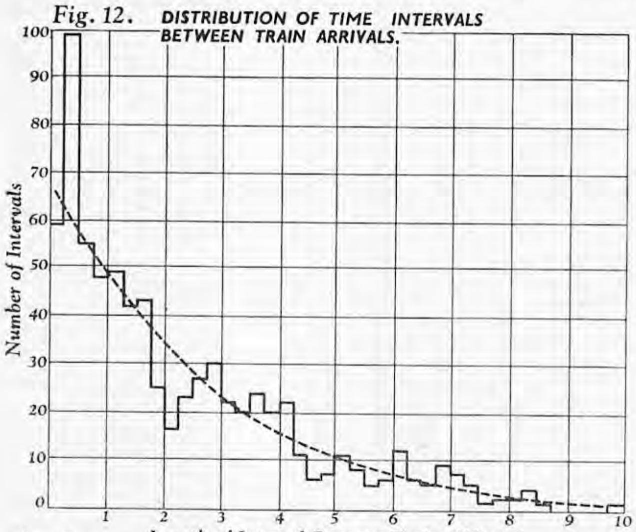
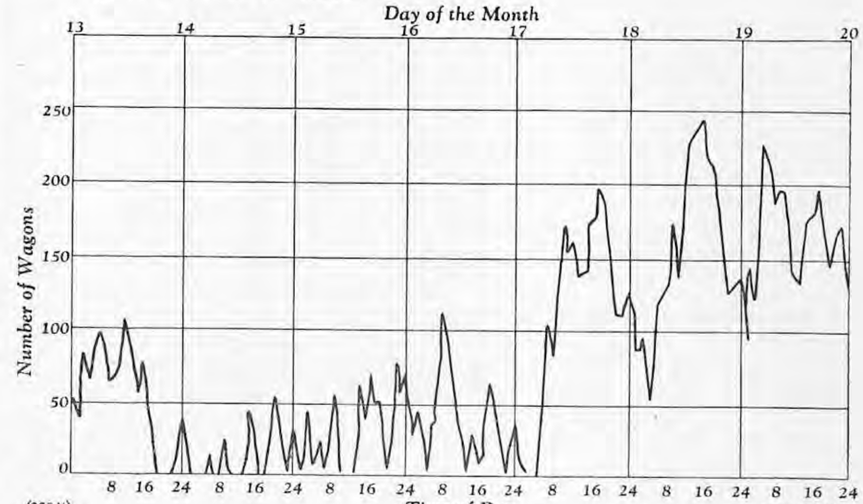


Fig. 13. NUMBER OF WAGONS IN SIDINGS.



first, which is shown by the fact that the bell curve is narrower. If a penalty were imposed on the operator for overloading wagons, this would have the effect of displacing the curve towards the left, as shown in Fig. 10, on page 295, as he would then take good care not to exceed the correct load. If, in addition to the penalty for "overloads," a bonus scheme were introduced for "getting near the mark," the distribution would tend to follow the shape shown in Fig. 11, on page 295, with the tendency to overload wagons tailing off rapidly. Studies of the type just described can be made, therefore, to determine (i) regularity at all stages of production; (ii) the relative capabilities of different operators; (iii) the effects of imposing penalties and bonus schemes; and (iv) the existence of systematic faults.

What has been said for rails and wagons applies just as well to practically any engineering operation, such as all forms of quality control, from the filling of cement sacks to the most careful chemical and metallurgical analyses. Here, too, accounting and stock records will frequently supply the applied research engineer with the necessary basic data for his work. Wagons are weighed and so are cement sacks; records are kept of chemical and metallurgical analyses; rail inspection records yield much useful information; and home scrap is usually accounted for.

Management in Transport Problems.

One of the first problems facing managements and engineers when considering the installation of new plant is to fix the size. Plant dimensioned to handle average throughputs may be quite satisfactory when the range of variation in throughput is small; but at times it might become hopelessly congested. For example, if an aerodrome were designed to handle only average landings it could not cope with peak arrivals; this would result in much delay and inconvenience to passengers. The same applies to harbour facilities, to 'bus services—especially in the Metropolitan area, subject to rush hours—to platform facilities at railway stations, to marshalling yards for goods traffic, in fact, wherever peak-load problems occur.

Reverting to the case of train arrivals at works: clearly, if the pattern of arrivals were known in advance, provision could be made for siding accommodation, traffic operations, and marshalling of commodities; locomotive operations could also be planned and consuming departments assured of supplies without having to hold large quantities of idle stock; in short, emergencies would not arise or, at least, the probability of emergencies arising would be greatly reduced.

Future events can be forecast, in some cases, with reasonable certainty. Failing this, it is generally possible to estimate the chances of particular events occurring. Provided that the accuracy of such a forecast can be assessed, its usefulness to the management and to engineers is beyond question. Here, more than anywhere, the study of past records can help in providing data for quick investigations which might otherwise take many months to gather.

A typical example was an analysis made of train arrivals at a works. There was a suspicion that irregularities in arrivals were a major cause of congestion in works sidings. On closer examination, it was found that train arrivals were, in fact, substantially random. When these were plotted on a frequency/time-interval basis, a distribution was obtained as shown in Fig. 12, herewith. The theoretical random distribution is shown by the dotted line and it will be seen that there is, indeed, good agreement between the actual pattern of train arrivals and the completely random distribution. Notwithstanding the efforts made to schedule arrivals, this was also found to be substantially the case for ship arrivals in port and for aircraft arrivals at airports.*

This element of randomness is, to some extent, inherent in all transport problems, which are essentially "self-aggravating" systems, i.e., systems in which a small change leads to a further change which aggravates the situation.† If even scheduled arrivals are random, it is little wonder that congestion occurs so frequently with road transport in busy areas.

The direct result of this type of investigation is that, once the pattern of arrivals is known, it is possible to plan measures to cope with them. Siding capacities, airport strips and berthing facilities can be properly dimensioned, and provision can be made for dealing with cargoes and passengers with a minimum of delay. It was shown in one case that random train arrivals were responsible for frequent congestion in sidings. ‡ A count made over a week showed the number of wagons in sidings to vary as shown in Fig. 13, herewith.

Congestion invariably means slower turn-round, whether of wagons, aircraft or ships. If the possibility of congestion can be forecast, it is possible to take measures to prevent it, either by exercising controls while the wagons, aircraft or ships are still in transit, or, failing this, by speeding up terminal operations. If, for example, the wagons shown in Fig. 13 could have been discharged more rapidly, their numbers would never have built up to the extent shown.

The data for the investigations which have been described were obtained largely from office forms and records compiled for administrative and accounting purposes. Simple statistical analyses of these records make it possible to marshal facts in the manner described, bringing out general trends and showing how apparently unrelated causes can account for a particular state of affairs. This is only one example of how provision can be made for the future by examining records of the past, and how applied engineering research can be used to interpret these records and to provide recommendations which can be of use to industry, transport and management.

* "Delays in the Flow of Air Traffic," by E. G. Bowen and T. Pearcey. *Jl. Royal Aero. Soc.*, vol. 52 (1948).

† "Operational Research," by Sir Charles Goodeve. *Nature*, vol. 161, page 377, March 13, 1948.

‡ "The Traffic of Iron and Steel Works: Train Arrivals, Handling Costs, and the Holding and Storage of Raw Materials." Brit. Iron and Steel Res. Assn. Report No. PE/E/14/52, April 1952 (not yet published).

Steel Economy.—The Ministry of Works have issued the first of a series of bulletins on steel economy, entitled "The Design of Buildings," emphasising the present acute shortage, and drawing attention to the means whereby the use of steel can be reduced. In general, the recommendations are in accordance with B.S.S. 449 and the Codes of Practice. The bulletin points out that structural members are often made heavier than is necessary for stress requirements, so as to achieve stiffness, and the Ministry proposes that increased deflections should be accepted. It is suggested also that design by plastic theory should be adopted wherever possible and that savings can be made by using minimum bolt and rivet centres in all connections. The replacement of steel by reinforced concrete is encouraged and mass concrete, brickwork and stonework proposed as alternatives where possible. Copies of the bulletin, price 3*d.* each, may be obtained from H.M. Stationery Office, Kingsway, London, W.C.2.

Airways Apprenticeships.—British Overseas Airways Corporation and British European Airways offer two types of apprenticeship to boys wishing to enter the air-transport industry. All apprentices are indentured for five years without a premium. Boys between 16 and 18 who have been educated at a technical, grammar or public school with a good grounding in mathematics, physics, chemistry and English, and who have passed the Civil Service Commission's open competitive examination for engineering apprentices, are accepted as engineering apprentices and are trained for executive or technical positions with the Corporations. The whole of their five-year training period is spent at the Royal Aircraft Establishment, South Farnborough, Hampshire. In addition, boys of 16 to 17, from secondary grammar, technical or modern schools, with ability in mathematics, science and English, are accepted as craft apprentices and are trained as airframe or engine fitters, aircraft electricians, instrument repairers, and radio mechanics. The first part of their training is spent either at Ministry of Supply training establishments or with industrial firms; they receive their final training in the hangars and workshops of the airways.

INTERNATIONAL ASSOCIATION FOR BRIDGE AND STRUCTURAL ENGINEERING.

As reported in our columns last week, the 4th Congress of the International Association for Bridge and Structural Engineering was held at Cambridge during the week commencing August 25. The technical business of the Congress was divided into three parts and was discussed at six working sessions, two to each of the main parts, which were: A, general questions relating to theoretical analysis and safety; B, metal structures, design and practice; and C, concrete structures, which was concerned with the properties of the material and with unsolved problems on this topic. There were more than 50 papers, which had been submitted for discussion and had been issued to the attending members in the form of a volume described as the *Preliminary Publication*; this volume also contained the papers of the six general reporters, who had surveyed the papers submitted in their respective sections. The papers were published in one of the three official languages of the Congress—English, French or German—but each paper was concluded by summaries in the other two languages. The *Preliminary Publication*, forming the basis of the work of the 4th Congress, is a book of 920 pages. At each working session, the general reporter for the session briefly introduced the papers, and he was followed by the contributors to the discussions. In order to ease the difficulties of comprehension and language, summaries of the contributions of speakers who had signified their intention of speaking were circulated in each of the three languages. Where members spoke impromptu their contributions were immediately summarised and rendered by the translater in the alternative languages, if requested by the delegates. A brief résumé of each working session is given below, covering both the papers and the discussions.

BASES OF CALCULATIONS: SAFETY.

The first working session was concerned with general questions under the title "Bases of Calculations; Safety." Among the papers contained in the *Preliminary Publication* was one by Mr. C. Scruton (Teddington) concerned with the investigations undertaken at the National Physical Laboratory on oscillations of suspension bridges, in particular the proposed bridge crossing the River Severn; articles on this subject have already appeared in ENGINEERING. Two other papers were also concerned with dynamic loading, the first by Mr. E. Friedrich (Graz) on "The Damping of Oscillations in Bridges," and the second, "Dynamic Increments in an Elementary Case," by Mr. A. Hillerborg (Stockholm). Five further papers were then grouped under the sub-heading of "Consideration of the Actual Conditions for Deformation (Plasticity, Creep, etc.)," and were devoted to analytical and experimental investigations on the load capacity of structural members, either singly or in multiple frames, when stressed into the plastic condition. Of this group of papers, two by Dr. M. R. Horne (Cambridge) were of interest. The first was entitled "Determination of the Shape of Fixed-ended Beams for Maximum Economy According to the Plastic Theory," and set out to determine the economies in material that could be effected by varying the cross-section of a beam so that it was just sufficient to carry any prescribed loading. The maximum theoretical economies were found to be of the order of 35 to 50 per cent., when compared with a beam of uniform section, able to sustain the maximum moments. Practicising engineers may be tempted to reject this paper because of the obviously considerable production difficulties in manufacturing a beam of continuously varying section, but these difficulties had been recognised by the author, who took his investigations a stage further and examined the effects obtained by relatively simple reinforcement of the centre and ends of the beam. It was found that only negligible advantage was gained in reinforcing the centre, but reinforcing the ends did lead to an appreciable saving in material. The second paper by Dr. Horne described an experimental investigation he had conducted to justify the results deduced from the simple plastic theory that the collapse loads of mild-steel continuous and fixed-ended beams may be calculated by considering merely the requirements of equilibrium in relation to the external loads and full plastic moments of resistance of the beams. The experiments, though made on small-section beams, were conducted with great precision and the results gave consistent confirmation of the simple plastic theory and showed that the collapse loads could be calculated with sufficient accuracy for practical purposes by the simple theory, using only a load plasticity factor.

The final paper of the first section was the "Safety Factor Calculation," by Professor E. Torroja and Mr. A. Paez (Madrid). The paper rejected the unqualified use of a factor of safety of 4, which has been accepted practice for so long, and had as its purpose the establishment of a general method of calculation of a suitable numerical value of the factor of safety in any particular case. The calculated value so obtained had to be free from arbitrary or subjective factors and should be derived only from the factual circumstances appropriate to the particular design. The problem was tackled by the authors in a rigorous mathematical manner. Laws of probability, based on existing experimental data, were applied to assess the probability of failure of a structure. In addition, the authors deduced a further equation from the condition that the insured cost of the work should be a minimum; and when conjoined with the former, an appropriate value of the design factor of safety could be calculated, compatible with a suitable margin of safety.

During the course of the discussion, Dr. T. P. O'Sullivan (London) instanced two extreme cases where the permissible factor of safety differed widely. In the case of a tank containing fluids, the moments and load conditions of the walls were known to a high degree of certainty and a factor of safety of $1\frac{1}{4}$ could justifiably be used. In contrast, however, were the possible extremes to which the deck beams of a road bridge might be loaded, so that a more conventional value of between 4 and 5 for the factor of safety should be used.

The dynamic effect of loading on reinforced-concrete structures was dealt with in a contribution by Professor S. Mortada (Cairo), read in his absence by his colleague, Professor F. Reinitzhuber. The particular structures concerned were high diving towers which were constructed of long cantilever members and were necessarily very sensitive to the dynamic action of loads; due to their low natural frequencies, resonance was set up by the rhythmic movements of the divers. Tests were conducted when the structures, of highly-reinforced good-quality concrete, were about a year old, and resonance tests showed that the peculiar loading to which this type of structure was subjected had high impact values, over 400 per cent. being observed.

The preliminary results of some French tests by Mr. A. Lazard (Paris) on the plastification of plate-web girders of mild steel had shown that there was an increase in the elastic limit of the steel in girders that had been tested to rupture under cyclic loading. It had also been found, from the results of tests on perforated and lattice-braced girders, that the conditions were less favourable to the development of plastification than in plate-web girders. Dr. G. de Kazinczy (Sweden) suggested that plasticity developed "in steps," and not continuously, as the load increased. He continued by pointing out that plastic theories were not limited to steel structures but could be applied equally well to reinforced-concrete structures.

Besides the contribution of Dr. O'Sullivan previously noted, the topic of calculation of the factor of safety brought forth contributions from four other members. Mr. A. Holmberg (Sweden) proposed that when designing reinforced-concrete structures a certain error in placement of the reinforcement bars should be assumed, this error being the one most likely to lead to premature failure. Consideration should also be given to the contributory factors of the concrete, the steel bars and the bond between them, so that an equal risk of failure was incurred throughout the structure. Dr. K. Hajnal-Konyi (London) suggested that further factors were concerned with the degree of supervision and of maintenance after completion, and that these should be added to those factors already noted. A statistical note on the need for investigating the randomness of the several factors involved was put forward by Mr. J. F. Borges (Lisbon). In a final contribution on this topic by Mr. R. Levi (Paris), it was stated that the degree of safety generally achieved in bridge construction was such that a 10 per cent. reduction in strength increased the probability of failure tenfold. It was concluded by Mr. Levi that the accurate calculation of the most economical probability of failure was, therefore, unnecessary.

In the course of the open discussion, Professor J. F. Baker (Cambridge) referred to the great number of problems that had been tackled by the plastic-design methods developed at Cambridge during the past 16 years, and instanced the success of the theories by the extent to which design offices in this country were adopting plastic-design methods for the solution of day-to-day problems.

DEVELOPMENT OF METHODS OF CALCULATION.

Like the first, the second working session was also concerned with general theoretical questions, namely, "The Development of Methods of Calculation." The first three papers in this group discussed analytical methods of the theories of elasticity and plasticity. The first considered the use of orthogonal functions for solving torsional problems, and the second was a mathematical contribution to the theory of elasticity of shells. The third paper, by Mr. A. Holmberg (Sweden), developed an approximate method for dealing with problems of loaded plates when various boundaries existed; though only approximate, the method was claimed to be sufficiently accurate for the solution of most practical problems. The fourth paper of the group, by Mr. W. J. van der Eb (Holland), dealt at some length with a theoretical study of two cases of buckling, by the application of the method of finite differences. The first problem referred to the buckling of latticed struts with long battens only, and the second to the buckling of bars elastically supported at any number of intermediate and equidistant points, as well as at the two end supports, which were also elastic, so permitting lateral movement, and having the same rigidity as points of support. The work of the second session was completed by eleven papers of diverse character under the heading "Other Methods of Calculation."

One of these papers, by Mr. M. Rocha (Lisbon) was not concerned with theoretical analysis, but with a general review of the present methods of experimental design, wherein models were used to resolve design difficulties. The author recommended this practice in all works of importance, for he claimed that models, even to a much reduced scale, gave a more faithful image of the prototype under load than did the hypothesis of analytical methods. Apart from two-dimensional "bar" models for solution of problems by determining the influence lines using the reciprocity equation of Müller-Breslau, extensive reference was made to the use of plasters and mouldable plastics for tackling these dimensional problems. The paper also contained a brief survey of the various measuring tools available, electrical-resistance strain gauges receiving most attention; the author maintained that "with the appearance of the electrical resistance gauges the difficulties of measuring strains in models have almost ceased to exist." The following paper, by the same author, and a colleague, Mr. Ferry Borges (Lisbon), was entitled "Photoelasticity Applied to Structural Design," and described some experimental studies carried out in the Laboratório de Engenharia Civil at Lisbon. The problems tackled in this manner included the design of a large aqueduct, and the stress distribution around the spillway openings of an arch dam, particular attention being paid to the forces from the mountings of the two flood gates, each of which had to support a thrust of about 4,000 tons. In order to simulate the supporting action of the rock behind the prototype, the models were carried on bases of a cork agglomerate and of rubber. Distributed loads of the prototype were replaced by adequate concentrated loads from the plungers of small oil jacks. The authors claimed that their photoelastic investigations materially eased the design problem and ensured the most satisfactory placing of the reinforcing bars in the concrete.

The next two papers were concerned with the design of ground beams on elastic foundations and were submitted by Mr. S. P. Banerjee (London) and Professor P. Lardy (Zurich). In the paper by the first author, the forces acting on the beam were considered to be divided into two systems: the first comprised all the superimposed loads on the beam together with the pressure supporting the beam, as would occur if the beam were perfectly rigid, consideration being given to eccentricity of loading, if any; the second system comprised the additional pressures, positive and negative, due to deflections brought about by the first system. The superposition of the two systems gave the information required to calculate the variation in bending moment along the length of the ground beam, the maximum deflection and the maximum ground pressure. Professor Lardy's paper considered the same problem with a rather more mathematical approach. Starting with the fundamental differential equations involved in the problem, he converted them into equations of finite differences and solved the resultant expressions by relaxation methods. This he found to lead to sufficiently accurate results of the practical problem and the purely analytical method, which was unusable in practice, had been replaced with advantage. The numerical examples with which Professor Lardy illustrated his paper emphasised the necessity of such calculations and of the important influence of the elasticity of the soil on the conditions of stress in, for example, the foot of a dam-wall.

The final paper of this second session, "Lateral Stability of Beams," by Mr. K. Bentley (Cambridge), developed an approximate solution of the problem for the two cases of a beam subjected to either pure bending or a central concentrated load. The theory was extended to allow for beams fabricated from materials whose stress-strain curves were not linear, as was the case with the light alloys; the method used was essentially that originated by Engesser for struts when the usual constant elastic modulus was replaced by an effective modulus. Support for the theoretical analysis was provided by the results of some tests on small section I-beams made out of the light alloys, D.T.D. 364 and M.G. 5. On the whole, the experimental results agreed well with the theory, the greatest discrepancies being found, as was to be expected, in the neighbourhood of the proportional limit, where the so-called elastic curve departed from that calculated by the use of the effective modulus, due to the rapid change in slope of the stress-strain curve.

In all, 18 members contributed to the discussions of the second working session, and their subjects covered the whole field of the section. Perhaps the most startling contribution was that made by Mr. R. Vallette (France), who, when considering stress-strain deformations, suggested that shear and sliding did not exist; after recalling the general elastic relationships which had favoured the conception of shear and sliding, the speaker demonstrated that they did not exist, and that only the principal stresses were required to represent the equilibrium of the group stresses that characterised the state of the material. He continued by pointing out that all deformations were dependent upon the action of the principal stresses along their own lines of action. Mr. Vallette ended by indicating that his remarks did not in anyway detract from the hypothesis of maximum principal strain as a criterion of failure. There followed a spirited exchange of remarks with the president, Professor F. Stüssi, who asked how Mr. Vallette accounted for the typical failures found in compression tests of timbers; Mr. Vallette contended that timber was not a valid example, its properties not being those of the material he had specified at the commencement of his argument.

(To be continued.)

RE-OPENING OF LONDON METAL EXCHANGE.—It has now been definitely arranged to re-open the London Metal Exchange, for dealing in lead, on October 1. The Ministry of Materials will make no new contracts, after September 30, for the sale of lead to consumers.

DEVELOPMENTS IN ELECTRICITY SUPPLY PRODUCTIVITY.

DURING the latter part of 1949 two teams, dealing respectively with electrical generation and distribution, visited the United States under the aegis of the Anglo-American Council on Productivity. On their return they published a report, upon which we have already commented* and which has since been considered by the various British Area Boards. It has also been discussed by the local advisory committees and District Joint Advisory Councils, as well as being exhaustively studied by officers in all departments and at all levels throughout the industry. As a result, action has been taken in a number of cases. These are reviewed in a statement issued recently by the Council, from which the following extracts are taken.

GENERATION PROBLEMS.

Under the heading of generation, it is pointed out that, although a major cause or delay in the construction of power stations since the war has been the time taken to obtain ministerial consent, this is not all wasted, since detailed design and layout work proceeds while the discussions are taking place. Moreover, endeavours are now being made to reduce delays further by obtaining consent to develop a site, although it may only be intended to finish the station under a later extension programme. In order to improve the planning of station construction, manufacturers now work to a production programme. Increasing attention is also being paid to projects by the Generation Division, although there is still some difficulty in finding staff to carry out detailed layouts and designs. While it is not thought feasible to extend the field of competitive tendering for power-station plant at present, the Authority considers that competition might be encouraged by allocating orders on the basis of information received from sample or "type inquiry" tenders.

As regards design, British engineers have accepted the American view that boiler availability is comparable with turbine availability, in spite of differences in the qualities of the fuels used in the two countries. "Unitisation" is being adopted in the United Kingdom on plant aggregating 4,727·5 MW, and one semi-outdoor station is being built. The re-heat cycle is being considered for three projected power stations and its use is likely to increase. A great improvement has been made in the speed with which generating plant is returned to service after repair, owing to careful planning and the institution of schemes of priorities for replacement parts.

TRANSMISSION AND DISTRIBUTION.

As a result of a suggestion in the report that armour rods should be used instead of arcing horns on overhead lines, some pre-formed rods are being obtained from Canada to allow detailed tests to be carried out. A study is also being made of the possibility of using circuit-breakers of low rupturing capacity at 132 kV and 275 kV. Double-circuit construction has to be used almost exclusively in Great Britain, owing to the way-leave problem. There is, therefore, little room for the use of "H"-type wood-pole construction for single-circuit feeders, as recommended in the report. The use of a conductor of heavier section for the grid is not considered desirable.

The desirability of re-assessing British design and practice in the temperature rating of transformers has been accepted; and the conclusion has been reached that it would be safe to operate this plant in emergency when the peak load exceeds the full load capacity by 30 per cent. Research has been carried out into the use of nitrogen filling for distribution transformers. The maintenance of high-voltage lines while the conductors are alive, which is essential in the United States owing to the number of single circuits, is not considered worth while in this country, where double-circuit construction is necessary for other reasons. Moreover, it can only be carried out when the humidity is less than 70 per cent., a condition which is infrequent in the British Isles. The same argument applies to tower painting where the circuits are alive, but the saving of time and labour by adopting the American practice of using one coat of special paint instead of two or three of normal quality is being considered. Aerial surveys to obtain line profiles do not offer the same advantages in Great Britain as in the United States, owing to the easier type of country, although limited use is being made of them. Line patrolling by helicopter is thought to be uneconomic under British conditions and the laying of lines by this means, while spectacular and rapid, is only likely to be occasional.

In dealing with distribution, the team drew attention to the American policy of setting a standard of continuity to meet particular circumstances. In this country the Eastern Board has adopted a policy of grouping the requirements of different classes of consumer separately and relating the cost to the consumer to the degree of continuity necessary. As a result standards have been relaxed in some parts of the area and improved in others, while substantial economies have been achieved. Several Boards have been, or are, developing the use of more elaborate statistical records to allow closer control of their activities.

Recently there has been a tendency towards the American practice of having a very large number of small substations, although some of the Boards consider that conditions in this country do not justify their exclusive use. The South Eastern and South West Scotland Boards favour the adoption of outdoor substations; indeed the only objection to them is likely to come from the town and country planning authorities. One of the most interesting suggestions made in the report was that the high speed re-closing of circuit-breakers should be extended to all voltages in use on British overhead circuits, thus improving continuity of supply and saving operational costs. The Midlands Board is testing 50 automatic re-closers obtained from the United States for this purpose and other Boards are awaiting the results, which should assist British manufacturers in developing this equipment. The Eastern Board has fitted automatic re-closing on overhead circuits in various parts of its area with satisfactory results. On the other hand, the South West Scotland Board is using arc-suppression coils.

Forced oil circulation and oil-blast cooling are standard practice on large British transformers, which are almost 100 per cent. reliable. The Eastern Board therefore considers that the proposal to add extraneous apparatus to them should be critically examined. In the United States all modern transformers with capacities exceeding 10 MVA are nitrogen-cooled, thus allowing higher operating temperatures and reducing fire risks. As it has been agreed that British transformers may in future be operated at higher ratings this practice may also have to be adopted in this country to prevent oil deterioration. The first large unit of this kind is shortly to be installed by the Midlands Board. As a result of information obtained by the team, the practice of operating transformers on a thermal-rating basis has been extended by the Midlands Board; and the maximum load which can be carried by this Board's transformers is now dependent on the load cycle and the temperature rise under load conditions. The North-Eastern Board also uses this basis of assessment and other Boards are considering its employment. The adoption of the completely self-protected, pole-mounted, low iron loss transformer, which is in general use in the United States and combines in one assembly the transformer, the low-voltage circuit-breaker and the protection and control devices, is being considered by the South-Eastern and Eastern Boards. As regards maintenance, the Eastern Board reports that it is instituting uniform practice for the more usual items of plant and equipment. It is also considering the establishment of centralised sub-area maintenance gangs for particular items, such as transformers.

URBAN AND RURAL DISTRIBUTION.

As a result of the reports, tests are being made with pole-boring machine, and cold-compression jointing is being developed. Lightweight tools for making these joints, upon which the use of aluminium as a conductor depends, have been designed. Although agreement has recently been reached

* See ENGINEERING, vol. 170, page 409 (1950).

ELECTROMAGNETIC COUPLINGS FOR M.V. "SURREY."

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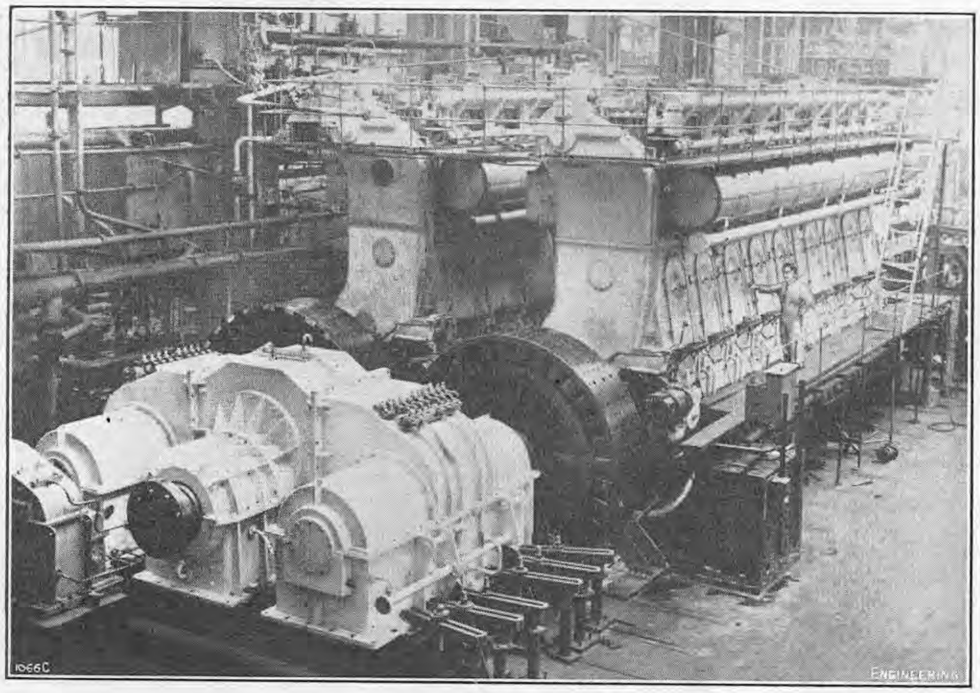


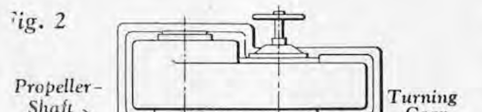
FIG. 1. ENGINES, COUPLINGS AND GEARBOX ON TEST.

between the British Electricity Authority and the Post Office for the common use of existing power supply and telephone poles, this joint usage is not likely to be on the same scale as in the United States. The Merseyside and North Wales and the North Eastern Boards state that they are considering the use of expanding anchors and mechanical-clamp stay-wire make-offs, as recommended in the report. In commenting on the statement that the greatest use is made in America of mechanical aids to speed and cheapen the job, many Boards remark that they would like to use such aids but that limitations of capital expenditure and lack of supplies prevent it. The use of radio communication for maintenance is likely to be extended as more equipment becomes available. Considerable interest was taken in the fact that, in the United States, small-capacity meters are frequently erected outside the buildings and careful consideration is being given by both the Eastern and Merseyside and North Wales Boards to the possibilities of adopting this practice.

ORGANISATION AND ADMINISTRATION.

Under the heading of organisation and administration, reference is made to the system of budgetary control which is now being developed in this country, and to the possibility of establishing a central organisation for checking the quality of electrical goods, although most Area Boards have arrangements for testing specimens of appliances before they are sold on their service centres. As a result of a comment in the report, the Utilisation Research Committee is investigating methods of carrying out sample surveys to discover the effects of various types of consumers and appliances on the peak demand. When tariffs are standardised, special rates for off-peak supplies will be more widely applied. In this connection, the Eastern Board is conducting a research into the probable reduction in demand that would result from installing time switches on thermal-storage water heaters. While it is generally agreed that power specialists to assist consumers in the large industries with specifications and layouts are justified, it is also considered that the service given in the United States is an ideal which it would be impracticable to achieve in this country. In the United States, installations have to conform to a National Code, and the question whether some minimum code of wiring practice should not also be imposed in this country is being considered by the two working parties which are revising the Electricity Supply Regulations.

'ig. 2



While the value of the American Rural Electrification Administration, which issues loans at a low rate of interest to assist rural development, was mentioned in the report, it is pointed out that such special aid has not so far been necessary in this country. Difficulties may, however, be encountered when the more sparsely inhabited parts of the country have to be tackled. The provision of a service which conducts repairs for domestic consumers at reduced charges, the balance being covered in the price charged for current (as is provided in the United States), would, in this country, be considered to contravene the agreement made between the Electricity Boards and the Electrical Contractors Association. Now that standard tariffs have been introduced by the Area Boards, local advisory committees are emphasising the advantage of a simplified application form similar to those in use in the United States.

Though the employment of office machinery has recently been extended in this country there is some doubt as to its value in the smaller establishments. It is doubtful too whether the statutory requirements regarding financial statistics would enable results to be more rapidly produced than at present. It is also pointed out that, while American cost statements and final accounts are often only estimates, British figures have been fully checked.

The team commented on the efforts made in the United States to impress upon individual employers that they were essential participants in a great public service. The Authority and Area Boards are, however, concentrating on the same end by means of courses and joint consultative machinery. Consideration is also being given to methods of rating the relative requirements of each job in determining wage rates and to the employment of aptitude and intelligence tests as a means of selecting apprentices. Further, it is becoming generally recognised in this country that supervisors are responsible for the proper induction of new employees, while in some cases induction courses covering the structure and organisation of the industry and questions of negotiation and joint consultation have been arranged. Courses and week-end conferences for training potential supervisors have been arranged.

The team was very interested in the importance that is attached in the United States to keeping employees informed of the company's policy and progress. In this country, the South-West Scotland Board issues a bulletin to the senior staff giving statistics illustrating their work, while the Merseyside and North Wales Board has arranged week-end conferences to train employees to take an active part in consultative committees. Throughout the industry chairmen of local advisory committees are presenting progress reports and initiating discussions on schemes of development. Courses of training for jointers and commercial staff have been held, although the Merseyside and North Wales Board considers that over-specialisation may prejudice the employee's future prospects.

GEARBOX AND ELECTRO-MAGNETIC COUPLINGS FOR TWIN-ENGINED SHIP.

Two electromagnetic couplings which have been fitted between the two 4,500-h.p. Diesel engines and the single screw of the m.v. Surrey (8,400 tons) have been shown, on trials, to give marked flexibility and ease of control. In addition, the elastic and damping characteristics of the couplings reduce the magnitude of the torsional oscillations transmitted from the engines to the twin-pinion reduction gearbox to such an extent that tooth separation does not occur and the risk of damaging the gears is thus lessened. By running one engine in the ahead direction and the other astern, the screw can readily be run in either direction simply by energising the appropriate coupling. Using this method, power can be applied or removed more quickly than by normal means. Less starting air is used and the adverse effects on the engine cylinders due to repeated influxes of cold air are reduced. When one engine is already running, no starting air is required if the other is to be run up in the same direction, since this can be done merely by energising the two couplings. If both engines are running ahead and they are required to run astern, the couplings are de-energised, the engines are stopped, and then started in the astern direction under no load and the power applied to the screw by re-exciting the couplings. The twin-pinion single-reduction gearbox has a fabricated case with a shallow bottom half, which has certain advantages. The overall efficiency of the complete gearbox and couplings is about 96·5 per cent.

The couplings and gearbox were constructed by the British Thomson-Houston Company, Limited.

ELECTROMAGNETIC COUPLINGS FOR TWIN-ENGINED SHIP.

BRITISH THOMSON-HOUSTON COMPANY, LIMITED, RUGBY.

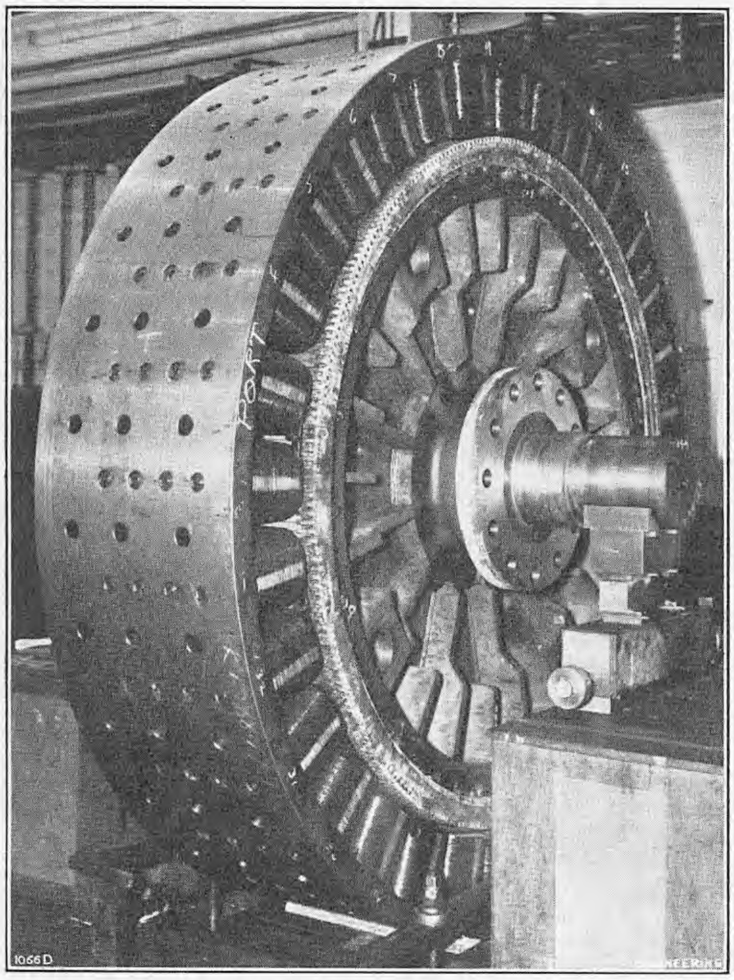


FIG. 3. ELECTROMAGNETIC COUPLING.

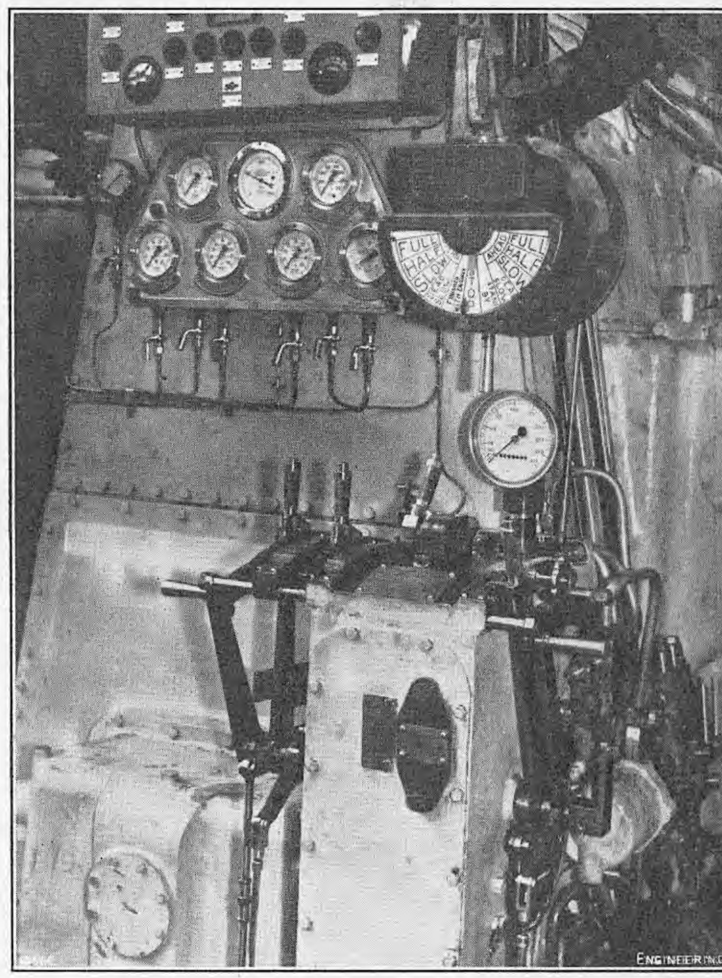


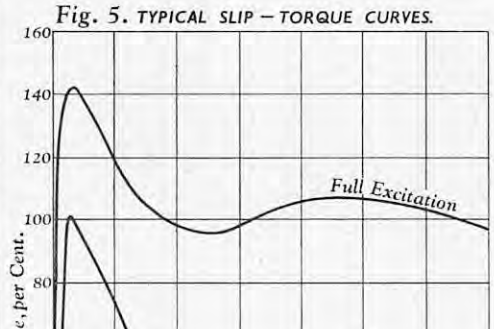
FIG. 4. ENGINE CONTROL PEDESTAL.

Rugby, and the m.v. Surrey was built by Messrs. Alexander Stephen and Sons, Limited, Linthouse, Govan, Glasgow, for the New Zealand Shipping Company. Each of the two nine-cylinder Sulzer engines, developing 4,500 h.p. at 225 r.p.m. each, drives one of the pinions through a coupling, and the reduction ratio of the gearbox is 2·23 to 1, giving a propeller speed of 100 r.p.m. at full power. The couplings, which are analagous in principle to a conventional induction motor, give a slight slip between the driving and driven portions, so that the pinion speed at nominal full power is actually about 223 r.p.m. Fig. 1, on page 299, shows the engines, couplings and gearbox on test in Messrs. Sulzer's works; Fig. 2 is a half-plan of the couplings and gearbox; and Fig. 3, above, shows one of the couplings.

ELECTROMAGNETIC COUPLINGS.

The two couplings are identical, each consisting of two concentric rotating members, one mounted on the engine crankshaft and the other overhung from the pinion shaft. The couplings themselves have no separate bearings. The outer member of each coupling consists of a welded steel ring which forms a magnetic yoke. Thirty-two non-laminated poles, of high-permeability steel, located around the inner periphery and secured by dowels and set-screws, carry the excitation winding, which consists of rectangular copper strip wound on edge with treated asbestos between the turns and insulated with mica protected with varnished press-board. The coils are supported in position between moulded insulation end-flanges, and the whole insulated assembly complies with Class "B" standards. The couplings are self-ventilating, drawing air into the sides and discharging it through holes in the periphery. At coupling speeds below 150 r.p.m., the excitation is reduced in order to avoid the risk of overheating which might be caused by the reduction in the flow of ventilating air. A steel

Fig. 5. TYPICAL SLIP – TORQUE CURVES.



disc with stiffening ribs is welded to one side of the coupling yoke and the centre is bored and faced to form the coupling flange. For leading the magnetising current to the windings, two phosphor-bronze slip-rings are provided, working in conjunction with a brush-gear assembly which is mounted on the adjacent bearing housing. The inner member consists of a segmental rotor core built up from punchings of low-hysteresis steel, enamelled before assembly and clamped between steel end-flanges. The core is mounted on a fabricated steel spider which carries a coupling flange in a similar manner to the outer member. The inner member carries a double squirrel-cage winding, the upper bars of which are of high-resistance alloy and the lower bars of copper. Each cage has its own short-circuiting connections, which take the form of copper rings, silver soldered to the bars of the cage windings. There is no insulation between the windings and the punchings, a feature which assists conduction of heat away from the windings.

The coupling control gear is mounted on an insulated panel housed in a steel drip-proof cubicle. On the panel are the main cam-operated contactors for the excitation of the couplings, the coupling tripping circuits and fuses, and the electronic time-switch and Klaxon relay which comes into operation if the excitation is left on when the couplings are stationary. Four field-discharge rectifiers for each coupling are mounted on top of the cubicle, together with the series resistances for varying the excitation applied to the outer members. Separate from the control cubicle, and mounted near the engine gauge board, is an instrument panel which carries the ammeters indicating the excitation current supplied to each coupling, various warning lamps, and the Klaxon cut-out switch. The engine control pedestal, illustrated in Fig. 4, on this page, carries the two main control levers, one for each coupling. The excitation current, amounting to about 40 kW for each, is supplied from the ship's main direct-current system through the main switchboard and the coupling control cubicle. The main control levers have three positions: off, no excitation applied; position No. 1, reduced excitation applied; and position No. 2, full excitation applied. The degree of excitation corresponding to position No. 1 was adjusted as a result of experience during the trials to a value at which the torque imposed on the engines during manœuvring could be allowed for by the governors without risk of stalling. In addition to the excitation warning device, already mentioned, various interlocks are provided.

REDUCTION GEARBOX.

The gearbox case is a fabricated structure consisting of a double-walled bottom half-casing and

DOUBLE-PINION MARINE GEARBOX.

BRITISH THOMSON-HOUSTON COMPANY, LIMITED, RUGBY.

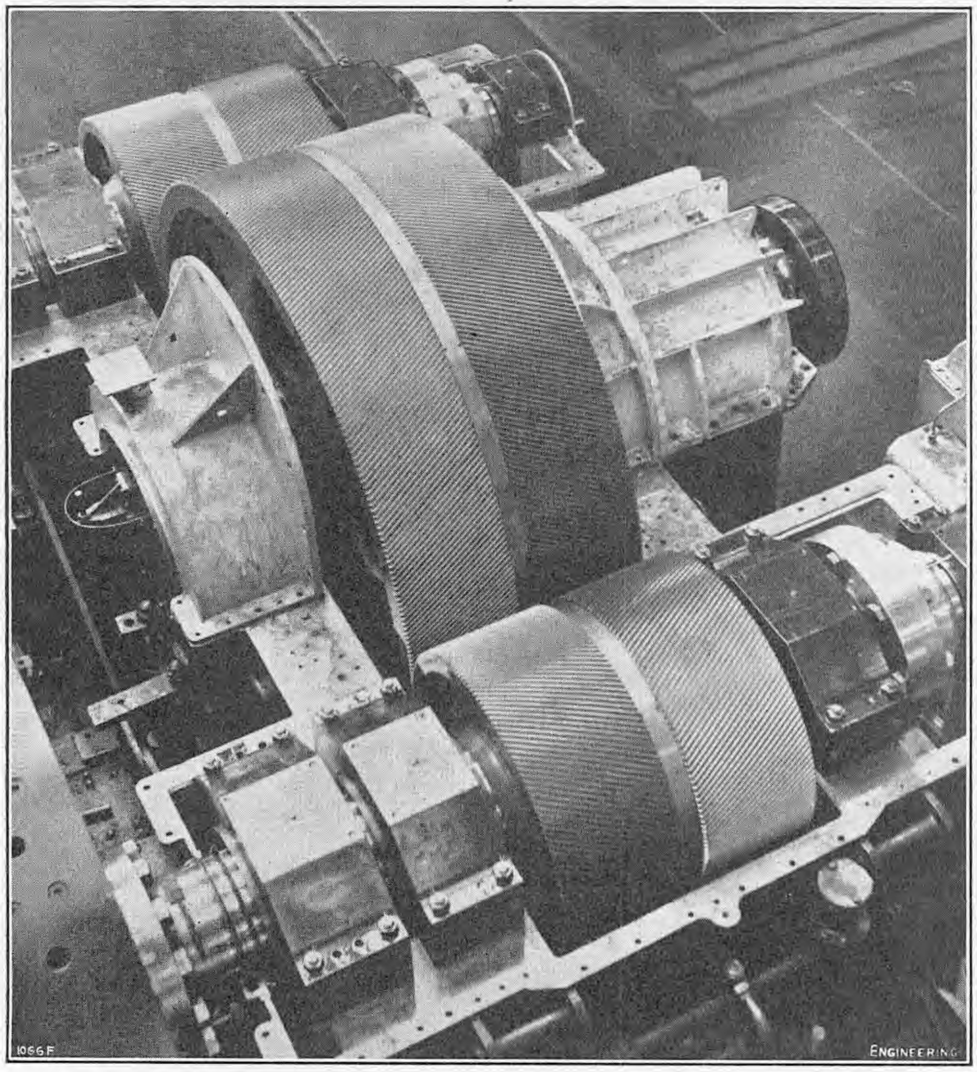


FIG. 6. GEARBOX WITH TOP HALF-CASING REMOVED.

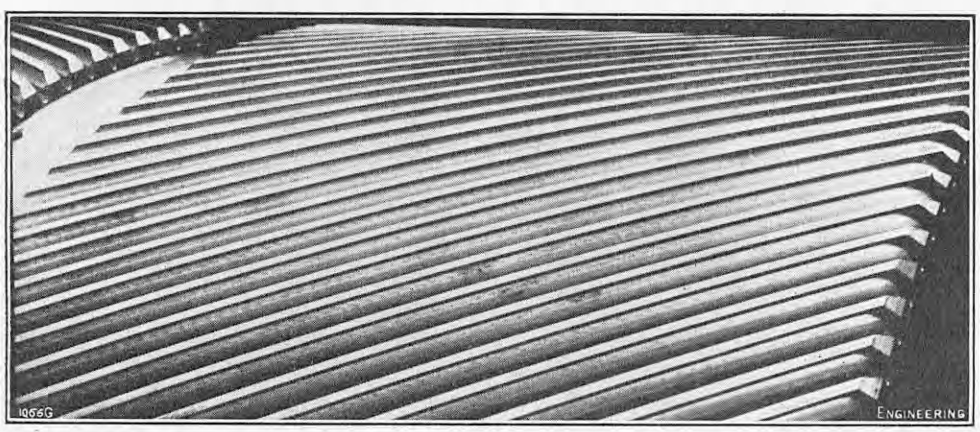


FIG. 7. PINION TEETH AFTER RUNNING.

thin-walled top and bottom covers which are sectionalised to facilitate inspection and maintenance. Integral with the bottom half-casing are the main-bearing oil supply pipes and the main thrust-bearing seating. The use of a shallow bottom half-casing has the merit that the journal and thrust bearings of the gearbox are brought as close as possible to the holding-down bolts which secure the assembly to the ship's seatings, thus forming a rigid support for the gears. A secondary, but valuable, feature of this arrangement is that, during shop trials of the complete equipment, the whole set can be erected much closer to the floor than would be possible with a full-depth gearcase. Fig. 6, on this page, shows the gearbox with the top half removed.

The two pinions mesh with the main wheel at 6-ft. centres and lie in the same horizontal plane. Each pinion assembly consists of two shafts and a gear-type coupling, but an inner shaft, supported in its own bearings, carries one member of the electromagnetic coupling, overhung at the forward end and connected at the aft end through the gear-type coupling to a quill shaft carrying the pinion. The quill shaft is also supported in its own bearings and is thus relieved of the overhung load of the coupling; and, though the inner shaft is located axially, the pinion is free to move through the medium of the gear-type coupling. These arrangements ensure good alignment between the pinions and the wheel, with consequent accurate meshing of the gear teeth. This was demonstrated by the perfect bedding obtained over the whole 36-in. face width of both pinions after the first full-load run. Fig. 7 shows one of the pinions.

The gearwheel is also of fabricated construction, the shroud being of forged steel. The gearwheel hub has a parallel bore and the wheel is pressed on to the slow-speed shaft. Integral with the slow-speed shaft is the main thrust collar, 36 in. in diameter, which also serves to locate the gears. The main gearbox bearings are mild-steel shells with Glacier thin white-metal linings, the pinion bearings measuring 18½ in. by 16 in. and the slow-speed shaft bearings 19 in. by 18 in. The double-helical gear teeth, which have a normal pitch of ¾ in., were cut in the B.T.H. works at Rugby on solid-table hobbing machines which are housed in temperature-controlled cubicles in the gear factory. The pinions have 162 teeth, the wheel 361 teeth, and the helix angle is approximately 30 deg. Lubrication of the gear teeth is by overhead sprays only, a total of 16 (four per face per side) being fitted. Each sprayer has its own filter and sight-flow indicator and is of the retractable type, which can be removed without shutting off the main oil supply. All the bearings are fed with oil by internal pipes, the only external pipes being the main supply pipes from the header tank. Gauge boards on each side of the gearbox show the bearing temperatures and oil manifold pressures. The turning gear is also lubricated from the main gearing oil system.

The turning gear is a triple-reduction unit giving the propeller shaft ⅕ r.p.m. Power is supplied by a 3-h.p. 750-r.p.m. motor, and the gears give a reduction of 1,800 : 1 through a 30 : 1 worm gear and a 36 : 1 double-reduction spur gear. Concentric with the third reduction gearwheel is a sliding dog-clutch which, under the control of a handwheel, engages with a similar clutch on the end of the port pinion shaft. The operating handwheel is interlocked to prevent the main engines from being started with the clutch engaged, and also to prevent the turning-gear motor from being started with the handwheel locked in the "out" position.

COUPLINGS AND GEARBOX IN OPERATION.

The characteristic (slip-torque) curves of the electromagnetic couplings (torque expressed as a percentage of full-load engine torque, plotted against slip expressed as a percentage of full speed, for the values of excitation given by positions 1 and 2 of the control levers) are given in Fig. 5. They show that at zero slip, when no current will be induced in the squirrel-cage windings since there will be no cutting of the flux set up by the outer member, no torque will be transmitted. At 100 per cent. slip, the torque transmitted at position 2 of the excitation control is about 100 per cent. of full-load torque, and at position 1 it is about 55 per cent. of full-load torque. When the couplings are running at full power and speed there is a slip of about 0·9 per cent. between the two members, which corresponds to an actual slip of about 2 r.p.m.

The speed at which manœuvring is carried out, as described briefly at the beginning of this article, was chosen on the trials as 110/115 r.p.m., the port engine running ahead and the starboard astern. When either coupling control lever was engaged at position 1, the propeller accelerated steadily from rest to approximately 40 r.p.m., in eight to ten seconds. The procedure for going astern in an emergency after a period of ahead running, as distinct from the conditions when manœuvring, is for the engine speed to be reduced and the excitation removed from the couplings. The engines are stopped, then restarted in the opposite direction, and the excitation applied to the couplings again. During the trials, a "full-astern" order was received with the shaft running ahead at 90 r.p.m. The engine speed was reduced and the coupling excitation removed. The engine starting levers were then removed to the "off" position and held for 10 seconds before the admission of astern air. The engines were then run up astern, the coupling levers moved to position 1, and thence to position 2 as the engine fuel was increased. The time between the receipt of the order "full-astern" and stopping the shaft was 42 seconds. In 61 seconds from receipt of the order the shaft speed was 90 r.p.m. astern. During the sea trials the equipment functioned perfectly satisfactorily and the Surrey sailed from the Clyde on July 5.

NOTES FROM THE INDUSTRIAL CENTRES.

SCOTLAND.

GLASGOW CORPORATION WATER SCHEMES.—In the course of a special visit of Glasgow Corporation councillors to the Loch-Katrine waterworks area on August 28, the site of the city's proposed new water supply reservoir at Glenfinlas was inspected. This scheme, entailing an expenditure of 2,250,000*l*., will be preceded by a shorter-term project costing 600,000*l*. Instead of a dam, which would give a supply of 19,000,000 gallons a day, it is proposed to erect a low intake weir, which will divert at least 7,250,000 gallons a day into Loch Katrine. Assuming that the consent of the Secretary of State is given soon to an Order now being prepared, work on the modified scheme is expected to begin in the first half of next year. The Glenfinlas water will be taken to Loch Katrine by a tunnel 2½ miles long. This tunnel would be an essential part both of the modified scheme and of the deferred full scheme. In connection with a detailed geological survey carried out, between 60 and 70 borings have been undertaken. Among other works seen in progress was the construction of the new West Main, costing 990,000*l*., including 380,000*l*. for a tunnel to carry it under the river Clyde.

VACUUM TOWER FOR GRANGEMOUTH REFINERY.—A 40-ton vacuum tower for the Anglo-Iranian oil refinery at Grangemouth has now completed a 400-mile journey by road and sea. Part of a distillation unit, it was launched into the Thames from Messrs. G. A. Harvey's works at Greenwich, and was towed down the Thames and up the East Coast to Grangemouth. There it was lifted from the water and taken the last two miles on a 32-wheel bogie vehicle, hauled by a 100-h.p. Diesel-engined tractor.

LAIGHPARK SEWERAGE SCHEME.—After three years' work, the first section of a new sewage-purification scheme is expected to be brought into operation in a few weeks at Laighpark, on the east bank of the river Cart, north of Paisley harbour. The main sewage connection to the works is a 7-ft. diameter pipe, capable of carrying 89,000,000 gallons a day.

RURAL ELECTRIFICATION IN S.W. SCOTLAND.—Mr. W. H. George, Clyde sub-area engineer, said at a luncheon of the South-West Scotland Electricity Consultative Committee, held in Greenock on August 21, that the number of farms now supplied with electricity in the sub-area was 700. He added that there were still more than 200 farms awaiting a supply, but it was hoped to complete the scheme by March, 1954, two years ahead of schedule.

ALUMINIUM SHEET AND STRIP MANUFACTURE.—Price reductions of 2*d*. per pound for bulk quantities of their special range of thin-gauge sheet and coiled-strip aluminium for boxmaking and capping purposes, announced on August 27 by the British Aluminium Co. Ltd., follow the completion of substantial extensions to their Falkirk rolling mills, including the installation of a new high-speed tandem rolling mill and finishing strip mills. The reductions, which came into effect on September 1, are claimed to make aluminium for boxmaking and capping more competitive with tinplate than at any period since the conclusion of the war.

THE ELECTRICITY LOAD IN SCOTLAND.—Mr. Charles Murdoch, chairman of the Scottish Board for Industry, has announced that Scottish industrialists will be asked to reduce their demands for electricity by 10 per cent. during peak working hours next year, i.e., between 8 a.m. and 12 noon, and 4 to 5 p.m., from Mondays to Fridays. Despite an increase in plant capacity of 54,000 kW compared with the end of last winter, the total availability in Scotland during the coming winter will be below requirements by 47,000 kW, because plant having a capacity of 72,000 kW had to be scrapped to make room for new plant.

CLEVELAND AND THE NORTHERN COUNTIES.

NORTHUMBERLAND AND CUMBERLAND COLLIERY DEVELOPMENT.—The proposed use of methane from the Haig Pit, Whitehaven, by the Northern Gas Board for both industrial and domestic consumers has been referred to by Mr. James Bowman, chairman of the Northern (Northumberland and Cumberland) Division of the National Coal Board, following a meeting with the Cumberland Area Miners' Council. Mr. Bowman stated that, for some time, methane extracted from the Haig Pit had been used in the colliery boilers in place of coal. Mr. Bowman added that more boreholes could be sunk and the immediate aim was to extract methane equivalent to 600 tons of coal weekly, which was the amount of coal used in the colliery boilers before the present experiment was begun. Lord Adams, O.B.E., a member of the Northern Gas Board, said that the Gas Board had plans for a gas grid and were keenly interested in the methane tests at the Haig Pit. Mr. Bowman also referred to plans for improvements at local collieries. A new layout was planned at the shaft bottom of Risehow Colliery, where new coal resources were to be tapped; further coal resources were also to be tapped at the St. Helen's pit; and a new winder had been planned at Allerdale and a new layout plan for the shaft bottom prepared. Mr. Bowman referred to Walkmill pit, where a loss of 50*s*. a ton was being made when the National Coal Board took over. It was now a profitable concern, he said, possessing vast resources still to be used.

ELECTRICITY-SUPPLY PROBLEMS AT SUNDERLAND.—Two generators, each of 20,000 kW capacity, are out of commission at Sunderland electricity works for damage repairs and the works are operating on two machines only, each of 10,000 kW. The works are connected to the grid and although it has been possible to cope with the summer electricity load without interference, it is likely that load-spreading will be needed in the winter. One of the damaged generators may be restored in two or three months. Meanwhile, work has begun on alterations to the cooling towers, to prevent spray falling on to the surrounding property. Complaints of falling moisture from the works have been made for years, and, recently, the Town Council have complained concerning the delay in commencing remedial measures.

VENTILATION AT WEARMOUTH COLLIERY.—A novel scheme for the improvement of ventilation at Wearmouth Colliery, Sunderland, was referred to by Mr. George Williams, manager of the colliery, addressing a meeting of Rotarians at Seaburn, Sunderland. He stated that on account of the poor ventilation at the colliery it was not possible to work more than three miles from the shaft bottom. A considerable portion of the workings were under the sea, and serious consideration was being given to the creation of an artificial island in the water, off Roker and Seaburn, to carry a ventilation shaft. Wearmouth Colliery was sunk in 1826, to a depth of 1,000 ft., at a cost of 100,000*l*.

DEVELOPMENTS AT ULGHAM.—Plans have been submitted to Morpeth Rural Council by the National Coal Board for developments at Ulgham. These include a new drift mine, offices, baths, a canteen and railway connections, together with a new mineral railway from Linton to Longhirst.

PROPOSED TWEEDMOUTH INDUSTRIAL ESTATE.—The Planning Committee of Northumberland County Council are supporting a proposal by Berwick Corporation to acquire 12½ acres of land at Tweedmouth for a small industrial estate.

HOUSING VERSUS DOLOMITE MINING.—When an inquiry was held at Sunderland into Sunderland Corporation's plan to use 250 acres of land at Grindon for housing purposes, it was stated, on behalf of the Washington Chemical Co. Ltd., that there were dolomite deposits under the site. It was stated that there was a national need for dolomite, but if houses were built on the land it would be completely sterilised for purposes of mineral extraction.

LANCASHIRE AND SOUTH YORKSHIRE.

PURCHASE-TAX PROBLEMS.—The incidence of purchase tax is a contributory factor in the decline in the demand for cutlery. Efforts have been made, from time to time, to secure exemption, or partial exemption, but, so far, nothing has been achieved. A further effort is being made to induce the Board of Trade to exempt Coronation cutlery souvenirs from purchase tax. Sheffield cutlery manufacturers complain that wholesalers are not yet placing orders until they know the outcome of the discussions. An official of the Sheffield Cutlery Manufacturers' Association points out that some Coronation souvenirs have been exempted and there seems to be no reason why exemption should not be extended to cutlery.

CUTLERS GOING TO OTHER WORK.—Cutlery craftsmen in Sheffield have begun to despair of the future of this industry, in the light of growing competition from Germany, Italy and France, and the growth of the number of import restrictions imposed by various countries. The leader of the National Cutlery Union in Sheffield, Mr. H. Slack, says that it is not just the men on three days a week, but also men working full time, who lack confidence in the future and are taking new employment. Some have gone to electric steel furnaces, many into the twist-drill trade, and some have become blacksmiths. Many have been in the cutlery industry since their apprenticeship.

THE MIDLANDS.

BIRMINGHAM MUSEUM OF SCIENCE AND INDUSTRY.—A small lecture room has been opened at the Birmingham Museum of Science and Industry, Newhall-street, Birmingham, 3. The room, which seats about 50 people, is fully equipped for the projection of films and lantern slides. Provision is also made for practical demonstrations of scientific interest, a long table being placed near the screen, with water, gas and electricity points. The sound-film projector and lantern are housed in a separate room. The new lecture room was inaugurated by the display to the public of two films, the Shell Film Unit's "The Cornish Engine," and the British Iron and Steel Federation's "Steel." A series of film programmes, lectures, and demonstrations is now part of the Museum's normal activities.

IMPROVEMENT IN ZINC SUPPLY.—The easing of the restrictions on the use of zinc, as a result of the improved supply position, has removed a difficulty under which numerous Black Country factories have been working since March, 1951. At that date, the use of zinc for galvanising many non-essential articles was banned, and the Black Country manufacturers of galvanised hollowware found it necessary to introduce short-time working, and in some cases to reduce their personnel. Several experiments were tried with anti-corrosive finishes ranging from porcelain enamel to stoved paint, but no really satisfactory substitute for galvanising was found. Zinc may now be used freely for galvanising steel sheets, wire and tubes, and the few restrictions which remain are expected to be lifted shortly.

AMATEUR CANAL LABOUR.—The Docks and Inland Waterways Executive, faced with the problem of transporting greater quantities of zinc and copper ingots than the available labour could handle, has been making use of amateur canal enthusiasts to man one of its boats. The Kimberley, a narrow boat 70 ft. long by 7 ft. beam, and fitted with a single-cylinder 9-h.p. Bolinder semi-Diesel engine, has recently made several journeys from Wolverhampton to West Point, Runcorn, to collect cargoes of ingots, which were delivered in the Birmingham-Wolverhampton district. The journeys were made via the Shropshire Union Canal, the Anderton boat lift, and the Weaver Navigation, and each lasted about a week. Fuel was provided, and canal dues were paid, by the Executive, and the volunteer labour was remunerated at ordinary boatmen's rates.

SOUTH-WEST ENGLAND AND SOUTH WALES.

LAND FOR COLLIERY TIPS IN MONMOUTHSHIRE.—The National Coal Board will require 1,297 acres of land in Monmouthshire during the next 20 years for tipping purposes. This statement was made at a meeting of the Monmouthshire County Council, when it was pointed out that the County Planning Committee had asked the Board to reduce the acreage they needed for this purpose, but had received the reply that it was not always possible to stow waste material underground. Conditions suggested by the County Planning Officer, Mr. J. Kegie, included proposals for tipping the waste in steep valleys, to agreed levels, so as to provide land for recreation.

PIT-HEAD BATHS AT PONTYCYMMER.—New pithead baths have been opened recently at Ffaldau Colliery, Pontycymmer. The baths have cost about 75,000*l*. and can accommodate 1,155 men. They will be used by mineworkers from the Glenavon and International Collieries, Blaengarw, as well as by the 700 men at Ffaldau.

LABOUR TROUBLE AT SWANSEA.—A meeting of the Welsh Engineers' and Foundry Conciliation Board, due to be held in Swansea to consider a "substantial increase in wages," was cancelled at the last minute by the employers' side. This was because of a strike of members of the Amalgamated Engineering Union at an affiliated works. The men's side, however, met, and afterwards it was stated that they had expressed indignation at the action of the employers. The strike was at the Welsh Boxes and Engineering Company's works at Landore, Swansea, where 120 members of the union had ceased work, following the dismissal of six of their number for alleged faulty workmanship.

BUILDING WORK IN WALES.—Mr. Geraint G. Walters, Ministry of Works director for Wales, has told members of the South Wales and Monmouthshire Chapter of the Incorporated Association of Architects and Surveyors, that during the year ended June 30 1952, building work in Wales amounted to 54,000,000*l*

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.

ILLUMINATING ENGINEERING SOCIETY.—*Sheffield Centre:* Monday, September 8, 6.30 p.m., University of Sheffield, Western Bank, Sheffield, 10. Centre chairman's address, by Mr. H. Dick.

INSTITUTION OF PRODUCTION ENGINEERS.—*Birmingham Graduate Section:* Tuesday, September 9, 7 p.m., James Watt Memorial Institute, Great Charles-street, Birmingham. "An Introduction to the Development of Machine Tools," by Mr. G. Wilding. *Coventry Graduate Section:* Tuesday, September 9, 7.30 p.m., The Hare and Squirrel Hotel, Cow-lane, Coventry. Open Discussion on "Production." *Rochester and District Sub-Section:* Thursday, September 11, 7.30 p.m., The Sun Hotel, Chatham. "Productivity and the Machine Tool," by Mr. Norman Stubbs. *Edinburgh Section:* Wednesday, September 17, 7.30 p.m., The North British Station Hotel, Princes-street, Edinburgh. "The Social Functions of Industry," by Dr. A. Roberts.

INCORPORATED PLANT ENGINEERS.—*East Lancashire Branch:* Tuesday, September 9, 7.15 p.m., Engineers' Club, Albert-square, Manchester. Open Discussion Meeting. *Newcastle-upon-Tyne Branch:* Thursday, September 11, 7.30 p.m., Roadway House, Oxford-street, Newcastle-upon-Tyne. "Liquid-Fuel Firing," by Mr. Alan Moore. *Liverpool and North Wales Branch:* Monday, September 15, 7.15 p.m., Radiant House, Bold-street, Liverpool. "Amenities in Industry," by Mr. H. S. Crump.

INSTITUTE OF ROAD TRANSPORT ENGINEERS.—*Midlands Centre:* Tuesday, September 9, 7.30 p.m., Crown Inn, Broad-street, Birmingham. "Some Factors Influencing the Choice of a Crankcase Lubricating Oil," by Mr. A. Towle. *North-West Centre:* Wednesday, September 17, 7.30 p.m., Adelphi Hotel, Liverpool. "Heavy Haulage," by Mr. E. Skelton. *North-East Centre:* Thursday, September 18, 7.30 p.m., The Hotel Metropole, Leeds. "Some Factors Influencing the Choice of a Crankcase Lubricating Oil," by Mr. A. Towle.

INSTITUTE OF PETROLEUM.—Wednesday, September 10, 5.30 p.m., Manson House, 26, Portland-place, W.1. "Mud Control in the Fields of the Iraq Petroleum and Associated Companies," by Mr. A. W. Paxton.

INSTITUTE OF MARINE ENGINEERS.—*Junior Section:* Friday, September 12, 7 p.m., 85, The Minories, E.C.3. (i) "Some Post-War Sailing Adventures," by Commander A. J. Villiers. (ii) Films: "The Gas Turbine Goes to Sea" and "The Building of Fawley." *Institute:* Tuesday, September 16, 5.30 p.m., 85, The Minories, E.C.3. Presidential Address by Lord Howard de Walden.

INSTITUTE OF METALS.—Monday, September 15, to Friday, September 19, 44th Annual Autumn Meeting. Monday, September 15, 8.30 p.m., Sheldonian Theatre, Broad-street, Oxford. Autumn Lecture: "On the Foothills of the Plastic Range," by Professor H. W. Swift. Tuesday, September 16, and Wednesday, September 17, 9.30 a.m., Clarendon Laboratory, Parks-road, Oxford, various papers for discussion. Thursday, September 18, 9.30 a.m., Clarendon Laboratory, informal discussion on "Grain Boundaries." Various visits and excursions will take place on the afternoons of Tuesday, Wednesday and Thursday, and all day on Friday. For further particulars, see page 223, *ante*.

NEWCOMEN SOCIETY.—Wednesday, September 17, 5.30 p.m., Science Museum, South Kensington, London, S.W.7. Special General Meeting, followed by: (i) "History and Particulars of the Brass Battery Process," by Mr. B. de Soyres; (ii) "Memorials to Engineers and Men of Science," by Eng. Capt. E. C. Smith; and (iii) "Twenty Problems" on the identification of "some bygone gadgets," exhibited by Mr. James F. Parker.

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.

SEAWARD DEFENCE BOATS.—The first of an entirely new series of vessels for the Royal Navy, to be known as Seaward Defence Boats, is under construction by Yarrow & Co., Ltd., Scotstoun, Glasgow, and was launched on August 21. These vessels will be 117 ft. 3 in. in length, will have a beam of 20 ft., and will be propelled by Diesel engines. Their purpose is to detect and destroy submarines, including midget submarines, in the approaches to defended ports. They will be equipped with guns, depth charges, flares and electronic apparatus. The first public reference to these vessels was made by Mr. J. P. L. Thomas, First Lord of the Admiralty, when presenting his statement on the 1952-53 Navy Estimates.

CONTRACTS.

THE DE HAVILLAND AIRCRAFT CO. LTD., Hatfield, Hertfordshire, have obtained, from Japan Air Lines, orders for two Comet Series 2 jet air-liners for external services; three four-engined, 14-17 passenger, Heron light air-liners for internal operations, and four twin-engined Dove light transport aeroplanes.

THE GENERAL ELECTRIC CO. LTD., Magnet House, Kingsway, London, W.C.2, have been entrusted by the National Coal Board with a contract for two 3,700-h.p. electric skip winding plants, together with the whole of the control and protective gear, to be installed at Silverwood East and Cadeby Main Collieries, in No. 3 Area, North Eastern Division. Each winder is designed to raise 528 tons of coal an hour from a depth of 2,299 ft., and is fitted with twin parallel drums 18 ft. in diameter. The drums are driven, through reduction gearing, by a 0 to 320 r.p.m. direct-current motor. The 0 to 600 volts direct-current supply for this motor is provided by a 2,650-kW Ward Leonard set driven at 500 r.p.m., by an 11-kV synchronous motor.

HEAD, WRIGHTSON & CO., LTD., Thornaby-on-Tees, have received an order from the National Coal Board for skip winding plant for Herrington Colliery, County Durham. The plant will be capable of handling 350 tons an hour.

WALTER HALL & CO., LTD., Barnsley, have secured an order from the National Coal Board for Maltby Main Colliery, near Rotherham, Yorkshire, comprising mine-car winding plant. This incorporates two treble-deck cages, each capable of carrying a three-ton capacity mine car. Another order is for skip winding plant for a South Wales Colliery, designed to deal with over 500 tons of coal an hour.

THE BUTTERLEY CO. LTD., Engineering Works, Butterley, near Derby, have obtained an order from British Railways, London Midland Region, for the fabrication of steelwork for the reconstruction of bridge No. 151, under the down track, Baswick viaduct, Trent-Valley line.

LAUNCHES AND TRIAL TRIPS.

S.S. "LADY CHARRINGTON."—Single-screw collier, built by S. P. Austin & Son, Ltd., Sunderland, for Charrington, Gardner, Locket (London), Ltd., London, E.C.3. Main dimensions: 270 ft. by 41 ft. by 19 ft. 6 in.; deadweight capacity, about 2,900 tons on a summer draught of 18 ft. Direct-acting triple-expansion engine, developing 850 i.h.p. at 80 r.p.m., constructed by the North Eastern Marine Engineering Co. (1938), Ltd., Wallsend-on-Tyne. Service speed, 10 knots. Launch, August 19.

M.S. "ST. LEONARD."—Single-screw trawler, built by Cochrane & Sons, Ltd., Selby, Yorkshire, for Saint Andrew's Steam Fishing Co., Ltd., Hull. Main dimensions: 112 ft. 6 in. by 25 ft. by 12 ft. Eight-cylinder direct-reversing Diesel engine, developing 600 b.h.p. at 300 r.p.m., constructed by Crossley Brothers, Ltd., Openshaw, Manchester, and installed by Amos and Smith, Ltd., Hull. Launch, August 21.

S.S. "HALLINDENE."—Single-screw cargo vessel, with accommodation for a small number of passengers, built and engined by William Gray and Co., Ltd., West Hartlepool, for the Dene Shipping Co., Ltd., London, E.C.3. Main dimensions: 406 ft. between perpendiculars by 56 ft. by 36 ft. 4½ in. to shelter deck; deadweight capacity, about 8,900 tons on a draught of 25 ft. 0½ in. Triple-expansion steam engine, working in conjunction with a Bauer-Wach exhaust turbine. Service speed, 10½ knots. Launch, August 21.

S.S. "HAWKINGE."—Single-screw cargo vessel, built and engined by William Gray & Co., Ltd., West Hartlepool, for Constants (South Wales), Ltd., Cardiff. Last of three vessels for these owners. Main dimensions: 340 ft. overall by 46 ft. 6 in. by 24 ft. 3½ in. to upper deck; deadweight capacity, 4,600 tons on a mean draught of 20 ft. 6 in. Triple-expansion steam engine, developing 1,250 i.h.p. at 75 r.p.m. and two oil-fired boilers. Speed in service, 10½ knots. Trial trip, August 21.

S.S. "BINNA."—Single-screw cargo vessel, strengthened against ice for use as a timber carrier in the Baltic, built and engined by Hall, Russell & Co., Ltd., Aberdeen, for Fred. Olsen & Co., Oslo, Norway. Main dimensions: 265 ft. between perpendiculars by 44 ft. by 19 ft. 3 in. to main deck; deadweight capacity, about 2,500 tons on a draught of 16 ft. 10 in. Hall Russell-Fredriksstad double-compound four-cylinder steam motor and two oil-fired cylindrical boilers. Launch, August 21.

M.S. "PRINCESS ANNE."—Single-screw trawler, built by Cook, Welton and Gemmell, Ltd., Beverley, Yorkshire, for Saint Andrew's Steam Fishing Co., Ltd., Hull. 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 22.

PERSONAL.

LORD HURCOMB, G.C.B., K.B.E., the chairman, and three full-time members of the British Transport Commission, MR. JOHN BENSTEAD, C.B.E., LORD RUSHOLME and SIR WILLIAM WOOD, K.B.E., whose present appointments expired on August 31, 1952, have been re-appointed by the Minister of Transport for a further term of one year. The other members of the Commission, whose appointments are not affected, are MR. F. A. POPE, C.I.E. (full-time), CAPTAIN SIR IAN BOLTON, Bt., O.B.E. (part-time), MR. JOHN RYAN, C.B.E., M.C. (part-time), and MR. H. P. BARKER (part-time).

AIR COMMODORE F. R. BANKS, C.B., O.B.E., has been appointed pr ncipal director of aeroplane engine research and development at the Ministry of Supply.

AIR COMMODORE G. B. M. RHIND, B.A., at present director of servicing research and development, Ministry of Supply, has been appointed senior technical staff officer, at headquarters, 2nd Tactical Air Force, Germany. He will be succeeded at the Ministry of Supply by AIR COMMODORE W. A. OPIE, until recently commander of the Royal Air Force base at Seletar, Singapore. AIR COMMODORE L. R. S. FREESTONE, at present senior technical staff officer, at headquarters, 2nd Tactical Air Force, is to become director of armament engineering at the Air Ministry, in October.

The Ministry of Supply has appointed, with effect from September 1, REAR ADMIRAL M. S. SLATTERY, C.B., R.N. (retd.), to be chairman of Short Brothers and Harland Ltd., Belfast, the Government-controlled aircraft company. He succeeds SIR EDWARD HERBERT, who has resigned owing to the greatly-increased pressure of other business interests. Admiral Slattery has been managing director of the company for the past 4½ years.

MR. C. T. MELLING, M.Sc., M.I.E.E., M.I.Mech.E., is to be the next President of the Association of Supervising Electrical Engineers, 54, Station-road, New Barnet, Hertfordshire, in succession to Mr. T. G. N. HALDANE, M.A., M.I.C.E., M.I.E.E., who is retiring after two years in office. The new President will be inducted on October 21.

MR. C. A. OAKLEY, Board of Trade Controller for Scotland since 1946, is retiring on September 30 and will take up an industrial appointment. He will be succeeded by MR. ALLAN YOUNG, Controller for the Southern Region.

MR. R. BRIDGMAN, who joined the Nigerian Railway in 1938 and was appointed new works engineer in 1950, has now been promoted assistant chief engineer.

MR. C. B. BAILEY-WATSON, lately the technical editor of *Flight*, has joined the staff of the Bristol Aeroplane Co. Ltd., Filton House, Bristol, as public relations manager. The position of publicity officer continues to be held by MR. L. A. KINGSMAN. Mr. Bailey-Watson took up his new duties at Filton on August 18.

MR. C. C. VINSON, a joint assistant managing director of the Fairey Aviation Co., Ltd., Hayes, Middlesex, has relinquished that position and also his directorship of the company and of its subsidiary companies.

MR. F. B. FINDLAY, A.R.T.C., who was appointed general manager of Duncan Stewart and Co., Ltd., Glasgow, in 1939, has retired after 49 years of service with the company.

MR. E. ALFRED DYMOND has resigned his position on the board of Sangamo Weston Ltd., Great Cambridge-road, Enfield, Middlesex.

After 15 years with the Northern Gas Board and its predecessor, the Newcastle and Gateshead Gas Co. Ltd., MR. J. W. PRINGLE, chief technical officer (utilisation) of the Board, has been appointed chief development officer to Thomas de la Rue & Co. Ltd., Warwick.

ELECTRICAL REMOTE CONTROL CO. LTD., 13 and 15, Evanston-avenue, Highams Park, London, E.4, are taking over a new factory in the Harlow New Town Industrial Area. To-morrow, September 6, their address will be changed to Elremco Works, East Industrial Area, Harlow New Town, Essex. (Telephone: Harlow 3032.)

REVOLVO LTD., 399, Edgware-road, London, W.2, are the sole concessionaires in Great Britain for RIV Officine di Villar Perosa, makers of ball and roller bearings, Turin, Italy.

W. CROCKATT AND SONS, LTD., Darnley-street, Glasgow, S.1, have been appointed sole Scottish representatives for Pelapone Engines Ltd., makers of Pelapone-Ricardo marine and industrial Diesel engines, Derby.

METALOCK (BRITAIN) LTD., Grand Buildings, Trafalgar-square, London, W.C.2, announce that under the direction of MR. BRUNO CIRILLI, a new company, the SOCIÉTÉ ANONYME METALOCK (FRANCE), 80, Boulevard de Marseilles, Casablanca, Morocco, has been formed. The firm continue to be represented in Paris by their agents at 20, Rue Charchat.

FLYING DISPLAY OF BRITISH AIRCRAFT.

(*For Description, see Page* 309.)

FIG. 1. "VALIANT" BOMBER; VICKERS-ARMSTRONGS LIMITED.

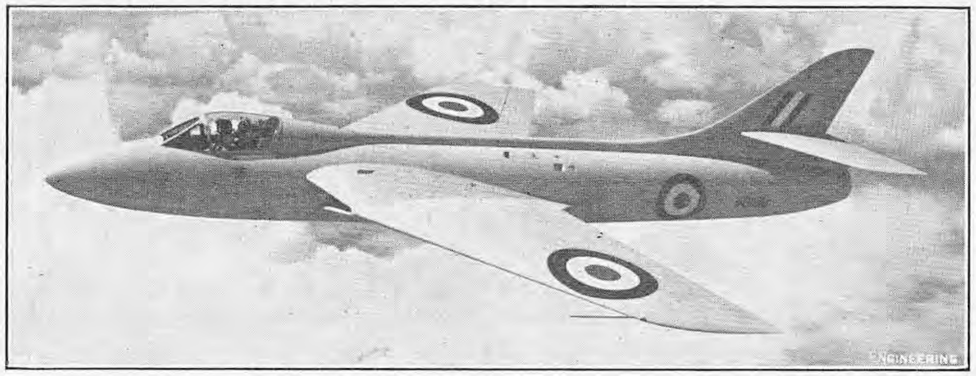


FIG. 2. "HUNTER" SINGLE-SEAT FIGHTER; HAWKER AIRCRAFT, LIMITED.

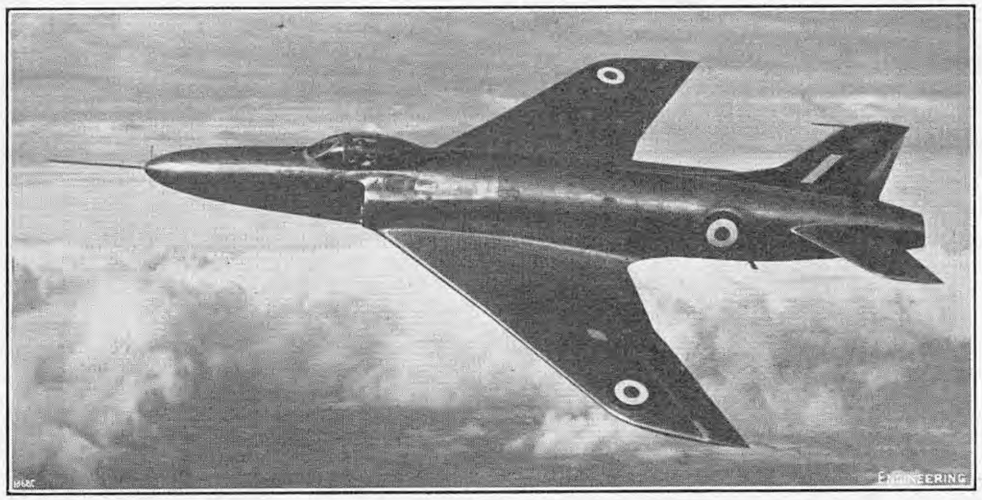


FIG. 3. "SWIFT" SINGLE-SEAT FIGHTER; VICKERS-ARMSTRONGS LIMITED.

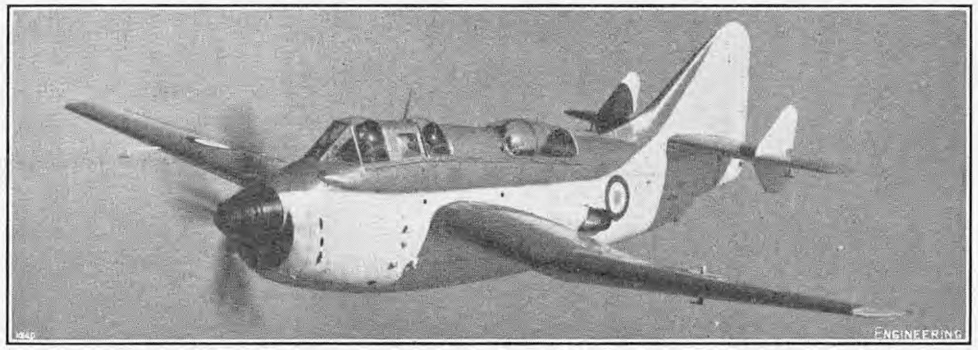


FIG. 4. "GANNET" ANTI-SUBMARINE AIRCRAFT; FAIREY AVIATION COMPANY, LIMITED.

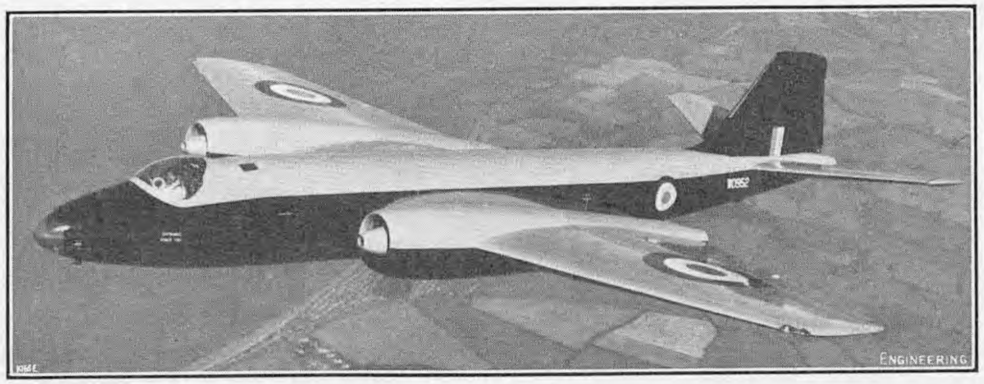


FIG. 5. ENGLISH ELECTRIC "CANBERRA," USED AS TEST-BED; BRISTOL AEROPLANE CO., LTD.

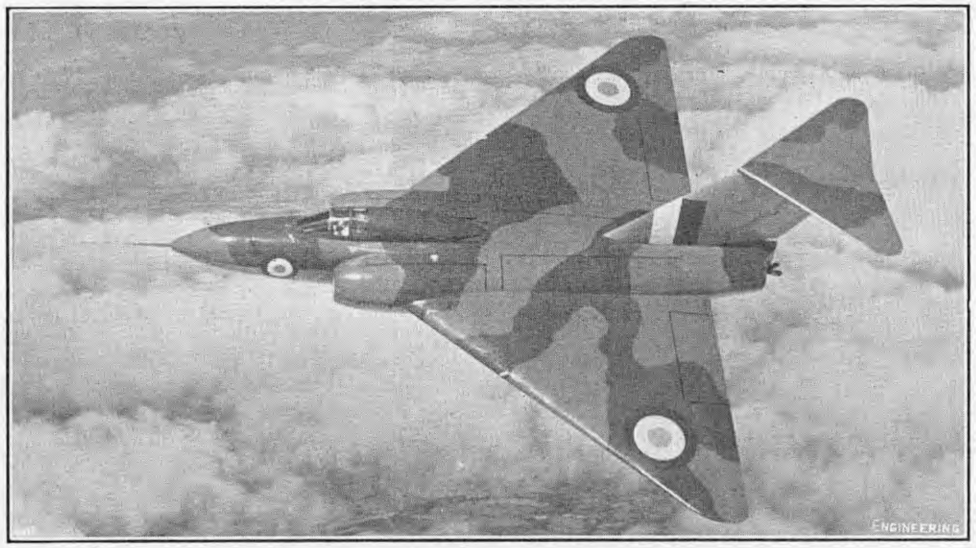


FIG. 6. "JAVELIN" ALL-WEATHER FIGHTER; GLOSTER AIRCRAFT COMPANY, LIMITED.

ENGINEERING

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CONTENTS.

ENGINEERING

FRIDAY, SEPTEMBER 5, 1952.

VOL. 174. No. 4519.

THE BRITISH ASSOCIATION AT BELFAST.

THOUGH frequent emphasis is laid, in the popular Press and elsewhere, on the increasingly important role that science now plays in the daily life of all civilised peoples, the fact remains that the original purpose of the British Association for the Advancement of Science is as much needed to-day as ever it was in the past. There appears, however, to be a gradual but significant change in that, whereas the initial aim was mainly that of interpreting science to the intelligent layman, the function seems to be changing slowly into that of presenting the results of current progress in particular branches of science to scientists who are concerned principally with other branches. That, at least, is the conclusion most likely to be drawn from a study of the papers in any given section, for most of them, if not beyond the comprehension of the assumed "intelligent layman," exhibit a tendency towards a specialisation too pronounced to make any general appeal. This is, perhaps, an inevitable consequence of the greatly accelerated pace of scientific development in recent years, but it does suggest that the time may be approaching when either the public will begin to lose interest in the activities of the British Association or some change of policy may be necessary as a guide to the selection of subjects and the preparation of papers. To some extent, indeed, this need has been recognised already by the provision of the various "evening discourses," which are definitely of a more popular character than most of the papers delivered to the 13 Sections of the Association.

In one respect, however, the nature of the annual programme shows no perceptible change; and it is a matter for congratulation that it should be so, for that particular characteristic is the consistently high quality of the presidential addresses. The Presidents of the various Sections, and the authors of the papers presented to the Sections, are necessarily specialists who are more or less constrained to remain strictly within the fields to which those Sections relate; but the President, *pro tem.*, of the Association has a more difficult task in that, while maintaining a technical or scientific level appropriate to the mentality of a predominantly scientific audience, he must bear constantly in mind that he has also to convey to a much larger public some impression of what the Association is and does and stands for. That so long a succession of Presidents—for this is the 114th meeting of the Association since its foundation—has been found, men all of the highest standing in their special spheres and most of them of international repute, who have been able with such success to fulfil this triple requirement of being at once scientist, philosopher and interpreter, is a remarkable tribute to British science, and to the selective (and persuasive) abilities of the Council.

Of the presidential address of Professor A. V. Hill to the present meeting of the Association, much might be written, but it is preferable from every point of view that the address itself should be studied before any comments upon it are read. We commence to print it, necessarily with some abridgment, on page 310 of this issue of ENGINEERING, and the concluding portion will appear next week. It poses a problem which has been much in the minds of scientists for the past decade certainly, and, to a less extent, in the minds of a proportion of them for, perhaps, half a century. Engineers, too, who must usually bear the responsibility of detailing and constructing the machines and apparatus which scientific progress initiates, are not unmindful of the possible results of supplying them in quantity to vast and still growing numbers of users who, apparently, are incapable of taking thought for the morrow; there is no merit in making two blades of grass grow where only one grew before, if the result is that, in a few years, no grass grows at all.

Limitations of space prevent us from dealing *in extenso* with the papers presented in any other Section than G (Engineering), but it is noticeable how, in process of time, the special studies of other Sections involve the work of the engineer not merely to apply the results in commercially or industrially usable form, but to construct the very apparatus with which the researches are conducted. The order of the Sections might, indeed, induce some philosophical reflections on the changes in the relative significance attributed to the various subjects a century ago and now. None would dispute, we are confident, the pre-eminence accorded to Mathematics and Physics (Section A) or fail to appreciate the clarity of vision that bracketed them together instead of treating them as separate subjects; but should Chemistry (B) precede Geology (C)? Is it justifiable to marry Anthropology and Archaeology in one Section (H) while separating Botany (K) from Agriculture (M) by the intrusion of Education (L)? Some might be tempted to question whether Education should be included at all, or, for that matter, Psychology (J); but that is verging upon the pernickety. There are at least as many who would deny to Engineering the implied quality of a science, holding that it is no more than a branch of the applied arts; but it would be difficult to imagine a British Association meeting without the familiar Section G.

Professor A. M. Tyndall, the President of Section A, in his address to that Section on "Some Contributions to Experimental Physics from Britain," observed of the late Professor Allan Ferguson, who was general secretary of the British Association from 1935 to 1946, that "he was the embodiment of the spirit of the policy of the Association to act as a meeting ground between colleagues in sister sciences"; but, without disagreeing in any way with this tribute to Professor Ferguson, we incline to wonder whether, in these days of specialisation, the Association accomplishes that aim so successfully as might be desired, at least so far as attendance at the Sectional meetings is concerned. There are, of course, numerous occasions of a more or less social nature, in the intervals between the technical sessions, when the members as a whole have fairly ample opportunity to fraternise, though it may be supposed that, on such occasions, their topics of discussion and conversation tend also to be sociable rather than scientific. It is, however, such a common cause for complaint that engineers, at any rate, are too narrow in their interests and outlook that it would seem even more desirable that they should attend the meetings of other Sections than to follow closely the proceedings of Section G; but this becomes increasingly difficult as the number of Sections grows, and with it the multiplicity of papers.

Another doubt to which constant attendance at the B.A. meetings gives rise is whether the leaders of local industry in the chosen centres, most of which have some actively industrial character, go as far as they might in promoting the objects of the Association and in encouraging their own staffs—and especially the younger employees—to take a personal interest in the facilities for acquiring miscellaneous scientific knowledge that the Association affords in such liberal measure. A glance through the programme of visits to works shows that, in the present instance, as on previous occasions, practically every industrial undertaking of any consequence in the neighbourhood is throwing open its doors to parties of the members; the list for the afternoon of September 4, for example, contains the names of no fewer than 33 firms who are extending hospitality to the Association. It would be interesting to know, however, how many of the employees of those firms, in any grade, take advantage of the meeting to attend the presentation of papers, and whether or not the sessions that they do attend are those bearing a direct relation to their employments. Some few there may be who are sufficiently eager for knowledge to devote some part of their annual leave to this purpose, but it is unlikely that they constitute more than a small proportion of the total membership of the meeting, even though the total, on Wednesday, was 4,350—over 300 more than the membership at Edinburgh last year.

This is a research which might well be undertaken as the basis of a paper for Section F (Economics). It should yield information which could be a valuable guide to the Council of the Association when proposals are under consideration for modifying the scope and arrangement of future programmes. In recent discussions on this country's need for more trained scientists—or perhaps it should be expressed, more men of scientific training—it has been remarked more than once that there must be a considerable reserve of serviceable personnel in the ranks of those who have not the opportunity, or do not quite possess the requisite capacity, to attain to an examination standard that will secure them admission to a university or to the higher-grade technical colleges; yet it may be that they lack only the stimulus that such gatherings as those of the British Association are particularly fitted to provide. Most of the thousands who, every year, attend B.A. meetings do not need that stimulus; they have it already, or else science in some form is their regular occupation and interest. A careful analysis of the nominal rolls of those attending B.A. meetings over a period of years would probably show that, in most cases, the authors of papers are preaching to the converted. Surely it is at least as important that the British Association should make new converts as to "act as a meeting ground" for the old.

TOWARDS THE UNIFICATION OF STANDARDS.

THE representatives of the United States, Britain and Canada who are charged with the responsibility of reaching agreement on the unification of engineering standards have a difficult task, that requires diplomacy as much as technical knowledge. Conscious, as they must be, of the expense and inconvenience to which they might commit their countrymen by agreeing to a modification of standards, they are yet aware of the benefits to be gained all round. The latest report of their discussions, published in this country last week,* reveals some tangible progress, but it also shows—if the discussions can be judged fairly on the basis of a necessarily abridged report—how hard it is to decide each case on its technical merits.

The conference was held in New York from June 2 to 5 this year, under the chairmanship of Mr. Howard Coonley. The British team of 25 was led by Mr. Stanley J. Harley, chairman of the engineering divisional council of the British Standards Institution, who was supported by Mr. S. W. Rawson (Director General of Machine Tools, Ministry of Supply), Sir William Stanier, F.R.S., and Mr. H. A. R. Binney (Director of the B.S.I.). At the conclusion of the conference, "continuing committees" were set up, with representatives from each country, to carry on the work that had been started by the discussions, and another meeting is expected to be held in New York in October. The British members of the continuing committees are Mr. S. W. Rawson and Mr. F. H. Rolt (screw threads), Dr. J. S. Blair (pipe threads), Mr. N. R. K. Wheatley (gas-cylinder connections), Mr. H. G. Conway (limits and fits), and Mr. T. R. Houston (drawing-office practice).

The screw-thread committee received a report from the British delegates on the progress of unified screw threads since 1945 (when unified threads were recommended). This recorded that B.S. 1580 had been published in 1949, in accordance with the 1945 recommendations; that certain modifications were now being considered, particularly with regard to dimensional limits of threads plated with soft metals; and that strong criticism had been received that the specifications of the basic form of unified thread, as shown in the American and British standards, were not identical. The British standard follows the form recommended at Ottawa in 1945, i.e., a radiused root on bolt and nut, a radiused crest on the bolt, and a truncated crest on the nut; but the first, second and third editions of the American standard showed other forms. The British committee felt that agreement should be reached on a single basic form.

According to the main conference report this point was not fully answered. The British delegates, apparently, regarded a rounded root in external threads as essential for the prevention of stress concentration, whereas the American standard showed a square corner in dotted lines for convenience in tool manufacture and because "any more definite description might lead to attempts at measurement or gauging of the root shape." There, it seems, the matter rests, though, of course the interchangeability of threads made to the two standards is not prejudiced. The screw-thread committee also discussed American and British gauging practice. The chief difference lies in the fact that, in the United States, a screwed component is acceptable even when the "not-go" gauge will screw into or on it provided "a definite drag results from metal-to-metal contact on or before the third thread of entry"; whereas in British practice the gauge must not go more than two turns.

As regards other types of threads, the committee noted that the B.S.I. are to cover, in their forthcoming standard for acme threads, only general-purpose threads in agreement with the American standard. For buttress threads it was only possible to agree to recommend that the next printing of British and American standards should include details of the other country's standards in their respective appendices. As a result of experiments which indicated longer tool life, it was expected that the Swiss watch industry would be likely to advocate the adoption of the 60-deg. unified thread form for sizes even as small as 0·25 mm. diameter. A large part of the British and American watch industry have been using a 50-deg. thread, but if the Swiss adopt the unified thread it is likely that the British industry will follow, and the American industry is apparently not "beyond hope of change." The pipe-threads committee agreed unanimously that it was undesirable to recommend a new compromise system as a basis of unification. Unfortunately, it was not possible for either the United States or Britain to abandon their present pipe-thread standards. The British delegation were anxious for the British Standard pipe system to be adopted, up to and including 4 in. nominal size, especially as it was accepted by the International Standards Organisation. Unification already exists, in practice, in the production of threads on pipes for the petroleum industry.

On the subject of limits and fits, the three countries appear to have been pursuing their own ideas even since the war; nevertheless, the conference reached agreement on certain points. The Canadians had developed a system based on principles that had been adopted at a meeting in New York in 1945. The B.S.I. had decided to use the I.S.O. system (reported on pages 558 and 561 of ENGINEERING, vol. 173, 1952). The Americans, on the other hand, were inclined to doubt the need for a unified system. The main outcome of the conference, however, was that an agreement might possibly be reached on a table of fundamental tolerances and that these might be applied, to begin with, to basic holes.

The committee on gas-cylinder connections, finding it impossible to achieve uniformity, agreed to explore the possibility of a joint publication on American and British practice and designs for adaptors. The committee on drawing and drafting practice decided that it was inappropriate, at the conference, to attempt to reach specific agreements and that the objective should be confined to reaching mutual understanding of each other's standards. In the words of Mr. J. G. Morrow, speaking on behalf of the Canadian delegates at the end of the conference, "Clarification has come where conclusions have not." Before the conference, Mr. Harley "felt that none of us was sufficiently seized with the importance of these problems" to industry and to mutual defence. Just how important they are might be inferred from Mr. Chester Wilmot's book, *The Struggle for Europe*, which revealed how the aggressor nations of the last war lacked any long-term co-ordination of policy and strategy—because, being aggressors, they were jealous of each other—whereas the Allies, with one notable exception, set an example of co-operation unparalleled in history. As defenders of a faith they worked together; but only by much give and take. To encourage the same spirit to-day it might be helpful to the delegates if there were a general and informal expression of views, in the technical Press or elsewhere, on what is wanted, what is essential, and what could be conceded.

* *A.B.C. (American, British, Canadian) Conference on Unification of Engineering Standards: Screw Threads, Pipe Threads, Cylindrical Fits, Drafting Practice, Gas Cylinder Threads.* American Society of Mechanical Engineers, 29, West 39th-street, New York 18, N.Y., U.S.A. [Price 1.00 dol.]; Sales Branch, British Standards Institution, 24, Victoria-street, London, S.W.1. [Price 7s. 9d., post free.]

NOTES.

THE INTERNATIONAL ASSOCIATION FOR BRIDGE AND STRUCTURAL ENGINEERING.

WE commence on page 297 of this issue a report of the proceedings of the Fourth International Congress for Bridge and Structural Engineering, which was held last week in Cambridge. The technical sessions and various functions held there occupied practically the whole week, but on the Friday (August 29), the venue was transferred to London, where Her Majesty's Government held a reception on that evening in the Tate Gallery, the members and their friends being received by the Minister of Transport. During the present week, a programme of tours had been arranged to various places of interest, but, before entering upon this lighter side of the proceedings, there was one more formal meeting, this being the banquet held in Guildhall on Monday, September 1, when the chair was taken by Mr. Ewart S. Andrews, B.Sc., M.I.C.E., President of the Congress Organising Committee. The Rt. Hon. the Lord Mayor (Sir Leslie Boyce, Bt.), being still under his doctor's orders following his recent severe illness, was unable to be present, his place being taken by Alderman Sir Frederick Wells, Bt. The loyal toasts having been honoured, Mr. F. S. Snow, M.I.C.E., past President of the Institution of Structural Engineers, proposed that of "The Lord Mayor, the Sheriffs and the Corporation of the City of London," and took the opportunity to express the hope that the Lord Mayor would enjoy a speedy and complete recovery of his health. He then proposed the toast in English, French and German. Sir Frederick Wells, in reply, extended a welcome to the members on behalf of the City of London, outlined the history of Guildhall, and (as bearing more directly on the work of the Congress) described the part taken by the City in providing and maintaining the four bridges across the Thames which come within the City's jurisdiction. The only other toast was that of "The International Association for Bridge and Structural Engineering," which was proposed by the Rt. Hon. Mr. David Eccles, M.P., Minister of Works, who outlined the functions of his department, especially in bringing before the industry the results of research carried out under Government auspices and relating to building construction. The Ministry of Works, he added, also had a direct interest in steel allocations—in which direction it was still necessary to be "ruthlessly economical," an aim which he hoped would be promoted by the deliberations of the Congress. Professor F. Stüssi, President of the Association, who responded, expressed confidence that this expectation would be realised. Mr. Ewart S. Andrews, who also replied to the toast, said, with reference to steel, that all that engineers desired of the Ministry of Works in that respect was "more liberty and less licence."

THE NORTH OF ENGLAND INSTITUTE OF MINING AND MECHANICAL ENGINEERS.

Celebrations marking the centenary of the formation of the North of England Institute of Mining and Mechanical Engineers, to which a preliminary reference was made on page 243, *ante*, will be held at Newcastle-upon-Tyne, from Monday, September 22, to Thursday, September 25. The proceedings will open with a civic reception by the Lord Mayor of Newcastle-upon-Tyne (Alderman Mrs. V. H. Grantham) at luncheon, at the Mansion House on Monday, September 22, at 1 p.m. This will be followed by the official opening of the celebrations by the President of the Institute, Professor Granville Poole, B.Sc., at a meeting on the same day at the Institute's headquarters, Neville Hall, commencing at 3 p.m. After the opening ceremony, Dr. Arthur Raistrick will read a paper on "The Development of the Tyne Coal Basin." Also on Monday, a dinner and dance will take place at the Old Assembly Rooms, Westgate-road, at 7 for 7.30 p.m., at the invitation of the Durham and Northumberland Coal Owners' Associations. On Tuesday, September 23, from 10 a.m. to 12.30 p.m., and from 2.30 p.m. to 4.30 p.m., two simultaneous sessions will be held at Neville Hall for the discussion of papers. In the morning, one session will discuss "Coal Miners' Nystagmus in County Durham," by Professor R. C. Browne, and a paper on "Lighting," by the joint lighting research sub-committee of the Institute and King's College, Newcastle-upon-Tyne. The other session will hear papers on "Accidents from Falls of Ground," by Mr. H. F. Wilson and Mr. H. J. Perrins, and on "Control of the Strata in Mining: Investigations in the Durham and Northumberland Coalfield," by the Institute's strata control research sub-committee. In the afternoon, one session will discuss "Pneumoconiosis and the Coalfields of Durham and Northumberland," by Dr. R. I. McCallum; "Pathological Aspects of Pneumoconiosis," by Dr. E. N. Trounson; and "Dust Suppression," by Dr. J. H. Jones. The other session will consider "Methane Emission," by Mr. A. B. Dawson; and "Ventilation," by the joint ventilation research sub-committee of the Institute and King's College. Luncheon on Tuesday will take place at 1 p.m., at the Old Assembly Rooms, by invitation of Messrs. Hugh Wood and Company, Limited. The centenary dinner and dance will also be held on Tuesday at the Old Assembly Rooms, at 7 for 7.30 p.m. On Wednesday, September 24, at 6.45 p.m., Mr. J. S. Raine will deliver a paper on "The Mechanisation of Coal Mining in the North of England" to the associates' and students' section at the School of Mines, King's College. Throughout the week, there will be a Mining Exhibition in the School of Mines at King's College.

SYMPOSIUM ON ELECTRONIC INSTRUMENTS.

The fourth symposium on "Electronic Instruments in Research and Industry" was opened under the auspices of the Scientific Instrument Manufacturers' Association at the Examination Hall, Queen-square, London, W.C.1, on Tuesday, September 2, and continues until to-day (Friday, September 5). In the course of the proceedings a number of papers were presented, including one on "Electronic Control Systems for Large Astronomical Telescopes," by Messrs. G. H. Hickling and A. Gray. These control systems, said the authors, had been developed from methods based on the pendulum clock and the use of tuning forks as a standard of reference. To-day, the best known and accurate standard of reference was the quartz crystal with a frequency stability of the order of 1 in 10^8. The ability to introduce small variations of rate had been ensured by the employment of very stable "R-C tuned" oscillators, either as a source of reference frequency or as a means of introducing frequency variation in a crystal controlled source. In a paper on "Electronic Measurement and Control for Industry," Mr. J. R. Boundy described an electronically-operated controller for process purposes and a form of converter for changing various physical quantities, such as level, pressure and flow, which had to be measured, into a direct-current of from 0 to 30 millamperes. How the direct-current output from the controller was used to position an orthodox pneumatically-operated process control valve by means of an electro-pneumatic relay mounted on the valve was also described. A survey of the applications of electronics to temperature measuring and controlling devices and an assessment of the associated regulating apparatus, such as transformer voltage taps, continuously variable transformers, saturable reactors and thyratron control, was given by Mr. D. K. Das Gupta and Mr. R. J. Russell-Bates.

THE ASSOCIATION OF PUBLIC LIGHTING ENGINEERS.

A conference of the Association of Public Lighting Engineers will be held at Harrogate from Tuesday, September 16, until Friday, September 19. The proceedings will open with the annual general meeting after which the induction of Mr. E. Howard, city lighting engineer, Nottingham, as President for 1952-53 will take place and the conference and exhibition will be officially inaugurated by the Mayor of Harrogate (Councillor A. V. Milton). In the afternoon of the same day the President will deliver an address; and a paper on "Methods of Controlling Street Lighting," by Mr. N. Axford, will be read and discussed. In the evening there will be a civic reception. On Wednesday, September 17, a paper on "Illuminations and Outdoor Decoration Lighting" will be presented by Mr. H. Carpenter, and a second paper on "Street Lighting—U.S.A.," by Dr. A. F. Dickerson, will be read. Street lighting will also be the subject of a paper on Thursday morning, September 18, by Mr. N. Hudson, after which the annual luncheon will take place. The final meeting on Friday morning, September 19, will be devoted to the consideration of a paper by Dr. D. F. Orchard on "Design, Manufacture and Erection of Concrete Lighting Columns." A feature of the conference will be an exhibition of modern street lighting apparatus and equipment.

CONFERENCE ON ASH AND CLINKER.

Under the auspices of the Institute of Fuel, a conference is to be held on Tuesday and Wednesday, October 28 and 29, to make "A Special Study of Ash and Clinker in Industry." The meetings are to be held in the lecture hall of the Institution of Mechanical Engineers, Storey's-gate, St. James's Park, London, S.W.1, and will comprise two sessions on each day, at 10 a.m. and 2 p.m., respectively. A programme of eleven papers has been drawn up by the organising committee, under the chairmanship of Dr. A. C. Dunningham, F.Inst.F., and the subjects covered will include consideration of the occurrence and properties of ash, methods of sampling and analysis, and the partial removal of ash-forming constituents from coal by the various cleaning processes. On the practical industrial side, attention will be given to the treatment and disposal of ash and clinker, problems of deposition and corrosion, and the influence of ash on boiler design and boiler efficiency. Methods of comparing the real values of coals of differing ash content will be considered, with special reference to the new price structure of the National Coal Board; and attention will be directed also to methods of making use of high-ash coals, and the effect of ash on various industrial processes. At the opening session on October 28, when the chair will be taken by Dr. G. E. Foxwell, President of the Institute of Fuel, two papers will be presented; and there will be three papers at each of the subsequent sessions. A report will be supplied without additional charge to those who enrol for the conference, the fee for which is 21*s*. to members of the Institute of Fuel and 31*s*. 6*d*. to non-members of the Institute. Further particulars, and enrolment forms, may be obtained from the secretary, the Institute of Fuel, 18, Devonshire-street, Portland-place, London, W.1.

LETTERS TO THE EDITOR.

COMMEMORATION OF THOMAS NEWCOMEN.

TO THE EDITOR OF ENGINEERING.

SIR,—Supplementing the letter from Mr. Percy Russell, on page 275, *ante*, in which he mentioned that Thomas Newcomen died in London, perhaps I might add that, like so many other Nonconformists, he was buried in Bunhill Fields. The fullest account of his life is that contributed by Mr. Rhys Jenkins in 1913 to the *Transactions* of the Devonshire Association and reprinted in Vol. IV of the *Transactions* of the Newcomen Society (1923-24). A short time ago, it was stated that the Bunhill Fields burial ground was to be converted into a Garden of Rest, and that a tablet would be set up, giving the names of famous men who were buried there. When this was announced, the late Dr. H. W. Dickinson wrote to the authorities, expressing the hope that Newcomen's name would be placed on the tablet.

It was with great interest that I read the letter of Newcomen, dated December 30, 1727, which you reproduced on page 224, *ante*; with his advice to his three children, strangely reinforced by his reflections on the fate of the Russian Prince Menschikoff, who, from the lowliest station, rose to high rank under Peter the Great, was virtually ruler under Catherine, and then was degraded by Peter II. Menschikoff, who was born in 1670, died in exile in Siberia on October 22, 1729—two months after Newcomen's death in London.

Newcomen's reference to Russian affairs suggests to me that he may have been acquainted with Captain John Perry (1670-1733), "Comptroller of the Maritime Works to Czar Peter of Russia," who attempted to cut a canal from the Don to the Volga —a project which, as you recorded in ENGINEERING of June 20, has only recently been accomplished.

Yours faithfully,
EDGAR C. SMITH, Eng. Capt., R.N. (ret.).

Dalcouth,
Keeper's Corner,
Horley, Surrey.
August 30, 1952.

APPLIED PSYCHOLOGY AND MACHINE DESIGN.

TO THE EDITOR OF ENGINEERING.

SIR,—I have read with considerable interest the article on the above subject which appeared on page 265, *ante*. It has always seemed to me that the application of psychology in British industry has lagged too far behind that of the United States. Accordingly, it is reassuring to find that the Applied Psychology Research Unit is tackling the important aspects enumerated in your article.

While one shares the writer's hopes that the fillip now being given to this work will benefit Britain's engineering industry, it seems to me that the concluding words of the article bear repetition ". . . if the results and lessons are adequately published and applied." As a technical librarian, I have been disappointed at the paucity of information made available, firstly, to those who control our industries, and, secondly, to those who ultimately use these mechanisms at the design and operating levels. If psychology can be used to increase industrial productivity, surely it is not too much to hope that the same science can be applied to the propagation of the results of the researches that must of necessity precede their application.

Yours faithfully,
63, Sidney-road, S. C. MCKENZIE.
Rugby.
September 1, 1952.

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

TO THE EDITOR OF ENGINEERING.

SIR,—I am given to understand that the human frame in good working order produces methane, via Maple Lodge and elsewhere, sufficient in quantity to generate one unit of electricity per day. It appears, from your article on the above sewage works, on page 222, *ante*, that it is possible for carbon dioxide to pass from the digesting tanks to the factory making carbonated beverages and back to the sewage works on almost a closed cycle.

At the risk of exposing myself to the gibes of those who have forgotten more than I know about the system and the sludge, I would like to ask why the sludge cannot be transported without any pre-drying whatever and sprayed or sprinkled on fields. Obviously, a large amount of unnecessary water would be transported, but the cost of transport plus the cost of the water would surely not be more than a fraction of the cost of drying the product. Within easy reach of Rickmansworth there must be stretches of land which would benefit materially from systematic top dressing with the fluid sludge, and there are probably wide acreages of land, at present incapable of producing anything beyond ragwort and other bomb-site flora, which would benefit similarly.

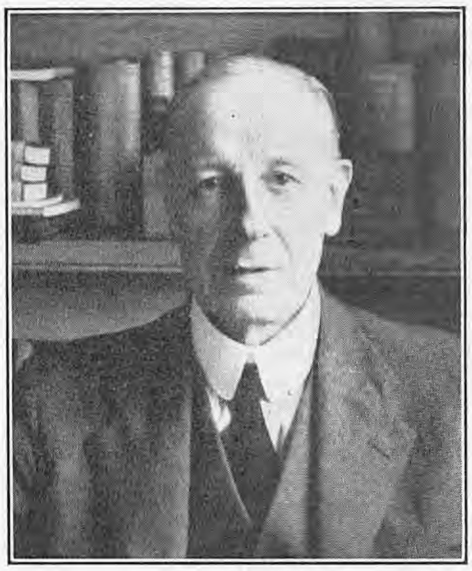
It is questionable whether a more criminal instance of the waste of natural resources exists than that of sewage disposal, but from your account of Maple Lodge the tide is definitely turned. Until sludge utilisation as a fertiliser is complete, however, waste of the resources inherent in the product remains.

Yours faithfully,
Rose Cottage, KYRLE W. WILLANS.
All Cannings,
Devizes, Wiltshire.
August 26, 1952.

OBITUARY.

MR. C. B. COLLETT, O.B.E.

MR. C. B. COLLETT, whose death on August 23 we recorded with regret in last week's issue of ENGINEERING, was chief mechanical engineer of the Great Western Railway from the time of the railway amalgamations after the 1914-18 War to July, 1941, when, in another war, the railways were under Government control and nationalisation was to follow. In those two decades he was responsible for continuing and expanding the great pioneer work of previous C.M.E.'s on a railway which retained its name at the time of the amalgamations (the only company to be so fortunate) and which still to-day, as the Western Region, preserves a character that is unique in railway history. As chief mechanical engineer he was responsible for the design and construction of the Castle and King classes of locomotive; he achieved a notable degree of standardisation in locomotive design without, in any way, sacrificing quality or efficiency; he devoted much of his time to carriage and wagon



THE LATE MR. C. B. COLLETT.

design; and he took a prominent part in equipping G.W.R. locomotives with automatic train-control apparatus.

Charles Benjamin Collett was born in 1871 and was educated at Merchant Taylors School and the City and Guilds College. He was articled as a pupil to Joshua Field of Maudslay, Sons and Field, Limited, London, from 1887 to 1893, and in May of the latter year he entered the Great Western Railway Company's drawing office at Swindon. Four years later he was made responsible for the buildings section of the drawing office, and in 1898 he became assistant to the chief draughtsman. In June, 1900, he was made technical inspector in the Swindon works, and a few months later he was appointed assistant manager. During the first World War, as works manager—the post to which he was promoted in December, 1912—he was intimately concerned with the company's production of munitions, and for this service he was made an O.B.E. After the war, in May, 1919, he became deputy chief mechanical engineer, and on January 1, 1922, he succeeded G. J. Churchward as chief mechanical engineer.

As C.M.E., Mr. Collett inherited a fine tradition; his predecessor, particularly, had been responsible for locomotive developments of which the full significance was only properly appreciated in later years. The increased boiler pressures and long-travel valves which Churchward had introduced on the Great Western were continued by Collett. The Castle class, which subsequently aroused wider interest in these features of design, was introduced in the year after his appointment, and four years later the "Kings" appeared—four-cylinder 4-6-0 engines with a high tractive effort. They remained the principal express passenger engines of the G.W.R. during Mr. Collett's term of office. On the question of standardisation, he appreciated the desirability of reducing the number of classes of engines which the amalgamations gave to the G.W.R. In 1921 the company's locomotive stock included 17 types, comprising 52 classes, but when Mr. Collett retired these figures had been reduced to 13 and 37, respectively. In addition, at the time of the amalgamations, the constituent companies had 18 types comprising 184 classes, but these figures also were reduced, to 8 and 57.

Mr. Collett was responsible for noteworthy developments in restaurant cars, sleeping cars and special train-sets and saloons. In connection with the fitting of automatic train control, Mr. Collett was a member of a special committee set up by the Ministry of Transport in 1927, under the chairmanship of Sir John Pringle, to consider the introduction of a standard system for the whole country. Mr. Collett was also concerned with the extension and reorganisation of Swindon works and the accurate production of standard boilers, and he was well respected and liked for the manner in which he dealt with labour problems. He was a member of the Institution of Civil Engineers from 1922 to 1941, and of the Institution of Mechanical Engineers from 1920 to 1941.

SIR WALROND SINCLAIR, K.B.E.

WE have also to record the death on August 30, after a prolonged illness, of Sir Walrond Sinclair, President of the British Tyre and Rubber Company, Limited, and previously chairman and managing director. He was 72 years of age.

Walrond Arthur Frank Sinclair had a distinguished military career before he began his close association with the British rubber industry. In the early part of the 1914-18 war, he was employed at the War Office on the staff of the Adjutant-General, eventually becoming Assistant Adjutant-General in 1917, with the rank of lieutenant-colonel. Later in the same year he was transferred to the Ministry of National Service as Controller of Registration, holding also the office of Director of National Service for the London and South-Eastern Region. For this work he was awarded the K.B.E. (Military Division) in 1918. After the war, he devoted himself to the development of the British Tyre and Rubber Company (originally the British Goodrich Rubber Company, Limited) of which he was managing director from 1925 to 1942, and chairman from 1927 until his recent retirement, when he was appointed President. Under his direction, the company acquired a controlling interest in a number of well-known rubber firms, including the India Rubber, Gutta Percha and Telegraph Works Company, Palmer Tyre, Limited, the Stepney Tyre and Rubber Company, the Willett Rubber Company, C. W. Randall and Company, the Morgan Ebonite Company, and the old-established firm of James Lyne Hancock, Limited. He was President of the Tyre Manufacturers' Conference from 1930 to 1936, of the Institution of the Rubber Industry from 1939 to 1945, and of the Federation of British Rubber Manufacturers' Associations in 1943-44.

During the war of 1939-45, Sir Walrond instituted and personally directed the voluntary scheme for the control of rubber from the outbreak of hostilities until October, 1940, when he went to South America with the British mission organised by the Department of Overseas Trade. He was also a member of the Board of Trade Consultative Committee and, subsequently, of the Rubber Secretariat; and, since 1941, had served on the Rubber Control Board of the Ministry of Supply. He was elected to the board of Williams Deacon's Bank in 1935, and became chairman in 1949; and was also a director of the Royal Bank of Scotland. For a number of years, too, he was a director of United Glass Bottle Manufacturers, Limited, and the B. F. Goodrich Company, of Akron, Ohio, U.S.A.

FLYING DISPLAY OF BRITISH AIRCRAFT.

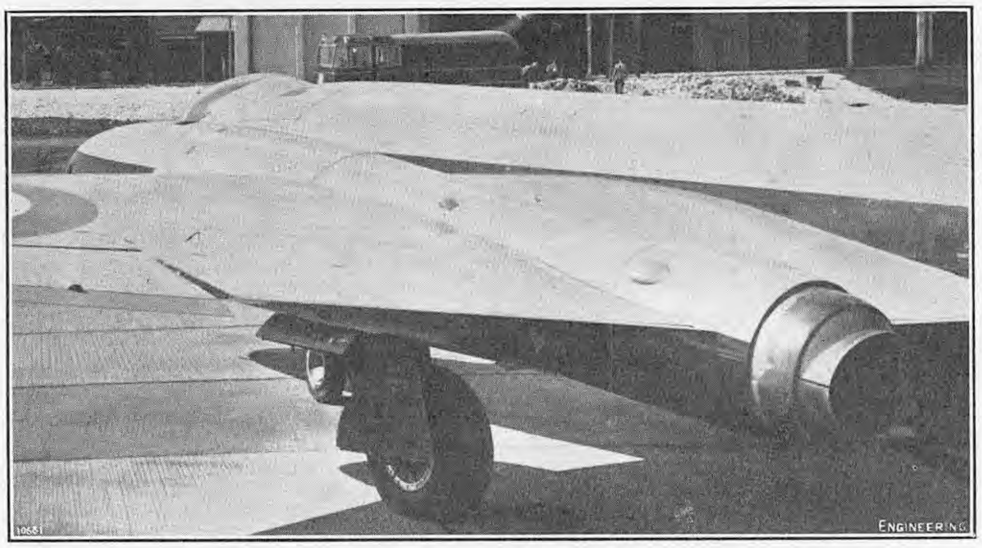


FIG. 7. TAIL-PIPE OF REHEAT "AVON" ENGINE; ARMSTRONG SIDDELEY MOTORS, LIMITED.

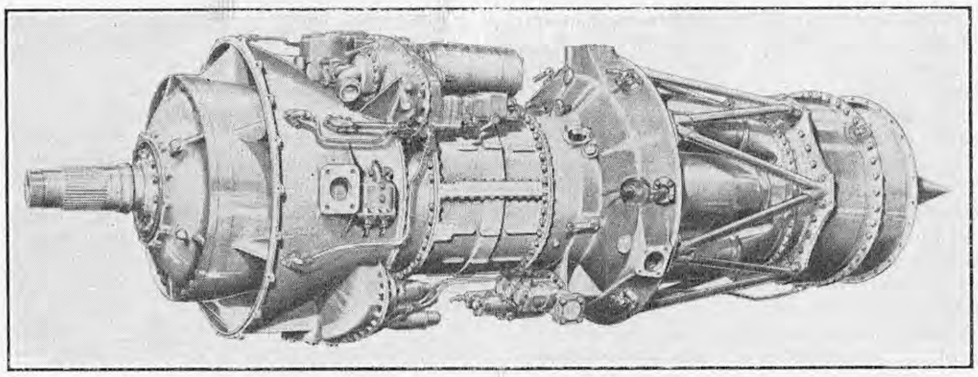


FIG. 8. "ELAND" PROPELLER-TURBINE ENGINE; D. NAPIER AND SONS, LIMITED.

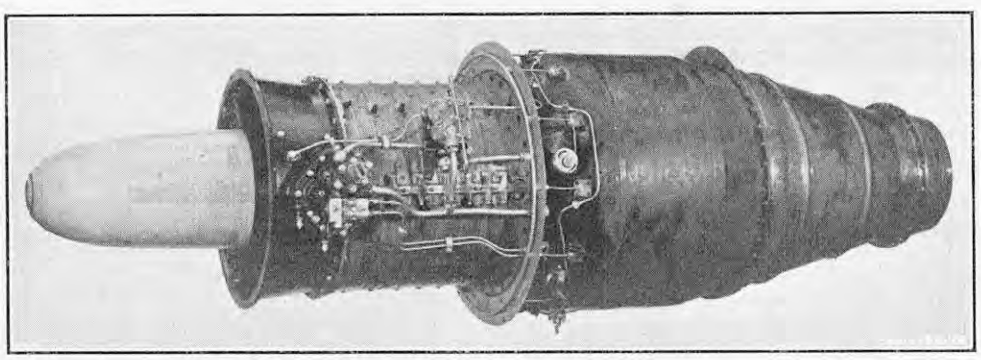


FIG. 9. "VIPER" SHORT-LIFE TURBO-JET; ARMSTRONG SIDDELEY MOTORS, LIMITED.

FLYING DISPLAY OF BRITISH AIRCRAFT.

THE annual flying display and static exhibition organised by the Society of British Aircraft Constructors opened at the aerodrome of the Royal Aircraft Establishment, South Farnborough, Hampshire, on Monday, September 1. It closes on Sunday, September 7, the last three days being open to the public. The year 1952 has been noteworthy for the introduction of the delta-wing configuration into aircraft destined for active service, and several aircraft appearing in the display can exceed the speed of sound. There are some new civil machines of great significance, but in general production aircraft are more prominent than prototypes.

SUPER-PRIORITY AIRCRAFT.

All the "super-priority" aircraft in production for the Royal Air Force and the Royal Navy—the Valiant, Hunter, Swift, Canberra, Gannet, and Javelin—are taking part in the display, and are illustrated in Figs. 1 to 6, on page 304. The four-jet Valiant medium bomber (Fig. 1), constructed by Messrs. Vickers-Armstrongs Limited, Weybridge, Surrey, and the Hunter single-seat fighter (Fig. 2), constructed by Hawker Aircraft, Limited, Canbury Park-road, Kingston-upon-Thames, Surrey, took part in last year's display and were described on page 342 of our 172nd volume (1951). The Swift single-seat fighter (Fig. 3), constructed by Messrs. Vickers-Armstrongs Limited, Hursley Park, Winchester, appears in public for the first time; it was intended that this machine should take place in last year's display, but a minor mishap prevented its appearance at the 1951 exhibition. This aircraft, it may be recalled, recently established an international record for the flight between London and Brussels, at an average speed of 665·9 m.p.h. It was described on page 343 of our 142nd volume (1949).

These three aircraft are powered by Rolls-Royce Avon engines, and so is the production Canberra aircraft constructed by the English Electric Company, Limited, Warton Aerodrome, Lytham, Lancashire. It is being demonstrated in flight in its new role of trainer, and is shown by three engine manufacturers as a flying test-bed for the Armstrong Siddeley Sapphire (which appeared last year and was described on page 391 of our 172nd volume, 1951), the Rolls-Royce Avon jet engine with reheat, and the Bristol Olympus jet engine. The latter version of the Canberra is illustrated in Fig. 5. In the static park may also be seen the production Canberra bomber aeroplane which recently crossed the Atlantic twice in ten hours, as reported on page 275, *ante*. The Gannet anti-submarine aircraft (Fig. 4), constructed by the Fairey Aviation Company, Limited, Hayes, Middlesex, appeared for the first time in 1950 and was described on page 269 of our 170th volume (1950). The production Gannet flying in the display this year differs from the prototype in that it now accommodates a crew of three; it also has a larger bomb bay, which has necessitated the shifting of the radome farther aft, and two additional auxiliary fins are fitted. The Gannet, it may be recalled, is powered by an Armstrong Siddeley Double Mamba propeller-turbine engine. The most recent of the super-priority aircraft is the Gloster Javelin all-weather patrol and interceptor fighter (Fig. 6).

GLOSTER "JAVELIN."

The Gloster Aircraft Company, Limited, Hucclecote, Gloucestershire, who produced the first British jet-propelled military aircraft (the Meteor), are demonstrating this year the second prototype of the first operational delta-wing aeroplane, the Javelin all-weather fighter, which is powered by two Armstrong Siddeley Sapphire axial-flow jet engines. The type-tested Sapphire Mark ASSa6 is known to have a static thrust of 8,300 lb. at sea level. It is apparent, therefore, that the Javelin is an extremely powerful weapon, and it has been revealed recently that it is capable of exceeding the speed of sound. In the flight demonstrations, the Javelin showed excellent manœuvrability. The delta-wing layout has been chosen not only on account of its aerodynamic and structural advantages, but also because it allows the undercarriage, the heavy fuel load, the complex and bulky radar search equipment, and the necessary armament all to be stowed within the smooth envelope of the airframe. The engines are installed in root nacelles that fair into the underside of the fuselage. A small "swept-delta" tailplane is mounted high on the fin, which, with the rudder, is also swept back. Fore-and-aft control is by elevators. The Javelin has a span of 52 ft., a length of 57 ft., and a height of 17 ft.

BRISTOL "BRITANNIA" AIR-LINER.

Visitors to the preview were disappointed by the non-appearance of the new four-engine delta-wing long-range bomber, the Avro 698, constructed by Messrs. A. V. Roe and Company, Limited, Greengate, Middleton, Manchester, but it flew over Farnborough, escorted by the Avro 707A and 707B delta research aircraft, on Tuesday. The Saunders-Roe Princess flying boat (described on page 289) also did not appear on the first day, but, at the time of going to press, it was expected that the Princess would appear later in the week. The other prototype long-range transport aircraft, the Britannia air-liner, constructed by the Bristol Aeroplane Company, Limited, Filton, Bristol, was described on pages 245 and 257, *ante*. In flight, it is outstandingly silent, this characteristic perhaps being emphasised by the fact that it is followed in the display by a Comet fitted with auxiliary Sprite rocket motors.

"SPRITE-COMET" FLYING TEST-BED.

The Sprite-Comet demonstration of assisted take-off is believed to be the first public demonstration of a British liquid-propellant rocket motor. The Sprite rocket motor is made by the de Havilland Engine Company, Limited, Edgware, Middlesex, and the prototype Sprite, on view in the static exhibition, was described on page 317 of our 168th volume (1949). It has an output of 55,000 lb. thrust per second. The Sprite was originally designed with a view to providing additional take-off power for the Comet air-liner when operating from airfields under tropical conditions and at high altitudes, but flying experience with the Comet has shown that the additional complication of rocket motors is not required. Water/methanol injection has been developed to improve tropical performance of the Ghost engine fitted in the Comet air-liner. At present, the Sprite is being developed mainly for military purposes, and it is not possible to give any details of the units fitted in the Comet, which forms a convenient test-bed. The technique demonstrated at Farnborough is to start the take-off on the normal Ghost engines, and to bring in the rocket motors as the aircraft begins to gather speed.

"REHEAT-AVON" AND "OLYMPUS" CANBERRA FLYING TEST-BEDS.

In contrast to the Sprite-Comet technique, Messrs. Rolls-Royce Limited, Derby, are demonstrating an accelerated take-off on the reheat-Avon Canberra test-bed, which is fitted with cartridge starters, in which re-heat or after-burning of additional fuel in the tail-pipe is brought in at the start of the take-off, and is maintained to give an exceedingly rapid initial climb. Fig. 7 shows the tailpipe of the Avon engine, fitted with an "eyelid" type of adjustable orifice, which is operated pneumatically and is opened to give a larger jet nozzle when "re-heat" is in operation.

The Olympus Canberra (Fig. 5, on page 304) entered by the Bristol Aeroplane Company, Limited, Filton, Bristol, is also notable for its high rate of climb, as would be expected. The appearance of the aircraft differs from the standard Canberra only in the additional length of nacelle forward of the wing. The Olympus turbo-jet was described on page 13, *ante*; it is rated, at present, at 9,750 lb. static thrust at sea level, and it may be recalled that it employs two-stage axial compressors mounted on separate shafts, each driven independently by turbines mounted on their respective shafts. This arrangement has resulted in a very rapid speed response to movements of the throttle levers.

NAPIER "ELAND."

Messrs. D. Napier and Sons, Limited, London, W.3, are showing, on their stand in the exhibition, a new propeller-turbine engine, the Eland, which, on account of its low specific weight, represents a considerable advance in the design of this type of power unit. It is now undergoing extensive testing. The engine has been designed mainly to fulfil the needs of the air-transport industry for a high-powered, economical, and light-weight engine suitable for the "tourist" type of air-liner operating over short and medium stage distances. The Eland, which is illustrated in Fig. 8, on page 309, develops a static power at sea level of 3,000 equivalent horse-power, with a corresponding specific fuel consumption of 0·624 lb. per horse-power per hour. In cruising flight, the estimated specific fuel consumption at a true airspeed of 350 m.p.h. at 30,000 ft. is 0·49 lb. per horse-power per hour. The net dry weight of the engine is 1,575 lb., giving a specific weight of 0·525 lb. per equivalent horse-power. This achievement is the result of much research and development work. The overall length of the Eland is 104½ in. and its maximum diameter is 36¼ in. The engine is of the single-shaft type, designed for a single constant-speed propeller. Both the compressor and the turbine are of the axial-flow type; six detachable combustion chambers are fitted.

ARMSTRONG SIDDELEY "VIPER."

The Viper expendable jet engine, which is on order for the Australian Jindivik radio-controlled pilotless aircraft, is on view for the first time on the exhibition stand of its designers and constructors, Messrs. Armstrong Siddeley Motors, Limited, Coventry. It is designed for a short life at full-throttle operation, and has recently been type tested, and cleared for piloted flight, with a sea-level static thrust of 1,575 lb. at 13,400 r.p.m., and a specific fuel consumption of 1·15 lb. per lb. thrust per hour. The Viper, illustrated in Fig. 9, on page 309, has an axial compressor and an annular combustion chamber. The engine mounting points comprise two trunnion mountings at the forward end of the combustion-chamber housing and a rear "steady" mounting attached to the forward end of the turbine casing. The Viper has a diameter, over the engine casings, of 23·25 in., and an overall length of 65·4 in. The net dry weight is 365 lb., and the static air-mass flow is 27·5 lb. per second.

(To be continued.)

THE ETHICAL DILEMMA OF SCIENCE.*

By PROFESSOR A. V. HILL, C.H., O.B.E., F.R.S.

EXACTLY a hundred years ago the British Association was meeting for the first time in Belfast; we are happy indeed to be gathered here to-day, in this hospitable city, to test your hospitality again and celebrate with you a century of progress of British science. The part which your kinsfolk have played in this makes a long and honourable story. Often their work was done in other parts of our Islands, or far away overseas: that belongs to your ungrudging tradition of service and adventure, and it does not stop you from producing, in every generation, plenty more of their kind. In 1660 the little town of Killyleagh was the birthplace of Hans Sloane, botanist, collector, physician, and president of the Royal Society, on whose bequest to the nation the British Museum in London was founded: its 200th anniversary will be celebrated next year. In the following century Joseph Black, the son of a native of Belfast and educated here, was a pioneer in chemistry and the theory of heat. In 1824, in this city, William Thomson was born, Lord Kelvin, the famous physicist and inventor. This city was the birthplace in 1866 of E. W. MacBride, the zoologist. Joseph Barcroft, the physiologist, was born at Newry in 1872; and among the living, Frederick Donnan, a native of Holywood, Co. Down, and a graduate of Queen's, whose imagination has fertilised both chemistry and biology, tells me that he took part in the meeting here in 1902. Thus it goes on. British science owes much to the fertile and imaginative minds, the vigorous temperaments and the warm hearts of your kinsmen; and in celebrating the centenary of our first visit to Belfast we and you can remember them with pride.

We can recall, too, that applied science is a partner in the great industries for which Belfast and Northern Ireland are famous, the city for shipbuilding, engineering and textiles, the country around for agriculture. In the Report of the British Association for 1852 there is a description of the vortex waterwheel, an early form of turbine, in working use at a near-by mill: James Thomson, elder brother of Lord Kelvin and for many years professor of civil engineering at Queen's College, had patented a vortex waterwheel in 1850. In the same Report is a long account, by the Professor of Agriculture at Queen's College, of the composition and economy of the flax plant: while 30 pages were devoted to the fattening of animals. In such practical arts, based alike on scientific knowledge and traditional skill, the contribution of Northern Ireland has been as distinguished as in the advancement of science itself; and we may confidently expect that the present meeting of the British Association will serve not only to celebrate the achievements of the last century, but to foster the endeavours of the next.

The President of 1852 was Edward Sabine, astronomer, explorer and geodesist, a Colonel then in the Royal Artillery. Sabine at that time was treasurer of the Royal Society. Sabine's address referred particularly to the subject of his own chief interest for many years, the periodic variations of terrestrial magnetism: indeed, he announced in his address the discovery of the connection between sunspots and magnetic disturbances in the earth. He finished his address by referring to "Allusions . . . made by influential men . . . to a direct representation of Science in Parliament." The benefit, he said, which the legislature might derive from such a change was a question rather for statesmen than for scientists; but as regards science itself he expressed his strong conviction that the possible gain would be far outweighed by inevitable loss, and that scientific men could not too highly value the advantage they possessed in the undisturbed enjoyment of their own pursuits, untroubled by the excitements and distractions of political life. The practical importance of science to-day, and its impact on public affairs, have greatly reduced that undisturbed enjoyment; and none would doubt the advantage to Parliament and the nation if more of its members had some personal acquaintance with science. It might be well, in a reformed Second Chamber, to provide the same representation to Science as is afforded to the Church and the Law.

Two famous young Irishmen were present at the meeting here in 1852. William Thomson, Lord Kelvin, elected to the chair of natural philosophy at Glasgow six years earlier at the unusual age of 22, was president of the Section of Physics: the other, George Gabriel Stokes, then 33, delivered a public lecture on fluorescence due to ultraviolet light passing through a solution of quinine. Both were among the foremost physicists of the following half century, and Kelvin succeeded Stokes as President of the Royal Society. The next meeting in Belfast was in 1874, when another Irishman, John Tyndall, presided. The last meeting at Belfast was 50 years ago, in 1902, under the presidency of James Dewar, famous for his work on the liquefaction of gases. Lord Kelvin, loyal to Belfast, read a curious paper in the Physics Section entitled "Animal Thermostat." The great physicist, arguing on thermodynamic principles, speculated whether the breath of an animal, kept a considerable time in a hot bath above the natural temperature of its body, might be found to contain no carbon dioxide at all; possibly even a surplus of oxygen, pointing to an "unburning" of matter in the body.

It is a very special pleasure to be called to the Presidency of the Association in succession to H.R.H. the Duke of Edinburgh, who won the confidence and esteem of scientific people at our meeting last summer, confirmed by many contacts with them since in Canada and the United States and recently in Britain. He concluded his presidential address last year with the words: "It is clearly our duty as citizens to see that science is used for the benefit of mankind. For of what use is science if man does not survive?" Here was a challenge to his successor: to discuss how far science has already contributed to human betterment, how far it has provided fresh problems, dangers and difficulties; and to suggest ways in which all who are concerned with science can help, to make sure that its results in fact are beneficial.

"As citizens": for scientists as such have no title to superior wisdom or virtue, and outside their special knowledge they are just as likely as others to be misled. The fundamental principle of scientific work is unbending integrity of thought, following the evidence of fact wherever it may lead, within the limits of experimental error and honest mistake. On this there can be no compromise. And, since science is a universal interest of mankind, recognising no barriers of race, class, religion, or opinion (provided that it is honest), a necessary condition of its advance and application is one of friendliness, frankness and equality. Goodwill and integrity, therefore, are indispensable alike to scientific progress itself and its successful employment for the benefit of mankind. Integrity and goodwill are the qualities chiefly required to utilise the opportunities, to resolve the problems and difficulties, which science has provided for present-day society.

The common phrase, "this scientific age," is all too apt to imply, with little justification, that the majority of people, at least in highly developed countries, now think and act scientifically; and, with no justification at all, to suggest that science can replace the older motives of human conduct. It is true that the external circumstances of life have been vastly altered by the applications of scientific discovery and invention, though as yet for only a minority of mankind. The future alone can decide whether natural resources and human ingenuity will prove sufficient, given statesmanship and goodwill, for the same transformation gradually to affect the whole of human society. If not, are stable conditions ultimately possible? Or will there be perpetual conflict between the "haves" and the "have-nots"? It is true also that the methods, ideas and results of scientific inquiry have penetrated widely, if not deeply, into popular thinking and belief: the jargon, at least, of science is widespread, and magic and superstition are gradually losing, if not their currency, at least their respectability. Yet such changes may have little real influence on the basic pattern of human behaviour. In clearing away old idolatries there is always a danger of allowing new ones to creep in: the unclean spirit went out when the house was

* Presidential address to the British Association, delivered in Belfast on September 3, 1952. Abridged.

swept and garnished, but only to return with seven others more wicked than himself. The improvement of man's estate by the application of scientific knowledge is one of the loftiest of adventures: but a belief that it can be achieved by scientific methods alone, without a moral basis to society, is a perilous illusion.

The conflict between new knowledge and traditional belief is no novelty. Again and again the attempt has been made to forbid the fruit of scientific knowledge. In 1874, in this city, John Tyndall delivered a presidential address to the British Association which provoked a hurricane of controversy: it was denounced from every pulpit in Belfast. Yet, reading it now, one is impressed not only by its courage, but by its reasonableness. It is true that he claimed that science will wrest from theology the entire domain of cosmological theory, whether of living or of non-living things; but he had previously referred to the immovable basis of the religious sentiment in human nature, bringing as he said "completeness and dignity to man."

The development which has brought most vividly to the public conscience to-day the ethical problems aroused by the advance of scientific knowledge lies in the field of nuclear physics; and groups of scientific people in the free countries of the world are vigorously debating its various consequences, among them particularly the secrecy attached to weapons as new and devastating as those provided by nuclear fission. Atomic physics, however, is only one of many scientific developments which have brought, or are bringing, a mixture of possible good and evil about which judgments of relative value must be formed. There is no secrecy about most of these developments. They occur gradually and continuously before our eyes. We tend to accept them without question as though they were natural phenomena; yet the consequences of one of them provide the most solemn problem in the world.

The dilemma is this. All the impulses of decent humanity, all the dictates of religion and all the traditions of medicine insist that suffering should be relieved, curable disease cured, preventible disease prevented. The obligation is regarded as unconditional: it is not permitted to argue that the suffering is due to folly, that the children are not wanted, that the patient's family would be happier if he died. All that may be so; but to accept it as a guide to action would lead to a degradation of standards of humanity by which civilisation would be permanently and indefinitely poorer. Conduct usually falls short of principles: but that would be the worst reason for abandoning principles.

In many parts of the world, advances in public health, improved sanitation, the avoidance of epidemics, the fighting of insect-borne disease, the lowering of infantile death rates and a prolongation of the span of life have led to a vast increase of population. Not only is the population increasing, but in many places its rate of increase is still rising: and these processes will take so long to reverse that for many years to come the shortage of natural resources, particularly of food, is bound to provide increasing deprivation and disturbance. That provides the practical motive of the Colombo Plan. In India, a Government Planning Commission, in a report of July, 1951, entitled *The First Five Year Plan*, has dared to face the facts. A doubling in the last 30 years of the survival rate (births minus deaths) has led to a rate of increase of nearly $1\frac{1}{2}$ per cent. per annum, a total of 5 millions every year in a population of 360 millions. "With all the effort that the First Five Year Plan will represent, it will be possible barely to restore by 1955-56 the pre-war standards in regard to food and clothing. Increasing pressure of population on natural resources retards economic progress and limits seriously the rate of extension of social services so essential to civilised existence."

The pre-war standard, in fact, was miserably poor; a large part of the population existed below the level of a decent life, scores of millions only just above that of famine. Yet the gigantic national effort proposed in the Five Year Plan, even if successful, may only just restore that miserable standard. Can it sustain it then if the rate of population increase continues? It is easy to answer that a higher standard of life has led in other countries to a gradually falling birth rate: but a higher standard requires a far greater charge on natural resources of all kinds, which cannot be met until the pressure of population is reduced.

In the meantime, there is more than danger that the emergency will result in an over-use of natural resources, leading by land erosion, deforestation and other factors to permanent and irretrievable loss: this has happened already, and is visibly happening now, in many parts of the world. In a special section on "Family Planning" the Indian Report recognises that "an alteration in population trends takes at least a few generations to materialise"; and steps are suggested for the education of public opinion on the need for limitation, and for experimental efforts to be made in the application of simple methods of birth control. For its wisdom and courage in acknowledging the gravity of the situation the Indian Planning Commission deserves every support: but the problem itself has not begun to be solved, and its consequences will dominate the development of India for many years.

Malaria is admitted by the Planning Commission to take an annual toll of a million lives, tuberculosis of half a million. The resolute use of insecticides and anti-malarial drugs could soon reduce the former to a small fraction: tuberculosis is bound to require more effort and a longer term. Nobody would dare to say that steps to combat these diseases, and others such as cholera, to improve rural and industrial health, to increase the supply of drugs and medical equipment and services, should not be taken on the highest priority: but the consequence must be faced that a further increase of a million people per annum would result. Thus science, biological, medical, chemical and engineering, applied for motives of decent humanity entirely beyond reproach, with no objectionable secrecy, has led to a problem of the utmost public gravity which will require all the resources of science, humanity and statesmanship for its solution.

The example of India has been taken because of the sheer magnitude of the problem and because its seriousness is now admitted by humane and responsible men: but the same conditions exist already in many parts of the world and will soon exist elsewhere. It is not a question only of food: if a higher standard of life is to become universal, with education, communications, housing, reasonable amenities and public health, a far greater demand will be made on all such natural resources as power, chemicals, minerals, metals, water and wood. One is left wondering how long these can possibly take the strain. Could world supplies conceivably hold out if the present requirement per head in the United States were multiplied in proportion to meet the same demand everywhere—even without any increase of present population; and if so, for how long?

By vast improvements in communications, which have made the world so small, applied science has been one of the chief agents in the present ferment of social, political and economic thought. Can one urge, after the event, that the application was a mistake and that the majority of mankind could better have remained isolated and in ignorance? By making world war technically possible, applied science has helped to stir up national ambitions and social revolutions which, if poverty and deficiency continue without hope, may lead to major world catastrophe. Should we therefore refuse to employ science in defence of liberty and resign ourselves to a universal police state where no scruples are permitted? Are we, in scientific research, to say that some subjects may be investigated, but not others, for fear of the consequences? Who then is to decide and by what international authority? And is it practical to insist that all scientific knowledge should be fully and openly disclosed, without secrecy or reservation of any kind, military or industrial? These are problems which cannot be solved by rhetoric, or by any simple formula. The purpose of setting them out is to make clear that we must face them with honesty and courage; for they will not solve themselves.

I have led you to the ethical dilemma which perplexes many of us by taking an example in which few would question either the motives of those who made the original discoveries, or the humanity of their application: or, indeed, could wish that the fruit of the tree of knowledge had been left untried. It is easy to say now that, side by side with the control of disease, there should have been an equal and parallel effort in education, particularly the education of women as responsible citizens: for there is no possibility, if women remain ignorant and illiterate, of intelligent widespread family planning and control. But education alone would not have been enough, or indeed possible itself without a substantial measure of material and social betterment: and the expense and effort involved in this would have been indefinitely greater than in the application of medicine and hygiene, which, after all, has been relatively cheap. Had it been possible to foresee the enormous success of this application, would humane people have agreed that it could better have been held back, to keep in step with other parallel progress, so that development could be planned and orderly? Some might say Yes, taking the purely biological view that if men will breed like rabbits they must be allowed to die like rabbits, until gradually improving education and the demand for a higher standard of life teach them better. Most people would still say No. But suppose it were certain now that the pressure of increasing population, uncontrolled by disease, would lead not only to widespread exhaustion of the soil and of other capital resources, but also to continuing and increasing international tension and disorder, making it hard for civilisation itself to survive: would the majority of humane and reasonable people then change their minds? If ethical principles deny our right to do evil in order that good may come, are we justified in doing good when the foreseeable consequence is evil?

I remember asking an eminent Indian who had taken part in drawing up the so-called Bombay Plan of 1944 why there was no mention of the gravest problem of all, overgrowing population: he replied that his colleagues and he had indeed discussed it, but decided to leave it to God. To a biologist aware of the methods by which animal population is controlled by Nature, this seemed pretty poor comfort: yet there are many who really take that view, admittedly with the element of reason that we never can be sure that things may not turn up to make all our calculations wrong. Should we then just continue to do the good we see in front of us, in confidence that, if our motives are humane, good and not evil will finally result? Or, taking that rather easy course, are we not showing a lack of the fundamental virtues of courage and integrity?

The dilemma is a real one, and cannot be resolved by any simple expedient. In another form it is perplexing many of those who are concerned with the development of nuclear physics, the ultimate service of which may be very great, possibly essential if our present type of civilisation is to continue when other sources of power dry up; while the benefits to medicine and industry are already substantial. But nuclear fission has released the threat of unprecedented violence, with the possible destruction of many millions of lives and the accumulated treasures, moral and material, of civilisation. The individual conscience may tell a man to have no part in it: that is easy enough, for there are plenty of other interesting things to do, but it does not solve the problem.

What, then, of the abolition of secrecy? In principle, yes, for the historic and unique contribution of science to international goodwill has been in sharing knowledge regardless of race and frontier, and the chief satisfaction of scientific work, the condition of its fruitful development, is frank and free discussion. Every possible endeavour should be made towards international agreement on sharing scientific and technical knowledge and controlling nuclear weapons: but this, like peace itself, is a concern of every citizen, not only of scientific people. It is hard enough to get international agreement in quite simple matters, such as the perilous state of the north European fisheries, where no secrecy is involved and little national prestige, and the scientific evidence is unequivocal: but we must go on trying.

(To be continued.)

ANNUALS AND REFERENCE BOOKS.

Year Book of the Heating and Ventilating Industry.

Technitrade Journals, Limited, 8, Southampton-row, London, W.C.1. [Price 7s. 6d. net, or 8s. 4d., including postage.]

THIS is the sixth edition of this year-book, which is compiled in collaboration with the Association of Heating, Ventilating and Domestic Engineering Employers, for whom it serves also as a list of members. It contains, however, many other reference sections in addition, notably a buyers' guide, an alphabetical list of trade names relating to the industry, a directory of manufacturers' addresses (but not telephone numbers, which might be added with advantage), and a list of technical and trade associations (with telephone numbers as well as addresses). These sections occupy the latter half of the book. The first half contains, in addition to various contributed articles, an index to the literature of heating and ventilating during 1951, with annotations; a selected list of British Standards and Codes of Practice; a reprint of the Model By-laws relating to water supply; and the texts of a number of forms of legal agreement, including agreements for apprenticeship in the shops and the drawing office.

Standard Methods for Testing Petroleum and Its Products.

Twelfth Edition. The Institute of Petroleum, 26, Portland-place, London, W.1. [Price 40s., post free.]

THE twelfth edition, that for 1952, of the Institute of Petroleum's book of standard methods contains detailed particulars of 121 British methods for the testing of petroleum and its various products, including bitumen emulsion, lubricating oil, motor fuels, Diesel fuels, aviation fuels, waxes and greases. The methods are arranged in alphabetical order, and, in some cases, are designated by the letters T and P, which stand for "tentative" and "proposed" methods, signifying that they have not yet been finally adopted. All methods bear a reference number, followed by the year in which they were adopted or were last revised. Two new methods have been incorporated in the present edition, the first concerns the determination of the oil content of unused and used soluble cutting-oil dispersions, and the second, the determination of the stability of aviation gasoline under accelerated oxidation conditions. In addition, 68 of the existing methods have been revised editorially, and, in over 20 methods, technical revisions have been made. Moreover, the range of analytical solvents for which specifications are given has been widened. Where comparable methods issued by the American Society for Testing Materials exist this fact is indicated in a footnote.

Guide to the Coalfields, 1952.

Edited by R. H. WALKERDINE and C. TREHARNE JONES. Published by the Colliery Guardian Company, Limited, 30 and 31, Furnival-street, London, E.C.4. [Price 20s., by post 21s.]

THE 1952 edition of this handy little reference book to the coalfields of Great Britain will be welcomed by readers who have known and consulted previous editions. The longest section of the book is that in which particulars regarding individual mines are given, and the data furnished include the type of coal and other minerals extracted, the names of the seams worked, the number of men employed above and below ground, whether electricity is utilised underground for lighting and power, the names of the managers and under-managers, and the Mines Inspectorate division and district. All these data are compressed into a relatively small compass by the use of abbreviations. The position of the collieries are shown on maps drawn to a scale of one inch to one mile, and these are correlated by nine key maps each covering a division of the National Coal Board. Lists of officials of the Board, the Ministry of Fuel and Power and the Mines Inspectorate, and of associations, societies, trade unions and other bodies interested in, or concerned with, coal mining are given in other sections. In addition to a general index, a mines index and personal index are given, and these are of considerable value in turning up information quickly.

UNIVERSAL MULTI-CONTACT RELAY.—A universal multi-contact relay recently introduced by the Electrical Remote Control Co., Ltd., Harlow New Town, Essex, is designed for use at coil voltages up to 450 volts alternating or direct current and for operating over 15 sets of contacts. Its current-carrying capacity is between ½ and 6 amperes at 230 volts, depending on the material and diameter of the contact tips. Each pair of contacts has one spring resting on or in the slot of a small Paxoline panel which is fixed to the end of the lifting arm, thus avoiding the use of spacers. The yoke and armature are of silicon-steel laminations to reduce eddy current and hysteresis losses, and the design is such that silent operation is secured.

LABOUR NOTES.

BANS on all overtime and piecework throughout the engineering and allied industries were recommended by the executive council of the Confederation of Shipbuilding and Engineering Unions, when it met at Margate on Sunday last, on the eve of the Trades Union Congress. This recommendation will be considered by a special delegate conference of the executive committees of the 38 unions affiliated to the Confederation, which is due to meet at York on September 10. If the recommendation is approved then, the bans may be expected to be put into operation shortly afterwards. The executive council suggested that engineering employees engaged at piece rates should be instructed, as from a date to be decided, to work no longer than will be required to bring their earnings up to the equivalent of 44 hours' wages at day-work rates. The decision to impose the bans will be reported officially to the Government, if the delegate conference on September 10 approves that course of action.

Overtime and piecework bans were recommended by the Confederation executive council as a protest against the further rejection of their proposals for an all-round increase of 2*l*. a week for all male employees in the engineering and cognate industries. The claim was presented to the Engineering and Allied Employers' National Federation on June 26 and rejected in full on July 31. On that occasion, Sir Alexander Ramsay, the director of the Federation, made a full statement to the trade-union representatives setting out the employers' reasons for their decision and dealing with almost every aspect of the subject. Some unions thereupon suggested strike action but the Confederation decided, on August 12, at its annual conference at Southsea, that its council should seek immediate meetings with the engineers' Federation, and the Shipbuilding Employers' Federation and the Railway Executive which had also rejected wage demands, to impress upon them the "serious situation" which existed as a result of the refusals to grant wage increases.

At a meeting between representatives of the Confederation and the negotiating committee of the Engineering and Allied Employers' National Federation on August 22, the claim was again rejected, but the committee agreed to consult the full management board of the Federation. The board met on August 28, when it re-affirmed the view of the negotiating committee that the Confederation's demand for an all-round increase of 2*l*. was unjustified. A letter from Sir Alexander Ramsay conveying this decision was considered by the Confederation's council at its meeting last Sunday. This stated that the issues involved had been fully discussed between the parties and their respective points of view made clear. It was the view of the management board that if the claim were conceded it would inflict grave damage on the engineering industry and seriously restrict sales at home and abroad. In consequence, unemployment would result and the balance of payments position would be worsened, with an adverse effect on the country's supplies of food and raw materials.

Some opposition has been declared to the bans on overtime and piecework. The decision taken last Sunday to recommend them was not a unanimous one, but was described by Mr. H. Brotherton, the President of the Confederation, as having been approved by an overwhelming majority. Mr. J. Matthews, the national industrial officer of the National Union of General and Municipal Workers, proposed, as an alternative, that the dispute should be referred to the Minister of Labour, with a view to arbitration, but this suggestion was heavily defeated. On Tuesday last, Mr. Tom Williamson, the general secretary of the N.U.G.M.W., announced that his union's executive council considered that the claim should be referred to the Minister of Labour for arbitration, and that this view will be pressed at the Confederation's meeting of delegates from affiliated unions at York on September 10. At the time of going to press, there were indications that a similar attitude may be adopted by the Transport and General Workers' Union. Both unions have an affiliated strength in the Confederation of about 95,000 members. A considerable proportion of the unskilled employees in the engineering industry belong to these two unions and the imposition of the bans would probably mean substantial financial loss to many of them.

When announcing the opposition of his union to the bans, Mr. Williamson stated that the executive committee of the union regarded the engineering employers' attitude as most unfortunate. It was not in the best interests of the industry or of the country, and the committee considered that the employers should be asked to concede the principle that a wage increase was justified. The committee felt that the employers' complete rejection of the wage claim was a great encouragement to unruly elements in the industry, whose only concern was to create chaos and disruption.

The 84th session of the Trades Union Congress opened at Margate on Monday last. In his presidential address, Mr. Arthur Deakin, C.H., C.B.E., condemned extravagant wage claims. He said that the guidance offered by the T.U.C. General Council last year remained equally valid under the circumstances of the present time. It was made clear then that the Council was not opposed to applications for wage increases, but recognised that, with a steadily rising cost of living, wage claims were justifiable. Nevertheless, the Council urged then, and still did, that reasonableness should be observed in the formulation of wage claims, and that good sense should be exercised. He ridiculed the idea of a national wage tribunal to devise a national wage policy. Mr. Deakin referred to the Scottish printing dispute as not the only recent event in which there was a threat to the trade-union movement. He considered that there was a tendency in some political quarters to encourage breakaway unions, but the movement would fight such organisations by every means at its disposal.

Mr. Winston Churchill, the Prime Minister, has agreed to meet representatives of the Trades Union Congress General Council at 10, Downing-street on Monday afternoon to discuss legal questions arising from the recent dispute between the Scottish printing firm of Messrs. D. C. Thomson and Company, Limited, and certain printing unions. The request for a meeting with the Prime Minister and Sir Walter Monckton, the Minister of Labour, was made by the General Council after the T.U.C. had discussed the implications of the dispute at a private session on Monday last. It is considered unlikely, however, that Sir Walter, who is on holiday, will return to London to take part in the meeting.

It may be recalled that the dispute involved questions of the trade-union membership of certain of the firm's employees and that a court of inquiry appointed by the Minister of Labour to investigate the points at issue presented its report in July. The court's findings were that both sides were within their rights in the matter, but it recommended them to reconsider their attitudes. Sir Walter reported to the House of Commons on August 1 that Messrs. Thomson had agreed to abandon their non-union policy subject to certain safeguards, with which the printing unions concerned were in agreement. Difficulties respecting the re-instatement of the firm's workpeople who took part in strike action against their employers, have, however, remained unsolved.

Statistics prepared recently by the Board of Trade show that 56 new factories exceeding 5,000 sq. ft. in area and 147 extensions of over 5,000 sq. ft. to existing factories were under construction in the Greater London area on June 30. According to the estimates made by the undertakings concerned when they applied for their industrial development certificates, the number of jobs which may be provided in these establishments amounts to about 11,800. These statistics relate to the area covered by the Greater London Plan, which includes the New Towns of Basildon, Harlow, Hatfield, Hemel Hempstead, and Stevenage.

VIBRATED CONCRETE.

Fig. 1.

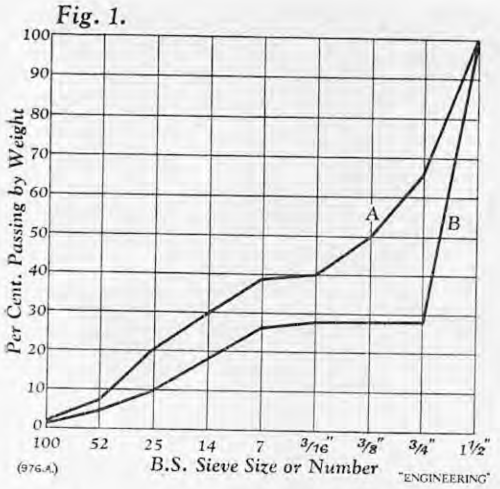


Fig. 2.

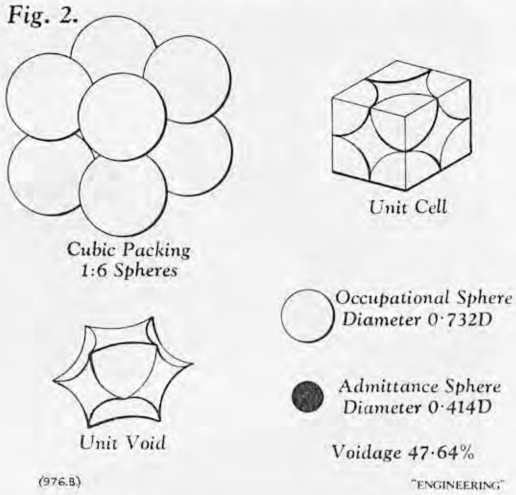
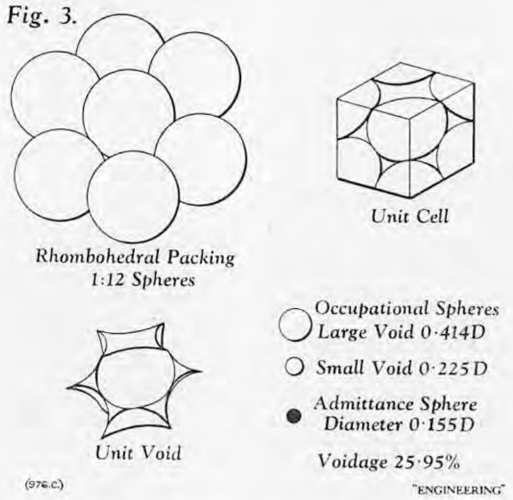


Fig. 3.



SOME RECENT DEVELOPMENTS IN CONCRETE TECHNOLOGY.*

By D. A. STEWART, A.M.I.C.E.

THE first half of this century has witnessed a rapid development in the practices related to the manufacture and placing of concrete, particularly in the field of civil engineering. The advance in our knowledge of the material itself, however, lags sadly behind modern requirements, leading us to an inefficient and hence uneconomic use of this malleable and remarkable structural material. This regrettable lack of understanding not only results in waste of concrete itself, because of the relatively low working stresses it is permitted to carry, but, where it is associated with steel in reinforced concrete, steel itself is also wasted. For instanac, if the compressive strength of a concrete in bending could be increased from 1,250 lb. per square inch to 2,000 lb. per square inch the following reductions would be possible, (1) the cross section of the member could be reduced, thus reducing the dead load and increasing the efficiency of the structure; (2) compressive steel might be eliminated; (3) shear steel might be eliminated; and (4) high-tensile steels could be efficiently employed, thus reducing the weight of steel required. In order that these economies may be achieved without endangering the structure, advances in scientific knowledge must be accompanied by a corresponding improvement in the technique of concreting, and this must be skilfully applied by the engineer in the field through the medium of his foreman and labour force.

It is not so many years ago that all mixing was carried out by manual labour, and the quantities of cement, sand and stone were measured by box. To-day volume batching is dying out, while weigh-batching is taking its place, even on contracts of quite a minor order. Weigh-batching, besides being more accurate in regard to the measurement of the materials and giving a greater degree of overall control, has proved itself the cheaper method of proportioning the various constituents of a mix. On large modern contracts, where upwards of 300 tons of concrete are mixed and placed day after day, these batching plants are indispensable. So great is their throughput that auxiliary plant, such as grabs or belt and bucket conveyors, have to be installed to maintain supplies of raw materials to them, while the mixed concrete is taken away by an assortment of transporting plant including concrete pumps, specially constructed trucks, dumpers or skips. Thus, with all this technical development, the placing of the concrete in the formwork remains the last stronghold of manual labour; but here again mechanisation is gradually asserting itself, the work of rodding and punning being performed by one or other of the various forms of vibrator now being manufactured in considerable quantities.

The introduction of mechanisation is beginning to have a profound effect upon the practice of concreting, as might well be expected. This is particularly noticeable in regard to road and aircraft runway slabs, where a uniform surface finish of a particular type is required and where variations in the compacted state of the concrete after the passage of the compactor are easily discernible. In the past, when a slab was laid manually, variations in the concrete could be doctored or otherwise adjusted to match the surrounding work by the men employed in placing, as laying proceeded; the modern machine, which gives a relatively uniform treatment to the material supplied to it, cannot discriminate in this way, and hence, unless the material supplied to it is uniform in composition, behaviour and initial density after spreading, the machine in treating it will not produce a homogeneous pavement. Thus it will be seen that the development of mechanisation has made it necessary to make a careful and analytical study of mix design with the object of substituting a scientific method for the existing empirical one. While faults and discrepancies in mix design, mixing and placing are more readily perceived in machine-compacted pavements, the same troubles frequently arise in other types of concreting. When the concrete in question is to be compacted by vibration, segregation may be produced as easily by the presence of excessive fine aggregate as by the addition of middle sizes; that is to say, those sizes at the finer end of the coarse aggregate range. The effect of excessive sand will be to produce a layer of mortar at the upper surface of the work, while the blockages produced by excessive middle sizes may bring about patches of honeycombing or a shortage of filler in relation to the void space in the coarse aggregate, caused by particle interference.

Mix Design.—Many attempts have been made to design mixes on mathematical lines and probably as many empirical curves have been produced which purport to give the answer by way of the best grading to the engineer seeking the mix for the job. Most of these attempts have been related to manual placing, in which the compacting effort per unit volume of concrete is small compared with modern vibrational treatment and in no way so thorough. Manually-placed concrete has to be of such a nature that a pile of freshly mixed material, when given two or three light strokes with a trowel, will develop a smooth, well-filled and glistening surface. The required effect is readily produced by the use of a rich mix containing coarse aggregate of a small maximum size, $\frac{3}{4}$ in. or $\frac{3}{8}$ in., and a liberal supply of sand and water. The exact proportioning of the various ingredients is by no means critical, neither is it considered necessary to vary the proportions of coarse to fine aggregate, no matter from what source these might have been obtained or what combined grading may result. So-called "ideal" gradings have been produced which are intended to give concretes of maximum density or strength, but many, if not all, fail to deal with the design of concrete mixes in all its aspects. That this should be so is not surprising, since our knowledge of the "anatomy" and "physiology" of concrete is very meagre. Concrete does not possess those well defined characteristics in its freshly mixed state which allow of a simple classification; features such as "workability," "mobility" and "fluidity" defy exact definition, each aspect merging into the other to some extent. For instance, a harsh lean gap-graded concrete may compact very readily under the influence of the vibration imparted to it by the skip in which it is being conveyed, but on reaching the placing point it is found to be quite unworkable and immobile because of the ease with which it has already compacted. If, however, vibration is applied once more, the concrete will flow quite readily from the skip into the formwork. Some hint is given here that the above-mentioned characteristics must be considered in relation to the method of handling and compacting the concrete, although it has been maintained by the Road Research Laboratory that workability is an intrinsic quality of the concrete which is defined as the "useful internal work necessary to produce full compaction." Others, including the author, have been forced to the conclusion that workability, thus defined, refers chiefly to the compactability of the concrete, whereas the term workability might be expected to cover both mobility and fluidity. It is a little difficult to distinguish between these two qualities and so the following approximate definitions are given. Mobility is equivalent to turbulent flow in a liquid, i.e., the concrete does not move forward by one layer sliding over the adjacent layer. Fluidity is equivalent to free flow where one layer slides over the adjacent layer, i.e., the rate of flow at any section is proportional to the velocity gradient. As will be observed from these definitions, fluidity in concrete is hardly possible mechanically owing to particle size and distribution, and hence mobility is of more practical interest to the engineer.

Those who have observed the behaviour of concrete in the process of compaction will have noted that the initial settlement or downward movement of the mix is rapid, but that the movement quickly slows up as the voids in the mass are reduced. This suggests that both mobility and fluidity of concrete are dependent upon the degree of separation of the particles of which the mix is formed and that, where mobility is required, measures must be taken to maintain a suitable degree of separation. This may be done in one of two ways, the alternatives depending upon the method of handling the concrete after mixing and during placing. Consideration of the post-curing behaviour of the concrete will be omitted for the moment. Flow may be encouraged by maintaining the separated condition of the coarse particles in the mix from one another. This may be achieved by introducing into the particle assembly material in the coarse aggregate group of a size capable of causing "interference." The quantity and size of this "interference" material must be correctly gauged so that, while decreasing the total voids, the individual void size will not be reduced to an extent which will inhibit the free passage of the larger particles in the fine aggregates, as the failure

* Paper read before Section G of the British Association at Belfast on Thursday, September 4, 1952.

of the fine aggregate to act as a filler will cause an increased demand for cement paste. Alternatively, the coarse particles in the mix may be adequately separated in the semi-compacted state by the application of vibration. Thus concrete may be expected to flow readily, provided that the intensity of vibration is sufficient to produce dilatancy in the system of particles and that the effective maximum size of the coarse aggregate allows these aggregates to move freely within the formwork; that is to say, the correct size relationship exists between coarser particles and the spacing of the opposing shutters.

The foregoing consideration indicates that concretes may be divided into two classes, the first of which is characterised by possessing within itself, by virtue of the aggregate grading, the essential requirements of mobility and fluidity, but lacking to a varying degree the quality of stability on compaction. The other class of mix relies upon external stimulation in the form of appreciable vibration to provide it with its mobility and fluidity. This class of concrete is highly compactable and, once compacted, develops an extremely rigid internal structure of interlocked particles. What is particularly interesting about this view of the subject is that it illustrates the use to which the two principal systems of grading may be put. These systems are generally known as continuous and gap grading. The continuous-grading system makes use of all the nominal particle sizes from the largest to the smallest and may cover the range 6 in. to B.S. sieve No. 200. Gap grading, as the term implies, is characterised by the absence of certain nominal sizes, specially chosen so as to reduce interference to a minimum. Fig. 1 shows two grading curves for natural river gravels; that marked A is continuous, while B is typical of a gap grading. The essential difference between concretes made from these two gradings is that the use of continuous grading does not permit the mix to be predetermined mathematically on a basis of knowledge of the physical characteristics of the individual and collective aggregates, while a gap-graded concrete can be very closely designed as regards proportions, water : cement ratio and workability, once the necessary tests have been made to determine the design factors of the coarse and fine aggregates.

Before going into the design of concrete mixes specifically, it will be useful to consider the packing of particles in theory and practice, because the whole of the technique of modern mix design is dependent upon our knowledge of the behaviour of particle assemblies. The study of particle packing was first undertaken in America by L. C. Granton and H. J. Fraser, their work being published in the *Journal of Geology*, Chicago, 1935, Dr. H. Heywood and others continued the work and published papers at various times between 1935 and 1946. The application of the principles founded on these experimental and mathematical researches have been applied principally to the group behaviour of fine dusts and powders, and it is only of recent years that the structure of concrete has been examined on the same basis.

In order to simplify as far as possible the examination of the highly complicated particle assemblies found in concretes we may consider a system of uniform spheres. It is found that there are six regular group formations or methods of arranging sets of spheres of uniform size. These formations have various interesting characteristics which are of particular importance to the concrete technologist, two of which are illustrated in Figs. 2 and 3 herewith. From the figures, it can be seen that the various groupings have varying degrees of stability and hence of potential. It is evident that to arrange a large number of spheres in cubic packing would be a matter of very delicate adjustment and could be undertaken only in a container in which the sides were of a length equal to multiples of the diameter of the spheres. This system of packing is most unstable. The next and somewhat more stable system is that in which the even rows are offset in one dimension only. The third system has the greatest stability and hence the lowest potential, and here even rows are offset in two dimensions. This is the formation which the application of vibration tends to produce in any heterogeneous grouping and which can be seen developing in Fig. 4, which shows a concrete having glass spheres as the coarse aggregate.

VIBRATED CONCRETE.

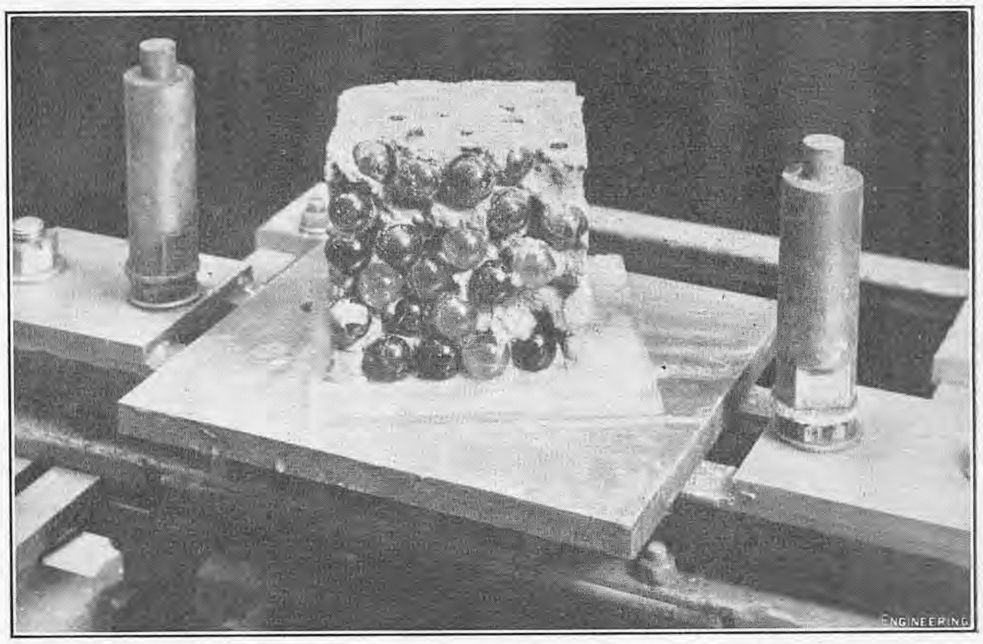
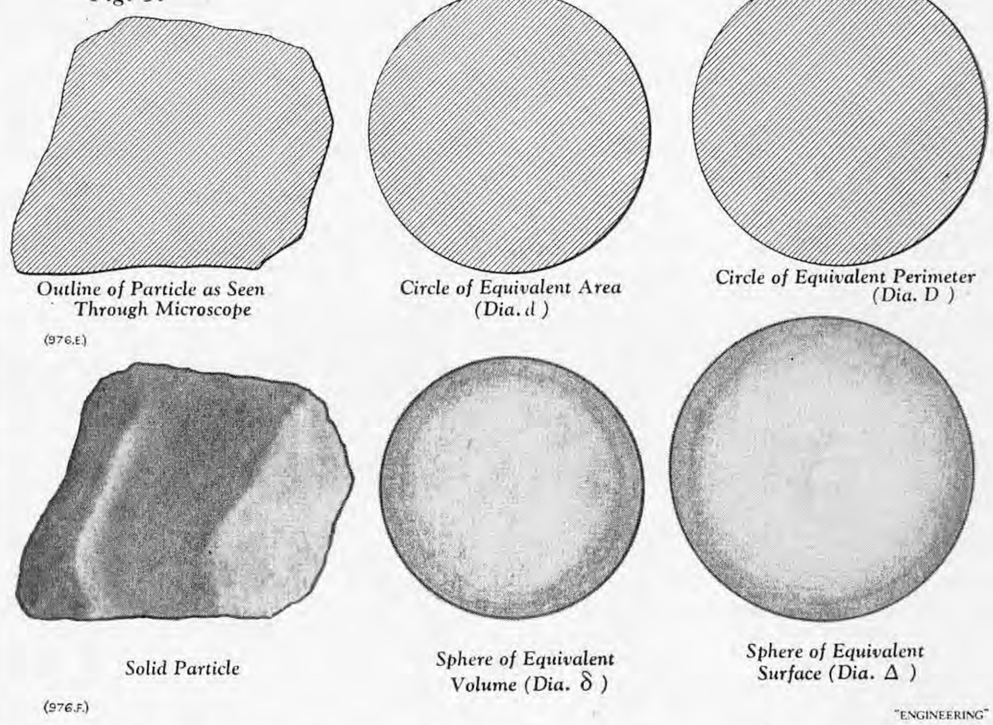


FIG. 4. CONCRETE WITH GLASS SPHERES AS COARSE AGGREGATE.

Fig. 5.



Attention may now be directed to the two sizes of spheres which can be used to reduce the void ratio in a regular system of packing. These two sizes are related as to their diameters to the major particle size and these ratios remain constant for a particular system of packing. The occupational sphere is that which may be built into the major void space contained by any unit of the system, while the second size is the passing or admittance sphere, which has a diameter less than the throat opening into the unit void. In the design of gap-graded concrete, it is the admittance size of particle which is of particular interest, because it is particles of this size which provide the filler for the coarse aggregate and upon which we rely in bringing up the bulk density of the aggregates to the value required to accommodate the predetermined quantity of cement paste.

If we consider an assembly of single-sized spheres, having a specific form of packing and contained in a vessel having dimensions which are very great compared with the diameters of the spheres, so that side effect may be neglected, it will be found that the void ratio is constant, irrespective of the diameter of the spheres used to fill the vessel. However, both the number and size of the individual voids vary with the size of the spheres, the voids increasing in number and decreasing in volume as the sphere diameter is reduced. This phenomenon is of importance when considered in relation to the design of concrete mixes because of the effect upon the specific surface of the combined aggregates and hence upon the workability of the concrete, which is greatly affected by the inter-particle friction. Furthermore, the smaller the specific surface of the aggregates, the smaller the quantity of water required for lubrication and the lower will be the water : cement ratio for a given proportion of aggregate to cement. It is therefore desirable to make use of as coarse a grading as possible in designing a mix, and this point is illustrated by Table I. The values in Table I are worked out for ideal conditions of minimum voids in the coarse and fine materials, and, although such an idealised state of packing will never be found in normal concrete, the tendencies indicated by the Table still apply, that is, the rapid increase of surface area with reduction in the maximum size of aggregate.

When the packing and other characteristics of concreting aggregates are examined mathematically, the simple calculations employed in analysing single or dual-sized sphere assemblies cannot be utilised and a number of other devices have to be brought into play to deal with the vast variations in size and shape that arise in the general run of crushed rocks and natural gravels. These devices consist in dividing the particles into size groups by passing the material through a series of screens and expressing the quantities lying between each consecutive pair of sieves as a percentage by weight of the whole sample tested. It is usual to arrange the

TABLE I.

Max. Sphere Size.	Admittance Size.	Surface Area.
$1\frac{1}{2}$ in.	0·2325 in. dia.	76 sq. in.
$\frac{3}{4}$,,	0·116 ,,	152 ,,
$\frac{3}{8}$,,	0·058 ,,	304 ,,

aperture of each successive screen so that it is half the linear dimension of the previous one. It will be seen from this that no very exact determination of the distribution of the sizes of the particles within any one group can be made. However, if the specific gravity of the material is known and a representative sample is taken from a group, weighed and the number of individuals forming the sample are counted, the sphere of mean volume may be found and hence a mean diameter established. This diameter, unfortunately, is not very much used in making a direct calculation of the surface area, since the surface : volume ratio is almost certain to be greater than that associated with spheres. In fact, any one particle of irregular shape requires four diametric values to express its characteristics; these are given by Heywood in his paper "Calculation of the Specific Surface of a Powder," as :—

Diameter of a circle of equivalent area d
Diameter of a circle of equivalent perimeter D
Diameter of a sphere of equivalent volume δ
Diameter of a sphere of equivalent surface Δ

and are shown in Fig. 5, taken from that paper.* He shows that, where the direct measurement of the surface area of the particle is impossible, an assessment may be made of its value if it can be demonstrated that the ratios $\frac{D}{d}$ and $\frac{\Delta}{\delta}$ are equal. Since the values D and d may be determined by direct measurement from the projection of the particle upon a screen, as illustrated, an expression can be built up which will give a "shape factor" $\frac{f}{K} = \frac{\delta\,\Delta^2\,d}{\delta^2} = \frac{4{\cdot}84\,\gamma^2}{K^{\frac{1}{3}}}$, where $Y = \frac{\Delta}{\delta} = \frac{D}{d}$ and f = "surface constant," the value to be found and which is equal to π for a sphere; and K = "volume constant"—in the case of a sphere this is $\frac{\pi}{6}$—and is found from the "circle of equivalent area" and the measured volume of the particle.

(*To be continued.*)

UNITED KINGDOM PRODUCTION OF PIG IRON AND STEEL.—Statistics issued by the British Iron and Steel Federation, Steel House, Tothill-street, London, S.W.1, show that the output of steel in this country in July, although affected by holidays, nevertheless reached an annual rate of 14,236,000 tons, compared with 13,317,000 tons in July, 1951. The production of pig iron in July was at an annual rate of 10,482,000 tons, compared with a figure of 9,484,000 tons in July, 1951.

THE BRITISH INSTITUTION OF RADIO ENGINEERS.—The General Council of the British Institution of Radio Engineers, 9, Bedford-square, London, W.C.1, have awarded the Clerk Maxwell Premium for 1951 to Dr. H. Paul Williams, for his paper, "Subterranean Communication by Electric Waves." Other awards in respect of 1951 include the Heinrich Hertz Premium to Mr. R. E. Spencer, the Louis Sterling Premium to Mr. Emlyn Jones, the Leslie McMichael Premium to Mr. R. G. Kitchen, the Brabazon Premium to Mr. G. E. Roberts, and the Marconi Premium to Mr. E. G. Rowe. The above awards and a number of examination prizes will be presented at the Institution's annual general meeting on October 8.

* *Proc.I.Mech.E.*, vol. 125, page 383 (1933.)

CALCULATION OF TRANSMISSION-LINE CONSTANTS.*

By REGINALD O. KAPP, B.Sc., M.I.E.E.†

LET me begin by mentioning a few well-known facts. One often wishes to express the voltage and current at one end of a transmission line in terms of the voltage and current at the other end. It is usually the conditions at the receiving end that are known; for these are determined by the load conditions. Hence one generally expresses sending-end voltage and current, $\mathbf{E}_s$ and $\mathbf{I}_s$, in terms of the corresponding, known, receiving-end quantities, $\mathbf{E}_r$ and $\mathbf{I}_r$. The relation between these is expressed accurately by the formulæ

$$\left.\begin{aligned}\mathbf{E}_s &= \mathbf{A}\,\mathbf{E}_r + \mathbf{B}\,\mathbf{I}_r\\ \mathbf{I}_s &= \mathbf{A}\,\mathbf{I}_r + \mathbf{C}\,\mathbf{E}_r\end{aligned}\right\} \quad . \quad . \quad (1)$$

All these symbols do, or may, represent complex quantities; hence the heavy script, which is all too often neglected in such formulæ although it conforms to British Standards. **A**, **B**, **C**, are called the line constants. Unless the line is long no great error is made if the above formulæ are replaced by the simpler ones :

$$\left.\begin{aligned}\mathbf{E}_s &= \mathbf{E}_r + l\,\mathbf{Z}\,\mathbf{I}_r\\ \mathbf{I}_s &= \mathbf{I}_r\end{aligned}\right\} \quad . \quad . \quad (2)$$

Z is the impedance of the line per unit length and equals R + j X, and the length of this line is l. In these simpler formulæ the shunt admittance of the line is neglected. The simplified formulæ are obtained by putting $\mathbf{A} = 1$, $\mathbf{B} = l\mathbf{Z}$, $\mathbf{C} = 0$. The last of these assumptions is not always permissible, even on a short line, when the current is very small; for $\mathbf{C}\,\mathbf{E}_r$ may be large compared with $\mathbf{I}_r$. Then the charging current may not be neglected and **A** cannot be treated as equal to 1; it is, in fact, a little less than 1, as will become apparent in a moment, and hence the receiving-end voltage is higher than the sending-end voltage, this observation being known as the Ferranti effect.

Formulæ for the line constants are to be found in many text books; they are :

$$\left.\begin{aligned}\mathbf{A} &= \cosh\sqrt{\mathbf{Z}\,\mathbf{Y}}\,l\\ \mathbf{B} &= \sqrt{\frac{\mathbf{Z}}{\mathbf{Y}}}\sinh\sqrt{\mathbf{Z}\,\mathbf{Y}}\,l\\ \mathbf{C} &= \sqrt{\frac{\mathbf{Y}}{\mathbf{Z}}}\sinh\sqrt{\mathbf{Z}\,\mathbf{Y}}\,l\end{aligned}\right\} \quad . \quad . \quad (3)$$

where l is the length of the line and **Z** and **Y** are, respectively, the series impedance and the shunt admittance of the line per unit length. $\mathbf{Z} = \mathrm{R} + j\,\omega\,\mathrm{L}$, and, as leakance is neglected in practice, $\mathbf{Y} = j\,\omega\,\mathrm{C}$, so

$$\mathbf{Z}\,\mathbf{Y} = -\,\omega^2\,\mathrm{L}\,\mathrm{C} + j\,\omega\,\mathrm{R}\,\mathrm{C}. \quad . \quad (4)$$

The simple formulæ, equations (2), are rarely accurate enough for long lines. For these, values of **A**, **B**, and **C** have to be evaluated. It can easily be deduced from (4) that

$$l\sqrt{\mathbf{Z}\,\mathbf{Y}} = l\sqrt[4]{\omega^4\,\mathrm{L}^2\,\mathrm{C}^2 + \omega^2\,\mathrm{R}^2\,\mathrm{C}^2} \text{ at an angle of } 90 \text{ deg.} - \tfrac{1}{2}\tan^{-1}\left(\frac{\mathrm{R}}{\omega\,\mathrm{L}}\right) \quad . \quad . \quad (5)$$

When this expression has been evaluated, one can find **A**, **B**, **C**, with the help of tables of the hyperbolic functions of complex quantities. The process is laborious and the tables are not always available. One may avoid their use by the still more laborious process of expanding $\cosh\sqrt{\mathbf{Z}\,\mathbf{Y}}\,l$ and $\sinh\sqrt{\mathbf{Z}\,\mathbf{Y}}\,l$ to as many terms as may be needed for the required accuracy. To do so one writes :

$$\cosh\sqrt{\mathbf{Z}\,\mathbf{Y}}\,l = 1 + \frac{\mathbf{Z}\,\mathbf{Y}}{2\,!}\,l^2 + \frac{\mathbf{Z}^2\,\mathbf{Y}^2}{4\,!}\,l^4\,\frac{\mathbf{Z}^3\,\mathbf{Y}^3}{6\,!}\,l^6 + \ldots$$

$$\sinh\sqrt{\mathbf{Z}\,\mathbf{Y}}\,l = \sqrt{\mathbf{Z}\,\mathbf{Y}}\,l\left(1 + \frac{\mathbf{Z}\,\mathbf{Y}}{3\,!}\,l^2 + \frac{\mathbf{Z}^2\,\mathbf{Y}^2}{5\,!}\,l^4 + \ldots\right) \quad . \quad . \quad . \quad (6)$$

These expressions give some information not evident from equations (1). For lines that are not very long the series can be shown to be rapidly convergent; so each successive term introduces no more than a small correction to the quantity obtained by summing the previous ones. Thus it will be seen that the approximations represented by equations (2) for **A** and **B** are equivalent to selecting only the first terms of the series; for the first term of the series expressing $\sqrt{\frac{\mathbf{Z}}{\mathbf{Y}}}\sinh\sqrt{\mathbf{Z}\,\mathbf{Y}}\,l$ can be easily shown to be $\mathbf{Z}\,l$.

The second approximation to the value for **A** is given by taking the second terms of the expansion, namely, $\frac{\mathbf{Z}\mathbf{Y}}{2\,!}\,l^2$ into account. It will be seen from equations (4) that the value for this is $\frac{1}{2}(-\,\omega^2\,\mathrm{L}\,\mathrm{C} + j\,\omega\,\mathrm{R}\,\mathrm{C})l^2$. The information obtained from this expression is that **A** is a vector quantity that leads the vector $\mathbf{A} = 1$ by the angle $\tan^{-1}\frac{\frac{1}{2}\,\omega\,\mathrm{R}\,\mathrm{C}}{1 - \frac{1}{2}\,\omega^2\,\mathrm{L}\,\mathrm{C}}$ and that this vector has a real component less than unity.

Though informative, the expanded series do not make for easy computation; but there is a third well known way of manipulating the equations and I propose to show that this does make the purely mechanical work of computation very much easier. The first step towards this is to represent the hyperbolic functions of complex quantities as complex quantities, the terms of which are hyperbolic and circular functions of real quantities only. The formulæ on which these manipulations are based are

$$\cosh(\alpha + j\,\beta) = \cosh\alpha\cos\beta + j\sinh\alpha\sin\beta$$

$$\sinh(\alpha + j\,\beta) = \sinh\alpha\cos\beta + j\cosh\alpha\sin\beta.$$

For the present purpose it is necessary to put

$$\sqrt{\mathbf{Z}\,\mathbf{Y}}\,l = \alpha + j\,\beta,$$

so that

$$\left.\begin{aligned}\mathbf{A} &= \cosh\alpha\cos\beta + j\sinh\alpha\sin\beta\\ \mathbf{B} &= \frac{\mathbf{Z}}{\mathbf{Y}}(\sinh\alpha\cos\beta + j\cosh\alpha\sin\beta)\\ \mathbf{C} &= \frac{\mathbf{Y}}{\mathbf{Z}}(\sinh\alpha\cos\beta + j\cosh\alpha\sin\beta)\end{aligned}\right\}. \quad (7)$$

It is easy to deduce from equations (5) that

$$\left.\begin{aligned}\alpha &= l\sqrt[4]{\omega^4\,\mathrm{L}^2\,\mathrm{C}^2 + \omega^2\,\mathrm{R}^2\,\mathrm{C}^2)}\sin\left[\tfrac{1}{2}\tan^{-1}\left(\frac{\mathrm{R}}{\omega\,\mathrm{L}}\right)\right]\\ \beta &= l\sqrt[4]{\omega^2\,\mathrm{L}^2\,\mathrm{C}^2 + \omega^2\,\mathrm{R}^2\,\mathrm{C}^2)}\cos\left[\tfrac{1}{2}\tan^{-1}\left(\frac{\mathrm{R}}{\omega\,\mathrm{L}}\right)\right]\end{aligned}\right\}. \quad . \quad . \quad . \quad (8)$$

Further information is to be obtained from equations (7). It is worth noting that these equations contain only hyperbolic functions of α and only circular functions of β. This observation is instructive. Hyperbolic functions increase with increasing angle while circular functions are periodic. There are, therefore, recurrent values of l for which alternately $\sin\beta$ or $\cos\beta$ is zero, while the other function of β is unity. At these values **A** is either wholly real or wholly imaginary. **B** and **C** are nevertheless complex at these values because $\sqrt{\frac{\mathbf{Z}}{\mathbf{Y}}}$ is complex.

The physical meaning of **A** is that it represents the difference in magnitude and also the phase displacement between the sending-end and the receiving-end voltages. Consider the crest of a voltage wave that starts its journey from the sending end of the line. If the applied voltage is sinusoidal this voltage will be zero after the crest has travelled for a certain distance. The voltage phase at the sending end will then be at an angle of 90 deg. to the voltage phase at the position reached at that moment by the crest. Cos β will be zero and **A** will have the imaginary value $j\sinh\alpha$. By the time the voltage at the sending end has reached a crest value with the same sign as that of the crest being considered, the latter will have travelled a distance known as a wavelength. For this distance, sin β is unity and **A** has the real value $\sinh\alpha$. It will be seen that the scalar value of **A** increases with every wavelength. But in power engineering this observation has no practical significance as all the lines at present in service are well under a quarter wavelength.

Formulæ (8) are no easier to handle than any of the others but they can be simplified a good deal. Let ω^4 and $\omega\sqrt{\mathrm{L}\,\mathrm{C}}$ be taken out of the fourth root

* Paper read before Section G of the British Association at Belfast on Thursday, September 4, 1952. Abridged.

† Professor Emeritus in the University of London.

and we obtain

$$\alpha = l\,\omega\sqrt{\mathrm{L\,C}}\sqrt[4]{\left(1+\frac{\mathrm{R}^2}{\omega^2\mathrm{L}^2}\right)}\sin\left[\tfrac{1}{2}\tan^{-1}\left(\frac{\mathrm{R}}{\omega\,\mathrm{L}}\right)\right]$$

$$\beta = l\,\omega\sqrt{\mathrm{L\,C}}\sqrt[4]{\left(1+\frac{\mathrm{R}^2}{\omega^2\mathrm{L}^2}\right)}\cos\left[\tfrac{1}{2}\tan^{-1}\left(\frac{\mathrm{R}}{\omega\,\mathrm{L}}\right)\right].$$

Let $\frac{\mathrm{R}}{\omega\,\mathrm{L}} = \tan\,\theta$. One can give a physical meaning to this angle, which is appreciated when one writes:

$$\theta = 90\text{ deg.} - \psi.$$

For ψ is the phase displacement between the current and the voltage in a circuit having the reactance ω L and the resistance R. It is known in transmission-line work as the phase angle of the line. The above expressions can be further simplified by the following process, as I have shown already in the B.E.A.M.A. *Journal* for October, 1950:

$$\alpha = l\,\omega\sqrt{\mathrm{L\,C}}\sqrt[4]{1+\tan^2\theta}\,\sin\left(\frac{\theta}{2}\right)$$

$$\beta = l\,\omega\sqrt{\mathrm{L\,C}}\sqrt[4]{1+\tan^2\theta}\,\cos\left(\frac{\theta}{2}\right)$$

As $1 + \tan^2\theta = \sec^2\theta$

$$\sin\left(\frac{\theta}{2}\right) = \sqrt{\frac{1-\cos\theta}{2}},$$

and

$$\cos\left(\frac{\theta}{2}\right) = \sqrt{\frac{1+\cos\theta}{2}},$$

we can write

$$\alpha = l\,\omega\sqrt{\mathrm{L\,C}}\sqrt{\sec\theta\left(\frac{1-\cos\theta}{2}\right)}$$

$$\beta = l\,\omega\sqrt{\mathrm{L\,C}}\sqrt{\sec\theta\left(\frac{1+\cos\theta}{2}\right)},$$

so that

$$\left.\begin{aligned}\alpha &= l\,\omega\sqrt{\mathrm{L\,C}}\sqrt{\frac{\sec\theta-1}{2}}\\ \beta &= l\,\omega\sqrt{\mathrm{L\,C}}\sqrt{\frac{\sec\theta+1}{2}}\end{aligned}\right\} \quad . \quad . \quad (9)$$

The expressions (9) are simpler and more manageable than the expressions (8). They also lead to a better understanding of the physics of transmission.

It will be remembered that a line is said to be one wavelength long when a crest reaches the receiving end at the moment when the next crest is entering the sending end. The receiving-end and sending-end voltages are then in phase and the time that it takes for a crest to traverse the line from one end to the other is the time of one cycle; at the frequency standardised in this country it is $\frac{1}{50}$th of a second. Let us consider the exact value of one wavelength, for which l_0 is a suitable symbol.

For a line of this length β is 2π and so we can write

$$2\pi = l_0\,\omega\sqrt{\mathrm{L\,C}}\sqrt{\frac{\sec\theta+1}{2}}.$$

Writing $f = \frac{\omega}{2\pi}$, we find

$$l_0 = \frac{1}{f\sqrt{\mathrm{L\,C}}\sqrt{\frac{\sec\theta+1}{2}}},$$

and the velocity of wave propagation along the line is

$$l_0 f = \frac{1}{\sqrt{\mathrm{L\,C}}\sqrt{\frac{\sec\theta+1}{2}}}. \quad . \quad (10)$$

In free space $\sqrt{\mathrm{L\,C}}$ is the reciprocal of the velocity of light, but for a metallic conductor this is not quite correct.

$$\mathrm{L} = \left(\frac{\mu_0}{2\pi}\right)\left[l_n\left(\frac{\mathrm{D}}{r}\right)+\tfrac{1}{4}\right].$$

and

$$\mathrm{C} = \frac{2\pi\kappa_0}{l_n\left(\frac{\mathrm{D}}{r}\right)},$$

in rationalised units, so

$$\mathrm{L\,C} = \mu_0\kappa_0\frac{\left[l_n\left(\frac{\mathrm{D}}{r}\right)+\tfrac{1}{4}\right]}{l_n\left(\frac{\mathrm{D}}{r}\right)},$$

where D is the conductor spacing and r the radius of each conductor. Were it not for the number $\frac{1}{4}$ in the above formulæ L C would be exactly equal to $\mu_0\,\kappa_0$, which is the reciprocal of the square of the velocity of light in free space. It appears therefore that the term $\frac{1}{4}$ represents a reduction in the velocity of a wave along a transmission line as compared with the velocity of a wave not tied to a metallic conductor.

As can be found from any text-book on calculation of the inductance of a transmission line, this term of $\frac{1}{4}$ is introduced by taking into consideration the magnetic field inside the conductor. No corresponding term occurs in the expression for the capacitance of a transmission line because there is no electrostatic field inside the conductor. Hence the wave that is tied to a transmission line travels in a medium that can accommodate a greater magnetic flux relative to the electrostatic flux than free space can accommodate. The medium behaves, in other words, like a medium with a permeability a little greater than μ_o while its permittivity is exactly κ_o. In practice, the increase is about 2 per cent., so that it is very nearly true to write $\sqrt{\mathrm{L\,C}} = \frac{1}{0\cdot98\,c_0}$ where c_0 is the velocity of light in free space.

Let us now turn our attention to the other square root in formula (10). If this were unity, the velocity of wave propagation along a transmission line would be about 98 per cent. of the velocity of light. It will be seen that $\sqrt{\frac{\sec\theta+1}{2}}$ would be unity if θ were zero and θ would be zero if the line had no resistance. From this it follows that the resistance of the line causes a reduction in the velocity of wave propagation. It is a reduction accompanied by a loss of energy expressed in terms of $\mathrm{I^2R}$. In other words, the resistance puts the brake on. In this respect its effect differs from that of the magnetic field inside the conductor, which neither consumes energy nor is analagous to a brake.

It will be remembered that θ is $\tan^{-1}\left(\frac{\mathrm{R}}{\omega\,\mathrm{L}}\right)$ and so it decreases with increasing values of ω. This means that the brake imposed by line resistance becomes less effective the higher the frequency. At infinite frequency a finite resistance would have no retarding effect and at zero frequency the retarding effect is infinite and no wave is propagated. This conclusion is really obvious, for with no rate of change of current in a conductor (which is the direct-current condition) a charge applied to one end could never reach the other end.

In practice tan θ varies between $0\cdot1$ and $0\cdot2$. For such values sec-θ is very little more than unity and so the error is small and certainly less than $\frac{1}{2}$ per cent. if $\sqrt{\left(\frac{\sec.\,\theta+1}{2}\right)}$ is put equal to 1. This means that for practical transmission lines the braking effect of ohmic resistance has considerably less influence on the propagation velocity of a wave than does the non-uniform nature of a medium traversed by a metallic conductor. The combined result of these two effects is that one wavelength at 50 cycles is a little over 3,600 miles, a wavelength at the same frequency in free space being 3,720 miles. At lower frequencies θ is greater and the braking action of ohmic resistance therefore more pronounced. Thus it can be easily calculated that at a frequency of one cycle per second the speed of wave propagation along a transmission line would be about half that of light.

Such figures are of only theoretical interest. They convey something to the mind but they do not help the man who has to calculate the performance of a given transmission line. But the formulæ (7), (8) and (9) do lead to other formulæ from which the work of evaluation is made easier for the practical engineer. The simplifications are obtained when one has recognised that in practical cases certain modifications to the formulæ can safely be introduced without making any appreciable error.

The first step is to put $\sqrt{\frac{\sec\theta+1}{2}} = 1$, which, as I have stated above, introduces an error of less than $\frac{1}{2}$ per cent. and usually of much less.

The next step is to replace $\sqrt{\mathrm{L\,C}}$ by $\frac{1}{0\cdot98\,c_0}$. Using this value and expressing β in angular degrees instead of in radians, we obtain for β the simple expression

$$\beta = \left(\frac{360}{2\pi}\right)\left(\frac{l\,\omega}{0\cdot98}c_o\right).$$

At 50 cycles this gives the simple expression

$$\beta = 0\cdot099\,l \text{ when } l \text{ is expressed in miles.}$$

β has a special significance when the line is transmitting a load the impedance of which is equal to the characteristic impedance of the line. Such a load is called the natural load of the line and the characteristic impedance Z_o is defined as $\sqrt{\frac{\mathbf{Z}}{\mathbf{Y}}}$. At this load $\mathbf{I}_r = \mathbf{Z}_o\,\mathbf{E}_r = \sqrt{\frac{\mathbf{Y}}{\mathbf{Z}}}\,\mathbf{E}_r$. It follows from equations (1) and (3) that for this load:

$$\mathbf{E}_s = (\cosh\sqrt{\mathbf{Z\,Y}}\,l + \sinh\sqrt{\mathbf{Z\,Y}}\,l)\,\mathbf{E}_r$$

which can also be written:

$$\mathbf{E}_s = e^{\sqrt{\mathbf{Z\,Y}}\,l}\,\mathbf{E}_r = e^{(\alpha+j\,\beta)}\,\mathbf{E}_r$$

In this expression $e^{\alpha}\,\mathbf{E}_r$ is the scalar value of $\mathbf{E}_s$ and β is the phase angle between $\mathbf{E}_r$ and $\mathbf{E}_s$. It will be seen that for 50 cycles this amounts to $9\cdot9$ deg. per 100 miles. It is customary to work long transmission lines at or near their natural load, for at this load the power factor can be unity in all parts of the line. Hence the phase displacement between any two parts of the line separated by 100 miles is, for most practical operating conditions, roughly 10 deg. It is noteworthy that to a very close approximation the phase displacement per unit length of line is a function only of the frequency and of the velocity of light. The designer of the line cannot hope to influence this displacement.

The next simplification of the formulæ is justified by the fact that for lines up to a few 100 miles in length α is very small. It will be seen from formulæ (8) that $\alpha = \beta\,\tan\,\theta$, where $\left(\frac{\theta}{2}\right)$ is expressed in radians. I have already said that in practice tan θ varies between $0\cdot1$ and $0\cdot2$ and so $\tan\left(\frac{\theta}{2}\right)$ will not exceed $0\cdot1$. For a line 500 miles long, β is $0\cdot86$ radian and if $\tan\left(\frac{\theta}{2}\right)$ is $0\cdot1$, α will be $0\cdot086$. For such small values of α no great error is made if one puts $\cosh\alpha = 1$ and $\sinh\alpha = \alpha$.

Yet another simplification is justified by the small values of θ that occur in practice. It is to put

$$\tan\left(\frac{\theta}{2}\right) = \frac{\theta}{2} = \frac{\mathrm{R}}{2\,\omega\,\mathrm{L}}$$

When this has been done we can write

$$\alpha = \left(\frac{l\,\omega}{0\cdot98\,c_o}\right)\left(\frac{\mathrm{R}}{2\,\omega\,\mathrm{L}}\right)$$

which gives for 50-cycle working

$$\alpha = 0\cdot86\left(\frac{\mathrm{R}}{\omega\,\mathrm{L}}\right)l \times 10^{-3}$$

$\frac{\mathrm{R}}{\omega\,\mathrm{L}}$ is a line characteristic with which transmission engineers are familiar as I have said above and which, usually as its reciprocal, enters into many calculations. It will be convenient to put $\frac{\mathrm{R}}{\omega\,\mathrm{L}} = r$. When this has been done, one can express the three line constants by the following simplified formulæ.

$$\left.\begin{aligned}\mathbf{A} &= \cos(0\cdot099\,l) + j\,0\cdot86\,r\sin(0\cdot099\,l)\,l\,10^{-3}\\ \mathbf{B} &= \sqrt{\frac{\mathbf{Z}}{\mathbf{Y}}}\,[0\cdot86\,r\cos(0\cdot099\,l)\,l\,10^{-3}\\ &\qquad + j\sin(0\cdot099\,l)]\\ \mathbf{C} &= \sqrt{\frac{\mathbf{Y}}{\mathbf{Z}}}\,[0\cdot86\,r\cos(0\cdot099\,l)\,l\,10^{-3}\\ &\qquad + j\sin(0\cdot099l)]\end{aligned}\right\} \quad (10)$$

It will be seen that these formulæ can be used, without tables of hyperbolic functions. They require only the circular functions, which are easily accessible in any office. Though the formulæ are arrived at by making a series of approximations the errors are not all additive; some of them tend to cancel out. Consequently, the total error is very small and does not reach $0\cdot7$ per cent. for either the real or the imaginary component of any of the constants for line lengths up to some 600 miles.

In practice, a very high degree of accuracy is rarely necessary in the calculation of transmission-line constants; for the operating conditions are so uncertain that close prediction of the line performance is never possible. The approximate formulæ (10) are likely to suit all practical purposes.

PROGRESS IN AERONAUTICAL SCIENCE AND ENGINEERING.

Fig. 1.
COMPLETELY LAMINAR BOUNDARY LAYER.

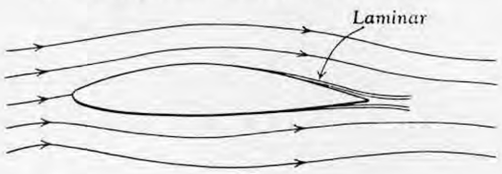


Fig. 2.
LAMINAR AND TURBULENT BOUNDARY LAYER.

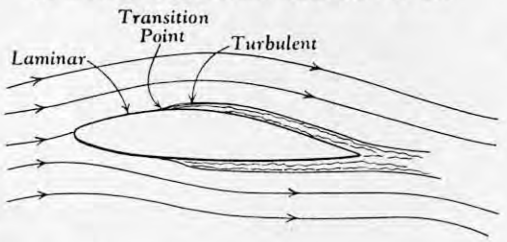


Fig. 3.
LAMINAR AND TURBULENT BOUNDARY LAYER FOLLOWED BY FLOW SEPARATION.

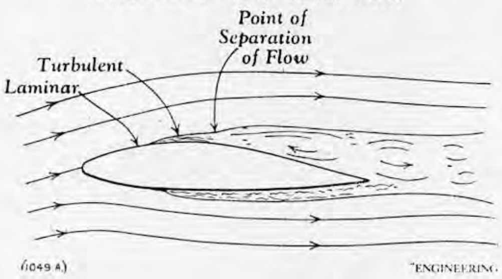


Fig. 4. DRAG OF A "SPITFIRE" AT SEA LEVEL: EFFECT OF COMPRESSIBILITY.

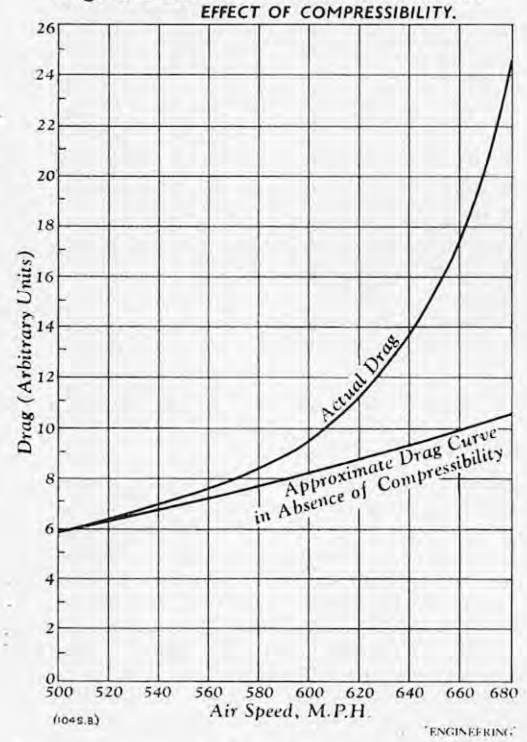
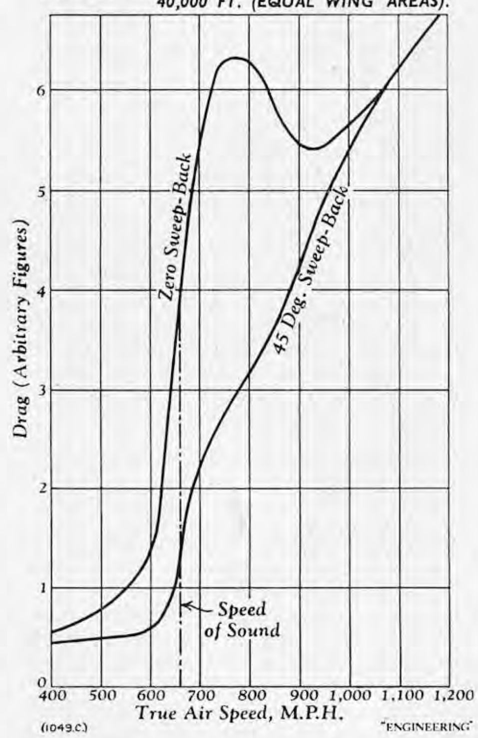


Fig. 5. EFFECT OF SWEEP-BACK ON DRAG AT 40,000 FT. (EQUAL WING AREAS).



PROGRESS IN AERONAUTICAL SCIENCE AND ENGINEERING.*

By SIR BEN LOCKSPEISER, K.C.B., F.R.S.

IT is exactly fifty years since the British Association held its last meeting in Belfast. When the President of this Section, Professor John Perry, gave his address, a century was opening that was about to witness more changes in the space of fifty years than had ever occurred in so short a time before. Industrialisation had already come to Britain, and with it the manufacturing power to command the markets of the world. The rising standard of living and the rapidly growing population confirmed the current belief in the inevitability of progress, but nobody foresaw the rapidity of the advance of science and the swift growth and spread of its power throughout the world. Science and engineering have transformed the old social and economic world that John Perry and his audience knew, and we are still in the process of adapting ourselves to the new technological civilisation in which we find ourselves.

Nothing so surely puts a stamp on an era as the means of communication, travel and transport. England of the Eighteenth Century and the stage-coach were all of a piece; industrialisation and the railways went hand in hand. Now we can fly. It is too soon to estimate the full consequences of so momentous an achievement, but they are bound to be far-reaching. Already we have discovered its consequence in war, for the last decisive military event in our history, the Battle of Britain, was won not, as formerly, on the land or sea, but in the air. In peace, the trend of events is indicated by the striking growth of air traffic. Last year nearly one-third of all the people who crossed the North Atlantic went by air.

Man first took to the air in balloons, but he was at the mercy of all the winds that blew and there was still a year to go when the British Association last met in this city, before the Wright brothers flew in a machine that lifted itself by its own power. The flight at Kitty Hawk in the United States was not more than a few hundred yards at a speed of some 30 miles an hour. It is doubtful whether this machine ever climbed more than 10 ft. above the ground, for it had too much drag, too much weight and too little power to leave much margin for climb. But it was enough. The Wright brothers succeeded where so many others had failed, because of the relentless scientific attack they made on the problem of flight. As Kelly puts it in his biography of the Wright brothers, "It is doubtful if the difficulties and full value of the Wrights' scientific researches within their bicycle shop are yet appreciated. The world knows they were the first to build a machine capable of sustained flight and the first actually to fly; but it is not fully aware of all the tedious, gruelling scientific laboratory work they had to do before flight was possible. Important as was the system of control with which the Wrights' name has been connected, it would not have given them success without their wind-tunnel work which enabled them to design a machine that would lift itself."

The wind-tunnel was their own invention, in which they measured wind forces and determined centres of pressure on curved surfaces at various angles of attack. They studied the difficult problem of stability, particularly that of lateral stability, and it was their mastery of this problem, and the type of control they invented, which enabled them to overcome side-slipping and to avoid the tragic fate which overtook earlier experimenters. They were engineers also. They designed and built their aeroplane on the scientific data they had accumulated, and designed and developed their own engine of some 20 h.p., weighing no more than 240 lb.—itself a triumph of engineering. The achievement of the Wright brothers was, in fact, the outcome of a rare combination of science, invention and engineering. It came as a climax to a long period of human endeavour and was one of the epoch-making achievements in man's history.

It required no great gift of imagination to visualise the revolution this flight had started. The main principles having been established and successfully demonstrated, progress was rapid. Six years after the flight of the Wright brothers, Bleriot crossed the Channel in 40 minutes, and within 16 years Alcock and Brown flew the Atlantic, for the first time, in less than 17 hours. These three machines have changed the course of history.

These three aircraft were probably as good as anybody could have designed and made with the materials, knowledge and techniques available at the time. None of these aircraft, however, could pass muster to-day. In a space of 30 years or so the aeroplane has evolved from a wooden skeleton, covered in fabric, to a streamlined all-metal monoplane built up of hollow shells in aluminium alloy. A glance at the most modern and cleanest of our aircraft, the Comet, in flight, shows the magnitude of the change.

The aeronautical engineer uses the term "clean" to signify design excellence, and if we wish to understand what has happened in the air during fifty years we might take this criterion as a starting-point and ask what it implies. A clean design is one of low air resistance, or drag, as it is usually called. This is obviously of the first importance because the work done in level flight between two points is a product of the drag and the distance. The less the drag the smaller the engine thrust required; and since drag varies with air density and therefore decreases with altitude for any given incidence, it pays, over long distances, to fly as high as possible consistent with the load to be carried and the power characteristics of the engine.

Aerodynamic drag is quite a complicated affair, but certain things are obvious from the start. A fixed undercarriage carried in the air stream creates drag, contributes nothing to lift and is a plain liability on the engine. So also are external struts and bracing wires, and, in fact, any parts of the structure that need not be exposed to the air stream. It is the business of the aeronautical engineer to get rid of drag from these causes. Indeed, as the first step to progress, he was obliged to do so. He tucked the undercarriage away after take-off. He turned from biplanes to monoplanes and eliminated struts and wires, leaving only external wing supports. These, too, disappeared when his increased knowledge of structures, and the production of better materials, brought into being the cantilever wing. He enclosed the cockpit and mounted the engines in nacelles. Now he has buried the engines in the structure, and virtually nothing remains to-day of drag from unnecessary excrescences.

But a clean design means something more than absence of unnecessary projecting parts. It implies certain standards of excellence in its shape and lines. Streamlined, in fact, and the lines we speak of are lines of air flow which, could they be made visible, as they can be experimentally by means of smoke, would be seen, in a perfect shape, to bend smoothly

* Presidential address to Section G of the British Association, delivered at Belfast on Friday, September 5, 1952. Abridged.

PROGRESS IN AERONAUTICAL SCIENCE AND ENGINEERING.

Fig. 6. COMPARATIVE PROPULSIVE EFFICIENCIES.

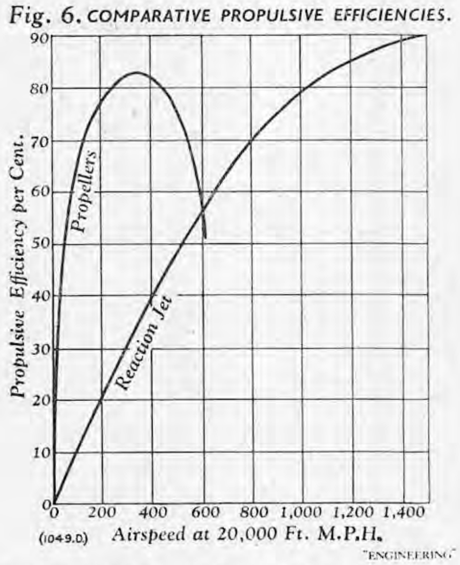


Fig. 7. COMPRESSION ACHIEVED IN RAM-JET BY PLANE NORMAL SHOCK WAVE.

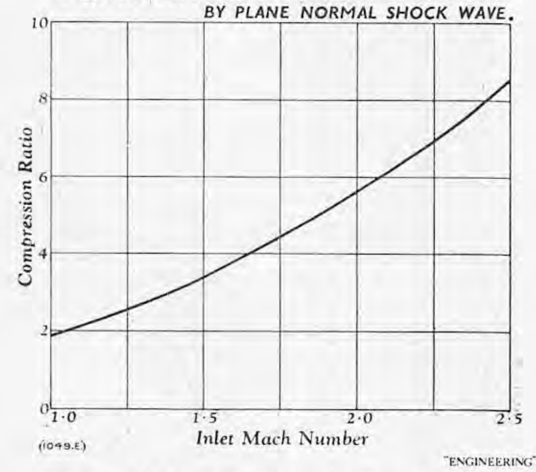
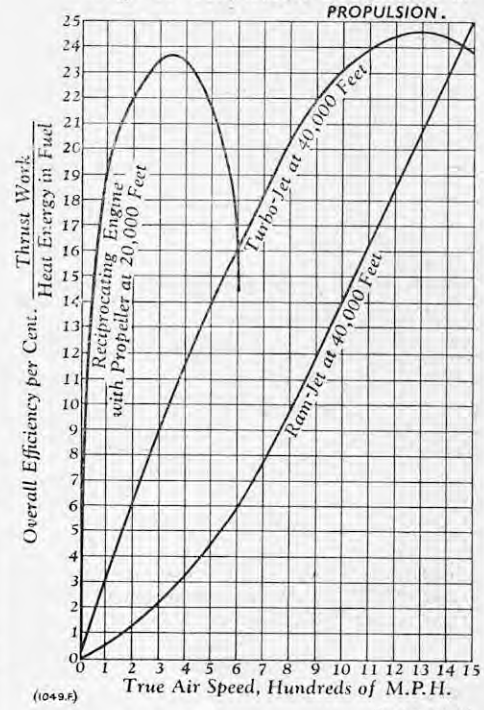


Fig. 8. COMPARISON OF METHODS OF PROPULSION.



and flow snugly round curved surfaces of the structure, leaving no turbulent wake. Any departure from the ideal aerodynamic shape promotes the breakaway of the air flow from the surface and the formation of large-scale eddies of turbulence. This churning up of the air is sheer waste, and the power to produce it makes an unnecessary call on the engine. How large it was, and how great the savings of power which would be possible if profile drag were reduced to its ideal minimum, were first pointed out by Melvill Jones in 1929. His lecture on the subject was first regarded as an exercise in idealism, but something approaching what Melvill Jones foretold was accomplished within 20 years.

The other source of drag, known as induced drag, is bound up fundamentally with lift. Flight is only possible because of shaped bodies called aerofoils whose lift is many times their drag, but, however great this ratio, we cannot have lift without induced drag, both of which arise from the circulation of air around the aerofoil. Induced drag can be reduced by using wings of high aspect ratio (the ratio of the span to the chord) but the choice of aspect ratio in design is mainly determined by other reasons.

Profile drag arises from the normal pressures on the surface of a body and the skin friction which occurs in the boundary layer. Ideally, if the flow within that thin layer were laminar over the whole of the surface we should be down to rock bottom. But, although great advances have been made, we have not attained this ideal state. In laminar flow every particle of air moves tangentially to the surface of the body, and this is not difficult to achieve when the air is first encountered. But in its passage over the wing the boundary layer becomes thicker, and, normally, a transition point is reached when the character of the air flow changes to that of a small-scale turbulence, involving a correspondingly large increase in drag. Figs. 1 to 3 indicate the various types of flow.

A considerable aerodynamic effort in recent years has been devoted in several countries to achieving as large a percentage of laminar flow as possible, and wing sections have been designed and constructed capable of maintaining laminar flow over 60 per cent. of the chord. The design data in this country have come largely from the brilliant mathematics of Goldstein and the construction from the high-class engineering of the aircraft industry. The conditions required are twofold. Firstly, the pressure conditions along the wing must be favourable—that is, the pressure must fall steadily; and secondly, the surface of the wing must be very smooth and free from waviness. This condition is very exacting, as the surface smoothness must be equivalent to that of writing paper, and any waviness of the surface must be restricted to one or two thousandths of an inch, in two inches measured in the direction of the chord. Rather more waviness can be tolerated in the direction along the span. Engineering difficulties in producing so true a wing surface and maintaining it in service are obvious enough.

It is possible to control the boundary layer and delay the onset of turbulence by sucking part of the layer away through slots or a porous surface. Much effort has been given to the solution of this problem both in the United States and in this country, particularly by Griffith. Sufficient experimental work has been done to show the possibility, by wing suction, of moving the point of transition from laminar to turbulent flow back to about 75 per cent. of the chord, and if this principle were applied to the best modern design practice we might, at a conservative estimate, expect to reduce the total aircraft drag by about 25 per cent. This is a big factor which, translated in terms of range, would give a gain of 10 to 15 per cent. for the same take-off weight.

The real obstacle to taking advantage of these scientific and engineering advances arises from the liability of the wing to pick up at low altitudes dust particles and insects which are frequently sufficiently large to cause local breakdown of the laminar flow to the turbulent form. A photograph obtained in flight at the Royal Aircraft Establishment, using an ingenious method, shows up the sharply defined dark triangular patches where local breakdown from laminar to turbulent flow occurs. Each breakdown has been initiated by a minute foreign body at the apex of the triangle. A possible method of minimising this kind of breakdown is to withdraw the turbulent boundary layer through a slot and thus to re-establish laminar flow downstream.

Implicit in the theory underlying the achievement of low drag is the conception of air as an incompressible fluid and, for bodies moving at speeds below and not comparable with the speed of sound, this conception is substantially true in practice. The velocity of sound in air at sea level is about 760 miles per hour and the effect of the compressibility begins to make itself sensibly felt above about 500 miles per hour. One effect of compressibility is to produce an increased drag, rapidly increasing with rising speed and reaching, near the speed of sound, a value very much greater than would be encountered under conditions of incompressible flow. Fig. 4, derived from data obtained by diving a Spitfire from high altitudes, illustrates this.

This is fundamental, for it is impossible to avoid the formation of shock waves, which are the source of the largely increased drag, whenever the velocity of the air relative to the surface appreciably exceeds the local speed of sound. This is bound to happen at a forward speed appreciably below the speed of sound in the atmosphere, because the air is accelerated in its flow over a curved body such as a wing. The shock wave occurs at the downstream end of the local region of supersonic flow, and behind it the speed is subsonic. The position of the shock wave depends on the shape of the wing section and its incidence, as well as on the forward speed. When the shock wave moves back, the low pressure, in the region of supersonic flow ahead of it, extends over a larger fraction of the aerofoil surface, and there is therefore a movement of the centre of pressure with speed and incidence. This causes a considerable change in the stability of the aircraft. The presence of the shock wave may also cause a control surface located at the rear of the aerofoil to become ineffective. At supersonic forward speeds a bow wave is formed, and the flow again becomes stable, with no serious changes in the position of the centre of pressure as the speed or incidence are varied.

The speed of sound in air varies as the square root of the absolute temperature and therefore decreases with altitude. It falls continuously from 760 m.p.h. at sea level until the stratosphere is reached, where the speed is 660 m.p.h. A given aircraft speed represents a higher fraction of the speed of sound at altitude than at sea level, and since it is this fraction, rather than the velocity itself, which is the significant factor in compressibility phenomena, it is usual, in dealing with the performance of high-speed aircraft, to speak of the Mach number, i.e., the ratio of the forward velocity to the local velocity of sound.

It is clear that the onset of shock-wave conditions at high subsonic speeds can be delayed by reducing the acceleration produced by curvature, and high-speed flight therefore calls for thin wings and slim nacelles and bodies. These increase the critical speed, which can be raised still further by the use of swept-back wings, the effect of which is to reduce the effective thickness-to-chord ratio of the wings in the direction of flight. This great advance in, aerodynamic design was first made in Germany and its effect in delaying the rise of drag is illustrated in Fig. 5 (derived from figures given by Sir Harry Garner in his Wilbur Wright lecture, 1952) which compares the drag curves of two hypothetical modern aeroplanes of equal wing areas—one square-winged and the other swept back 45 deg. The diagram illustrates also that the advantages of sweep-back disappears at high Mach numbers.

The drag to be overcome at transonic speeds can therefore be considerably reduced by slimming and sweep-back, and may be further reduced by more knowledge of the behaviour and control of the boundary layer immediately behind the shock waves, perhaps by suction, to prevent turbulence and breakaway of the flow. The speed of sound was thought at one time to constitute an impassable barrier, partly because of the excessive drag to be overcome and partly because of the instability and loss of control likely to arise from the changing flow conditions. Both were, of course, very real difficulties, but in the event both have turned out to be less formidable than anticipated. Much of the information which led to surmounting these obstacles came from rocket-propelled models, and mainly from those experimented on by the National

Advisory Committee on Aeronautics in the United States.

The air resistance at these high speeds is, however, formidable enough, and the thrust to overcome it has only become possible by the introduction of the gas turbine and propulsion by reaction from a very high-speed jet of gas. Propellers, like aircraft wings, are subject to compressibility drag effects, and the combination of forward and rotational velocities introduces increasing drag conditions over a considerable portion of the blade area after about 400 m.p.h. Up to this point from comparatively low speeds the propeller is a very efficient means of propulsion, efficiencies of about 85 per cent. being not uncommon, but beyond this, compressibility drag becomes of increasing significance and the efficiency drops sharply. This is shown in Fig. 6, which contrasts this behaviour with the rise of efficiency of the jet as a means of propulsion.

On this showing, the propeller ought to hold its own with the jet up to speeds of at least 600 m.p.h. and, theoretically, even beyond this figure by the application to propellers of the principles of wing design for reducing compressibility effects, already referred to. But, in practice, propulsion by jet is ahead of the propeller at lower speeds than this, because of other considerations. The elimination of the propeller eliminates also the disturbance of the air flow over the wing. The turbo-jet engine is much lighter and occupies less space than a corresponding piston engine and propeller, offset though this is by the jet engine's higher specific fuel consumption. Range, of course, plays a determining part in the balance of these factors, but it is not the only one. The turbo-jet, particularly with axial-flow compressor, can be built with a much smaller frontal area per unit of thrust than any other type of air-consuming engine, and it can be made to develop thrusts far in excess of anything hitherto obtainable. These very high thrusts obtained from the jet of the gas turbine, coupled with its small frontal area, are the main reasons why it is so eminently suitable for propulsion at high speeds.

The highest credit attaches to Whittle for his pioneering work on the gas turbine, but it is still in its infancy and its future lies in higher efficiency of compression, higher compression ratios and higher gas temperatures. Advances will come from more knowledge on air flow through rows of aerofoils, involving the same kind of problems of compressible flow as we have already encountered in the flow over a wing. The intake of air in a modern gas-turbine engine amounts to about five tons a minute, and we are now just as much concerned about the behaviour of air flowing through an aircraft as over it. A heavy price is paid for turbulence and separation wherever they occur. Higher working gas temperatures may become possible with blade cooling, either by air or liquids, and from materials possessing better creep-resisting properties at high temperatures. It is anticipated that steady advances in aerodynamics, gas dynamics and metallurgy, together with the development of lightweight rotary heat exchangers, will bring about a progressive reduction in the present rather high specific fuel consumption of the gas turbine.

At supersonic speeds the total head pressure at the intake may become so high as to make a compressor superfluous, and, since the turbine is only necessary to drive the compressor, the turbine becomes superfluous also. This leads directly to the simple conception of a shaped tube, called a propulsive duct or ram jet, without any moving parts, as a power unit for supersonic flight. Air is encountered at supersonic velocity and is reduced to subsonic velocity through a shock wave at entry before reaching the combustion chamber. Fig. 7 shows compression ratios at various Mach numbers ideally obtainable from this natural compressor. The duct is designed to permit a suitable reduction of speed through the combustion chamber, where fuel is burned under conditions of constant pressure. The burnt gases are then ejected through the jet pipe. The thermodynamic cycle is thus precisely similar to that of the turbo-jet. Fig. 8 shows estimates of variation of overall propulsive efficiency of the ram jet with aircraft velocity, and compares them with the efficiencies of turbo-jets and reciprocating engines with propellers at their optimum cruising altitudes. At low speeds, the ram jet is, of course, very inefficient, and some form of boost is required to accelerate the aircraft to a sufficiently high speed at which the ram jet can operate economically.

Another type of power unit of limited use in special circumstances in aircraft propulsion is the rocket motor, the characteristic feature of which is that, unlike the power units already described, the oxygen for combustion is not drawn from the surrounding atmosphere but is self-contained within the fuel. The main advantages of the rocket motor are (i) its comparative simplicity and cheapness; (ii) the high thrust per unit area of combustion-chamber cross-section that can be obtained—10,000 to 30,000 lb. per square foot are common, and (iii) the maintenance of approximately constant thrust with altitude. This is peculiar to the rocket motor and is of particular significance in obtaining high rates of climb at high altitudes.

But, of course, a heavy price has to be paid for these characteristics. The rocket motor burns fuel extravagantly to provide the maximum possible thrust. Its specific fuel consumption is very high, about 15 to 20 lb. of fuel being consumed per hour per pound of thrust, as compared with a corresponding figure of about 1 to 2 lb. for the various air-consuming jet-propulsion systems. This type of propulsion is best suited for special purposes, as, for example, for assisted take-off for aircraft, for increasing the performance of interceptor aircraft during the climb and during combat, or for boosting aircraft from the subsonic to the supersonic range.

The rocket motor was developed to a remarkable degree of excellence by Walter in Germany, one of whose motors formed the power unit of the Me. 163 interceptor fighter of the last war. In the first example of an aircraft powered solely by a rocket motor, the main interest in the design (apart from the use of a landing skid) is the large sweep-back of the wings, introduced eight years ago, and the absence of the conventional tail unit. A very similar power unit propelled the German V.2 rocket.

(*To be continued.*)

TRADE PUBLICATIONS.

Air Duct Heating Units.—In a leaflet issued by Eltron (London), Ltd., Accrington Works, Strathmore-road, Croydon, Surrey, are set out the overall dimensions and particulars of the firm's standard air-duct heating units, comprising black-heat safety-sheathed rod-type elements.

Aluminium-Alloy Nomenclature.—On August 3, 1952, T.I. Aluminium, Ltd., Redfern-road, Tyseley, Birmingham, 11, introduced a new coding system for their aluminium alloys. In the new system, which is described in a leaflet issued by the firm, reference numbers are related to the chemical composition of the alloys.

Electric Motors.—An abridged price list of the three-phase alternating-current and fractional horse-power motors, both alternating and direct current, manufactured by them has been received from Higgs Motors Ltd., Witton, Birmingham, 6. Details are also given of the direct-current motors and generators, alternators, and control gear which they produce.

Steam Temperature Control.—A leaflet published by Bailey Meters and Controls Ltd., Moorgate Hall, Moorgate, London, E.C.2, describes the three-element system of steam temperature control for the design and manufacture of which they are responsible.

Trunk and Auto-Manual Exchanges.—A bulletin received from Automatic Telephone and Electric Co. Ltd., Strowger Works, Liverpool 7, deals with trunk and auto-manual exchange switchboards of the sleeve-control type and details the various facilities available and class of service provided.

Heaters and Dryers.—We have received from Birlec, Ltd., Tyburn-road, Erdington, Birmingham 24, two leaflets, one of which describes their high-frequency induction heating unit for soldering and brazing, and the other gives particulars of high-frequency induction heating equipment for forging and upsetting. They have also issued three leaflets dealing, respectively, with their Lectrodryer moisture absorbers for removing water vapour from air or gases; their Lectrodryer de-humidifiers for controlling the relative humidity of process or storage rooms; and their Lectrofilters for removing oil from compressed air. Lectrodryers and Lectrofilters employ activated alumina for the moisture-absorbing element.

Gas Boilers.—Frederick Kay (Engineering), Ltd., Nashleigh Works, Chesham, Buckinghamshire, have issued an illustrated booklet containing operating instructions and specifications of their gas boilers for central heating and hot-water supplies.

CONFERENCE ON PROPERTIES OF METALLIC SURFACES.

A SYMPOSIUM dealing with the "Properties of Metallic Surfaces," arranged by the Metal Physics Committee of the Institute of Metals, will be held at the Royal Institution, Albemarle-street, London, W.1, on Wednesday, November 19, from 9.45 a.m. until 5 p.m. The object of the meeting is to bring together chemists, engineers, metallurgists and physicists to discuss problems of mutual interest. In order to stimulate discussion at the meeting, the papers are supplied in the form of a book, bound in paper covers, to those—whether members of the Institute or not—who register to attend the symposium. Subsequently, the papers and the discussion to which they give rise will be published in cloth-bound form, as a volume in the Institute of Metals "Monograph and Report" series. At the meeting on November 19 two sessions will be held, a morning session from 9.45 until 12.15 p.m., and an afternoon from 2 to 5; the papers will be presented at each of the two sessions by *rapporteurs.*

Seven papers are to be dealt with at the morning session, namely: "Specialised Microscopical Techniques in Metallurgy," by Professor S. Tolansky, F.R.S.; "Radio-isotopes in the Study of Metal-Surface Reactions in Solutions," by Dr. M. T. Simnad; "The Crystalline Character of Abraded Surfaces," by Dr. P. Gay and Dr. P. B. Hirsch; "Diffusion Coatings," by Mr. D. M. Dovey, Dr. I. Jenkins and Mr. K. C. Randle; "The Nature and Properties of the Anodic Film on Aluminium and its Alloys," by Mr. H. W. L. Phillips; "Chemical Behaviour as Influenced by Surface Condition," by Dr. U. R. Evans, F.R.S.; and "The Effect of Method of Preparation on the High-Frequency Surface Resistance of Metals," by Dr. R. G. Chambers and Dr. A. B. Pippard.

Six papers are to form the basis of the discussion at the afternoon session. They comprise: "The Influence of Machining and Grinding Methods on the Mechanical and Physical Condition of Metal Surfaces," by Mr. P. Spear, Mr. I. R. Robinson and Mr. K. J. B. Wolfe; "The Effect of Lubrication and Nature of Superficial Layer after Prolonged Periods of Running," by Dr. F. T. Barwell; "The Effect of Surface Conditions on the Mechanical Properties of Metals, Mainly Single Crystals," by Professor E. N. de C. Andrade, F.R.S.; "The Effect of Surface Condition on the Strength of Brittle Materials," by Professor C. Gurney; "The Influence of Surface Condition on the Fatigue Strength of Steel," by Mr. R. J. Love; and "The Influence of Surface Films on the Friction and Deformation of Surfaces," by Dr. F. P. Bowden, F.R.S., and Dr. D. Tabor.

Registration forms and advance copies of the papers may be obtained, by persons who intend to be present at the meeting, on application to the secretary, the Institute of Metals, 4, Grosvenor-gardens, London, S.W.1. The registration fee for the meeting is 5*s*.

"MULTIPLY-LOADED AND CONTINUOUSLY-LOADED STRUTS": ERRATA.—We regret that two errors occurred in the mathematics of this article, in the middle column on page 202, *ante*. In the 14th line, 2·0167 should read 2·067; and in the last line, the minus sign is missing before the 2.

NORTHAMPTON POLYTECHNIC, LONDON.—Prospectuses of the part-time day and evening courses in engineering, available at the Northampton Polytechnic, St. John-street, London, E.C.1, and of the National College of Horology and Instrument Technology, which is accommodated at the Northampton Polytechnic, have been published. Detailed particulars of the courses, time-tables, fees and other matters are given. Numerous leaflets of special courses of lectures, usually of an advanced or post-graduate character, to be given at the Polytechnic during the coming autumn and winter have also been issued. The courses are concerned with electrical measurements, electrical pulse techniques, servomechanisms, electric traction, analogue computing machines, automatic digital computing machines, applied physics, refractories, limits and fits in engineering design, mechanical vibrations, aircraft materials and structures, soil mechanics, and transductors and magnetic amplifiers. The autumn term begins on September 22.

NOTES ON NEW BOOKS.

Hydraulische Antriebe und Druckmittelsteuerungen an Werkzeugmaschinen.

By A. DÜRR and O. WACHTER. Second edition. Carl Hanser Verlag, Leonhard-Eck-strasse 7, Munich 27, Germany. [Price in paper boards, 12.50 DM.; cloth-bound, 14.80 DM. net.]

THIS book on hydraulic drives and control gears is a revised and enlarged version of a first edition which we reviewed on page 324 of our 168th volume (1949). Some chapters—for instance, those dealing with the requirements of hydraulic oils and the elements of hydraulic drives—have been extensively rewritten, and various more new examples of actual machine tools have been included. The book contains only applications which have been in actual use. Particularly interesting are the chosen examples of hydraulically-operated machine tools, such as lathes, single-spindle automatics, vertical boring and turning mills, copying lathes and boring machines, multi-spindle drilling machines, boring mills, milling and hobbing machines, circular saws, and planing machines. These examples are illustrated by half-tone reproductions, hydraulic layouts and line drawings of details. It is somewhat surprising that there is no example of a grinding machine, because this is the classical hydraulic machine tool. The arrangement of the first edition has been retained. The authors have intentionally abstained from a purely theoretical treatment of hydraulics, and avoid the mistake of seeing in the hydraulic principle a universal remedy for all difficult drives; on the contrary, they point out in the concluding summary that hydraulic drives have definite limitations and are not to be applied indiscriminately to any and every machine tool.

The Watchmaker's Lathe and How to Use It.

By DONALD DE CARLE, F.B.H.I. N.A.G. Press, Limited, 226, Latymer court, Hammersmith, London, W.6. [Price 30s.]

BOOKS on lathes and their operation are legion, but we do not recall one which approaches its subject in quite the manner of this one, or which covers its special field with the same completeness. The watchmaker's lathe is a precision tool *par excellence* and requires correspondingly delicate handling, which can only be ensured by a proper appreciation, on the part of the user, of its construction and capabilities. This understanding Mr. Carle seeks to provide by detailed descriptions of its parts and methods of use, aided by a large number of excellent line illustrations, the work of Mr. E. A. Ayres. Nine chapters are devoted to this fundamental knowledge and the tenth, which occupies about a third of the book, presents ,in alphabetical sequence of the makers' names, or the trade names of the lathes, every lathe of this type now on the market. Thus the book is a reference catalogue as well as a users' text-book, in both of which capacities it should attain to the status of a classic.

The Law Relating to Building and Engineering Contracts.

By W. T. CRESWELL, K.C.; revised by T. R. D. DAVIES. Fifth edition. Sir Isaac Pitman and Sons, Limited, Parker-street, Kingsway, London, W.C.2. [Price 30s. net.]

THIS work, first published in 1921, was originally written for the purpose of reviewing the common types of difficulty and dispute likely to arise during the preparation and execution of building contracts, i.e., contracts between the building owner and the builder, and was based on the experience as an architect and surveyor of the original author, the late Mr. W. T. Creswell. Mr. Davies has now brought the work up to date by the inclusion of references to recent statutes and judgments. The book is not intended for lawyers, but is addressed particularly to the layman, who ought to have considerably more than an acquaintance with the law which can so easily and so seriously affect his daily work; therefore, a full glossary of terms is included. The book deals simply and methodically with the law; relevant extracts from judgments and, where necessary, sufficient of the issues are given to make the whole a logical sequence. The chapter on the prevention, etc., of disputes begins with the counsel of perfection that all disputes would be avoided under a reign of righteousness: a desire to do all as agreed and an absence of desire to exact the pound of flesh. The text fully justifies the title but, though a contract is a contract, whether it is for an insurance office or a hydro-electric scheme, the appendices are taken exclusively from the Standard Forms (Revised 1951) of the Royal Institute of British Architects. No reference is made to the kindred, and almost precisely similar, forms of the Institution of Civil Engineers and the joint publications of the Institutions of Mechanical and Electrical Engineers, all revised at about the same time. This is not a criticism, since one standard form is as good as another, but emphasises the point that the societies publishing the various forms each spend considerable sums of money and absorb the time of busy people in preparing almost identical documents, necessarily subject to an almost continuous process of revision. This is a waste of effort, and perhaps unwise, too, when it is considered that the employer, the building owner, the purchaser (i.e., the person or body who has to pay) according to which Standard Form is used, is more and more tending to become a single entity, the State. It might be suggested that an agreed British Standard form of contract conditions is long overdue.

Data Book for Civil Engineers. Vol. I—Design. Vol II—Specifications and Costs.

By ELWYN E. SEELYE. Second edition. John Wiley and Sons, Incorporated, 440, Fourth-avenue, New York 16, N.Y., U.S.A. [Prices, Vol. I, 10 dols., and Vol. II, 13 dols.]; and Chapman and Hall, Limited, 37, Essex-street, London, W.C.2. [Prices, Vol. I, 80s., and Vol. II, 104s. net.]

THE first editions of these two weighty volumes were published in 1945 and 1946, respectively, Vol. I being reviewed on page 219 of our 161st volume (1946) and Vol. II on page 257 of the 163rd volume of ENGINEERING (1947). In reviewing them, we suggested a few additions which seemed to be desirable, and some of these appear to have been introduced; but the scale of the work is such that, inevitably, the ordinary processes of technical development in seven years have expanded civil engineering so greatly that to have absorbed all the new material into the text would have involved a complete re-writing of many sections. The work is still, of course, almost wholly a compendium of American practice, but many of the short cuts, etc., which are indicated are concerned with physical standards that are common to this country also.

Treatise on Powder Metallurgy. Vol. III.—Classified and Annotated Bibliography.

By PROFESSOR CLAUS G. GOETZEL, Ph.D. Interscience Publishers, Incorporated, 250, Fifth-avenue, New York 1, N.Y., U.S.A. [Price 22 dols.]

THIS is the concluding volume of a trilogy of which Vol. I dealt with the technology of metal powders and their products and Vol. II with applied and physical powder-metallurgy. It comprises two main divisions, Part I being a survey of the literature of the subject and Part II a survey of the relevant patents. Each Part is further sub-divided, Part I under the headings of " Powder Metallurgy—General," " Production and Composition of Powders," " Powder Processing Methods and Equipment," " Powder Metallurgy Products: Their Composition, Properties and Manufacture " and " Theoretical Discourses "; and Part II into three main sections dealing, respectively, with " Production and Composition of Powders," " Powder Processing Methods and Equipment," and " Powder Metallurgy Products, Their Compositions and Manufacture." The work is completed with a cross index of patents, a subject index, and a name index in which references to the literature section and the patents section are distinguished by the use of Arabic and Italic numerals, respectively. The whole may be truly described as a basic work of reference, which the user may well believe to have required, in the compiler's words, " over a dozen years of tedious and sometimes painstaking effort and long hours of work."

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.

Synthetic-Resin Bonded-Paper Insulating Tubes.—A new specification, B.S. No. 1885, has just been published in which are set out the minimum requirements for synthetic-resin bonded-paper insulating tubes of rectangular cross-section for use on electrical power circuits up to 1,000 volts. The new specification constitutes an addition to the published series dealing with insulating material and, apart from the voltage limitation, is complementary to B.S. No. 1314, which covers circular tubes of similar material. The new publication deals with two types of rectangular tube intended for use with direct current and with alternating currents at frequencies of up to 100 cycles per second. The internal side dimensions of the tubes specified range from $\frac{1}{4}$ in. up to 6 in. with wall thicknesses of from $\frac{1}{32}$ in. to $\frac{1}{2}$ in. Tolerances on dimensions and electrical and mechanical properties are specified. Methods of test, including the preparation and conditioning of specimens prior to testing, are described in detail in appendices. [Price 2s. 6d., postage included.]

Code of Practice on Mastic-Asphalt Roofing.—The Council for Codes of Practice for Buildings Construction and Engineering Services, Lambeth Bridge House, London, S.E.1, have now issued, in final form, Code 144.201, covering mastic asphalt roofing and the various accessory materials generally used in conjunction with it. The Code includes recommendations on the preparation of various types of sub-structure, on the thickness and number of coats required for varying conditions, and on methods of protection from solar heat. Advice is given on the preparation for, and the technique of, laying the mastic asphalt. The Code includes a large number of diagrams illustrating methods of laying mastic-asphalt roofing and arrangements for certain closely-associated damp-proof courses. The Code carries the usual warning that, under present conditions, it may not be practicable to carryout all the recommendations [Price 5s. 6d., postage included.]

Code of Practice for Heaters and Stoves.—The Council for Codes of Practice for Buildings, Construction and Engineering Services, Lambeth Bridge House, London, S.E.1, have also issued, in final form, Code No. 403 which relates to open fires, heating stoves and cookers burning solid fuel. It has been drawn up by a committee convened by the Royal Institute of British Architects on behalf of the Council, and is a revision, following comments received, of the draft Code previously issued. The appliances dealt with are open fires, including the convector and non-convector types, with and without back boilers; heating stoves of the openable and closed types; and cookers of the free-standing and combination back-to-back-grate types. General information is given on the fire precautions to be observed when designing hearths and walls adjacent to an appliance. Recommendations are also made on the design of the throat, fireback, flue adapters, air inlets, fireplace recesses, etc. General advice is given on inspection, testing and maintenance. [Price 7s., postage included.]

BOOKS RECEIVED.

United States National Bureau of Standards. Circular No. 531. *Extension and Dissemination of the Electrical and Magnetic Units by the National Bureau of Standards.* By FRANCIS B. SILSBEE. The Superintendent of Documents, U.S. Government Printing Office, Washington 25, D.C., U.S.A. [Price 25 cents.]

Steam Trap Maintenance. By A. S. WADSWORTH. Mechanical World Monographs No. 66. Emmott and Company, Limited, 31, King-street West, Manchester 3. [Price 2s. 6d. net.]

Statistical Tables and Formulas. By PROFESSOR A. HALD. John Wiley and Sons, Incorporated, 440, Fourth-avenue, New York 16, U.S.A. [Price 2·50 dols.]; and Chapman and Hall, Limited, 37, Essex-street, Strand, London, W.C.2. [Price 20s. net.]

Statistical Theory with Engineering Applications. By PROFESSOR A. HALD. John Wiley and Sons, Incorporated, 440, Fourth-avenue, New York 16, U.S.A. [Price 9 dols.]; and Chapman and Hall, Limited, 37, Essex-street, London, W.C.2. [Price 72s. net.]

Hydraulics and the Mechanics of Fluids. By DR. E. H. LEWITT. Ninth edition. Sir Isaac Pitman and Sons, Limited, Pitman House, Parker-street, Kingsway, London, W.C.2. [Price 25s. net.]

Proceedings of the Engineering Production Convention. Sydney, May, 1951. The Organising Committee of the Engineering Production Convention, The Institution of Engineers, Science House, Gloucester- and Essex-streets, Sydney, Australia.