UNIVERSAL TUBE AND SECTION MILL.

THE Henderson universal tube and section mill, described below and illustrated in Figs. 1 to 5, on this and the following pages, has been designed and is made by Tube Making Machines, Limited, of Blaenrhondda, Glamorganshire, and Birmingham, to produce not only welded tube in a variety of materials and cross-sections, but also a similarly wide range of cold-rolled sections, all at one pass through the machine. Certain other operations, such as piercing, embossing or indenting, can also be carried out if required, by the use of ancillary equipment. A working model of the mill was exhibited on the makers' stand at the recent British Industries Fair, at Castle Bromwich.

The general appearance of the mill will be seen from Fig. 1, herewith. Basically, it consists of seven specialised units, which, starting with a strip uncoiler, deal progressively with shearing of strip edges, section-forming, welding, finishing, and cutting-off. The whole mill is controlled from a centrally-situated desk, with complete electrical interlocking. Those units which are not needed for certain operations can be taken out of use as required. If, for instance, the mill is working on rolled sections, the welding unit can be cut out; in the case of a mill which is to be used solely on sections, the welding unit could be omitted altogether. An important feature of the mill, however, is its double-sided construction, which permits the rolling of welded tubes to proceed on one side while the other is set up to produce sections or other unwelded products.

Two sizes of mill are at present in production; their capacities, dimensions, and other particulars are set out in the Table on page 672. Apart from size and capacity, both mills are similar, and can be used for producing tube at speeds varying from 20 ft. to 100 ft. per minute, depending upon the size of the finished product. The speed at which rolled sections can be produced depends upon the nature of the section and the lengths of the pieces required to be cut off. Under certain conditions, it is possible for the maximum figure of 100 ft. per minute for tubes to be exceeded when rolling sections. The mill can be run at different speeds, according to the nature of the product.

The strip uncoiler, to be seen on the left of Fig. 3, stands independently of the main body of the mill. It is of fabricated-steel construction and is double-sided, to permit fresh strip to be loaded while the mill is in operation. When a coil of strip is exhausted, the new coil is brought into line with the operating side of the mill by turning the uncoiling head through 180 deg. The head is carried by a full row of steel balls, and is locked in position by a spring-loaded plunger, which is raised by hand to free the head for rotation. The width of the uncoiler is such that the two coil drums are in line with the two sides of the mill; thus either side can be used for feeding strip according to how the mill is being used. The outer sides of the coil drums are quickly detachable to allow new coils of strip to be swung into position by an overhead crane or other handling equipment. Coils up to 6 ft. in diameter can be accommodated by the uncoiler; the maximum width varies according to the size of the mill, and is shown in the Table. Lubrication of the drum bearings is by means of wick-feed spring-lid oilers, communicating by drilled oilways with a reservoir in the hub.

The shearing unit, in the centre of Fig. 3, on page 671, is situated between the strip uncoiler and the forming section of the mill. It is similar in construction to the roll stands used in the forming and finishing units, to be described later, and shears the edges of the strip to uniform and accurate width by means of four circular shearing discs. It consists of a pair of cast-iron stands, with an outrigger bracket which can be used on either side as required. Mounted in the stands are two shafts carrying the cutters, the top shaft being vertically adjustable in exactly the same way as the roll shafts on the forming and finishing stands. The unit, which is mounted on a fabricated steel base, is provided with entry and leaving rollers and an adjustable strip-guide platform, which, together with the cutters themselves, can be mounted on either side of the base, according to which side of the mill is in use. No drive is necessary on this unit, the cutters being rotated by the friction of the strip as it is drawn through by the mill rolls. If sheared-edge stock of the correct width is being used, the shearing unit can be taken out of commission by removing the cutters and allowing the stock to pass through freely.

The forming unit, on the left of Fig. 2, page 670, is the first of four units which are bolted together to form the main assembly of the mill. It comprises five passes of horizontal rolls, and three passes of auxiliary rolls on vertical shafts, the use of the latter being optional. Their carrying brackets may be attached between any pair of main rolls on either the forming or finishing units, and if not required they may be removed.

Each pass of the main rolls is carried in a pair of cast-iron roll housings, equipped with an outrigger bracket. The roll stands are double-sided and the shafts are identical on each side. The roll shafts are of 3 per cent. nickel-chrome steel, heat-treated to 60 tons per square inch ultimate tensile strength, and ground all over. They are carried in heavy phosphor-bronze bearings, made to B.S.S. 1058, which are continuously lubricated under pressure from the main oiling system. Oil seals are provided on the outer faces of the bearings. The ends of the shafts have keyways and are provided with nuts, threaded to suit the direction of rotation, to retain the interchangeable forming rolls. At each extremity of the shafts is a hardened steel sleeve which forms the inner race of a heavy-duty roller bearing, carried in a housing in the outboard bearing bracket. This bracket can be fitted to either side of the mill, as required. When light products are being run, the outboard bearings may be left out of use.

Adjustment of the height of the top roll shaft in each stand is by means of a detachable handwheel, operating totally-enclosed worms and worm-wheels, which are interconnected to ensure constant alignment of the shafts. The outboard bearing has similar worm and wheel adjustment, connected to the main roll stand by means of a detachable coupling shaft and sleeve couplings.

The forming stands are built on a self-contained fabricated-steel base with a built-in oil sump, and have machined tenons to ensure alignment of the roll stands. In the base of the section is a built-in lubrication system, comprising a gear-type oil pump driven from the main shaft, and an Auto-Klean strainer. From the delivery side of the filter the oil is piped to an adjustable drip feed for the main driving chains, drip feeds to each worm and wheel, and pressure feeds to each main worm-shaft pedestal bearing and roll-shaft journal. A oil-pressure switch is connected to the extremity of the oil supply pipe remote from the pump, so that any reduction of oil pressure below a pre-determined value is notified to the operator by the extinction of a green signal light on the control desk.

The roll driving system comprises an electric motor, mounted on a hinged base to permit adjustment of the chain tension, driving through a multiple-roller chain to a main worm-shaft extending the whole length of the bed. The worm shaft has a splined end to facilitate removal of its driving sprockets, four of which are provided to give different running speeds. Chains of the correct length to suit each size of sprocket are also furnished.

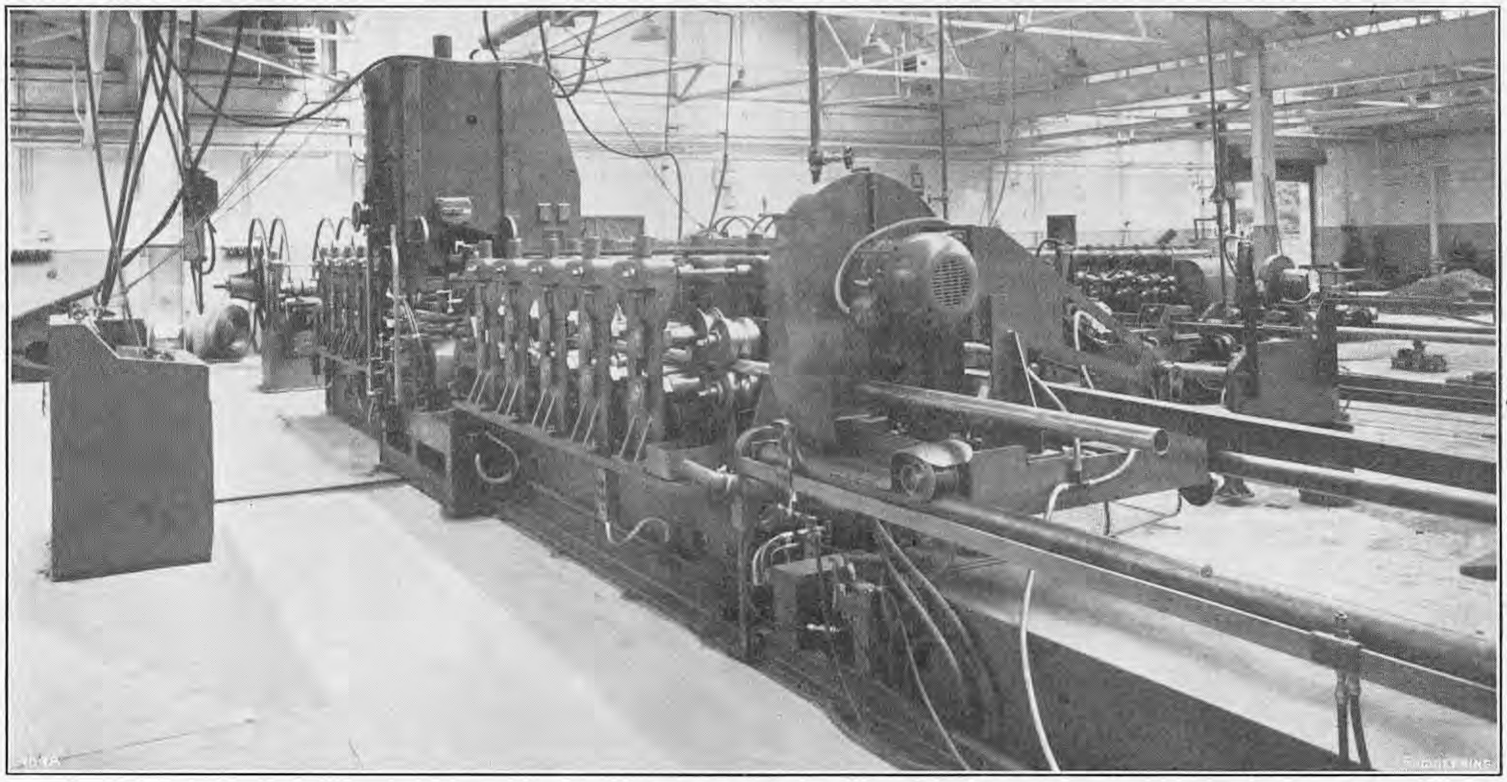

FIG. 1. VIEW OF MILL FROM FINISHING END.

UNIVERSAL TUBE AND SECTION MILL.

TUBE MAKING MACHINES, LIMITED, BLAENRHONDDA, GLAMORGAN.

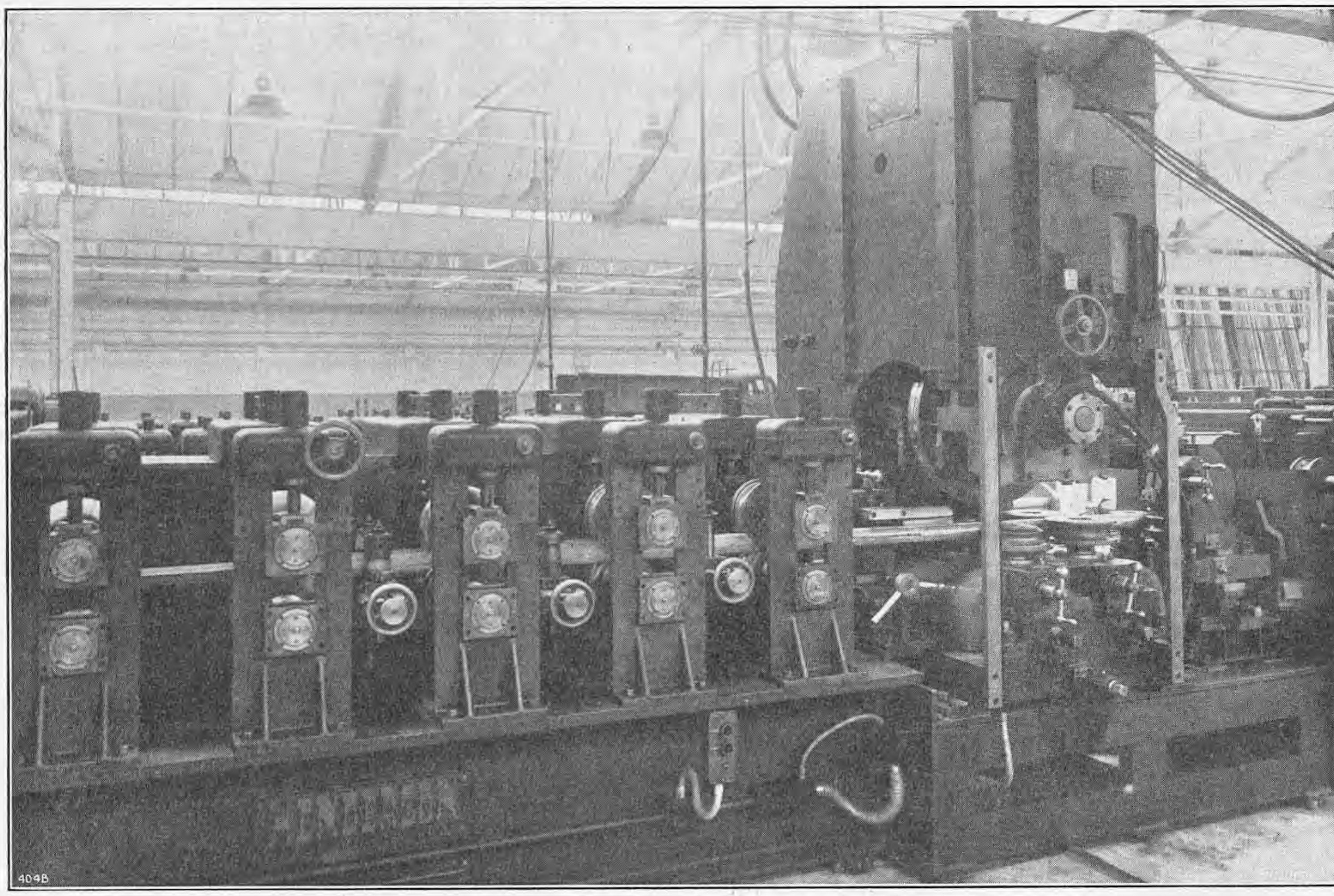

FIG. 2. DRIVE ROLLS AND WELDING HEAD.

to obviate any need to alter the chain length. This composite main-drive shaft is made up in sections carrying two or three worms each. Between each pair of hardened and form-ground worms is a split bronze-lined pedestal bearing, having oil fling grooves and drain holes. The sections of shaft within one bed section are joined together by solid flanged couplings with locating spigots. The end pedestal of each bed section is provided, in addition, with a two-way ball thrust bearing to take the reaction of the drive; the coupling shaft which passes through the welding unit is therefore relieved of any end loading. It is connected to the worm shafts of both the forming and finishing units by means of internally-toothed sleeve couplings which permit a certain amount of angular and axial misalignment between the sections.

The welding unit, Fig. 2, is for automatic electric fusion welding, and is the type most commonly used; but the mill can be fitted, if desired, with an atomic-arc welding head for dealing with stainless steel and other alloys, for which the resistance method is not suitable.

When the formed tube enters the welding unit, it is roughly circular in section, with its longitudinal joint uppermost. The first assembly on the welding unit consists of a hardened and polished steel blade which enters the joint in the tube, and is provided with vertical and lateral adjustment. Its function is to present the joint of the tube in correct relationship to the welding electrodes which immediately follow it. These electrodes are approximately 24 in. in diameter, the side discs being separated by a disc of insulating material. They are also split diametrically for ease in changing. The electrodes therefore comprise four semi-circular rings, through each of which is cut a water-way, furnished with unions at each end for connection to the cooling-water supply. The electrode rings are mounted on an assembly consisting of two hollow drums, bolted together but insulated from each other. Inside each drum, cooling water flows, while the drum rotates with a small clearance in a segment-shaped copper-beryllium alloy casing carrying the mountings for the heavy-duty ball bearings supporting the electrode assembly.

The castings comprising this casing are dowelled and bolted directly to the cast-copper secondary of the transformer; thus, when the space between the water-cooled drums and the machined segment is filled with mercury, an efficient transforming unit results. This has a very short secondary-current path and dispenses with collecting brushes, rotating transformers or other means of current transference. Its rugged mechanical construction and efficient internal cooling give trouble-free service, and long electrode life is ensured by cool running and the absence of water or other coolant on their external surfaces.

To support the tube, and to close its joint under the electrodes, there is a pair of rolls having concentric adjustment controlled by a balanced ball-handle on the front face of the unit. Bodily lateral and height adjustments are provided for these rolls in the form of pre-set controls which need to be adjusted only when setting up for a particular product. Another pair of rolls, similarly adjustable, follows immediately and serves to forge and consolidate the welded seam as the tube passes between them. The final operation on the tube, which is performed on the welding section, is the removal of the external weld fin. This is accomplished by a tool, tipped with tungsten carbide, which is held in a tool holder mounted on a compound slide, against the action of which the tube is supported by a pair of adjustable rolls immediately below. By means of a lever handle, working against limit stops in both directions, provision is made for quick removal of the tool from the work, and replacement to its exact former position. The hot weld fin, removed in the form of swarf by this cutting tool, is coiled by a belt-driven and easily detachable skeleton taper drum, shown in Fig. 4, from which it can be conveniently removed and easily handled as coiled scrap.

For the purpose of producing and occasionally restoring the required exterior form on the electrodes, provision is made to rotate them under power by mechanism within the weld head and to apply a turning tool, Fig. 5, with compound adjustment, the action of which is regulated by a form-generating mechanism. The production of the required form does not depend upon the skill of the operator; it is accurately generated when the operating handwheel is rotated. This method ensures that the minimum of metal is removed at each trimming, while the ability to repeat the form accurately leads to consistent welding results. The fact that the electrodes are turned in position and revolved on their running axes guarantees the concentric truth of their formed surfaces.

The electrode and transformer assembly is mounted in a carriage, with rollers which run on four vertical fixed tracks. Above the carriage is a jack-screw, operated by a worm and wheel, and having a collar upon which bear helical springs, mounted in the carriage. Further lowering of this collar by means of the jack-screw, after contact has been established between the electrodes and the work, will gradually reduce the proportion of the weight carried by the springs, and so increase the electrode pressure, until a point is reached when the whole of the weight of the transformer and electrode assembly is carried by the rotating electrode on the work-piece. Further operation of the jack-screw in a downward direction will bring into use additional springs above the carriage, thus enabling the electrode pressure to be increased still more, so that infinitely variable adjustment between zero and maximum is provided. A simple linkage

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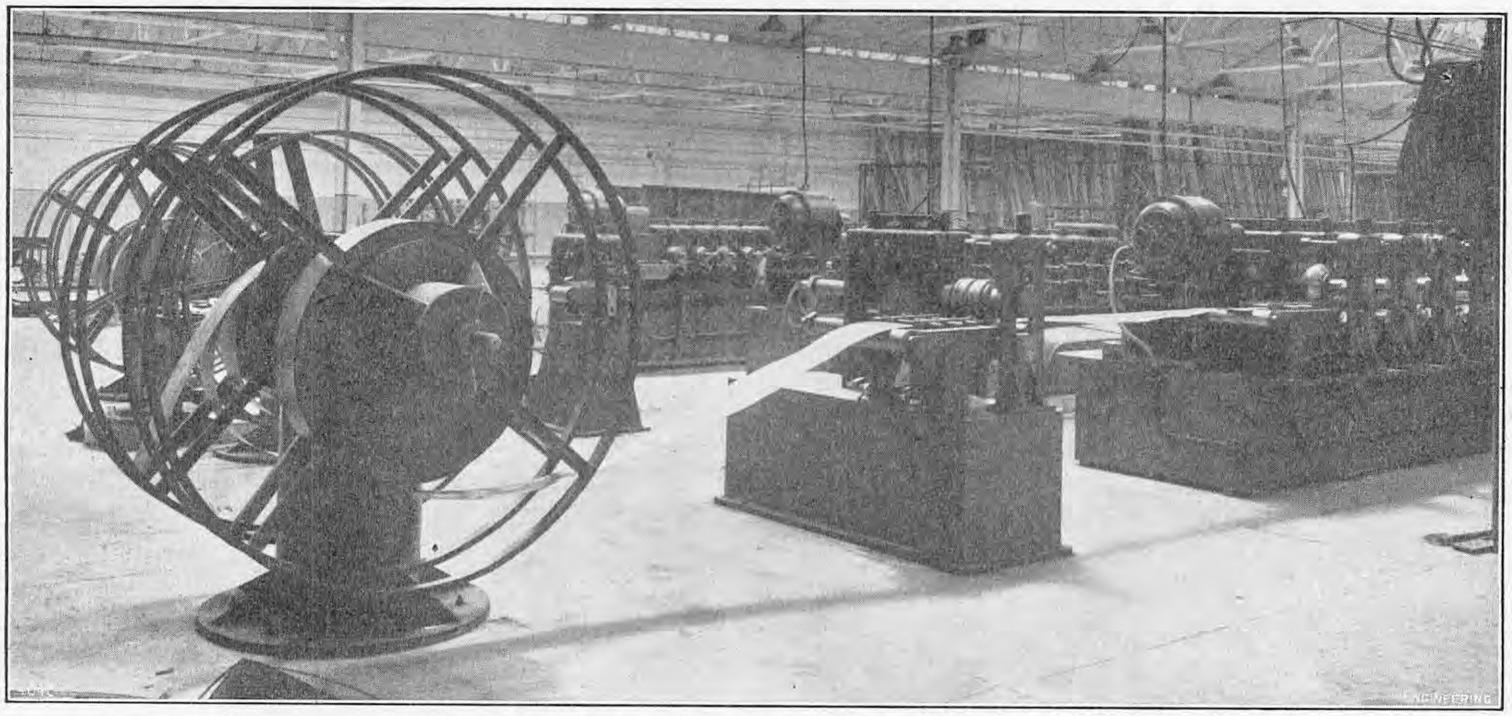


FIG. 3. UNCOILER AND SHEARING MACHINE.

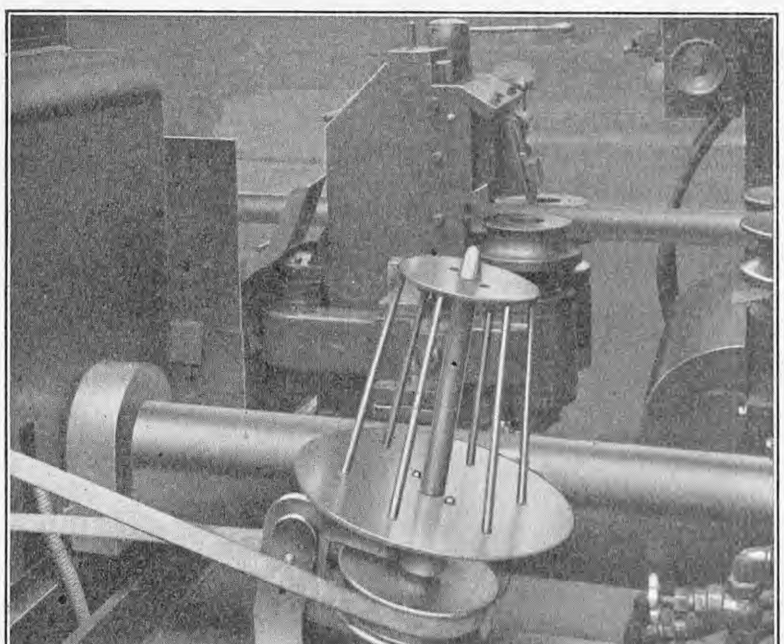


FIG. 4. COILING DRUM FOR WELD FIN.

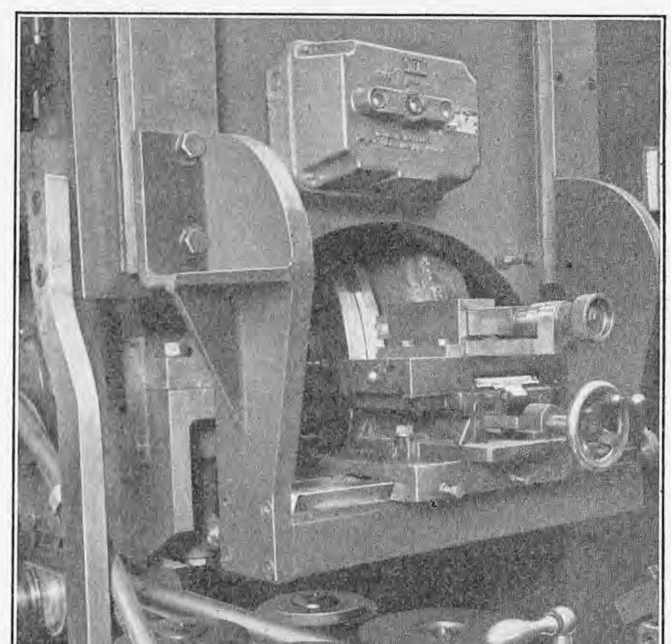


FIG. 5. WELDING UNIT.

and multiplying lever with a pointer working over a graduated scale (it can be seen to the right of the handwheel on the welding unit in Fig. 2) indicates to the operator the pressure exerted.

Power-operated mechanism is also provided within the weld head for raising and lowering the electrode assembly, the control being by two push buttons within easy reach of the operator. Over-running under power, in both directions, is guarded against by adjustable stops working in conjunction with limit switches. The precise final adjustment of electrode pressure is carried out by means of a handwheel mounted on the front face of the welding head, the pressure exerted being registered on the scale. When the pressure-adjustment handwheel is engaged in the driving position, the power drive is automatically rendered inoperative to avoid any possibility of personal injury from a rapidly revolving handwheel.

The finishing of the tube or section is carried out in the five-stand unit, to be seen in Fig. 1. This is similar structurally to that used for forming, and is driven, as already stated, by a flexibly-coupled shaft passing through the welding unit. It has an independent oil sump, and pressure lubrication similar to that on the forming unit Circular tube can normally be finished in three rolling operations after the welding stage, but five stands are provided to enable shapes other than round to be made in one pass. When not required, the idle stands are left without rolls, and the product passes freely between the shafts. On first entering the finishing unit, the tube passes through a container into which coolant is being pumped. The tube is totally immersed and the most of the heat is thereby removed. The residual heat is dissipated by coolant spraying nozzles having an adjustable flow, and situated between each pair of roll shafts. An additional pair of rolls is used for straightening the tubes after sizing and cooling in the main roll stands. They have coupled vertical and individual lateral adjustment, by means of loose handwheels.

The cut-off unit, in the centre of Fig. 1, automatically cuts the finished tube or section into predetermined lengths at mill operation speed. A motor-driven circular saw is mounted on a movable carriage on ball-bearing rollers, and may be used on either side of the mill as required. The operation of the cut-off mechanism is electro-pneumatic, and the sequence is controlled by adjustable trip valves and limit switches. As the tube or section issues from the finishing unit, it passes through clamps on the saw carriage, which are normally open, and enters a run-off channel at the extreme end of the mill. A flag-operated limit switch is set to contact the end of the tube or section at the appropriate length, and, when contact is made, the clamps close, and the saw carriage commences to travel with the tube or section, at the same time beginning the cutting operation. The rate of cut and the length of the saw-carriage travel are adjustable to accommodate different products. At the end of the cut, the saw is lifted clear by a pneumatic cylinder and the clamps open, thus allowing a gravity counterweight to return the carriage to its starting position, the tube or section meanwhile passing through the open clamps to the run-off channel.

The detailed layout of the control system varies according to the type of welding equipment being used. The layout described below relates to the fusion-welding head. If the atomic-arc process is substituted for that of fusion welding, the control desk is modified accordingly. Similarly, if the mill were used for the production of sections only, welding being dispensed with, further simplifications would be possible. The control of the whole mill is centralised in the floor-mounted desk, which is equipped with warning lights and interlocking mechanisms to prevent the mill being operated under wrong conditions, or started in an incorrect sequence. In addition, six push-button stations are provided (three on each side of the mill) giving "start," "inch" and "stop" control of the main driving motor; thus the operator has control of the whole mill from the one position. Push-button control is also provided on the weld head for raising or lowering the head, rotating the welding electrodes for trimming, and for initiating or stopping the welding process.

Electrical interlocking ensures the correct starting sequence as set out below:

(1) No controls are operative unless the air supply is turned on, and its pressure is up to a pre-determined minimum. Conversely, should the supply fail or its pressure drop below this minimum, the whole mill is automatically shut down.

(2) With the air supply present, it is possible to start the motor on the cut-off unit.

(3) Only when the motor of the cut-off unit is running is the main drive control operative.

(4) When the main drive motor is running, the welding process can be initiated, and if the drive motor is stopped the welding current is also stopped automatically. It is thus impossible to have the weld current on when the tube is stationary or not up to running speed, thus eliminating any risk of the damage which might occur to the electrodes if they burned their way into a stationary or slowly-moving tube.

Further conditions that are necessary before the weld start buttons become operative are that the cooling water must be flowing through the welding transformer, and also through the Ignitron tubes. That this cooling water is flowing in sufficient volume is indicated by a green signal light on the control desk. Failure of the flow, or its reduction below a safe minimum, will automatically stop the welding current. Also, the thermal relay in the Ignitron cubicle must be closed. Its operation is automatic and ensures a sufficient delay, after initially switching on the electric supply, for the thermionic valves to reach their working temperature before they are subjected to the working anode voltage. The closing of this relay is indicated by a green signal light on the Ignitron cubicle. In addition to these operational safeguards, a green signal light on the control desk shows that sufficient pressure exists in the two lubrication systems, and a red warning light denotes that the weld current is on.

Two meters are provided or the sloping face of the desk, one indicating the current flowing in the primary of the welding transformer and the other, the current taken by the main driving motor; a constant check is therefore available that the operating conditions are remaining at their set optimum values. Another control enables the main driving motor to be reversed, should it be necessary to back out a length of partly-formed tube at the conclusion of a run of one particular size, or because of faulty entry between the rolls when setting up.

Welding heat control is effected electronically; thus an infinitely variable stepless control is obtained which can be applied "on load." Operation is by a "finger-light" adjustment on the control desk. The electronic gear for this control is housed in a small cubicle, standing on the floor and usually placed near to the control desk. Its function is to control the firing angle of two Ignitron tubes, connected "back to back," which pass the applied voltage to the primary of the welding transformer for a greater or lesser portion of the cycle of the impressed wave form. The control of the Ignitron firing angle is applied by two Thyratron valves, the grid potentials of which are varied in voltage and phase by means of a resistance capacity network, regulated by the hand adjustment. By providing a phase-shift adjustment of approximately 100 deg., the effective current in the primary of the welder transformer can be smoothly varied over a range of about 20 to 1, and, since the heating effect varies as the square of the current, a variation of welding heat is obtained over a 400 to 1 ratio.

Dimensions and Capacities of Mills.

Type.	H/125/25.	H/200/45.
Floor space:		
Length	69 ft.	86 ft.
Width	5 ft.	7 ft.
Height	11 ft. 4 in. at control desk 6 ft. 6 in. 9 ft. 9 in. at welding section	13 ft. 4 in. at control desk 6 ft. 6 in. 9 ft. 9 in. at welding section
Welder capacity	125 kVA	200 kVA
Tube diameter, in.:		
Maximum	$2\frac{1}{2}$	$4\frac{1}{2}$
Minimum	$\frac{1}{2}$	$\frac{3}{4}$
Tube-wall thickness, in.:		
Maximum	0·144	0·187
Minimum	0·028	0·036
Maximum developed width for sections, in. ..	$8\frac{1}{2}$	13
Section thickness, in:		
Maximum	0·144	0·187
Minimum	0·018	0·028
Horse-power of driving motors:		
Main drive	25	30
Cut-off saw	7·5	7·5
Coolant pump	$\frac{1}{4}$	$\frac{1}{4}$
Weld head raise ..	1	1
Electrode rotator ..	1	1
Roll-shaft diameter, in. ..	2	3
Horizontal rolling longitudinal centres, in. ..	16	20
Nominal vertical rolling centres, in.	6	9

THE IRON AND STEEL INSTITUTE.

(*Concluded from page 657.*)

The last two papers on the agenda for the morning session on Thursday, May 1, the second day of the recent two-day annual general meeting of the Iron and Steel Institute, dealt with air infiltration and roof wear in open-hearth furnaces.

Air Infiltration and Roof Wear in Open-Hearth Furnaces.

The first paper was entitled "Measurement of Air Infiltration in Open-Hearth Furnaces," and was by Mr. R. Haynes; the second dealt with "Aerodynamic Factors Associated with the Wear of Open-Hearth Furnace Roofs," and was by Mr. J. A. Leys and Mr. E. T. Leigh. Dr. A. H. Leckie, who presented the first paper, stated that Mr. Haynes had now left the British Iron and Steel Research Association and was engaged on atomic research. Since the paper had been written, added Dr. Leckie, a great deal of additional work had been done and would be reported in due course. In his paper, Mr. R. Haynes, who, at the time of writing it, was head of the Industrial Experimentation Section of the Steelmaking Division of the Association, in Sheffield, stated that, on account of the high operating temperatures of open-hearth furnaces, to attain the greatest efficiency, the entry of cold air must be avoided, except when a controlled amount of excess air was permissible for metallurgical purposes. The present paper referred to means devised for measuring the air which reached the combustion ports. This, it was felt, would be a guide to the correct control of the initial air: fuel ratio, irrespective of the excess air which entered the melting chamber later. For the present work a water-cooled Pitot static tube had been considered to be the best practical method and the measurements had been made in the uptakes of the furnaces, near the actual combustion port, yet easily accessible from outside. The main results of these trials had been to show that, where air fans were employed, infiltration to the ingoing-air system was limited to times when the supply of fan air was restricted. At high rates of blowing there was a tendency for air to escape between the fan and the furnace port. Most of this presumably escaped across the reversing valve directly to the stack. Since the normal running range of positive air fans supplying steel-melting furnaces was appreciably below their full power, the results obtained during the investigation had suggested that, under normal conditions, the actual air reaching the furnace port was much nearer to the metered quantity than had been anticipated hitherto. Efforts to "blow hard" led to considerable leakage of air, and, hence, the air fans now used were apparently more powerful than was necessary; the extra capacity was held in reserve for blowing-through blocked chequers or for burning extra fuel.

In presenting their paper on "Aerodynamic Factors Associated with the Wear of Open-Hearth Furnace Roofs," Mr. J. A. Leys and Mr. E. T. Leigh, who are members of the Aerodynamics Section of the Physics Department of the British Iron and Steel Research Association, said that the flow conditions existing in a model open-hearth furnace had been investigated. A $\frac{1}{24}$-scale model had been built in which the jet direction could be varied, the air uptakes had independent control of the flow rate, and the furnace shape could be altered easily. The experiments had shown that the region of heaviest erosion on the roof was associated with a high-velocity stream of gas which impinged on the surface and turned sharply and in which combustion might still be taking place. It was also associated with the deposition of solid and liquid particles of iron oxide picked up by the jet. As the model technique indicated the location of the regions of heaviest wear, steps taken on the model to suppress the two effects mentioned above could also be applied to an actual furnace. The results suggested that localised erosion could be diminished, firstly by directing the burner, when possible, forward of the furnace centre-line; secondly, by using a single air port, either centrally placed or extending across the whole furnace end; and, thirdly, by using a vertical back wall instead of the more usual sloping one. The control of the burner direction was by far the most important of these three effects. The logical and necessary extension of model work would be the determination of the flow distribution in a working furnace. Some of the problems to be overcome were: the maintenance of the furnace under steady conditions for sufficient time for such a trial to be carried out; the development of an efficient instrument for measuring gas velocities at steelmaking temperatures; and the accurate manipulation of such an instrument in a furnace chamber.

Discussion.

Mr. M. W. Thring, who opened the discussion, said that when open-hearth operators were discussing open-hearth furnaces they usually dwelt upon output in tons per hour, fuel in tons or in therms per ton, and refractories, usually in shillings per ton.

Until excess air was properly measured and controlled, there could be no fair comparison between two open-hearth furnaces. Mr. Haynes's paper was important, because he was concerned with the air which really went through the furnace and not with the air which was thought to go through it; it was important to measure this excess air. Mr. Haynes's paper constituted a challenge to those who built open-hearth furnaces, and the main conclusion was that it was time that an air-tight open-hearth furnace was designed. The paper by Leys and Leigh was concerned primarily with the question of impact and with the erosion of the refractories, and the model technique was quite a suitable one for that purpose. He wondered whether it would be useful to construct the inside surface of furnace models of salt, to replace the silica bricks, and put a water spray in with the fuel stream.

Mr. J. W. Till said that following suggestions obtained from model results, with regard to the alteration of the burner angle, back wall and single air uptake, they were able, at the works of John Summers and Sons, Limited, to modify the furnace structure and reduce the effect of a deep gouge along the back wall. They had been able to straighten out the back wall, and had succeeded in reducing the severe wear. Wear still occurred there, as it must, owing to the type of the furnace, but it was not the deep gouge that occurred formerly. Moreover, they were able to put in a hot patch over the week-end, and that gave them a roof life of 28 weeks. Subsequent rebuildings of the furnace had caused them to merge the two uptakes and produce virtually a single-uptake furnace, and that had maintained the improvement in roof life; in fact, a roof life of from 30 to 33 weeks, including the patch, was not unknown.

Mr. M. P. Newby stated that the results obtained by Mr. Haynes depended very much on accurate gas-velocity measurements, and such measurements were extremely difficult to carry out when the gases were at high temperatures. This was a problem which remained to be solved, namely, to invent a new type of instrument to measure such velocities. Because of this, investigators were still relying on Pitot tubes, although they were not sure whether they were quite good enough for high-temperature measurements. Dr. Leckie had mentioned that a hot wind tunnel was being built to calibrate Pitot tubes under high-temperature conditions, so that their behaviour could be ascertained with certainty. At Battersea, at present, a simple but large piece of apparatus was being built in which town's gas was burnt, producing a high-temperature stream of gas in a known section of a tunnel. The temperature of the stream of gas and the quantity flowing were measured so that the velocity was known accurately, and this enabled their tubes to be calibrated.

Dr. A. H. Leckie and Mr. Leys briefly replied to the discussion and the President adjourned the meeting until 2.15 p.m. The whole of this, the last session of the meeting, was devoted to the discussion of four papers concerned with the presence of hydrogen in steel.

HYDROGEN IN STEEL.

The first paper, entitled "Determination of Hydrogen in Liquid Steel," was by Mr. R. M. Cook, of the United Steel Companies, Limited, and Mr. J. D. Hobson, of the Brown-Firth Research Laboratories. The authors stated that, in the paper, a comparison was made between two methods for the determination of hydrogen, employing a sealed mould and a quenched notched "pencil." The pencil was a specimen produced by pouring liquid steel into a special cast-iron mould. A sample for analysis, nominally $\frac{1}{4}$ in. in diameter by $\frac{1}{2}$ in. long, was broken from the pencil. Figures for hydrogen content, in ml. per 100 grammes, determined on 15 casts of steels made by the acid and the basic open-hearth and the basic electric-arc processes indicated that satisfactory agreement was shown for comparative results obtained by the two methods.

The second paper, "Diffusion of Hydrogen in Iron and Iron Alloys at Elevated Temperatures," was an Andrew Carnegie Research Report of work done at the University of Sheffield by Dr. P. L. Chang and Mr. W. D. G. Bennett. The authors stated that they had investigated the effects of chromium, nickel and molybdenum on the rate of hydrogen permeation in iron. Chromium, it had been found, had little effect on permeation in the γ range but greatly reduced the rate of permeation in the α range.

The title of the third paper was "Distribution of Hydrogen in Large Ingots and Forgings," and was by Mr. J. D. Hobson and Dr. C. Sykes, F.R.S. It described work carried out in the Brown-Firth Research Laboratories, Sheffield, in which the distribution of hydrogen in several cores trepanned from large ingots and forgings had been investigated. The results had indicated that wide variation in hydrogen content existed in the centre of large ingots and forgings. Single determinations, therefore, might give a misleading impression of the average hydrogen content.

"Effect of Hydrogen on the Properties of Low-Alloy Steels" was the title of the fourth paper, concerned with the presence of hydrogen in steel. Like the previous paper, it was by Mr. Hobson and Dr. Sykes and was the last paper on the agenda for the meeting. The authors stated that hydrogen had been introduced into steel specimens by heating them in the gas at high pressures. The results obtained had shown that although there was some loss of notched-bar impact strength in steels containing hydrogen, the main effect of the gas was reflected in loss of ductility. Hydrogen had little effect on the shape of tensile stress/strain curve, but resulted in fracture before elongation and necking reached normal values. The results had also shown that hydrogen introduced by electrolysis or by high-pressure treatment had the same effect. The ductility of transverse and radial test pieces, which was often lower than that of longitudinal specimens, was decreased by the presence of hydrogen. It was concluded to be desirable to adopt steelmaking methods which yielded finished material having low hydrogen contents.

DISCUSSION.

Dr. L. Reeve, in opening the discussion, said that it was symptomatic that of the three major elements in which much interest was taken in the early days of work on gases and non-metallic inclusions, the original emphasis, when the subject had been taken up seriously about 20 years ago, was on oxygen, with a lesser emphasis on nitrogen, but the practical aspects of gases and non-metallic particles seemed now to be favouring hydrogen as the most important of these three elements. In connection with the determination of hydrogen in liquid steel, it was generally implied that samples taken from liquid steel and kept in dry ice should be examined within 24 hours. It was not stated in so many words that they must not be kept longer, but there was a suggestion to that effect. As a matter of practice, it was convenient sometimes to be able to keep the samples for several days. At the Appleby-Frodingham Steel Company it had been found that by the careful storage of the box of dry ice in which the samples were kept in another suitable well-insulated container, the loss of hydrogen which occurred even after seven days (168 hours) was surprisingly small. The samples, therefore, could safely be kept for two or three days, provided due care was taken with regard to the container used.

Another small point, but one of practical importance, was that the particular pencil specimen described in the first paper had been found to be a little too small in diameter, and, if the steel sample which was being poured happened to be on the cold side, there was a danger of a cold shut being formed in the sample, which led to the kind of error mentioned by the authors of the fourth paper. This was that voids occurred down the centre of the specimen and abnormal results were obtained. They had increased the sample diameter from $\frac{1}{4}$ in. to $\frac{3}{8}$ in. with markedly improved results.

The final paper provided the background information to explain what was well known in most test shops in this country: that if there were any doubt concerning the ductility or elongation of a test specimen, it was wise to put off the test for as long as possible. It had always been assumed that hydrogen was a cause of rejects due to "marginal" ductility. It was known that, in the case of ordinary carbon steels, large specimens, if kept under mercury for a period of weeks, and sometimes for months were still giving off a gas which was substantially hydrogen. Thus, no doubt, the improvement in ductility was due to the same phenomenon as was reported by the authors. The special interest of the paper was that the authors had reversed the procedure; they had taken samples of normal ductility and had "pumped" hydrogen into them. The purists had pointed out that although hydrogen was given off from a carbon steel over a long period, and although the ductility of the steel might improve in the course of this evolution, it did not follow that the hydrogen was the cause of the low ductility; there might be two independent phenomena occurring at the same time. The present paper, however, showed that the reverse order was also true, and that if hydrogen were forced into a steel the ductility dropped. That, in his view, clinched the matter.

Mr. D. R. Wood said that Mr. Hobson and Dr. Sykes had put forward evidence to confirm earlier impressions that, while a simple relationship existed between average hydrogen content and ductility, no such relationship existed with hair-line cracking, and the implication of the results quoted in their two papers seemed to be that the segregation of hydrogen was a more significant factor affecting hair-line cracking than was average hydrogen content. It would therefore appear to follow that the hydrogen content of the molten alloy was insufficient evidence on which to predict the formation of hair-line cracks on processing. Considering the effect of hydrogen on ductility, it was surprising, at first sight, to find that the relationship between the average hydrogen content and the reduction in area was both simple and reproducible, in view of the marked segregation of hydrogen which had been shown to occur. If segregation caused erratic hair-line cracking, why did it not cause ductility measurements to be similarly erratic? The explanation might be that cracking required what might be termed activation, such as would be involved in the production of molecular hydrogen in pores, whereas ductility, except in severe cases in which it was also associated with cracking, was dependent on atomic hydrogen in solution and was therefore controlled by diffusion.

Mr. J. E. Russell, referring to the paper by Mr. Hobson and Dr. Sykes on the distribution of hydrogen in large ingots and forgings, said that while, at the English Steel Corporation, Limited, they had never investigated any one core as thoroughly as the authors had done, they certainly would agree that there appeared to be very little systematic top-to-bottom variation of hydrogen content. The authors' work emphasised the need to take more than one hydrogen sample if any representative figures were to be obtained. His colleagues and he, however, had not come across such wide hydrogen variations as the authors had mentioned.

Mr. J. D. Hobson, speaking on the paper by Dr. Chang and Mr. Bennett, stated that if all the published data available on alloying elements were considered, the general conclusion seemed to be that all the elements added tended slightly to reduce the permeation as the amount of element increased, but if one attempted to cross-correlate the various data, some of them on steel and some on alloys, it was almost impossible to get a satisfactory picture, and the investigators did not agree among themselves. Their curves varied in position on the graph, though not in slope. He suggested, therefore, that, if the present authors or others were considering further work of this type, it needed very careful attention to get the absolute values standardised, because these values could not be used, as they stood, to make quantitative calculations applicable to commercial steel. Furthermore, work on these alloy steels had shown that the heat treatment and the structure of the steel had a considerable influence on the rate of permeation.

Mr. R. M. Cook, who was the first author to reply, said that it was gratifying to hear that the determination of the hydrogen content by the notched pencil test could be made several days after casting the specimen by storing this in contact with solid CO_2. Mr. W. D. G. Bennett and Dr. C. Sykes, F.R.S., also briefly replied. Votes of thanks to the authors of the papers, and to the President, concluded the proceedings.

TABULAR METHODS FOR CRITICAL-SPEED CALCULATIONS.

By A. J. MORTON, M.Sc., A.M.I.Mech.E.

THE whirling of rotors and non-uniform shafts is a perennial problem which continues to attract attention in spite of the large volume of work already published on the subject. In the field of the steam turbine in particular, the accurate prediction of critical speeds remains a matter of some difficulty, even though the basic mathematics has been well known to engineers for more than half a century. The complicated form of practical rotors necessitates the use of either graphical or approximate numerical methods, which frequently depend upon one or both of the following assumptions :—

(a) The deflected form of the whirling rotor resembles its static deflection under gravity, or some other arbitrary curve ;

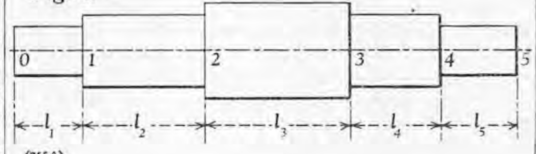
(b) the whole weight of the rotor is concentrated at a finite number of points.

These assumptions, though often very helpful, cannot always be justified, and a completely independent method is desirable. This requirement is fulfilled by the first of two methods of calculation to be described, both of which can be applied to rotors with any number of bearings, overhung or not. Account can easily be taken of gyroscopic couples or of lateral flexibility in the bearings. The methods are very adaptable and can be used either for quick rough estimates or for detailed final calculations. The application of either method yields an equation containing powers of the square of the critical angular velocity, each root corresponding to a different critical speed. Only a limited number of the roots will be trustworthy, this number depending upon the number of sections into which the rotor was divided for purposes of calculation. If, as is usual, only the first critical speed is required, a comparatively simple calculation will suffice. To determine, say, the third critical, a more detailed calculation would be needed, giving a single equation the first three roots of which would correspond accurately to the first three critical speeds. A feature which will appeal to many is that the calculations are performed throughout in terms having a simple physical meaning, mathematical abstruseness being almost entirely avoided.

If gyroscopic effects are ignored, the problem of determining a critical speed is the same as that of determining the natural frequency of a transverse vibration. The methods to be outlined are readily applicable to such problems as the determination of the natural frequency of vibration of turbine blades or beams in general. The present account is confined mainly to ordinary turbine work, for which the methods were first devised. Similar principles, however, can be applied successfully to problems of a different class, such as those involving torsional vibrations, and quite extensive development on these lines seems possible. Representative examples given in the text include a frequency calculation for a simple impulse blade, and critical speed calculations on a Metropolitan-Vickers turbine rotor and a rather unusual marine turbine rotor with a heavy overhung disc. In the final section, the accuracy of the methods for fundamental critical speeds is investigated. Alternative methods applicable to similar problems have been given by N. O. Myklestad,* M.A.Prohl,† A. I. Bellin‡, J. A. Fay§, and others.

In order to derive the fundamental equations, consider a length of uniform cross-section forming part of a rotor which may be assumed for the present to consist of a number of such sections of different lengths and diameters, as in Fig. 1, herewith. Let the junction points of the various uniform sections be 1, 2, 3, . . . n, the point 0 being at one end of the rotor. The rth section, of length l_r, will lie between the points $r-1$ and r.

Fig. 1.



Let x = axial position of a point in the rth section, measured from the point $r-1$;
,, y = lateral deflection of this point from the normal equilibrium position (positive downwards) ;
,, i = $\frac{dy}{dx}$ = slope of elastic curve ;
,, M = bending moment (positive hogging) ;
,, F = shearing force (positive when the external forces to the left of the point considered have a downward resultant) ;
,, Ω = critical angular velocity of rotor ;
,, E = modulus of elasticity ;
,, I_r = diametral moment of inertia of rth section ;
,, w_r = mass per unit length of rth section $\left(\frac{\text{lb.}}{g}\text{ per inch run of rotor}\right)$.

With this convention of signs we have the following relationship for the rth section during whirling :—

$$w_r\,\Omega^2\,y = \frac{dF}{dx} = \frac{d^2M}{dx^2} = E\,I_r\,\frac{d^3i}{dx^3} = E\,I_r\,\frac{d^4y}{dx^4},$$

which leads to the well-known equation

$$\frac{d^4y}{dx^4} - \frac{w_r\,\Omega^2}{E\,I_r}\,y = 0, \quad . \quad . \quad . \quad (1)$$

the orthodox solution of which is

$$y = A_r\cosh m_r x + B_r\sinh m_r x + C_r\cos m_r x + D_r\sin m_r x, \quad (2)$$

where

$$m_r^4 = \frac{w_r\,\Omega^2}{E\,I_r}, \quad . \quad . \quad . \quad (3)$$

and A_r, B_r, C_r and D_r are constants of integration.

For the present purpose, it is simplest to assume a solution in series of the form

$$y = a_0 + a_1 x + \frac{1}{2\,!}\,a_2 x^2 + \frac{1}{3\,!}\,a_3 x^3 + \ldots \quad (4)$$

which leads to

$$\frac{d^4y}{dx^4} = a_4 + a_5 x + \tfrac{1}{2}\,a_6 x^2 + \ldots$$

Equating coefficients of powers of x on each side of the equation

$$\frac{d^4y}{dx^4} = m_r^4\,y,$$

we obtain all the coefficients in terms of a_0, a_1, a_2 and a_3, giving

$$\left.\begin{aligned}
y &= a_0\left(1 + \frac{m_r^4}{4\,!}x^4 + \frac{m_r^8}{8\,!}x^8 + \ldots\right) + a_1\left(x + \frac{m_r^4}{5\,!}x^5 + \frac{m_r^8}{9\,!}x^9 + \ldots\right)\\
&\quad + a_2\left(\frac{1}{2\,!}x^2 + \frac{1}{6\,!}m_r^4x^6 + \frac{1}{10\,!}m_r^8x^{10} + \ldots\right) + a_3\left(\frac{1}{3\,!}x^3 + \frac{1}{7\,!}m_r^4x^7 + \frac{1}{11\,!}m_r^8x^{11} + \ldots\right)\\
i &= a_0\left(\frac{m_r^4}{3\,!}x^3 + \frac{m_r^8}{7\,!}x^7 + \ldots\right) + a_1\left(1 + \frac{m_r^4}{4\,!}x^4 + \frac{m_r^8}{8\,!}x^8 + \ldots\right)\\
&\quad + a_2\left(x + \frac{1}{5\,!}m_r^4x^5 + \frac{1}{9\,!}m_r^8x^9 + \ldots\right) + a_3\left(\frac{1}{2\,!}x^2 + \frac{1}{6\,!}m_r^4x^6 + \frac{1}{10\,!}m_r^8x^{10} + \ldots\right)\\
\frac{M}{E\,I_r} &= a_0\left(\frac{m_r^4}{2\,!}x^2 + \frac{m_r^8}{6\,!}x^6 + \ldots\right) + a_1\left(\frac{m_r^4}{3\,!}x^3 + \frac{m_r^8}{7\,!}x^7 + \ldots\right)\\
&\quad + a_2\left(1 + \frac{1}{4\,!}m_r^4x^4 + \frac{1}{8\,!}m_r^8x^8 + \ldots\right) + a_3\left(x + \frac{1}{5\,!}m_r^4x^5 + \frac{1}{9\,!}m_r^8x^9 + \ldots\right)\\
\frac{F}{E\,I_r} &= a_0\left(m_r^4x + \frac{m_r^8}{5\,!}x^5 + \ldots\right) + a_1\left(\frac{m_r^4}{2\,!}x^2 + \frac{m_r^8}{6\,!}x^6 + \ldots\right)\\
&\quad + a_2\left(\frac{1}{3\,!}m_r^4x^3 + \frac{1}{7\,!}m_r^8x^7 + \ldots\right) + a_3\left(1 + \frac{1}{4\,!}m_r^4x^4 + \frac{1}{8\,!}m_r^8x^8 + \ldots\right)
\end{aligned}\right\}\ (5)$$

The series converge very rapidly for practical values of $m_r x$, and for the present purpose all terms except the first in each bracket will be neglected. The error due to this procedure is considered later.

Since $x = 0$ at the point $r-1$,

$$y_{r-1} = a_0\,; \quad M_{r-1} = E\,I_r\,a_2$$
$$i_{r-1} = a_1\,; \quad F_{r-1} = E\,I_r\,a_3.$$

Making these substitutions and writing $x = l_r$, corresponding to the point r, equations (5) become, taking only the first term in each bracket,

$$\left.\begin{aligned}
y_r &= y_{r-1} + l_r\,i_{r-1} + \frac{l_r^2}{2\,E\,I_r}\,M_{r-1} + \frac{l_r^3}{6\,E\,I_r}\,F_{r-1}\\
i_r &= \frac{m_r^4\,l_r^3}{6}\,y_{r-1} + i_{r-1} + \frac{l_r}{E\,I_r}\,M_{r-1} + \frac{l_r^2}{2\,E\,I_r}\,F_{r-1}\\
M_r &= \tfrac{1}{2}\,E\,I_r\,m_r^4\,l_r^2\,y_{r-1} + \tfrac{1}{6}\,E\,I_r\,m_r^4\,l_r^3\,i_{r-1} + M_{r-1} + l_r\,F_{r-1}\\
F_r &= E\,I_r\,m_r^4\,l_r\,y_{r-1} + \tfrac{1}{2}\,E\,I_r\,m_r^4\,l_r^2\,i_{r-1} + \tfrac{1}{6}\,m_r^4\,l_r^3\,M_{r-1} + F_{r-1}
\end{aligned}\right\}\ (6)$$

Remembering that m_r^4 is defined in equation (3), we make the substitutions

$$a_r = l_r\,; \quad b_r = \frac{l_r}{E\,I_r}\,; \quad c_r = \frac{l_r^2}{2\,E\,I_r}\,; \quad d_r = \frac{l_r^3}{6\,E\,I_r}$$
$$e_r = w_r\,l_r\,; \quad f_r = \frac{w_r\,l_r^2}{2}\,; \quad g_r = \frac{w_r\,l_r^3}{6}\,; \quad h_r = \frac{w_r\,l_r^3}{6\,E\,I_r}\,;$$
$$u = \frac{\Omega^2}{10^6}.$$

Equations (6) reduce to the simple form

$$\left.\begin{aligned}
y_r &= y_{r-1} + a_r\,i_{r-1} + c_r\,M_{r-1} + d_r\,F_{r-1}\\
i_r &= 10^6\,h_r\,u\,y_{r-1} + i_{r-1} + b_r\,M_{r-1} + c_r\,F_{r-1}\\
M_r &= 10^6\,f_r\,u\,y_{r-1} + 10^6\,g_r\,u\,i_{r-1} + M_{r-1} + a_r\,F_{r-1}\\
F_r &= 10^6\,e_r\,u\,y_{r-1} + 10^6\,f_r\,u\,i_{r-1} + 10^6\,h_r\,u\,M_{r-1} + F_{r-1}
\end{aligned}\right\}\ (7)$$

The same result can be obtained from equation (2) by expanding the trigonometrical and hyperbolic functions as Maclaurin series, but the derivation is rather longer.

In applying the first of the two methods referred to above to calculate a fundamental whirling speed, the eight quantities a_r, b_r, c_r . . . h_r are first calculated for each section of the rotor and tabulated for reference. By applying equations (7) to section 1 of the rotor, we can obtain y_1, i_1, M_1 and F_1 in terms of y_0, i_0, M_0 and F_0, the quantity u appearing in some of the coefficients. Since the point 0 is at one end of the rotor, two of the four quantities y_0, i_0, M_0 and F_0 will usually be zero. Table 1, herewith, lists the three common cases, assuming for the present that the bearings are perfectly rigid laterally.

TABLE I.

Type of Bearing.	End Conditions.	Unknowns.
Short	$y_0 = M_0 = 0$	i_0, F_0
Long	$y_0 = i_0 = 0$	M_0, F_0
No bearing (free end)	$M_0 = F_0 = 0$	y_0, i_0

Thus, in general, y_1, i_1, M_1 and F_1 can be expressed as linear functions of two unknowns, some of the coefficients containing the quantity u which is to be determined. By applying equations (7) to section 2 of the rotor, y_2, i_2, M_2 and F_2 can be expressed in terms of y_1, i_1, M_1 and F_1 and, hence, in terms of the two original unknowns. This can be repeated for each section in turn until the point n at the other end of the rotor is reached. We now have y_n, i_n, M_n and F_n all expressed as functions of the same two unknowns, with powers of u appearing in the coefficients. The known conditions at this point will require two of these four quantities to be zero, as in Table I, giving two simultaneous equations of the form

$$F_1(u)\,\alpha_0 + f_1(u)\,\beta_0 = 0$$
$$F_2(u)\,\alpha_0 + f_2(u)\,\beta_0 = 0,$$

where F_1, F_2, f_1, f_2 all contain powers of u, and α_0

* "Vibration Analysis," page 184. McGraw-Hill (1944).

† "A General Method for Calculating Critical Speeds of Flexible Rotors." *Trans. A.S.M.E.: Journal of Applied Mechanics*, vol. 12, page A-142 (1945).

‡ "Determination of the Natural Frequencies of the Bending Vibration of Beams." *Trans. A.S.M.E.: Journal of Applied Mechanics*, vol. 14, page 1 (1947).

§ "A Method of Determining the Natural Frequencies of Bending Vibration of Uniform Beams." *Journal of he Am. Soc. Nav. Eng.*, vol. 60, page 316 (1948).

and β_0 are the original unknowns. These equations can only be true for real values of α_0 and β_0 if

$$\frac{F_1(u)}{F_2(u)} = \frac{f_1(u)}{f_2(u)}.$$

The equation is best solved for u by trial and error. In general it will have a number of real roots, but most of these will be useless since, for high values of u (i.e., high speeds of rotation), the quantities $m_r l_r$ for the various sections will be so large as to invalidate the approximations employed in deducing equations (6). The lowest root, representing the fundamental critical speed, will however be dependable if care is exercised initially in dividing up the rotor into sections, and as many of the higher roots as required can be made dependable by making the sections short enough. The entire calculation can be carried out in tabular form as shown in the following example, in which the natural vibration-frequency of a turbine blade is determined. All the numerical work was done on a 10-in. slide rule.

The term "whirling," applied to a rotating system, is rather loosely used to imply simultaneous vibration at the same frequency in two mutually perpendicular planes, resulting in a circular or elliptical motion. Either of the two components of the motion can also be excited independently without altering the frequency, in which case the rotor is merely vibrating laterally in a single plane. Consequently, the number of revolutions per minute which the rotor makes at its critical or "whirling" speed is the same as the number of cycles per minute with which it executes free uniplanar transverse vibrations. The problem of determining a natural frequency of transverse vibration is therefore the same as that of determining a critical speed, and the same equations apply to both cases. This is not true, however, where gyroscopic effects are of importance—a case which will be discussed later—but such instances are comparatively rare.

In the present example, gyroscopic couples are negligible, so that the natural transverse frequency of the symmetrical impulse blade shown in Fig. 2, herewith, can be found by the method for critical speeds described above, the problem forming a straightforward introduction to the numerical procedure. The blade is a cantilever, fixed at the root end, and consists of two uniform sections, details of which are given in Table II, below; w_r is obtained by dividing the weight per unit length by the gravitational acceleration g. To obtain a reasonably accurate result, the root is treated as a single uniform section, and the blade

TABLE II.

Section.	Length.	Moment of Inertia.	Weight of Blade per in. run.	w_r
Root	$1\frac{1}{4}$ in.	0·01537 in.⁴	0·1331 lb.	$0\cdot\overset{3}{0}3442$
Blade	$4\frac{1}{2}$ in.	0·001696 in.⁴	0·0408 lb.	$0\cdot\overset{3}{0}1056$

TABLE III.

r.	a_r.	$10^6 \times b_r$.	$10^6 \times c_r$.	$10^6 \times d_r$.	e_r.	f_r.	g_r.	$10^6 \times h_r$.
1	1·250	2·711	1·695	0·706	$0\cdot\overset{3}{0}431$	$0\cdot\overset{3}{0}2689$	$0\cdot\overset{3}{0}1121$	$0\cdot\overset{3}{0}2431$
2-4	1·500	29·50	22·10	11·06	$0\cdot\overset{3}{0}1585$	$0\cdot\overset{3}{0}1188$	$0\cdot\overset{4}{0}594$	$0\cdot\overset{2}{0}1168$

TABLE IV.—*Coefficients for Section 1 of Blade.*

—	M_0.	$u\,M_0$.	F_0.
y_1	1·695 (—6)		0·706 (—6)
i_1	2·711 (—6)		1·695 (—6)
M_1	1		1·250
F_1		$0\cdot\overset{3}{0}2431$	1

divided into three equal sections, making four in all. The constants $a_r, b_r \ldots h_r$, listed in Table III, above, are first calculated for each section on the assumption that

$$E = 30 \times 10^6 \text{ lb. per sq. in.}$$
$$g = 386\cdot4 \text{ in. per sec.}^2$$

Since the end 0 of the blade is encastré,

$$y_0 = i_0 = 0.$$

Equations (7) now give for the first section

$$y_1 = 10^{-6}(1\cdot695\,M_0 + 0\cdot706\,F_0)$$
$$i_1 = 10^{-6}(2\cdot711\,M_0 + 1\cdot695\,F_0)$$
$$M_1 = M_0 + 1\cdot250\,F_0$$
$$F_1 = 0\cdot\overset{3}{0}2431\,u\,M_0 + F_0.$$

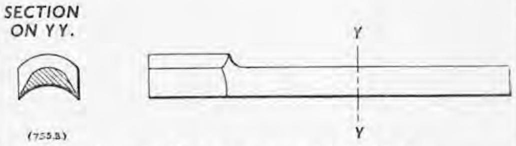
These expressions need only be set out as in Table IV, herewith, which shows coefficients of M_0, $u\,M_0$ and F_0. The number in brackets indicates the power of 10 by which the number immediately above must be multiplied.

Equations (7) are now used to calculate the coefficients of M_0, $u\,M_0$, F_0 and $u\,F_0$ which appear in the expressions for y_2, i_2, M_2 and F_2, the work being shown in Table V, below.

TABLE V.—*Coefficients for Section 2 of Blade.*

—	M_0.	$u\,M_0$.	F_0.	$u\,F_0$.
y_1	1·695		0·706	
$a_2\,i_1$	4·07		2·542	
$c_2\,M_1$	22·10		27·64	
$d_2\,F_1$		$0\cdot\overset{2}{0}2690$	11·06	
y_2	27·87	$0\cdot\overset{2}{0}2690$	41·95	
	(—6)	(—6)	(—6)	
$10^6\,h_2\,u\,y_1$		$0\cdot\overset{2}{0}1980$		$0\cdot\overset{3}{0}825$
i_1	2·711		1·695	
$b_2\,M_1$	29·50		36·88	
$c_2\,F_1$		$0\cdot\overset{2}{0}538$	22·10	
i_2	32·21	$0\cdot\overset{2}{0}736$	60·7	$0\cdot\overset{3}{0}825$
	(—6)	(—6)	(—6)	(—6)
$10^6\,f_2\,u\,y_1$		$0\cdot\overset{3}{0}2014$		$0\cdot\overset{4}{0}839$
$10^6\,g_2\,u\,i_1$		$0\cdot\overset{3}{0}1611$		$0\cdot\overset{3}{0}1007$
M_1	1		1·250	
$a_2\,F_1$		$0\cdot\overset{3}{0}3647$	1·500	
M_2	1	$0\cdot\overset{3}{0}727$	2·750	$0\cdot\overset{3}{0}1846$
$10^6\,e_2\,u\,y_1$		$0\cdot\overset{3}{0}2687$		$0\cdot\overset{3}{0}1120$
$10^6\,f_2\,u\,i_1$		$0\cdot\overset{3}{0}3220$		$0\cdot\overset{3}{0}2012$
$10^6\,h_2\,u\,M_1$		$0\cdot\overset{2}{0}1168$		$0\cdot\overset{2}{0}1460$
F_1		$0\cdot\overset{3}{0}2431$	1	
F_2		$0\cdot\overset{2}{0}2002$	1	$0\cdot\overset{2}{0}1773$

Fig. 2.



Proceeding in this way, we obtain finally

$$M_4 = (1 + 0\cdot0414\,u + 0\cdot\overset{4}{0}1643\,u^2 + 0\cdot\overset{9}{0}1865\,u^3)\,M_0$$
$$+ (5\cdot75 + 0\cdot07375\,u + 0\cdot\overset{5}{0}908\,u^2)\,F_0$$

$$F_4 = (0\cdot03549\,u + 0\cdot\overset{4}{0}3339\,u^2 + 0\cdot\overset{8}{0}1257\,u^3)\,M_0$$
$$+ (1 + 0\cdot07575\,u + 0\cdot\overset{4}{0}2881\,u^2 + 0\cdot\overset{10}{0}573\,u^3)\,F_0$$

where the figures above the ciphers indicate the number of ciphers.

Since the point 4 is at a free end,

$$M_4 = F_4 = 0.$$

Hence,

$$\frac{1 + 0\cdot0414\,u + 0\cdot\overset{4}{0}1643\,u^2 + 0\cdot\overset{9}{0}1865\,u^3}{0\cdot03549\,u + 0\cdot\overset{4}{0}3339\,u^2 + 0\cdot\overset{8}{0}1257\,u^3}$$
$$= \frac{5\cdot75 + 0\cdot07375\,u + 0\cdot\overset{5}{0}908\,u^2}{1 + 0\cdot07575\,u + 0\cdot\overset{4}{0}2881\,u^2 + 0\cdot\overset{10}{0}573\,u^3}. \quad (8)$$

Solving by trial and error for the least positive root in u, we obtain $u = 12\cdot15$, $\Omega = 3{,}486$ radians per sec., and frequency = 555 cycles per sec.

This result is probably $\frac{1}{2}$ per cent. to $\frac{3}{4}$ per cent. too low, as will be seen later. The error could be made imperceptible on a slide rule by dividing the blade into, say, six sections instead of the four here employed, but such accuracy is rarely justifiable in practice. All the terms in u^3 are negligible and need not be calculated. If, as just mentioned, more and shorter sections were employed, the result would be a slight modification of the coefficients in equation (8) and the addition of some quite insignificant terms in higher powers of u.

(To be continued.)

THE INSTITUTION OF NAVAL ARCHITECTS.

(Continued from page 647.)

Two papers were presented at the final session, on the afternoon of April 4, of the 1952 Spring Meeting of the Institution of Naval Architects. The first of these was a contribution from the National Physical Laboratory, by Dr. G. Hughes, and was entitled "Frictional Resistance of Smooth Plane Surfaces in Turbulent Flow—New Data and a Survey of Existing Data." The chair was taken by Mr. Lloyd Woollard, M.A.

FRICTIONAL RESISTANCE IN TURBULENT FLOW.

The purpose of the paper, Dr. Hughes explained, was to give in detail the results of new work on the frictional resistance of smooth plane surfaces in turbulent flow, carried out in recent years at the National Physical Laboratory. At the Conference of Ship Tank Superintendents held in London in 1948, there was a unanimous opinion in favour of departing from Froude's skin-friction coefficients in correlating model and ship results, but there was no general agreement on what might be accepted as the minimum turbulent-friction line, and the research was designed to provide further information on this line. A highly sensitive dynamometer was constructed and tests were made with thin "planks" of painted metal, plate glass with metal ends, and painted wood; also with a shallow flat-bottomed "pontoon" of painted wood. The paper also included results of some tests with small plastic planes, fully submerged. In most cases, the turbulence stimulator was fitted close to the leading edge. The results were corrected for air, form and stimulator resistance, but it was recognised that they were affected also by various other factors—e.g., change of trim and of wetted surface area, lack of absolute symmetry, and interference from supports—which could not be evaluated with sufficient accuracy. It was found that all the results, old and new, were consistent when account was taken of the length/breadth ratio of the planes. There was no single friction line, but a family of lines, varying with that ratio, and a line for its zero value, corresponding to two-dimensional flow, was approximately established for Reynolds numbers from 0·1 to 10 millions. An upper line, corresponding to a large value of the length/breadth ratio, was proposed over the range of Reynolds numbers from 1 to 100 millions. No formulæ for the lines were put forward, as it was hoped to carry out check experiments and to extend the range of Reynolds numbers before submitting final proposals.

DISCUSSION.

Professor E. V. Telfer, who opened the discussion, said that the table showing the particulars of the planes tested and other relevant data should be a model to all research workers who hoped to have their work used. Dr. Hughes, and most others, still worked in terms of Reynolds numbers. Fortunately, William Froude, though he must have had the opportunity to know Osborne Reynolds, never allowed his own work to be influenced by Reynolds, and saw nothing wrong in extrapolating his 50-ft. planks to a length of 300 ft. Then his son, R. E. Froude, began to consider how much the total resistance of the model exceeded that of the ship. There was no great gap between the specific resistances of the model and the ship. Reynolds himself restricted the use of his term to illustrating pipe flow; it was Lord Rayleigh, Professor Telfer believed, who applied it to planks. The Reynolds number, as such, had no positive meaning; but if it were turned upside down, it had a very definite and simple meaning. Any deduction of the frictional resistance of a plank or a pipe by dimensional reasoning always gave the simple statement that the resistance increased with increase of viscosity; there were no normal cases where the resistance decreased with increase of viscosity. He hoped that Dr. Hughes would continue to think in terms of relative flow viscosity and would not try to think in terms of Reynolds number. Appreciation of the outstanding facts in the problem would be hastened by thinking correctly rather than by regarding the subject as prohibitively difficult because of the huge gap which was supposed to exist between the model and the ship. There was a good case for continuing the work on pontoons with the greatest possible length and width; and he hoped that, in future work, Dr. Hughes would adopt the R. E. Froude tradition of merely investigating the reduction of total specific resistance as each geometrically similar pontoon was studied. Both were identical solutions, but he thought that the second method was likely to present the fewest experimental difficulties.

Professor A. M. Robb said that, so far as he knew, there was not, in the literature of naval architecture, any rational statement of the case for turbulence stimulation. Why was it essential, in the work described by Dr. Hughes, that the flow should be fully turbulent? The record of two experiments by Osborne Reynolds seemed to suggest the conclusion that there was inevitably laminar motion at the fore end of any body in a fluid, followed in any ordinary lengths, almost inevitably, by a region of turbulent motion when the local value of Reynolds number had reached the appropriate figure. The primary purpose of any model experiment was the determination of the residuary resistance of the model. How did turbulence stimulation come into that? The frictional resistance of a plane of the length of the ordinary model was a directly determinable quantity, or ought to be; if the method of experimentation was valid, the residuary resistance of the model was directly determinable without introducing any artificial condition. Thus the turbulence stimulation was no more than an admission that the method of experimentation was not valid. How did it help to explain the occurrence of negative residuary resistance?; or why the calculated frictional resistance, without any additions, could be greater than the total measure of the resistance—not an uncommon occurrence? Those were problems which the experts of the experiment tanks had not cleared away. If part of the energy put into turbulence stimulation were re-directed, it might bring nearer the solution of a problem which was much more complicated than they had been led to believe.

Mr. W. C. S. Wigley, while admiring the careful and long experimental work discussed in the paper, wondered whether practically any advantage would accrue to correspond with the great amount of labour involved. The information might prove useful in ways which had not been thought of, but his own opinion was that, while an approximate correction from the model of a ship could be made in the way that Froude did it, by the Schoenherr-Froude formula, and probably in dozens of other ways, more or less accurate, attempts to get any closer introduced innumerable difficulties. In the very ingenious method which Froude devised for correcting for difference of scale between model and ship, many assumptions were made, each of which would cause an error in the final result of perhaps 1 or 2 per cent. Those errors, when multiplied together, must mean that any correction based on simple plank experiments could not be physically accurate, and it seemed improbable that very much better results could be obtained than those given by the standard method. Mr. Wigley's impression was that Froude devised his method because, at that time (1870), the wave component of the resistance was an entire mystery; for that matter, so was the frictional resistance, but it looked simpler. Therefore, he took the frictional resistance as standard and measured the wave resistance in the tank. Since then, a lot more had been learned about wave resistance, but the equations which governed frictional resistance had not yet been solved for any speeds which were of practical use. Now, however, there was a first approximation to wave resistance, and more was known about that than about frictional resistance. It followed that the ideal method of correction would be to take the model results, deduct the wave resistance, and so arrive at the frictional resistance. That could not be done; but what could be done was to calculate the wave profile, say that the resistance corresponding to that profile was a certain amount, and so get the frictional resistance.

Mr. H. Lackenby considered that the paper was very timely, as the whole question concerning skin friction as between model and ship appeared to be in the melting pot. In the exhaustive series of tests described, great care had been taken to obtain accurate measurements; but the determination of the true turbulence friction data from the tests on the planes was a very difficult method of experimentation. One of the main difficulties appeared to be to stimulate a natural turbulence, whatever that might be. In some cases, apparently, turbulence could be under-stimulated and in others, over-stimulated. That was the first time he had seen any reference to over-stimulation; it was disturbing. The selection of the part of the curve which corresponded to natural turbulence seemed to be, to some extent, a matter of conjecture. Probably Dr. Hughes had chosen the right part of the curve; but added weight would have been given to his choice if steps had been taken to ensure that the flow was indeed turbulent, or even to the extent of examining the laminar area at the farther end. If laminar flow had been measured, it should have been possible to correct the results to correspond to the fully turbulent state. One of the main points stressed throughout the paper was that planes of different length/breadth ratios would have resistance lines at different levels, which was evident from the results. Some experimenters had not paid attention to that point.

Mr. W. Muckle thought that Dr. Hughes had proved that the influence of length/breadth ratio in tank work was important; when dealing with geometrical similarity, would the breadth/thickness ratio be likely to have any influence on the results? Was the length/breadth ratio to be taken as equal to nothing, or what value should be taken, in applying the results to ship form? He thought that the question of extrapolation was important and that there was a big step between the ship and the model. The method of R. E. Froude, in essence, was not very different from that suggested by William Froude for extrapolation. He asked how Dr. Hughes had extrapolated his curve to the higher Reynolds number. The question of form resistance, in attempting to apply plank results to ship forms, was important. Great benefit might result from experiments on totally-submerged three-dimensional bodies, comparing the results with plank results of the same area and trying to establish what addition to resistance was required for form.

Dr. J. F. Allan said that the extent of the discussion showed how important was the subject. At the National Physical Laboratory they were trying to get a clearer picture of what was actually happening as between the model and the ship. It might be reasonably fair to say that they had accepted the Froude picture over a long period of years, but had not dug very deeply beneath it. The question of changing the basis of calculation had been discussed at the International Conference and, as Dr. Hughes said, it had been agreed in principle to depart from the existing Froude method; facts were gradually emerging which showed that there was a strong case for such action. Such results as were available were from the power end, whereas they were arguing about the resistance end, and the scale effect of a propeller. It was clear that a more scientific basis must be adopted for interpreting the resistance of the model in terms of the ship. Unless that could be done with accuracy, he did not think they were justified in leaving the existing system. From the practical shipbuilders' point of view, the Froude method could be and had been entirely satisfactory for the prediction of ship power; before departing from the Froude method, therefore, it was necessary to be quite certain that they were adopting a method which would give a definitely clearer appreciation of the detail of the various elements of resistance of the ship. The paper devoted a lot of space to showing that the length/breadth effect was clearly demonstrable in plank work. Personally, he was inclined to share Mr. Lackenby's opinion that, so far as the ship was concerned, they were interested only in the case where there was no large effect. They wanted a turbulence friction line with edge effect, in applying it to the ship; then allowances had to be made for the form effect of the ship. It was necessary also to consider scale effect, and the theoretical approach indicated that there was a material scale effect. Finally, there was the question put up by Mr. Wigley, that they were wasting time by studying the problem from the friction end, and that the proper approach was from the wave-making end. They would be only too pleased if Mr. Wigley, and others who were specialists on wave calculations, would produce an accurate prediction of wave-making resistance, which would enable a check to be made on the work at the National Physical Laboratory and elsewhere on frictional resistance.

The Rev. R. T. Shiells, speaking as an independent investigator who had consistently received the support of the N.P.L., observed that there was a practical point about edge effect. It appeared that the keel edges of the vertical planes were rectangular; did that mean that two relatively sharp edges were left in place of the normal semi-circular section keel? If so, why introduce two sharp edges, thereby increasing the local resistance? Despite the enormous number of tests performed by Hiraga, his work seemed to be vitiated by the effect of laminar flow, since no attempt was made to stimulate turbulence; and the planks had parallel bodies, with the fore end and aft end only 3 in. long, which must have been responsible for considerable and almost unpredictable wave resistance. He urged the inclusion of the Newport News friction data, which he regarded as the most accurate of short-length determinations; that work had been carried out with beautiful towing apparatus, and over a range of temperature from 50 to 90 deg.

Dr. Hughes, replying to the discussion, said that time allowed him to deal only with generalities. Professor Telfer and he had spent several hours in discussion at the N.P.L. before the meeting, and had agreed to differ. Regarding turbulence stimulation, Professor Telfer had said that he (Dr. Hughes) did not take the opportunity to confirm that they had that stimulation or to make visual observation, which was true. They relied on the evidence of previous work on models, and were satisfied that, if stimulators were used, they would get the necessary stimulation. Professor Robb questioned whether it was right to attempt stimulation. Dr. Hughes firmly believed that it was. If they did not stimulate turbulence on the models or planks—in which case, they would have a good deal of laminar flow at the lower speeds—he did not see how it was possible to get an accurate prediction of plank results to the ship. Mr. Wigley asked whether, as the result of the work described, they would really do any better than by using the Froude method. Dr. Allen answered that, to some extent; and he himself thought that they would do much better. There were recent indications of the need for a correction to the ship which was quite different from that derived from Froude, and he predicted that the correction which most nearly fitted the ship-model correlation, i.e., the smooth model to the smooth ship, would ultimately be found not so far removed from that obtained from tank data.

In reply to Mr. Shiells, the edges were left rectangular in the tests with the glass plate. In the test with the thickness of the wood plank, the bottom edge was rounded to semi-circular form; in the pontoon, there was the equivalent edge, as at the surface. They did not taper the edge in any of the experiments, because the actual shape of the edge was not important. He thought that it was all a question of continuity. It was the discontinuity which he called the "edge effect"; but they had no data to show what was the mechanism in the flow.

(To be continued.)

EXHIBITS AT THE MECHANICAL HANDLING EXHIBITION.

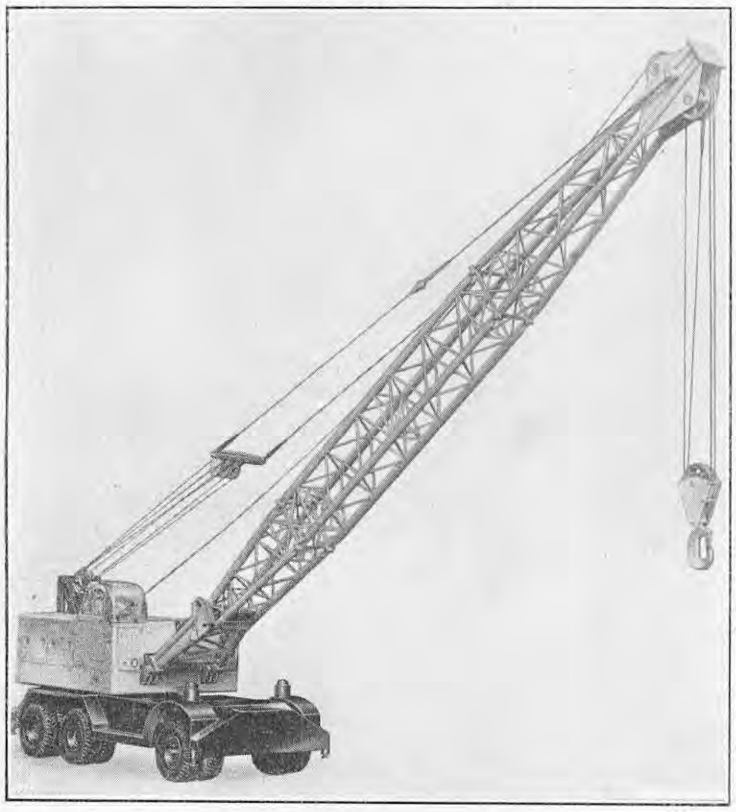


FIG. 1. COLES 20-TON CRANE; STEELS ENGINEERING PRODUCTS, LIMITED.

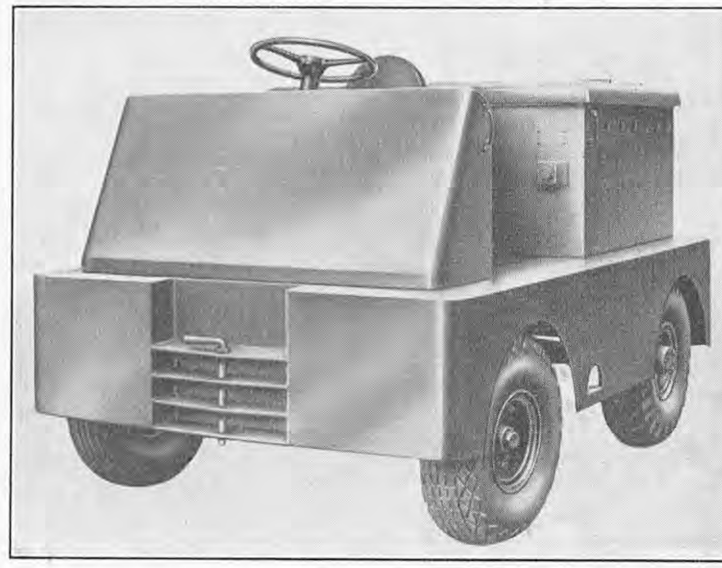


FIG. 2. INDUSTRIAL TRUCK; STEELS ENGINEERING PRODUCTS, LIMITED.

MECHANICAL HANDLING EXHIBITION.

THE formation recently of an Institute of Material Handling, mainly representing users of handling equipment, and the existence of the Mechanical Handling Engineers' Association, show that industry is increasingly aware of the part that mechanical handling can play in improving productive efficiency. At Olympia next week, nearly 200 manufacturers of mechanical-handling equipment will be displaying their latest developments, including many products that have not been shown in public before, at the third Mechanical Handling Exhibition, which is to open on Wednesday, June 4, and close on Saturday, June 14. The exhibition is sponsored by the journal *Mechanical Handling*.

MOBILE CRANE.

Messrs. Steels Engineering Products, Limited, Crown Works, Sunderland, will show examples of their electric hoists, trucks and tractors, and mobile cranes. They will exhibit for the first time a 20-ton slewing and derricking mobile crane, fitted with an 80-ft. jib, a photograph of which is reproduced in Fig. 1. The four motions—travelling, hoisting, derricking, and full-circle slewing—are each operated by separate variable-voltage direct-current electric motors, supplied by a variable-voltage generator driven by a 10-h.p. Ford V-8 petrol engine. Alternatively, an 80-h.p. Perkins P.6 Diesel engine can be fitted. The power unit and generator are mounted on the superstructure, which rotates on a live ring of steel rollers running on top and bottom steel roller tracks. The crane travels on six pneumatic-tyred road wheels, and has a maximum travelling speed of 2 m.p.h. fully loaded, and 8 m.p.h. unloaded, on level ground; the 32-h.p. motor drive is transmitted through a two-speed gearbox, a differential assembly, and a final chain drive to the rear road wheels, which are mounted on pivoted suspension beams. Brakes are applied to the rear wheels.

The hoisting, derricking, and slewing motions are all driven through totally-enclosed worm-reduction gearing and are fitted with automatic electro-magnetic brakes which arrest the motions immediately the current supply is interrupted. The speed of the motors is controlled entirely by the engine accelerator, the motor being switched in with the engine at idling speed. The maximum hoisting speed with full load is 15 ft. per minute, on four falls; the maximum slewing speed is $1\frac{1}{2}$ r.p.m.; and the jib is derricked from maximum to minimum radius in 90 seconds.

Also displayed on the stand of Steels Engineering Products, Limited, will be a Coles "Electric Eel" tractor with a drawbar pull of 4,000 lb., illustrated in Fig. 2. The tractor is propelled by a heavy-duty four-pole series-wound motor operating on an 80-volt circuit. Speed regulation is obtained by a direct-acting contactor type of controller giving four speeds, both forward and reverse; the speed selection is controlled by a pedal and the choice of forward or reverse motion by a hand control. The drive is taken through double-reduction gearing and a differential to the rear driving axle, which is mounted directly on the chassis. The wheels run on taper-roller bearings. The chassis frame is an electrically-welded steel structure with towing pins at the front and the rear, and reinforced steel bumper plates. The batteries, mounted behind the driver's seat, are easily accessible for changing. The front wheels are steered through a cam-type steering box; the steering axle is suspended on semi-elliptic leaf springs. Foot-operated Girling brakes are fitted on the driving wheels, and the motor shaft has a hand-operated external-contracting brake. The tractor is capable of hauling a 6-ton trailer up a 1-in-6 gradient. Fully loaded, it has a maximum level speed of 4 or 5 m.p.h.; unloaded, the maximum speed is 5 or 6 m.p.h.

CONVEYOR HEAD.

Power transmission equipment will be displayed on the stand of Messrs. Crofts (Engineers), Limited, Thornbury, Bradford, whose exhibits will include the conveyor driving-head assembly shown in Fig. 3, on page 678; in this a variable-speed pulley-drive transmits power, through a double worm reduction gear, with an overall reduction ratio of 3,100 to 1, to a welded-steel conveyor pulley coupled directly to the output shaft of a double worm gear. The conveyor pulley is fitted with a ratchet backstop which prevents the belt conveyor from running back, if the power supply is discontinued for any reason, by a pawl engaging with a ratchet wheel. Crofts standard steel pulleys are supplied for light, medium and heavy duty; they are totally enclosed to prevent foreign matter from entering, and comprise rims and end plates of rolled steel plates, the end plates being welded to strong mild-steel bosses provided with standard taper keyways and set screws. Also on view will be a motor-driven roller unit, illustrated in Fig. 4, such as is supplied to steel mills for handling 40-ft. lengths of 16-in. diameter tube.

1-TON AND $\frac{1}{2}$-TON FORK-LIFT TRUCKS.

Messrs. A. Hirst and Son, Limited, Crescent Works, Meadow-lane, Dewsbury, will show for the first time their Mark 11 ET battery-driven fork-lift truck, which is illustrated in Fig. 5, on page 684. The load capacity is 1 ton, with the centre of the load 18 in. from the heel of the forks, and the maximum lift available is 10 ft. With full load, the lifting speed is 20 ft. per minute, and the maximum travelling speed is 6 m.p.h. The tilting range is 3 deg. forward and 10 deg. back, full tilt being applied in about 5 seconds.

The truck is driven by a $3\frac{1}{2}$-h.p. traction motor through a reduction gearbox and differential. The crown wheel and pinion, differential, and bearings are standard Ford parts. The driving axle is housed in a steel casing. The road wheels run on heavy-duty taper-roller bearings. The rear wheel runs on a ball track built into a heavy casting which forms the rear of the truck and acts as a counterbalance. It also carries the towing attachment. The rear wheel is steered through a wormwheel and a worm on a horizontal shaft coupled to a heavy-duty bevel gearbox at the base of the steering column. The turning radius is 5 ft. 10 in. All the road wheels are fitted with 16 in. by 6 in. cushion tyres; the front wheels are provided with Girling brakes, operated by foot and hand controls.

The standard length of the lifting forks is 36 in., but other lengths are available. The forks and carriage are of welded construction, and are carried on Meehanite rollers running in steel lifting channels, which are constructed to give double extension by means of two roller chains. The lifting and tilting motions are hydraulically operated, pressure at 1,500 lb. per square inch being provided by a positive-displacement rotary pump driven by a separate $3\frac{1}{2}$-h.p. motor. Lifting is carried out by a single hydraulic ram with a stroke of 60 in., and two 4-in. diameter rams of short stroke provide the tilting motion.

The traction motor is controlled by a foot-operated three-step mechanical contactor. The contactor pedal must be released slightly before it can be depressed to give the second and third speeds; thus the truck can only be started at a crawling speed. Three forward and three reverse speeds are obtained, the selection of forward or reverse being controlled by a separate switch. The lifting and tilting control valves are operated by a single lever, which also brings into operation a mechanical contactor to start or stop the pump motor.

Messrs. A. Hirst and Son will also show their Mark 10 petrol-driven fork-lift truck, illustrated in Fig. 6, on page 684, with a load capacity of 1,120 lb.

EXHIBITS AT THE MECHANICAL HANDLING EXHIBITION.

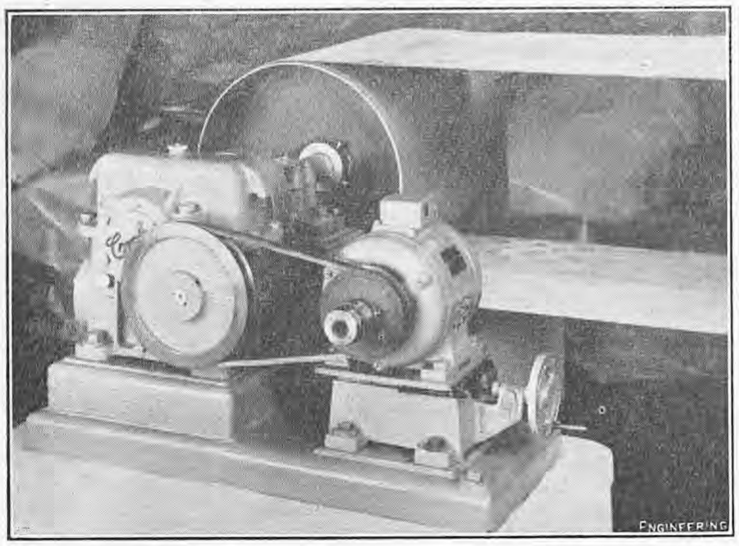


FIG. 3. CONVEYOR DRIVING HEAD; CROFTS (ENGINEERS), LIMITED.

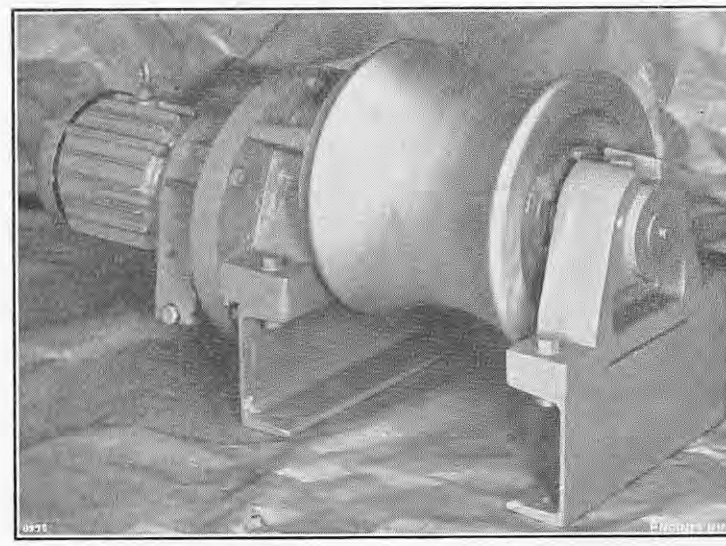


FIG. 4. MOTORISED ROLLER UNIT; CROFTS (ENGINEERS), LIMITED.

at 15 in. from the heel of the fork. It is available with a lift up to 12 ft. The power unit is an 8-h.p. Ford engine, which drives a three-speed and reverse-gearbox through a single dry-plate clutch. The driving axle is mounted directly on the gearbox and a special coupling is provided to the differential, which is made up from a standard Ford crown wheel and pinion and shortened half shafts. The truck has a maximum travelling speed of 9·75 m.p.h. forward and 2·35 m.p.h. in reverse, and can climb gradients up to 1 in 7. Girling brakes are fitted on the front wheels and are controlled by foot-operated and hand-operated control systems. A modified automobile steering box is connected to the rear wheel, which is mounted on a forging carried on heavy-duty taper-roller bearings. The lifting and tilting motions are hydraulically operated and are similar in principle to those of the E.11T truck, with the exception that the hydraulic pump is belt driven from the engine.

1-TON FORK-LIFT TRUCK.

One of the most interesting fork-lift trucks in the exhibition will be the new 1-ton truck displayed by Messrs. Mathew Brothers, Matbro Works, Sandy-lane North, Wallington, Surrey, which is illustrated in Fig. 7, on page 684. It is a versatile truck, intended for use in confined spaces and also over rough ground, for which purpose it is fitted with three large-diameter pneumatically-tyred wheels. The maximum lifting height with a 1-ton load is 9 ft., at a speed of 36 ft. per minute. It has a free lift of 2 ft. The power unit is a 10-h.p. Ford industrial petrol engine, driving through a single dry-plate clutch and a gearbox giving three forward speeds, with synchromesh second and top speeds, and one reverse speed; from the gearbox there is a chain drive to the propeller shaft, which runs in needle-roller bearings. The drive to the front wheels is conveyed through bevel gearing and a differential. Girling cable-operated brakes are fitted. The vehicle has a maximum speed of 15 m.p.h. and can climb gradients up to 1 in 4 with a full load. Conventional automobile controls are provided. Steering is by a hand-wheel through an adjustable chain drive, requiring no lubrication, to a worm and wormwheel over the single rear road wheel. All grease-lubrication points are located above the floor. The rear-wheel fork, which is mounted in taper-roller bearings, turns through an angle of 127 deg. The truck has a turning radius of 75 in.

The chassis comprises a welded box-section structure with a rigid bridge carrying the rear wheel. The mast assembly consists of high-tensile steel channels sliding on internal rollers. The fork carriage is mounted on rollers, and is fitted with replaceable rubbing strips. With the mast in its lowest position, the overall height is 7 ft. 5 in. Fully extended, the overall height is 10 ft. 11 in. Standard 30-in. forks of high-tensile steel are fitted. The lifting and tilting motions are hydraulically actuated and are controlled by a single lever operating a twin-valve unit. Pressure is supplied by a gear-pump belt-driven from the engine. Lifting is effected by a single-acting hydraulic cylinder and flexible steel ropes, in Meehanite sheaves with replaceable grease lubricated bushes. The tilting action is carried out by an overhead double-acting hydraulic cylinder mounted on a stanchion above the rear wheel and connected to a point about three-quarters up the mast assembly. The long stroke of the tilting ram, it is claimed, gives smooth and accurate control of the mast tilt, which ranges between 4 deg. forward to 12 deg. back. Another version of the truck is available with a greater lifting height—12 ft.—and a maximum load of 1,900 lb. Also on view on this stand will be examples of petrol-engine and Diesel-driven 2-ton heavy-duty fork-lift trucks.

4,000-LB. FORK-LIFT TRUCK.

Conveyancer Fork Trucks, Limited, of Liverpool-road, Warrington, will exhibit a range of battery-operated, Diesel-engine and petrol-engine fork-lift trucks and attachments, including their 6-20 truck with a turbo-transmitter acting as a torque converter and fluid coupling, which was described on page 582 of our 171st volume (1951). Fig. 8, on page 684, illustrates their G4-24 petrol-driven truck, which has a lifting capacity of 4,000 lb. at 24-in. load centre, and a standard maximum lifting height of 9 ft. Alternative masts with 6-ft. and 12-ft. lifts are, however, available. The power unit is a 16-h.p. Morris industrial petrol engine, driving through a Borg and Beck plate clutch and a two-speed forward and reverse gearbox, giving a maximum forward speed of $7\frac{3}{4}$ m.p.h. and a maximum reverse speed of $6\frac{1}{2}$ m.p.h. The working gradient is 1 in 8. Rear-wheel steering is provided, with Ackerman differential tracking. When fitted with 30-in. forks, a minimum aisle width of 11·5 ft. is required for a 180-deg. turn. The axle beam is supported by two longitudinal semi-elliptic leaf springs attached to fore-and-aft trunnions, allowing the axle to pivot when the truck is moving over rough ground.

The lifting and tilting motions are hydraulically operated, pressure being supplied by a gear pump which is automatically unloaded when the controls are in the neutral position. The maximum speed of lifting and lowering is 35 ft. per minute. The maximum tilting angles are $2\frac{1}{2}$ deg. forward and 10 deg. back. The truck is controlled by conventional automobile driving controls—foot-brake, parking brake, accelerator, clutch pedal, and two-speed gear lever. A separate gear lever controls the engagement of forward or reverse gear, and two inclined levers control the lifting and tilting motions. For easy servicing, the side panels are secured by Dzus fasteners.

(To be continued.)

METHANE AND COAL.*

By SIR ALFRED EGERTON, F.R.S.

THE history of some of the great series of scientific lectures does not bear out the theory that they start off with a flourish. The Bakerian Lectures of the Royal Society began in rather a queer way; the same person, Tiberius Cavallo, gave the lecture for 12 successive years. One of Cavallo's lectures, in 1782, was entitled "An Account of Some Experiments Relating to the Property of Common and Inflammable Airs of Pervading the Pores of Paper." The title of one of Davy's Bakerian Lectures (1810), "On Some of the Combinations of Oxymuriatic Gas and Oxygen, and on the Chemical Relations of these Principles to Inflammable Bodies," would have suited very well for the title of my lecture, if "carburetted air" (or, in other words, methane) replaced "oxymuriatic gas." "Inflammable airs" 150 years ago meant any gases which would burn; we know them now as hydrogen, carbon monoxide and methane. Nicholson's *Dictionary of Chemistry* (1795) says about methane that it is "Inflammable air of marshes which is emitted from the waters of standing pools . . .; when it is consumed by detonation with 'vital air,' it leaves a residue of 'Phlogisticated air'" (i.e., nitrogen). How primitive that sound nowadays, and yet it was only 150 years ago. In that short period, chemical science has been born and developed and has permeated every feature of our present-day existence.

The story of the laying of the foundations of the branch of chemistry which can be termed nowadays "combustion chemistry" is worth recalling. A Dr. Gray, rector of Bishopwearmouth, was a member of a society for preventing accidents in mines. He wrote to Davy on August 3, 1815, a letter which led Davy to obtain samples of gas from Wallsend. In less than a fortnight, he discovered some new and unexpected properties in the gas which had led to no less than four different plans for lighting the mines with safety. Thus Davy took hold of an urgent industrial problem—how to light a coal mine without igniting the firedamp. He established by chemical analysis that the firedamp was a "hydro-carbonate," as he called it—a chemical combination of hydrogen gas and carbon—or a "carburetted hydrogen." He then discovered at what concentration mixtures of methane and air were inflammable; he observed it would not explode with less than six times or more than 14 times its volume of air. He then found how these limits could be raised by removing the heat which kept the flame alive; in an $\frac{1}{8}$-in. tube, it would not even ignite.

Davy was very successful, and made a big jump forward in the understanding of combustion; but we still have the danger of firedamp in mines and we still do not understand fully what determines the limits of combustion or why a flame maintains itself and propagates. My lecture will have some connection with these matters.

THE ORIGIN OF METHANE IN COAL.

Coal is the main stored source of the energy supplies of the world; every 20 years, the world burns a volume of coal equivalent to the volume of Snowdon. In the

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main, coals are derived from the lignins and celluloses of plant debris and still retain some of the original structure of their vegetable origin. They are different chiefly because of the different pressure and temperature to which the material has been exposed; the higher-rank coals, in general, have been subject to higher tectonic pressure. The Coal Survey has been providing a valuable examination of the coal deposits in Britain. Although there have been tremendous upheavals, displacements and folding of strata, the higher-rank coals have their origin in the central regions of the several coal fields and the coals of descending rank towards the periphery of the whole area or basin. It is dangerous to generalise on these matters, but it seems to me that study of the further "coalification" of low-rank material by submitting it to high pressure at various temperatures, carrying forward the work of Berl, Petraschek, Bode and others, might give further information on what has occurred in past ages. The late Dr. Randall of the Fuel Research Station was commencing such synthetic work just before the war, but it has not yet been resumed.

The constitution of coals has been tackled mainly from the other direction; analytically, by looking at their structure or treating them with reagents. The first line of attack, by studying the microscopic structure, is associated with names such as Stopes, Stach and Seyler. The second, by dissolution or dispersion of the coal constituents in various solvents, with names from Wheeler to Dryden; and the third, by controlled oxidation, from Bone to Gillet and other investigators. These methods, along with the X-ray studies of Riley, Brusset and others, seem to show that, in the bituminous range, coal has a structure of interleaved or randomly oriented layer planes of hexagonally-arranged carbon atoms within which lies a still more jumbled, more complex structure with oxygen, sulphur and nitrogen atoms forming some of the links between the ordered carbon structure.

This picture of coal, as composed largely of colloidal particles with a very fine pore structure between the particles, fits reasonably with the pore size deduced from the density and the measured internal accessible surface area (100 sq. m. per gm.) obtained both by heat of wetting with liquid methyl alcohol and by adsorption at 25 deg. C. of the vapours of methyl alcohol, *n*-hexane, etc. The internal surface measured by adsorption of nitrogen at low temperatures (about -200 deg. C.) has given values about 20 times smaller, indicating that the pores are of larger average diameter and implying that the coals should be more porous to gases than they are. The discrepancy between these two methods of measuring the internal surface is one of the most interesting results of recent research at B.C.U.R.A. laboratories, and in South Africa and elsewhere.

Graham showed that a certain dried coal dust could absorb about 20 times its own volume of methane at 10 atmospheres; he also endeavoured to measure the pressure of the methane locked in the pores of the samples of coal taken from the coal face, the highest figures he got being a little over 7 atmospheres. Lindsay Wood (1880) got the highest figure recorded (34 atmos.) for the Bensham seam at 1,270 ft. At 1,000 ft. depth, however, earth pressures would still about twice as great. Graham's measurements of the amount of gas liberated when small lumps of coal are finely crushed showed that 200 to 600 c.c. are released per 100 gm. for different samples, depending on the type of coal. On the average, it would not be more than about ten times the volume of the coal—considerably less than 1 per cent. by weight. Measurements of the content of gas at the face of various seams under working conditions were, in many cases, considerably higher than would correspond to this release, particularly for the anthracite coals; and, Graham remarks, "the gas content of the anthracite samples stands out prominently, the maximum value being 1,685 c.c. per 100 gm. for a rapidly advancing heading. Analysis of the return air showed that evolution of gas in the heading was 25 cub. ft. per minute, hence the quantity evolved per ton of coal works out at 3,300 cub. ft. per ton. Since the content of gas in the coal itself was found to be only 600 cub. ft. per ton and the slow rate of evolution from the solid has been proved, it is clear that a very large proportion of gas must be finding its way through breaks in the coal and strata, well in advance and on either side of the heading."

Where does the methane come from? Precise knowledge is lacking. The peat-forming stages of decay of vegetable debris involve aerobic disintegration by action of micro-organisms and fungi. The biochemical process may cease with only partial decomposition of the woody substances or may proceed to more complete digestion of the plant material. The process sooner or later smothers itself and becomes anaerobic, and the product becomes consolidated and dehydrated under its own burden. From this stage down, biochemical reactions diminish, but the product is gradually further dehydrated, devolatilised and compacted. The degradation of the original plant celluloses and lignins in the production of bituminous coal would involve the removal of nearly twice the mass as gaseous products (methane and carbon dioxide) and water, and some have supposed that a quarter of the mass of the coal would have appeared as methane. In the production of bituminous coal, some suppose that dehydroxylation occurs and carbon dioxide and water are eliminated, but others are puzzled that methane as well as CO_2 is found. The "anthracitisation" of bituminous coals, however, certainly seems to require the production of about 10 per cent. of the mass of the coal as methane. Nevertheless, the amount of methane found associated with coal in mines is, on the average, only about 1 per cent. of the mass of the coal.

What becomes of the rest of it? If it had all remained in the atmosphere, from the stated mass of the reserves of coal in the world ($6 \cdot 10^{12}$ tons), one would expect that 0·02 to 0·03 per cent. of the mass of the atmosphere should consist of methane. As the amount of methane in the atmosphere is negligible, there is obviously a process removing it. Methane is also being discharged continuously into the atmosphere in great volumes from volcanoes, from sources of natural gas and oil wells, and from decaying vegetation, and yet it is practically undetectable in the atmosphere. No doubt, it gets oxidised; but that oxidation process must occur in such a way that it is carried beyond the formaldehyde and the CO stages through to carbon dioxide, and can therefore probably only occur in the upper atmosphere, in the regions where the ozone is appreciable or oxygen atoms exist.

The pressure of the methane in the pores of the coal, supposing it were the only gas formed in the later stages of coalification at high pressure, would be at the pressure corresponding to the depth of the seam. There is, in fact, a tendency for higher gas emission in seams of high-rank coals and at greater depths. In some places, where there are porous deposits above the coal, the gas can gradually diffuse out of the coal and soak away; in other places where this occurs, the gas collects in a porous region which is sealed by impervious rock. If a boring is made into this porous region or into faulting, the methane which has collected will be released under its own pressure. There are apparently not many coal areas in England where this occurs. There was a "blower" at the Wallsend Colliery giving 120 cub. ft. per minute a hundred years ago. At the Cymmer Colliery in Wales, the "blower" yielded gas for 50 years at a pressure of 45 atmospheres. The well-known Point of Ayr Colliery in Flintshire yields free gas (250-650 cub. ft. per minute, 98 per cent. CH_4) at considerable pressure (up to 20 atmospheres); there are other "blowers" in Staffordshire and elsewhere.

The many disasters from firedamp explosions in mines, and the measurements of the limits of inflammability, eventually led to legislation to keep ventilation of the mines well below the limiting concentration for danger. Men are withdrawn if the concentration exceeds 2·5 per cent. and electric current is cut off at 1·5 per cent. On the average, about 6 tons of air is pumped through the galleries for every ton of coal mined, and the methane in the outgoing air is seldom as high as 1 per cent. If the average were even as low as 0·25 per cent., the recovery of the energy in the methane which is at present wasted would be equivalent to 3 or 4 million tons of coal per annum and it is well worth an effort to save as much of it as possible. There are two main possibilities: either to drain off the methane before it gets into the ventilation air, or to utilise the energy of the methane in the ventilation air, without trying to separate it.

THE DRAINAGE OF METHANE AT COAL MINES.

The first of these two possibilities has recently come into prominence. In the Ruhr, in the Saar and in Belgium, methane is now being drawn off by a system of suitably positioned boreholes. Several systems have been developed, the cross-measure hole method being most in favour. This method is being applied in about ten British pits. The amount of methane drawn off appears to depend on the movement of the coal caused by the mining operations; disturbance of the coal causes disturbance elsewhere, increased permeability of the coal seam and flow of the methane along bedding planes to regions of lower pressure, and subsequent release into the galleries, unless it is caught on the way. The percentage of methane which is piped off from the boreholes is generally fairly high, up to 90 per cent. of that which would otherwise find its way out. A drop of 50 per cent. or better in the methane content of the ventilation air can therefore result. The old-established drainage system at the Point of Ayr Colliery is in a different category, for there the gas is present at high pressures in faults and it is essential to give it vent before working the coal. In Belgium, the mines are linked by pipelines and a supply of $3\frac{1}{2}$ million cub. ft. per day is maintained and is converted by cracking to a sulphur-free town's gas. In Germany, the gas is being compressed and used for motor transport. Whether "drainage" is worth while is very much a question of economics; each scheme has to be considered on its merits and in relation to local circumstances.. According to report, it has been found abroad that the value of the gas drained has generally more than paid for the installation and operating costs.

THE UTILISATION OF THE ENERGY OF FIREDAMP IN VENTILATION AIR.

With the second of the possibilities, the direct utilisation of the energy of the methane in the ventilation air, I come to the main subject of this lecture.

Dr. Roxbee Cox, Chief Scientist at the Ministry of Fuel and Power, described the projects which are in hand for development of gas turbines for industrial purposes in his Thomas Hawksley Lecture to the Institution of Mechanical Engineers last year.* One of the projects there described was one which had been suggested by C. H. Secord of that Ministry, that, if the waste methane in the ventilating upcast air from the coal mines could be burnt, the energy released could be converted by a gas turbine into sufficient useful work to provide a large part of the power needed in the collieries. Knowing that methane can be oxidised well below the limiting mixture strength needed for flame, the suggestion seemed worth pursuing and a few preliminary experiments were made which showed that fairly rapid combustion could be got in the region of 700 to 900 deg. C.

If the temperature rise caused by the combustion of about 1 per cent. of methane is 250 deg. C., and 900 deg. C. is the temperature to which it has to be raised for rapid ignition, if it enters at 450 deg. C. it will have to pick up 450 deg. C. from the booster, the temperature will rise to 1,150 deg. C. on ignition and, after giving up heat to the other leg of the booster, it will drop 450 deg. C. and go to the turbine at 700 deg. C. The booster, largely designed by P. D. Edmundson of the same Ministry, and constructed by the Incandescent Heat Company, has already undergone successful trials.

Except for upcast air with higher percentages of methane than are normal,† this straight cycle would not be efficient and the project therefore developed towards burning the upcast air along with an auxiliary fuel, so as to provide a higher rating for the turbine. The other waste fuel available at mines is coal fines and it is hoped to use this eventually, either directly or by means of a gas producer. In the first place, however, it is proposed to commence with oil as the auxiliary fuel.

The methane and air could either be preheated separately or after mixing. It was established that the reaction was taking place homogeneously in the gas phase, starting not at the surface, but between the boundary layer and the fast-moving core; and that the mixing of the two separate streams was very rapid and occurred well within 1 cm. of admission. Most of the work thereafter has been done by heating the methane and air separately, and bringing them directly into the reaction space.

I shall not attempt to give the results of all the experiments made on the effect of composition, pressure, etc., on the temperature and time of combustion of the methane. It will suffice to state that we have found that the effect of pressure up to $2\frac{1}{2}$ atmospheres only slightly decreases the temperature of combustion, but oxygen enrichment decreases it quite considerably; that the weaker the mixture (down to 0·5 per cent.), the lower the temperature for rapid combustion; and that 0·125 per cent. of hydrocarbons and hydrogen lower the ignition temperature, quite appreciably, but only in proportion to their contribution to the total heat content of the mixture in burning to CO.

Does the methane burn at once completely? It was important to know the answer to this question, for, if it is only partly burnt, the full available energy cannot be converted in the turbine. Mr. H. Hirsch has found that, with constant residence time (between 4 and 5 millisecs), the 1 per cent. methane burns more and more completely as the temperature rises until, at 1,020 deg., it has been completely burnt. Some formaldehyde is not burnt in the combustion process at the lower temperatures and remains in the exit gas, rising to a maximum just when the methane is commencing to burn rapidly; the formaldehyde then vanishes. Although the percentage of methane burnt is small (0·015) at the lower temperatures, the percentage conversion to formaldehyde is high (36 per cent.). Carbon monoxide is formed by the combustion of the methane and its combustion is inhibited by the methane, and it only begins to burn after practically all the methane is burnt. The carbon monoxide, however, does not burn completely in the time available unless the temperature is raised to 1,050 deg. C.

* See ENGINEERING, vol. 172, page 727 (1951).

† There are about a dozen collieries in which the percentage of firedamp in the fandrift exceeds 0·75 per cent., equivalent to winning an extra 150,000 tons of coal per annum.

MOTOR COACH FOR AIRWAYS SERVICE.

PARK ROYAL VEHICLES, LIMITED, LONDON.

(*For Description, see Opposite Page.*)

FIG. 1. COACH FOR BRITISH EUROPEAN AIRWAYS.

FIG. 2. LUGGAGE HOLD.

The carbon monoxide in each case does not burn until the methane has nearly all disappeared; also, the percentage of methane converted to carbon monoxide at the point where the latter is a maximum is greater for the lower initial concentrations of methane. These results show that the combustion of methane is not a single, but a dual process. It is composed of two separate processes of different rate, namely, the combustion to carbon monoxide, and the subsequent combustion of the carbon monoxide, the second being inhibited by the first.

There are now two ways open for the utilisation of the mines gas—either by drainage or by the direct combustion of the methane in the ventilating air. Which is the better way will depend on local circumstances and many other different considerations. They are not mutually incompatible. The drainage method only removes part of the methane that would otherwise find its way into the ventilating air. If, for safety reasons, methane drainage were necessary, it might still be thought worth while, instead of burning the methane under boilers or in Diesel engines, to burn it in a combustion chamber along with the ventilating air containing the rest of the methane and gain the power by gas turbine. But, having separated methane at high percentage, it seems a pity to burn it; it should be used so as to obtain its value as a high-grade fuel.

METHANE AS A FUEL FOR INTERNAL-COMBUSTION ENGINES.

Methane is an excellent fuel for spark-ignition engines. M. Pearce had shown that the same engine on methane with spark ignition at 14 : 1 compression ratio gives 34 per cent. more power than when running as a Diesel on oil. This is because of the high knock rating of methane. Although this high knock rating is consistent with its high ignition temperature, it has been rather a puzzle why it should knock and why it should be particularly lead-sensitive. Recently, the work of Downs, Walsh and Wheeler has indicated that there is a process involving a chain-carrier common to all hydrocarbon fuels and extending to methane, to formaldehyde and to hydrogen. The process of oxidation which leads to formation of cool flames is not much affected, but the process which succeeds the cool flame is.

Attention is drawn to the behaviour of methane in engines not only because of its special interest in relation to the problems of combustion, not only to show again how all these different aspects of the combustion of methane interconnect, but to suggest that its special value as an internal-combustion engine fuel should not be neglected. Methane obtained by the drainage method in the Ruhr district is being compressed and utilised for motor transport, and this may well be one of the most profitable ways of using it, rather than using it for heating coke oven or passing it into gas mains after suitable reforming, as in Belgium.

For many years we have been interested in the possibilities of methane in the liquid state (boiling point, −161 deg. C.) The late Lord Cadman drew my attention to the enormous volumes of methane which went to waste in the Persian oil fields. I suggested it might be liquefied and shipped as liquid, and transported like liquid oxygen. This half-crazy idea developed into a less crazy scheme to store town gas as methane; the storage capacity for the liquid for the same thermal energy would be about 1,000 times less than that for the gas. Another idea, that it might be used as a liquid for motor transport, was fully investigated in our Department during the war, and shown to be a possible substitute for petrol. The carbon content of coal could be more easily converted to methane than to oil, so that possible supplies of a fuel alternative to petrol were very great indeed, if coke oven and sewage gases did not suffice. 'Buses were run about 25,000 miles in the public service on liquid methane in special vacuum-jacketed tanks. When petrol became available again the interest flagged, but it is possible that it might revive with methane drainage, or possibly when a store of gas is required to meet special loads.

REPORT ON THE FIRE IN A PASSENGER TRAIN AT HUNTINGDON.

DISSATISFACTION with the steps taken by the Railway Executive to reduce the incidence and effects of fires in passenger trains is expressed in a Ministry of Transport report* on the fire which occurred in an express passenger train on July 14, 1951, near Huntingdon. The report is signed by Colonel R. J. Walker, an inspecting officer of railways. The fire started in the second coach (an "open," centre-corridor vehicle) of a 14-coach train; it spread and eventually destroyed the four leading coaches. Twenty-two passengers and the guard received burns and other injuries in escaping. From the evidence, Colonel Walker concludes that the fire was started by a piece of live coal from the engine, the coal having been thrown up into a hole in the underside of the floor, where it lodged. The hole was about 6 in. by $4\frac{1}{2}$ in., and a duct, 2 in. by $1\frac{1}{2}$ in., passed through it, but although the intervening space should have been filled with asbestos packing, there was no sign of such packing. The coal, it is concluded, caused the several layers of flooring material above it to smoulder for some time. Eventually, the smouldering fire reached a sponge-rubber floor covering (which had a high calorific value), but as this was covered with a carpet it did not ignite; it partially melted, however, and gave off heavy fumes. When the train stopped, the rubber burst into a small flame; this flame came in contact with a leather-cloth covering on the side of the coach, and in a very few seconds the end of the coach was fully ablaze and the fire was out of control.

In his remarks, Colonel Walker states that this was the third serious fire in a passenger train to occur in little more than two years. The others were at Penmanshiel in June, 1949, and at Beattock† in June, 1950. The characteristic features of all the fires have been the extremely rapid spread of flame inside the coaches and the difficulties encountered by the passengers in escaping. The rapid spread of flame has been due to either a nitrocellulose paint or a nitrocellulose-coated leather cloth; at Huntingdon it was due to the latter. After the Penmanshiel fire it was found that British Railways had at least 8,525 coaches in which nitrocellulose paint had been used; 6,831 of them have already been rectified, according to the report. Nitrocellulose-coated cloth is being replaced by a superior type of leather cloth coated with polyvinyl chloride.

A recommendation in the Beattock-fire report that there should be one fire extinguisher to each coach was adopted by the Railway Executive, though the coach in the Huntingdon fire had not been provided with one, and the extinguisher which the guard tried to use did not work properly. A water (gas-expelled) type of extinguisher is now standard on British Railways and the existing stock of soda-acid containers is being replaced. As regards communication cords, Colonel Walker found that throughout the length of the main body of the two leading coaches (which formed a twin set), there was no cord nor any notice to inform passengers where one was to be found, i.e., at the extreme ends of the twin set. He therefore recommends that, in view of the increase in numbers of "open" centre-corridor vehicles since the relevant Act of Parliament of 1868, "the whole question of passenger communication in coaches be reviewed to ensure that it is adequate in all types of passenger stock and that it has the approval of the Minister of Transport."

The time which elapsed from the first observation of the smoke to the stopping of the train was between 20 minutes and half-an-hour. This delay was due partly to the guard's assumption that the smoke came from a hot axlebox. In the Beattock-fire report, Colonel Walker asked the Railway Executive to consider the institution of a standard fire-fighting procedure so that each member of the train crew and dining-car staff would know what he should do. The Executive, however, thought this was impracticable, owing to the responsibilities of the train staff for protecting the train (i.e., from other trains, and safeguarding traffic). They have since agreed, however, to adopt a rule that, if signs of fire are seen or suspected, and the source cannot quickly be found, or having been found cannot obviously and easily be extinguished, then the train must be stopped at once.

On the question of coach design, Colonel Walker returns to his recommendation that in "open" centre-corridor coaches, and in sleeping coaches, additional exits should be provided along the sides. He points out that the Railway Executive have not accepted three recommendations of the Beattock report, namely, some form of organisation of the staff to deal with fires in trains; the additional doors; and an extra door in the corridors of sleeping cars. These recommendations were twice again referred to the Executive after the Huntingdon accident, but they were still found to be unacceptable. The design and construction of coaches have been modified in certain details, but, in relation to the general question, the Executive stated that "there is no limit to the number of safeguards which can be applied in the search for greater safety, but a reasonable balance must be held between the incidence of fire and the expenditure which is needed to remove the risk of it." In Colonel Walker's view, "where fires in passenger trains are concerned, there is no room for nice calculation on this point; unless the cost is really prohibitive, and if removal or reduction of the risk can reasonably be effected, then I think it should be."

* *Ministry of Transport. Railway Accidents. Report on the Fire which Occurred in an Express Passenger Train on 14th July, 1951, near Huntingdon in the Eastern Region, British Railways.* H.M. Stationery Office. [Price 1*s*. 6*d*. net.]

† See ENGINEERING, vol. 171, page 330 (1951).

LAUNCH OF M.V. "WINDSOR."

MOTOR COACH FOR AIRWAYS SERVICE.

IN order to match the increased load-carrying capacity of the aircraft which are to be introduced in service with British European Airways Corporation, 50 new coaches for transporting passengers between the town terminal station and the airport are being supplied by Park Royal Vehicles Limited, Abbey-road, Park Royal, London, N.W.10, to a specification prepared by the Corporation in collaboration with the London Transport Executive. The main considerations in the design of the coach have been ample luggage capacity, ease of loading and unloading, serviceability, and passenger comfort. Fig. 1, opposite, shows the vehicle, which accommodates 37 passengers. It is built on the Regal Mark IV chassis, with 16-ft. 4-in. wheelbase, built by Messrs. A.E.C. Limited, Southall, Middlesex. It will be observed that the stepped roof which has been a familiar feature in British airways vehicles has been abandoned, although the "deck-and-a-half" layout is still retained, 16 passengers being seated, on standard London Transport tubular-framed two-passenger seats, in the forward saloon at lower-deck level, and 21 passengers in the rear saloon, which is above the baggage hold. The baggage hold has a capacity of 250 cub. ft., i.e., 6·8 cub. ft. per passenger.

The overall length of the metal-framed body is 29 ft. $9\frac{1}{8}$ in., and the overall width 7 ft. $11\frac{1}{2}$ in. The height, unladen, is 11 ft. $10\frac{5}{8}$ in. The pillars of the body, of H-section extruded aluminium alloy, are attached to the main chassis outriggers in such a way that the body can be removed readily from the chassis, if desired. The pillars are braced by aluminium-alloy truss panels. The crib rails, waist and cant rails, and the channel-section roof "sticks," i.e., cross members, are of steel. The floor of the raised deck is carried on steel cantilever hoop "sticks," leaving an unobstructed space for the baggage, as shown in Fig. 2. The exterior panelling is of aluminium and is secured by hollow rivets.

The passengers' entrance door is in the centre of the coach on the near side. Immediately aft of the entrance door is a small enclosure for hats and coats, etc. Along each side of the two saloons, above the seats, there is a parcel rack. A three-step stairway, with non-slip treads, leads from the lower saloon to the upper deck. The saloon floors are cork tiled, with fluted rubber laid along the gangways and stairway. A heater and fan provide warm air to the saloons through concealed ducting. Two extractor ventilators are fitted in the roof. Five winder-operated quarter-drop windows in polished stainless-steel frames are fitted on each side of the body. The remainder of the glazing, other than the driver's windscreen, is fixed.

To provide for speedy loading and unloading of the passengers' baggage, the baggage hold has a large access flap, 5 ft. 4 in. long by 3 ft. 6 in. high, at the rear of the coach, hinged at the top and fitted with spring balances so that, when open, the flap is held, as shown in Fig. 2, completely clear of the loader. Additional access flaps, two each side, are provided in the sides of the body. Particular care has been taken in the design of the baggage hold to keep it free from sharp corners and obstructions which might damage the baggage.

LAUNCH OF THE M.V. "WINDSOR."

THE first of a new class of tramp motorship, the Windsor, was launched successfully from the Clydeholm shipyard of Messrs. Barclay, Curle and Company, Limited, Whiteinch, Glasgow, by Her Royal Highness the Princess Royal, on Friday, May 23. The Windsor is being built for the Britain Steamship Company, Limited, for whom Watts, Watts and Company, Limited, are managers, and takes a stage farther several of the original features incorporated in the Wanstead class, a series of cargo liners built for the same owners by the Caledon Shipbuilding and Engineering Company, Limited, Dundee. These vessels, it will be recalled, formed the subject of a paper, entitled "A New Cargo Liner Design," which was read by Mr. E. H. Watts at a meeting of the Institution of Naval Architects held in June, 1950. Features of the Windsor worthy of emphasis are: the fore and aft deck girders, integral with the hatch coamings; the water-ballast tanks between the hatches; the embodiment in the hull design of the special Watts "knuckle" to improve sea-going qualities; and the ventilating system, which is modelled on that employed in coal mines. The incorporation of fore and aft deck girders in the hatch coamings is not entirely new, having been used in the owners' Watford class of ship as long ago as 1927; in the Windsor class, however, the idea has been developed to include corresponding girders built into the double bottom, thus ensuring great longitudinal strength.

The launch of the Windsor is illustrated above. The dimensions of the ship are: length, 465 ft. overall and 435 ft. between perpendiculars; breadth, moulded, 58 ft. 6 in.; depth, to shelter deck, 38 ft.; and draught, when loaded, 27 ft. The vessel has been designed to carry approximately 9,950 tons deadweight on the draught mentioned at a service speed of 13 knots. There are three holds, together with associated 'tween deck spaces, forward of the machinery space and two abaft. A deep tank immediately aft of the engine room can be used for water ballast or cargo. The cargo-handling gear will consist of 12 totally-enclosed steam winches, ten to serve the five main holds and two the deep tank abaft the engine room. All accommodation will be amidships and each member of the crew will have a separate cabin.

The propelling machinery will consist of a Barclay Curle-Doxford four-cylinder opposed-piston two-stroke Diesel engine having a bore of 670 mm. and a combined stroke of 2,320 mm. The output in service will be 4,400 b.h.p. at 115 r.p.m. The engine will burn heavy oil as fuel. The forced-lubrication, fresh-water and sea-water circulating pumps and the two scavenge pumps will be operated by levers from the main engine. The standby pumps and other auxiliaries will be driven by steam, provided by a cylindrical exhaust-gas boiler fitted with an oil-fired furnace for use when the main engines are shut down. Steam for the winches will be supplied by another cylindrical boiler, fitted with superheater elements. Electric power will be provided by four 75-kW generators, one of which will be driven by steam and the remainder by Diesel engines. Particular care has been taken with the design of the engine-room ventilating system, which will consist of large natural-draught down vents led below the floorplates, and a series of motor-driven exhaust fans.

REPORT ON THE DERAILMENT OF A PASSENGER TRAIN AT WEEDON.

IN his report* on the derailment of a passenger train which occurred at Weedon on September 21, 1951, Lieut.-Colonel G. R. S. Wilson, chief inspecting officer of railways, concludes that the derailment was due to a lack of freedom of the leading axleboxes of the bogie in their horns. Prior to working the train which was involved in the accident, the locomotive had been in Edge Hill (Liverpool) running shed, where the leading and trailing bogie axles, complete with wheels and axleboxes, had been changed over (leading to trailing and vice versa) to even out the tyre wear in service. After the accident it was found that the fitter who had carried out the work had mismanaged the changeover. The leading horns and axleboxes, before the change, were smaller across the faces than the trailing horns and axleboxes; thus, after the change, the leading axleboxes were actually an interference fit in the horns. From measurements taken after the derailment, it was found that the interference was 0·013 in. on the left axlebox and 0·017 in. on the right axlebox; for new work and shop refits, the standard clearance is between 0·010 in. and 0·017 in. Colonel Wilson remarks that, though the fitter was at fault, "I cannot feel that there had been sufficiently direct supervision and control" of the changeover of the axles.

The sequence of events during the derailment was as follows. The 8.20 a.m. up express passenger train from Liverpool to London (Euston), comprising 15 coaches and a Pacific-type engine, was travelling at 60-65 miles an hour on the transition curve from a left-handed curve to the straight when the leading bogie wheels were derailed to the right. The derailment was not noticed by the enginemen at this stage and the train continued forward at speed for more than $\frac{3}{4}$ mile on the straight without serious damage to the flat-bottom track. No more wheels were derailed until the train reached the bull-head rails just beyond the short Stowe Hill tunnel (through which the train passed), when the leading bogie wheels began to smash the chairs and break up the track, with the result that the whole of the train, except the last two vehicles, left the rails. The engine went down the 12-ft. embankment to the left, and fell on its left side. The wreckage of the eight leading coaches was piled behind and alongside the overturned engine. Seven passengers and one of the dining-car staff were killed outright and seven passengers died subsequently.

The engine was No. 46207, "Princess Arthur of Connaught." It was of the 4-6-2 four-cylinder express passenger type and was built at Crewe in 1935. The comparatively light bar frames of the bogie, of which the long horn-stays form the lower members, carry no weight, serving only to locate the axles longitudinally and laterally. At a routine examination a few days before the accident, it was found that the left leading bogie-wheel flange was wearing sharp, and the two bogie axles (with axleboxes) were therefore changed over at Edge Hill shed on September 19 and 20. When the axles were out of the bogie, the fitter applied outside and inside callipers to the boxes and horn gaps, respectively, but Colonel Wilson reports that it was difficult to ascertain from him exactly how he made the comparison; at one time he had said that the inside callipers, which had been set from the horns, had a clearance in the outside calliper setting from the boxes. This, of course, would have meant an interference fit. In the report it is suggested that the fitter may have fallen into the simple error of interpreting the difference the wrong way round; what he thought was a clearance of about $\frac{1}{64}$ in. was, in fact, an interference fit of the same order.

Colonel Wilson says that the changing of bogie axles to even out tyre wear has hitherto been confined to the London Midland Region, but that the Railway Executive are now considering whether the operation should be standardised as a general practice for British Railways or discontinued altogether as not worth while. "I do not see," he says, "any inherent objection on safety grounds to a practice which may be economical and avoid premature withdrawal of engines from traffic for tyre turning, provided always that adequate precautions are taken to ensure that the work is properly done." Referring to the use of callipers for measuring horns and axleboxes, he remarks that they cannot be really satisfactory for measuring clearances, and suggests that the method of measuring should give the actual difference in dimensions between the horn gap and the axlebox in units of measurement. In conclusion, Colonel Wilson draws attention to the fact that the accident showed that flat-bottom track, with shallow baseplates and elastic-spike fastenings, is less vulnerable than bull-head track to damage by derailed wheels.

* *Ministry of Transport. Railway Accidents. Report on the Derailment which occurred on 21st September, 1951, near Weedon, in the London Midland Region, British Railways.* H.M. Stationery Office. [Price 3s. 6d. net.]

NOTES FROM THE INDUSTRIAL CENTRES.

SCOTLAND.

Developments in Glasgow's Water Supply.—During the past seven years, extensive developments of Glasgow's water supply have been proceeding, and about half of a 5,000,000*l*. programme has now been completed, mainly on distribution. The next major development will be to augment the sources of supply. Originally, it was proposed, by impounding the waters of the river Turk and flooding Glenfinlas Valley, to convey an additional 19,000,000 gallons a day to Loch Katrine through a 2½-mile tunnel. Meanwhile, however, in view of the present economic stringencies, a modified scheme has been prepared, designed to give about 7,000,000 gallons a day from Glenfinlas.

The Late Mr. John Robertson.—The death occurred on May 21 of Mr. John Robertson, chairman of Robertson and Fraser (Glasgow), Ltd., iron and steel merchants, at the age of 82. Mr. Robertson, who had been 60 years in business in Glasgow, was also chairman of the British Wedge Wire Company, Ltd., Warrington. He was a member of the Institution of Locomotive Engineers.

Prehistoric Toolbox.—A toolbox, claimed to be more than 1,000 years old, found in a peat bog in Orkney in 1885, has been presented to the National Museum of Antiquities of Scotland. The tools were still in the box when it was found, but the metal blades had perished. From the size of the handles, which are of wood, horn, and antler, it has been suggested that they formed a woodworker's outfit.

Extensions at Irvine Gasworks.—Plans for a new set of purifiers and four new retorts, to be erected at Irvine gasworks at an estimated cost of 32,000*l*., were passed by Irvine Dean of Guild Court recently. The alterations are expected to double the present output, giving a total production of about 1,000,000 cub. ft. per day.

Conference of Scrap-Metal Merchants at Pitlochry.—That, as a means of increasing the sources of scrap, steelmakers should approach the Government with a request that the total export of motor cars should be suspended for a period and the whole production put on the home market, was suggested by Mr. C. Fanshawe, the retiring president, at the annual conference of the National Federation of Scrap Iron, Steel, and Metal merchants at Pitlochry on May 21. This, he considered, would have the effect of causing thousands of old cars to be scrapped. Mr. R. M. Paterson, Glasgow, was elected president.

Bilston Glen Colliery.—A new mining project—Bilston Glen Colliery, in the Loanhead-Roslin district of East Lothian—was inaugurated by Mrs. William Reid, wife of Dr. William Reid, chairman of the Scottish Division of the National Coal Board, on May 19. It is intended to equip the colliery for an output of 1,000,000 tons a year. Two circular concrete-lined shafts, one 24 ft. and the other 20 ft. in diameter, will be sunk to a depth of 2,500 ft., tapping an area estimated to contain workable reserves of 100,000,000 tons. Productivity is expected to reach 40 cwt. per manshift.

Mobile Emergency Coalfield Laboratory.—A 22-ft. trailer caravan has been equipped by the Scottish Division of the National Coal Board as a self-contained mobile laboratory so that, in the event of an underground emergency, immediate service may be given by the scientific department at the scene of the incident. The laboratory is fitted with modern apparatus, the electrical equipment being capable of operating on any of the voltages found in the coalfield. The equipment will enable the department to determine the conditions of the air after an explosion, fire, or any other incident and to locate and trace the progress of underground fires.

Scottish Coal Exports.—Scottish coal exports during April showed both an increase in quantity and an improvement in quality. The total quantity shipped was 66,788 tons, which compares with 56,722 tons in the same month last year. Over a third of the tonnage was on Danish account. A proportion of silt and gum was included in the consignments, but there was an increase in that of nuts and other graded fuel. Swedish buyers tended to hold back, the month's shipments to Sweden being well below the average at 3,246 tons.

CLEVELAND AND THE NORTHERN COUNTIES.

The Steel Shortage and Shipbuilding.—Mr. S. Ombler, general secretary of the Ship Constructors' and Shipwrights' Association, Newcastle-on-Tyne, in his report for last year, stated that British shipyards had booked orders for 4,000,000 tons of shipping. There were 1,100 ships, aggregating 6,500,000 tons, under construction, and 31 per cent. were for export. The report stated that many yards had about four years of work in hand, but the fulfilment of these orders, to contract time, was dependent upon an adequate supply of steel. Covering much the same ground, Mr. E. J. Hill, general secretary of the United Society of Boilermakers and Iron and Steel Shipbuilders, Newcastle-on-Tyne, in his monthly report, said that, because of the steel shortage, work was proceeding more slowly in the shipyards and thus the industry could not make its proper contribution to the country's economic recovery. Mr. Hill said it was estimated that there were 6¾ million tons of shipping on order, valued at 650*l*. million.

Coal Traffic at Blyth.—Coal and coke shipments from Blyth, Northumberland, in April amounted to 418,920 tons, against 550,393 tons last year, the reduction being due to the strike of teemers and trimmers which was not over until April 7. For the first four months of this year, shipments aggregated 1,444,454 tons against 1,993,504 tons in 1951. Foreign shipments this year were 151,256 tons compared with 110,036 tons in the corresponding period of 1951.

Water Supplies for Tees-Side Factories.—The Tees Valley Water Board, at a meeting at Middlesbrough, criticised the Tees-Side Industrial Development Board for discussing water supplies with a firm seeking a factory in the area, without consulting the Water Board first. It was reported to the Water Board that the Development Board had written a letter stating that a South-East England firm of cement manufacturers had inspected sites on the Tees and had intimated that 2,000,000 gallons of water would be needed daily. The Development Board, it is stated, had told the firm that it would not be possible to promise that supply, whereupon the firm had decided on a site in the West of England. Alderman Allison, the chairman, said it was obvious that it would be some years before a factory needing this amount of water could be established, and it was not helpful for an outside body to take it upon itself to prejudge the water position. The Water Board were spending millions of pounds on new waterworks, and it might have been possible to enlarge these works for the benefit of the firm concerned.

Intensification of Scrap Collection Campaign.—A luncheon meeting between members of Newcastle-on-Tyne Corporation and the North-East Scrap Drive Committee has been held to launch an intensified campaign for the collection of scrap. A committee has been formed, representing both parties, to prepare details of the drive. It has been decided that the proceeds of the scrap collected shall be allocated to a charity. Mr. H. Boot, of the Consett Iron Co. Ltd., said that the iron and steel industry was not asking for the scrap for nothing, but desired to pay for it. He added that, as far as scrap was concerned, they were not "scraping the bottom of the barrel, but trying to find pieces in the joints between the staves."

Welded Dock Gates for Port of London.—From the tank-landing slipway used during the war the second pair of all-welded dock gates built by Messrs. Head, Wrightson and Co., Ltd., for the Port of London Authority have been launched at Thornaby-on-Tees. The gates are for the King George V Dock, and are interchangeable in any of the three positions of the 100-ft. wide entrance lock. Eight more gates for the London area are to be constructed by Messrs. Head, Wrightson, following the success of the installation of the all-welded gates at Calais by the company. The weight of each leaf of the welded design is 240 tons, against approximately 350 tons of the existing riveted type.

LANCASHIRE AND SOUTH YORKSHIRE.

Silicosis Risks.—A lecturer and a team of technicians from the Department of Social Medicine at Sheffield University are making researches at Sheffield steelworks and will examine and X-ray more than 800 employees with the object of determining the industry's silicosis risks.

Students' Vacation Work.—It is expected that about 300 Sheffield University students will be found temporary employment du ing the coming vacation, some in laboratories, and others in works offering experience allied to the subjects they are studying. Exemption had to be obtained from the Notification of Vacancies Act which requires employment to be sought through a labour exchange. Now students take a permit card from their own "exchange" when applying for jobs.

Australian Imports.—An Australian business man, Mr. Campbell W. S. Glenn, who has been visiting Sheffield works to negotiate representation for various lines, has expressed the opinion that there will soon be some relaxation of the Australian import regulations. He expects to see the development of manufacture in Australia under licence of British goods which cannot be made in sufficient quantity in this country.

Cutlery for Yugoslavia.—Representatives of the Tourist Direction in Belgrade may be visiting Sheffield in the near future to continue negotiations for the supply of hotel and hospital equipment, according to Mr. Frank Tomlinson, of Rockingham Plate, Ltd., who has just returned from Belgrade after reaching an initial agreement with senior officials of the Government-controlled hotel industry. Before the war, Yugoslav hotels and hospitals bought practically the whole of their cutlery from Germany.

THE MIDLANDS.

Employment in Mining and Engineering.—The Ministry of Labour has announced a considerable increase in the number of persons entering the coal mining industry in the West Midlands this year. A net increase of 2,000, to the end of April, brought the total number employed to 56,932. In other industrial work, the position is not so good as it was six months ago, though the figures still compare favourably with the rest of the country. Unemployment in the area represents 0·9 per cent. of the working population, as compared with 2·2 per cent. for the whole of Great Britain. Engagements in essential industries continue at a satisfactory rate, but there are still nearly 46,000 vacancies.

New Tube Mill.—Newman's Tubes, Ltd., Wednesbury, Staffordshire, who installed an American Yoder tube mill for producing electrically-welded steel tube in 1947, have a second mill of the same make on order. It is expected that it will be installed shortly.

Sand and Gravel Working in the Severn Valley.—The Ministry of Housing and Local Government has issued a report by an advisory committee on sand and gravel working. The Ministry state that they cannot recommend the complete cessation of sand and gravel working on all good-quality farming land in the lower Severn valley. The future demand is estimated at about 50,000 cubic yards a year in the region in question, and the report points out that supplies will have to be brought in from neighbouring districts, as local reserves are limited.

The Willenhall Lock Trade.—Willenhall, Staffordshire, which produces the greater part of all the locks made in Great Britain, is finding increasing difficulty in attracting boys to be trained as craftsmen. In spite of mechanisation, considerable numbers of craftsmen are still needed in the lock trade, and this position is likely to continue. The traditional source of supply has been the sons of men already employed on lock work, but the youth employment officer for Willenhall, Mr. F. W. Baker, has found that boys about to leave school have shown little interest in the trade.

Quarrying at Malvern.—The Malvern Hills, a well-known beauty spot on the Worcestershire-Herefordshire borders, are also the scene of considerable quarrying activities. At present, four quarries are at work, and about 200,000 tons of stone, mainly for road-making purposes, are worked every year. Three of the quarries, which are in Worcestershire, are restricted at present to working the faces which were in production at the time when the Town and Country Planning Act was passed in 1947. The fourth quarry, which is in the same range of hills, but is in Herefordshire, is working on somewhat less restrictive terms. Long-term plans have been prepared for the quarries, but the decision of the Minister of Housing and Local Government has been deferred for the present. It is not expected that a decision will be reached until it is seen how far the road stone required can be provided from other sources, and to what extent other materials can be used. Meanwhile, the Minister has announced that no further licences for quarrying will be granted without a public inquiry.

SOUTH-WEST ENGLAND AND SOUTH WALES.

Employment in Swansea and District.—Large numbers of vacancies for skilled workmen, chiefly fitters and turners, painters, plasterers, electricians and tinplate workers, have been reported by Mr. C. W. Stephens, the secretary, to the Swansea and District Employment Committee. Employment, he said, had been maintained at a high level in Swansea and the Swansea Valley and changes in demand for consumer goods and restrictions in supplies of raw materials had had little effect upon employment in the area.

ELECTRICITY BREAKDOWN AT BRIDGEND.—Members of the Tenants' Association at Bridgend Trading Estate have protested strongly, at a mass meeting, about the third electricity breakdown at the estate, which has meant the closing of 100 factories and unemployment for 3,500 persons. The breakdown, the third this year, occurred in the 4,400 yards of underground high-tension cable between a sub-station and the estate.

UNEMPLOYMENT ON SOUTH WALES TRADING ESTATES.—About 130 employees of Ferguson's radio factory at the Hirwaun Trading Estate have been given notice. It is intended to build up production of fluorescent lighting fittings at Hirwaun in place of radio apparatus. The Masteradio Ltd., Treforest Trading Estate, have dismissed 60 more workers. Whereas, at one time, 400 were employed at the factory, there are now only 40.

INDUSTRIAL AND DOMESTIC USES OF METHANE.—The National Coal Board scientific department are considering in what ways methane gas can be used, and the Gas Council are co-operating to explore the possibilities of using methane for household and industrial use; and the use of compressed methane or liquid methane as a fuel for driving internal-combustion engines is the subject of experiment, according to Sir Hubert Houldsworth, chairman of the National Coal Board, speaking at the Point of Ayr Colliery, Flintshire, on May 23. Reference to these developments was made by Sir Alfred Egerton, F.R.S., in his Coal Science Lecture on May 7, an abridgment of which appears on page 678 of this issue of ENGINEERING.

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.

CHEMICAL SOCIETY.—Thursday, June 5, 7.30 p.m., Chemical Society's Apartments, Burlington House, Piccadilly, W.1. Various short papers for discussion.

ROYAL INSTITUTION.—Friday, June 6, 9 p.m., 21, Albemarle-street, W.1. "Man at High Altitudes," by Professor G. I. Finch, F.R.S.

STOKE-ON-TRENT ASSOCIATION OF ENGINEERS.—Saturday, June 7, 6 p.m., The George Hotel, Stoke-on-Trent. Annual General Meeting.

ROYAL STATISTICAL SOCIETY.—*Study Section:* Wednesday, June 11, 6 p.m., The Electric Lamp Manufacturers' Association, 2, Savoy-hill, Strand, W.C.2. Annual General Meeting. "Measuring the Understanding of Educational Radio Talks," by Mr. J. Teenaman.

ROYAL SOCIETY.—Thursday, June 12, 4.30 p.m., Burlington House, Piccadilly, W.1. The Bakerian Lecture on "The Origin of the Solar System," by Professor H. Jeffreys, F.R.S.

WEST OF SCOTLAND IRON AND STEEL INSTITUTE and BRITISH IRON AND STEEL RESEARCH ASSOCIATION.—Friday, June 13, Institution of Engineers and Shipbuilders in Scotland, 39, Elmbank-crescent, Glasgow, C.2. All-Day Joint Meeting. 10 a.m., (i) "Some Experience with an All-Basic Tilting Furnace," by Mr. J. Mitton. (ii) "Some Measurements on Open-Hearth Furnace Flames," by Mr. G. W. van Stein Callenfels. 2.15 p.m., "The Problem of Correlating Laboratory Tests on Basic Bricks with Works Performance," by Mr. J. Mackenzie; followed by a general discussion on all three papers.

INSTITUTION OF PRODUCTION ENGINEERS.—*Eastern Counties Section:* Friday, June 13, 7.30 p.m., Garrett Memorial Hall, Ipswich. "Oil for Britain" Exhibition, arranged by the Esso Petroleum Co., Ltd., and Lecture on "Machine Lubrication," by Mr. C. J. Taylor. *Wolverhampton Graduate Section:* Tuesday, June 17, 7.30 p.m., Wolverhampton and Staffordshire Technical College, Wulfruna-street, Wolverhampton. Brains Trust Meeting on "Production Engineering Problems."

ROYAL SANITARY INSTITUTE.—Wednesday, June 18, 10.30 a.m., Central Library, High-road, Tottenham, N.17. Various papers, including "The Utilisation of Town Refuse," by Mr. H. Gurney.

ROYAL METEOROLOGICAL SOCIETY.—Wednesday, June 18, 5 p.m., 49, Cromwell-road, South Kensington, S.W.7. (i) "The Dissipation of Kinetic Energy in the Lowest Layers of the Atmosphere," by Mr. R. J. Taylor. (ii) "Structure of the Upper Westerlies: A Study of the Wind Field in the Eastern Atlantic and Western Europe in September, 1950," by Mr. R. Murray and Mr. D. H. Johnson.

CONTRACTS.

BRIMS & CO. LTD., Newcastle-upon-Tyne, are to carry out the civil-engineering work in connection with the construction of a new coal-shipping staith at Whitehill Point, North Shields, for the Tyne Improvement Commission. The work will include a jetty and ancillary equipment, the dismantling of existing staiths, excavation and foundation work, and the laying of railway sidings. Messrs. Brims are also carrying out extensions to two dry docks of the Middle Docks and Engineering Co. Ltd., South Shields. One dock is being lengthened by 25 ft. and the other by 71 ft.

During April the British Electricity Authority have placed contracts for equipment for power stations, transforming stations and transmission lines, amounting, in the aggregate, to 2,830,692*l*. The principal contracts include reinforced concrete cable tunnels for Deptford East power station, with A. WADDINGTON & SON; one 30,000-kW turbo-generator set for East Yelland power station, near Barnstaple, with C. A. PARSONS & CO. LTD.; ash and dust-handling plant for Portishead "B" power station, near Bristol, with B.V.C. INDUSTRIAL CONSTRUCTORS LTD.; control and instrument cables and accessories for Drakelow power station, Burton-on-Trent, with BRITISH INSULATED CALLENDERS CABLES LTD.; coal-handling plant for Ince power station, near Ellesmere Port, with SIMON CARVES LTD.; ash and dust-handling plant for Skelton Grange power station, Leeds, with BABCOCK AND WILCOX LTD.; pile foundations, access roads and main foundations for Fleetwood power station, with M. J. GLEESON (CONTRACTORS) LTD.; high and low-pressure pipework and valves for Blackburn power station, with Babcock and Wilcox Ltd.; and 132-kV 2,500-MVA and 3,500-MVA switchgear for West Melton and Neepsend substations, Sheffield, with the BRITISH THOMSON-HOUSTON CO. LTD.

BRITISH POLAR ENGINES LTD., Govan, Glasgow, booked orders for six Diesel engines and one auxiliary generating set during March. These include two M47M engines for a twin-screw cargo ship to be built by the AILSA SHIPBUILDING CO. LTD., for Watts, Watts & Co. Ltd., on behalf of a company in Gibraltar, and two 1,350 b.h.p. geared K47M engines for a cargo ship to be built by HENRY ROBB LTD., for the Currie Line. The auxiliary generating set ordered is of the K54E type and is for the CENTRAL MARINE ENGINE WORKS OF WILLIAM GRAY & CO. LTD.

THE ENGLISH STEEL CORPORATION LTD., Vickers Works, Sheffield, are to supply 12 large steel castings to a Canadian engineering firm for a 7,000-ton forging press. An 82-ton crosshead casting has been cast at the Corporation's Grimesthorpe works, Sheffield, and the other 11 castings have been allocated to the firm's subsidiary company, the DARLINGTON FORGE LTD.

THE BURNTISLAND SHIPBUILDING CO. LTD., Burntisland, Fife, have secured a contract to build two self-trimming colliers, each of 4,600 tons deadweight capacity, for Wm. Cory and Son, Ltd., London. The vessels will each have a length of 320 ft., a beam of 46 ft., and a depth moulded of 22 ft. 4 in. The load draught will be 20 ft., and the speed 10½ knots. The propelling machinery, which will be fitted right aft, will consist of triple-expansion superheated-steam engines supplied by the NORTH EASTERN MARINE ENGINEERING CO. (1938), LTD., Wallsend-on-Tyne.

MERRYWEATHER AND SONS LTD., Greenwich, London, S.E.10, have received an order from the London Fire Brigade for 20 Diesel-engined limousine-type dual-purpose fire appliances. The present contract will bring the total of Diesel pump-escape appliances in service in London to 38.

UNDERGROUND WATER PROBLEMS IN ARID ZONES.—The first symposium in Unesco's arid-zone programme was recently held at Ankara. Attended by 25 experts from 14 countries, it was concerned with the problems of underground water in the arid and semi-arid regions of the world. The subjects discussed included the physical and chemical properties, as well as the statics and dynamics, of underground water; the hydrological balance and the influence of utilisation of underground water and adaptation of drilling methods to local conditions; and the relationship between the hydrology of underground water and other sciences. Among recommendations made by an advisory committee prior to the symposium were that efforts should be made to obtain reports dealing with wind and solar energy and other energy sources; and that Unesco should study the possibility of setting up a sub-committee on wind power. In planning to develop improved living conditions in arid and semi-arid areas, the collection of certain basic data is a necessary preliminary. The complex interaction of different factors requires that such data should be collected in widely different fields, a careful balance being maintained between them. The committee recommended that Unesco should study the possibility of producing a handbook on the collection of such basic data for the use of technical personnel concerned with these problems.

PERSONAL.

Lord Brabazon of Tara, President of the Royal Institution, announced on May 25 that the managers of the Royal Institution had accepted the resignation of PROFESSOR E. N. DA C. ANDRADE, F.R.S., from the offices of Director in the Royal Institution, resident Professor in the Institution, Fullerian Professor of Chemistry, Superintendent of the House, and Director of the Davy-Faraday Laboratory.

LORD CUNLIFFE has been appointed to the board of the Brush Electrical Engineering Co., Ltd., Loughborough (the parent company of the Brush ABOE Group) and has resigned as a director and chairman of the National Gas and Oil Engine Co., Ltd., Ashton-under-Lyne. MR. A. P. GOOD has been appointed chairman of the latter company, MR. MILES BEEVOR has been made a director, and MR. A. E. CARRODUS has resigned from its board.

MR. NIELS MATHESON, technical director of British Oilfield Equipment Co. Ltd., has resigned his directorship to devote his full attention to his appointment as director of Associated Tube Wells Ltd. This firm is an associate company of the British Oilfield Equipment Co. Ltd., in the Brush ABOE Group of Companies.

MR. J. G. BRUCE, B.Sc., A.M.I.E.E., A.M.I.Loco.E., at present progress and planning engineer (Acton Works), in the department of the chief mechanical engineer (railways), London Transport Executive, 55, Broadway, S.W.1, has been appointed acting assistant mechanical engineer (works). MR. G. CLARK, at present acting production engineer, has been appointed production engineer (Acton Works).

DR. S. I. EVANS has resigned his position of lecturer in fuel technology in the University of Sheffield, on appointment as area chief scientist, East Midlands Division, National Coal Board.

MR. DAVID W. ROBERTS has been appointed assistant mechanical and electrical engineer at South Wales Docks by the Docks and Inland Waterways Executive. He had previously been assistant mechanical engineer at Newport Docks and at Cardiff Docks.

MR. CHRISTOPHER DYKES, M.A., M.Sc., informs us that after relinquishing his position as chief engineer (development) of the British Overseas Airways Corporation, he is establishing himself as an advising aeronautical engineer on aircraft problems, particularly on those relating to air transport, such as the selection of new aircraft and equipment. His address is 31, Pembroke-gardens, London, W.8. (Telephone: WEStern 9493.)

MR. GEORGE MORRISON, managing director of the Greenock Dockyard Co., Ltd., has been appointed President of the Greenock Chamber of Commerce for the ensuing year, with MR. J. GORDON INNESS, of John G. Kincaid & Co., Ltd., as vice-president.

MR. V. G. COOK has been appointed manager of the London and South Eastern area of the small-tools division of Burton, Griffiths & Co. Ltd. He will operate from the firm's London office and showroom at 93, Albert-embankment, S.E.11. (Telephone: RELiance 3891-7.)

MR. CHARLES RAMSDEN, overseas director of the Federation of British Industries, 21, Tothill-street, London, S.W.1, has retired after 33 years of service with the Federation. His successor is MR. PETER TENNANT.

MR. H. G. HERRINGTON has been promoted to the position of managing director of High Duty Alloys Ltd., Slough, Buckinghamshire, a member company of the Hawker Siddeley Group.

MR. WALTER SYMES has resigned from the board of the Metropolitan-Vickers Electrical Co. Ltd., and from the position of works manager at Trafford Park Works, Manchester, 17, in order to take up the appointment of manufacturing consultant, Associated Electrical Industries Ltd. MR. A. C. MAIN, B.E. (Adelaide), M.I.E.E., assistant works manager, Trafford Park Works, has succeeded Mr. Symes as works manager and has been elected a director of the Metropolitan-Vickers Co.

THE ENGLISH ELECTRIC CO., LTD. announce that the London section of their publicity department has been moved to Marconi House, 336-7, Strand, London, W.C.2. (Telephone: TEMple Bar 1577.)

FLETCHER MILLER LTD., Alma Mills, Hyde, Manchester, announce that their southern works have now been transferred from Hayes, Middlesex, to Alma Wharf, Dormay-street (off Armoury-way), Wandsworth, London, S.W.18. (Telephone: VANdyke 6033-4; telegrams: Kooledge, Put. London.)

The firm of BRITISH TUNGSTEN LTD. has been appointed agent for the Ministry of Materials for the import and distribution of tungsten ores. The firm has been constituted by the three firms which, hitherto, have been acting jointly as the Ministry's agents, namely, DERBY AND CO. LTD., 11-12, St. Swithin's-lane, London, E.C.4; METAL TRADERS LTD., 7, Gracechurch-street, London, E.C.3; and H. A. WATSON & CO. LTD., 448, Derby House, Exchange Buildings, Liverpool, 2. Inquiries should continue to be addressed to these firms at the above addresses.

EXHIBITS AT THE MECHANICAL HANDLING EXHIBITION.

(*For Description, see Page* 677.)

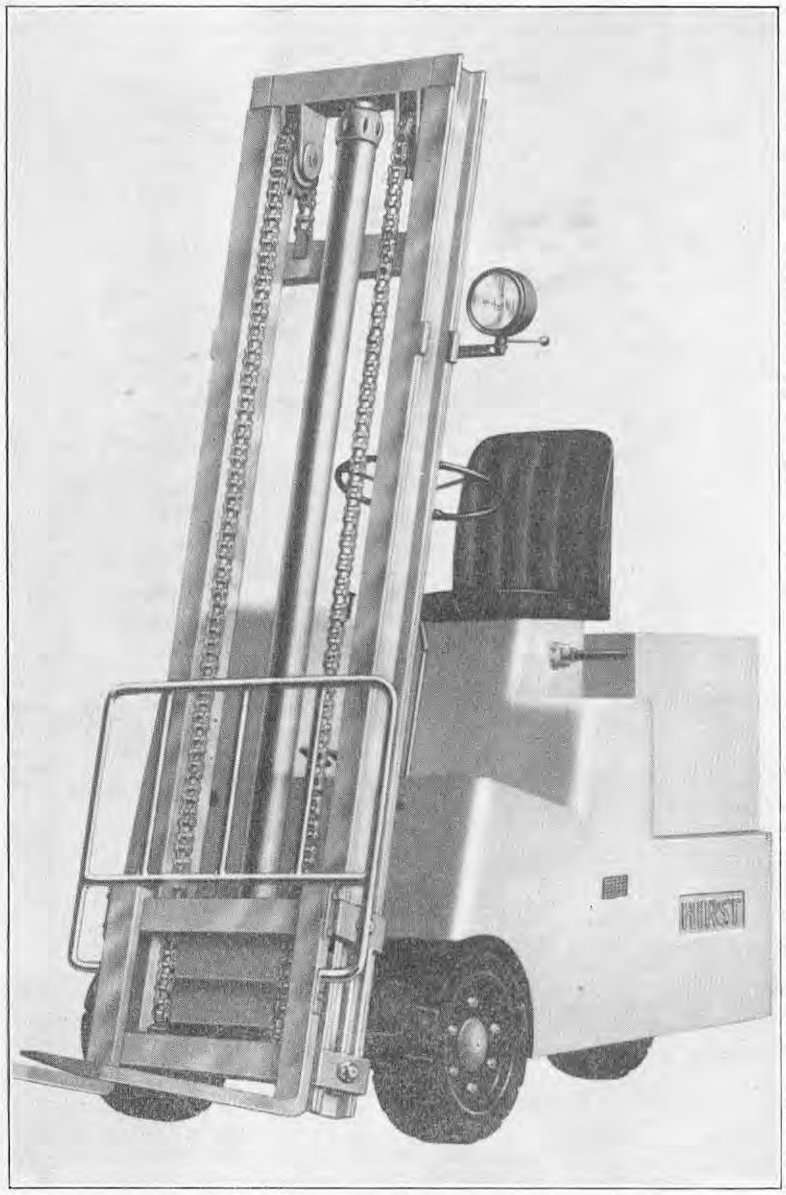

FIG. 5. 1-TON BATTERY-DRIVEN FORK TRUCK; A. HIRST & SON, LIMITED.

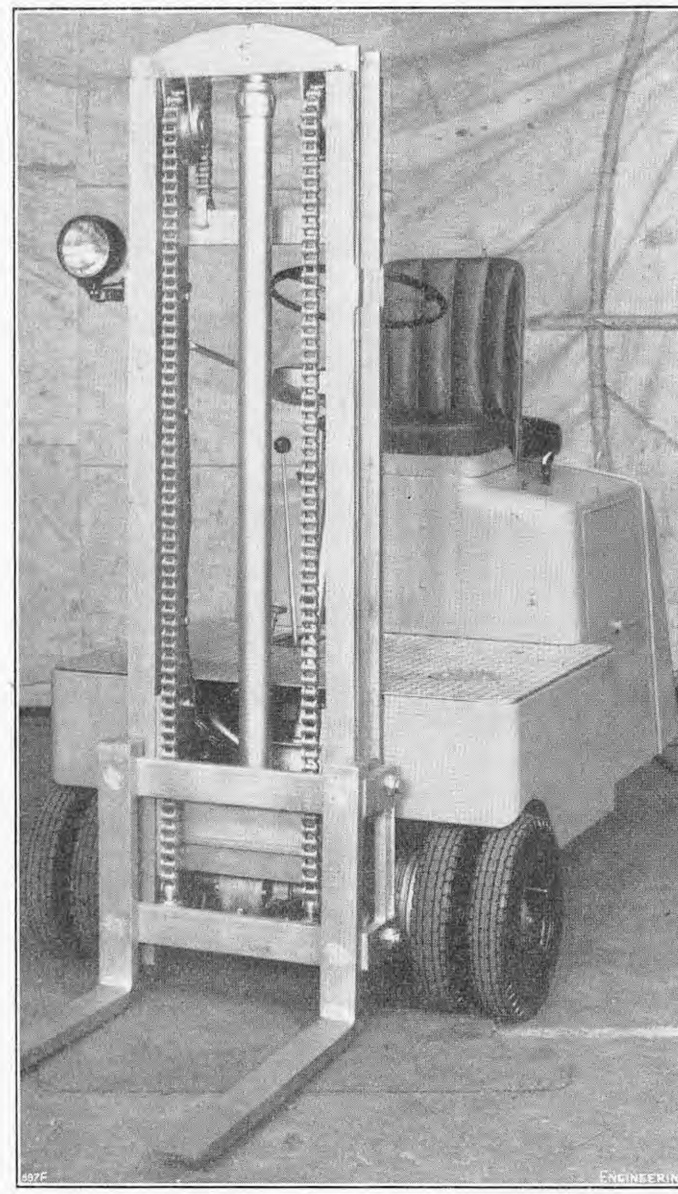

FIG. 6. ½-TON PETROL-ENGINED FORK TRUCK: A. HIRST & SON, LIMITED.

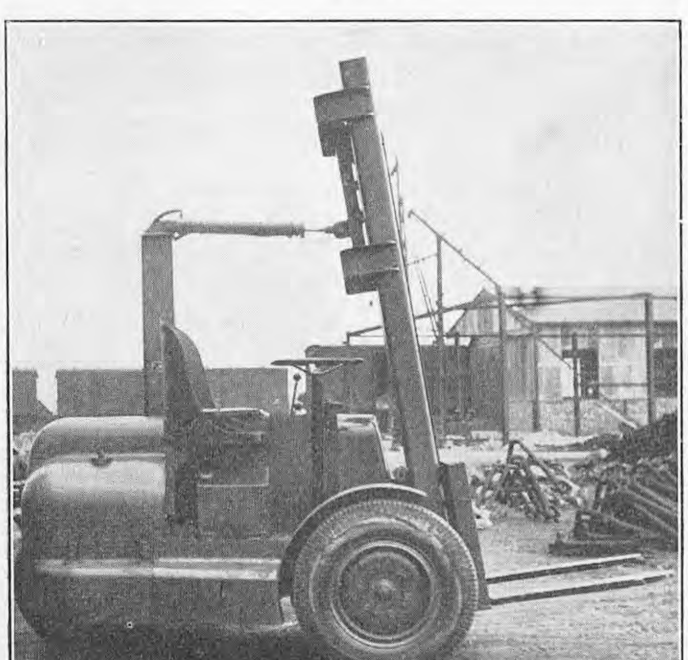

FIG. 7. 1-TON PETROL-ENGINED FORK TRUCK; MATHEW BROTHERS.

FIG. 8. 4,000-LB. PETROL-ENGINED FORK TRUCK; CONVEYANCER FORK TRUCKS, LIMITED.

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SURFACE WATERS.

IN broad general terms, it may be said that Great Britain is made up of two regions roughly of equal area, one mountainous and the other consisting of lowland plains. They are approximately delimited by a line connecting the mouth of the River Tees, in the North Riding of Yorkshire, with the mouth of the River Exe, in Devonshire. The separation between the two types of country is not exact, one fades into the other, and there are local exceptions to the general rule, the Cheshire Plain, for instance, lying within the mountainous section, but in broad terms the division of the country into upland and lowland areas is definite. One of the results of this configuration is that the western region has a higher rainfall than the eastern. The rain-bearing winds blowing from the west deposit much of their moisture in upland Britain, parts of which have a very heavy annual rainfall which is considerably greater than the corresponding figure for the lowland areas to the east.

These natural conditions have influence and bearing on questions of domestic and industrial water supply. Allowing for local exceptions, it may broadly be said that towns situated in the upland area are dependent on surface waters and those in the lowland area on wells. Many of the large towns lie to the west of the imaginary line from the Tees to the Exe but some, such as Manchester and Liverpool, have been able to tap suitable sources only by the construction of long pipe lines. The same thing applies to Birmingham which lies almost directly on the imaginary boundary line. London, lying far within the lowland area, has been able to satisfy most of its requirements by utilising surface waters drawn from the Rivers Thames and Lee or Lea. (The Ministry of Housing and Local Government does not seem to be clear about the correct way to spell the name of this river.) It has more than once been suggested, however, that London may ultimately be forced to follow the example of many other large towns and proceed to obtain water from the mountainous area of South Wales. The characteristic dependence of lowland area communities on wells is illustrated by the example of many of the smaller towns around London, and even the Metropolitan Water Board obtains one-sixth of its supplies from wells. This is, moreover, not a measure of the extent to which London is dependent on underground water; there are more than 700 wells in Central London and the Metropolitan area. Most of these are in private ownership and date from the time when individual exploitation of water resources was not controlled.

Water supply is by far the most important of all public services. It does not receive the controversial attention bestowed on gas, electricity and transport, but the population could continue to exist if these were greatly curtailed or, in some cases, discontinued, but without water, the people perish. In view of this, it might be supposed that complete information would be available about the water resources of the country. The necessity for a water survey was pointed out by a committee of the British Association as long ago as 1878, but the Inland Water Survey Committee set up in 1935, stated in its third report published in 1939, that "neither the information available from the water undertakers nor that from Catchment Boards is sufficient in scope or adequate in quality to enable a comprehensive survey to be made." In 1952, it is stated by Major-General G. Cheetham, the present chairman of the Inland Water Survey Committee, that "the survey of surface water is still in its infancy."

This remark is made in the foreword to a report* published by the Ministry of Housing and Local Government in conjunction with the Scottish Office. As indicated by its title, this 134-page report is not concerned with underground water, but the Central Advisory Water Committee has stated that three-quarters of the population of England and Wales is supplied with water obtained directly from rivers, streams or springs, and it may be surmised that in Scotland, lying entirely in the upland area of Great Britain, the proportion is even higher. In view of this it is clear that surface water should take precedence in any survey of resources, especially as there is a tendency for underground-water areas to take advantage of such surface waters as are available. In some cases this is due to wells at no great distance from the sea becoming brackish, as happened in Liverpool some hundred years ago.

The report follows two earlier ones, published in 1938 and 1939, which dealt with the two-year period ended September 30, 1937. The long delay in the preparation of this third report has been due to difficulties caused by the war. The examination and co-ordination of the large amount of material supplied by various types of authority, or by individuals, was a task of some magnitude. Officially, and it may be hoped actually, the amassing of statistical information on surface water will, from now on, be carried out on a wider scale and with more consistency, as one of the duties placed upon the River Boards created by the Act of 1948 is to record "the flow or volume of any river, stream or inland water in the area and for those purposes to install and maintain such gauges or other apparatus and works connected therewith as may be specified."

The incomplete nature of the information at present available is clearly illustrated by the

* *The Surface Water Year-Book of Great Britain,* 1937-45. H.M. Stationery Office. [Price 17*s.* 6*d.* net.]

report. For the purposes of record and presentation, Great Britain is divided into 100 surface-water areas, but figures for river discharge, run-off and rainfall are given for only 21 of these. There is, for instance, no information about any area south of a line joining the Thames and Severn Surface-Water Areas. No doubt, in due course, River Boards, when in effective operation, will undertake measurements on which records can be based, but the accumulation of consistent data for the whole of the areas is not likely to be accomplished for many years. It was originally planned to publish a report covering the years 1937 to 1950, but it was found that in many cases records available for later years had "not been sufficiently digested by their owners to permit of their being easily examined centrally and arranged uniformly for reproduction."

If consistent records for the whole country are to be prepared, it will be necessary for the large number of authorities and individuals concerned to agree on clear definitions of such terms as "river reach" and "average discharge." The setting up of the River Boards will no doubt assist in this matter, especially for the more important rivers. It is stated that no attempt has been made to define the accuracy of statistics given in the report. This would probably have been impossible and no doubt there is considerable variation. The measurement of river discharge is a difficult and by no means precise operation and the last few integers in figures quoted frequently have no meaning. The report restricts figures for discharge in cusecs to not more than one place of decimals.

Although, as stated above, statistics are given for only 21 surface-water areas, they cover reports from 52 stations. These, as would be expected, cover such important rivers as the Thames and Severn. For the River Severn Basin, measurements are recorded for the River Vyrnwy below the Vyrnwy Reservoir, on the River Avon at Evesham, and on the Severn at Bewdley. A special tribute is paid in the report to the enterprise shown by the Catchment Boards of the River Nene and the River Wye, and their respective engineers. It has been possible to include records taken at eight stations in the Nene Basin and seven stations in the Wye Basin. Contrasted with these, the River Trent Basin is represented only by figures for the River Blithe at Hamstall Ridware and the River Derwent at Yorkshire Bridge. For the Thames Basin, records for the main river at Day's Weir and Teddington are given together with those for the River Wandle at Beddington and Wimbledon.

Although the records do not extend beyond the year 1945, this is not an indication that they are out of date and of little service. On the contrary, the whole value of records of rainfall and river flow depends on the length of time they cover. No doubt river discharge will change with the years and the record for the River Elan in the Wye Basin will presumably be modified with the completion of the new Birmingham Corporation Water Works reservoir. Incomplete as the statistics are, they should prove of considerable service to anyone concerned with water supply or drainage problems. Study of the behaviour of one type of river in relation to rainfall and run-off over a period of years, should furnish broad general ideas from which the behaviour of other rivers of a similar type may be estimated, even if few or no data are available for them. The report will also help to stimulate interest in an important and largely neglected subject, although this latter adjective should cease to apply in a few years if the River Boards carry out all the functions imposed on them. Their duties in connection with river pollution have received most public attention, but the collection of hydrographic data is of equal importance and, indeed, information on flow and discharge will frequently be necessary in the proper consideration of the problems arising from pollution.

ATOMIC ENERGY RESEARCH AT HARWELL.

In the application of atomic energy to the production of power for industrial purposes, the question to which an answer is being sought is whether power production by that means can be economic. The most up-to-date authoritative statement in this connection is to be found in a book,* published this week, on the work of the British Atomic Research Establishment, at Harwell. It reads: "Clearly no very certain estimates can be made of the time-scale of this work [of development], but it is the opinion of those best qualified to judge that a decade will elapse before we shall be able to say whether economic generation of power by nuclear fuel is possible." Even if the answer is favourable, it is evident that a further period must elapse before atomic-energy power stations are operating on an appreciable scale. The outlook, therefore, is unchanged from what it has been for the past few years, but the programme of research and development at Harwell, in progress and planned, is now described in straightforward language though in sufficient detail to enlighten the technically-minded who are not in the main stream of atomic-energy work.

Indeed, the Ministry of Supply and the Central Office of Information have produced a commendable review of the activities at the Harwell Establishment since it was founded in 1946. For security reasons, a line has been drawn to mark the perimeter of material that can be published, and doubtless those engaged on the work could say exactly where it has been drawn; but other readers are not likely to be aware of it. The anonymous authors have painted a picture of the research that will satisfy a general need; those who wish to inquire further into the history and general background of atomic energy can turn to the books that are listed for reference (one, *The Story of Atomic Energy*, by Dr. Frederick Soddy, F.R.S., was first published in ENGINEERING in 1947, vol. 164); and those whose interests are in specific developments are given a long list of papers by members of the Harwell staff. In the past few years much information has been published—certainly more than is generally realised—though it is doubtful whether the new techniques have been applied, with benefit to industry, on a sufficiently wide scale.

The generation of power by atomic energy, if it becomes an economic proposition, will have the effect of greatly increasing the world's effective fuel reserves. In Great Britain, where there is no oil and relatively little water power, and where even the coal reserves are not inexhaustible, this development will be specially significant. The Harwell book admits that it is unlikely that the industrial use of nuclear power will lead to cheaper electricity since the costs of distribution of electricity represent a substantial proportion of the total costs, and the capital costs of nuclear power stations will be larger than those of conventional power stations, but the pattern of costs and availability are bound to alter in the future, and there are some possible applications, as in ships, where the small weight of nuclear fuel is important. The only method of producing nuclear power which is likely to be successful in the next decade or so is the use of a reactor as a furnace, transferring heat to a conventional electrical generating plant. A programme on reactor development was therefore drawn up at the Establishment. It is in two parts: the first is a theoretical examination to decide which kinds of reactor are most likely to be successful; and the second is a two-stage experimental programme to determine accurately the data required for practical design and to test prototype reactors. The main part of the theoretical programme has been completed and the first stage of the experimental programme is well advanced.

The main requirement in design is that the reactor shall develop heat at a temperature high enough to enable it to be converted into power efficiently. The three types of reactor that have been considered are the slow, intermediate, and fast, these adjectives referring to the relative speeds of the neutrons causing fission. Gleep and Bepo* are examples of slow-fission reactors. A moderator is used to slow down the neutrons to thermal energies, but no reactor of this kind has yet been built that will run at the desired high temperatures. Intermediate reactors, which also employ a moderator, can be smaller than corresponding slow reactors. Fast-fission reactors, on the other hand, require no moderator; fission is produced by neutrons while they are still moving with the high speeds with which they start. The heat generated in fission would be transferred to the power system by a coolant flowing past the metal-sheathed fuel elements.

Design and "feasibility" studies are proceeding at Harwell on three types of reactor: a slow-neutron enriched-uranium reactor designed as a prototype power unit for special applications such as ship propulsion; a slow-neutron natural-uranium reactor designed to develop power for electricity generation; and a fast or intermediate reactor designed to develop power and conserve fissile material by means of the "breeching" principle. "Breeching" offers the unique possibility of a furnace which, in developing energy by burning a primary fuel, will produce, in the process, a greater amount of an equally efficient secondary fuel than it consumes of the primary fuel. It is important because the primary nuclear fuel uranium 235 is scarce. Breeching may allow the secondary fuels plutonium 239 and uranium 233 to be produced from the more abundant uranium 238 and thorium 232, thus increasing greatly the potential reserves of nuclear fuel.

The first-mentioned design project, for a slow-neutron enriched-uranium reactor, envisages a pile rather similar to Bepo, but working at a much higher temperature—perhaps up to 600 deg. C.—the heat being transferred to a steam boiler. By using enriched uranium (i.e., uranium with the 235 isotope content increased) the size of the pilot plant can be kept within reasonable limits. It is hoped that it will be possible to start building the reactor this year. The project for a slow-neutron natural-uranium reactor, however, will require a longer time for study. The utilisation of uranium in this type of reactor is very inefficient. To supply the present annual electricity needs of the United Kingdom—about 38,000 million kilowatt-hours—would require 600 metric tons of uranium. Such large supplies of uranium could only come from low-grade deposits, so that the cost of power production by this means would depend on the cost of extraction. This inefficient use of uranium can be avoided in fast and intermediate reactors, by means of breeching, using plutonium, or uranium highly enriched in uranium 235, as fuel. The core of such a reactor would be quite small—about 1 ft. or 2 ft. in diameter—and the neutron flux would be very high. To overcome the difficulty of removing the heat from the small core, it is probable that the reactor would consist of fissile material enclosed in tubes past which liquid-metal coolant would flow in a closed circuit, the outer part of the coolant circuit being in the boiler or a heat exchanger. There are, however, many other possibilities.

The most important problem in these studies is the metallurgical problem of finding materials which will withstand high temperatures while being

* *Harwell: The British Atomic Energy Research Establishment.* 1946-1951. H.M. Stationery Office, York House, Kingsway, London, W.C.2. [Price 6s. net.]

* See ENGINEERING, vol. 166, pages 97 and 154 (1948); vol. 169, page 734 (1950); and vol. 170, page 497 (1950).

bombarded by dense streams of neutrons and other radiations. Beryllium and zirconium might be used to "can" the uranium, and methods are therefore being worked out of extracting these metals with the requisite purity, and of fabricating them. Investigations are also being made into methods of coating the uranium with a layer of the canning metal—an arrangement that would have the advantage of improving the rate of heat transfer. Heat is removed in graphite-moderated slow-fission reactors by air currents (as in Bepo) or by water (as in the American piles at Hanford). Experiments have been conducted on cooling by gas, which is used at high pressure and in a closed circuit, and the possibility is being studied of using liquid metals, such as molten sodium, a molten alloy of sodium and potassium, and mercury. Molten metals have the advantage that they can be pumped round a circuit by electromagnetic induction pumps, which have no moving parts. The chemists and chemical engineers at Harwell are engaged on the problem of separating secondary fuel elements from the breeding elements; a continuous process would be ideal, but at present "it is no more than a chemical engineer's dream." These are only some of the problems mentioned in the chapter on the reactor programme. The other chapters deal with the several branches of the work at Harwell, which, viewed as a whole, is the fundamental research and development in the British atomic-energy effort; complementary to it is the work of the production organisation at Risley, Lancashire.

NOTES.

SCIENTIFIC MAN-POWER.

THE Committee on Scientific Man-Power was appointed by the Advisory Council on Scientific Policy, in December, 1950, "to study the future needs of scientific and technological man-power for employment both at home and abroad, and to report to the Council from time to time." An important definition in the Committee's latest report (Cmd. 8561, price 6*d*. net, from H.M. Stationery Office) on the supply of and demand for scientists is the explanation, at the outset, that they "use the term 'scientist' in a general way to signify a man or woman trained either in fundamental or applied science to the level of a university degree or equivalent qualification." The report is concerned with four problems, namely, the supply of and demand for scientists during the current decade, the steps to be taken to rectify any deficiencies in the supply, the quality of Britain's scientific man-power, and, in conclusion, the steps that should be taken to improve its quality. The preamble states that the scope of the inquiry included both research workers and "the much larger number of scientists, in engineering and other technologies, whose task it is to apply the fruits of research to practical ends." In fact, the latter category occupies the greater space in the report, which is concerned much more with the functions or possible functions of scientists in promoting industrial productivity than with their employment in pure research. The Committee appear to take the view that the handicap represented by a steadily increasing average age of the population, with the consequent need to use the available man-power more efficiently, requires an increase, "both absolutely and relatively," in the numbers of scientists employed in industry—further defined as "men who know how to apply the latest results of scientific research to practical problems of production." Comparison is made particularly with the output (and presumed absorption into industry) of scientists in the United States and in Switzerland; in both countries, the ratio is much higher than it is in Britain, even after allowing for the admission by the Anglo-American Council on Productivity that the academic standard of the American first degree is lower than that of a British degree. It is considered, however, that the shortage in British industry is likely to persist for a considerable time, partly for lack of sufficient good teachers of science, and partly because of the need to educate parents and scholars to take a different view of the value of a qualification in science compared with the study of the humanities.

LARGE ELECTRIC POWER TRANSMISSION SYSTEMS.

The fourteenth assembly of the International Conference on Large Electric Systems, which is more familiarly known as C.I.G.R.E., opened in Paris on Wednesday, May 28, and will continue until Saturday, June 7. As on former occasions, the meetings are taking place in the handsome building of the Fondation Berthelot in the Rue Saint-Dominique, and, to complete a very crowded programme of 121 papers in the short space of ten days, two or more gatherings are being held simultaneously. The attendance is larger than on any previous occasion, it being officially stated that more than 1,300 delegates from 42 different countries are present. The opening ceremony was presided over by Mr. L. Saulgeot, Director of Gas and Electricity in the Ministry of Industry, in the absence of Mr. A. Louvel, the Minister of Industry, who was detained at a meeting of the French Cabinet. In the course of a short address, Dr. R. A. Schmidt, president of C.I.G.R.E., extended a welcome to the delegates and expressed their thanks to the French committee for undertaking the organisation of the conference. That conference might, he said, be described as a "feast of technics," and it was a feast in the sense that it provided them with an opportunity to meet and discuss the problems to which they were devoting their lives. Many of the problems they had considered at previous conferences had either been solved or were on their way to solution; and it might therefore be said that their deliberations represented a victory of mind over matter. The quality of many of the papers, which they would have before them at the present conference was high, and stressed the growing importance of their work. He hoped the discussions upon them would lead to fruitful results. After the thanks of the French-speaking delegates had been expressed by Mr. G. Silva and of the English-speaking delegates by Mr. E. V. Leipoldt, a short lecture on the generation and transmission of electricity in Sweden was delivered by Mr. A. Rusck, the general manager of the Swedish State Power Board. In this he described the development of the use of electric power in that country and pointed out that while the centres of population were mainly in the south, the greatest concentrations of water power were in the extreme north. This had naturally resulted in the examination of the possibilities of using very high voltages for transmission and had culminated in the construction of a line from Harsprånget to Hallsberg, which, since the early part of the present year, had been operated at 380 kV. Work on further lines operating at the same voltage was either in progress or projected. On Wednesday afternoon, a number of papers on alternators and interference were presented at two separate meetings. Subsequently, the latter of these two subjects was further considered in committee.

THE MAUDSLAY SOCIETY.

The annual general meeting of the Maudslay Society—which exists primarily "to perpetuate and preserve the memory and work of Henry Maudslay and his associates and successors in the engineering firm that he founded" by promoting "scholarships, exhibitions or other form of permanent memorial"—was held in London on Friday, May 23, under the chairmanship of the President, Mr. O. D. Smith. The President's report and the accompanying statements of accounts showed that the Society had a balance in hand at March 31, 1952, of some 715*l*. and that the Maudslay Scholarship Fund (which is held by the Charity Commissioners) amounted to 10,998*l*. in Government stocks. The third Maudslay Scholarship, of 125*l*., was awarded to Mr. John Robert Weaver-Smith in December, 1951, at the inaugural meeting, for the 1951-52 session, of the Junior Institution of Engineers, which began in 1884 as an association of apprentices in the works of Maudslay, Sons and Field, and, by reason of that connection, collaborates with the Maudslay Society in selecting recipients of the Scholarships. The income of the Scholarship Fund having amounted to 235*l*. in the last year, it has been decided to increase the value of the fourth Scholarship to 150*l*. (Particulars, and forms of application, may be obtained from the secretary of the Junior Institution of Engineers, 39, Victoria-street, Westminster, S.W.1; the closing date for the receipt of applications is August 1.) Prior to the annual general meeting, the annual luncheon of the Society was held in the King Charles suite, Whitehall-court, S.W.1, at which the President took the chair. The principal guest was the Rt. Hon. Lord Brabazon of Tara, P.C., who, in proposing the toast of "The Maudslay Society," observed that three remarkable changes had come about in the lives of people of his own age, resulting from the introduction of the motor car, radio, and the aeroplane. Henry Maudslay (1771-1831) had lived at the beginning of a change which had covered the country, namely, the industrial application of the steam engine, which had brought in its train a peculiar prosperity that would not have been so widespread but for him. Not only so, but he contrived to impart a notable beauty of line and proportion into his engineering, in pursuance of a policy which, a century or more later, Henry Ford had crystallised into the epigrammatic instruction to his designers to "Simplify and add more lightness." He was, in short, a great engineer and a great craftsman; and those who supposed, as some inclined to do at the present day, that they could be great engineers without being great craftsmen, were making a serious mistake. The President, in his reply, said that Maudslay and his associates had laid the foundation of modern engineering skill and knowledge. He lived in an age of trial and error—but many important engineering developments were still being made by that method. The toast of "The Guests," proposed by Mr. J. Foster Petree, historian to the Maudslay Society, was acknowledged by Mr. Geoffrey Tookey, Q.C., a former chairman of the Junior Institution of Engineers.

PRODUCTION OF PETROLEUM EQUIPMENT IN THE UNITED KINGDOM.

The Council of British Manufacturers of Petroleum equipment, it will be recalled, was formed by firms who manufacture equipment, or provide services to the petroleum industry. In the words of its articles of association, its object is "To promote and develop in the United Kingdom of Great Britain and Northern Ireland the industry of petroleum equipment manufacture . . ." It is not a trade association, however, and does not intervene in the commercial activities of the member firms, being concerned mainly with technical matters. The field covered is wide, the 375 members being drawn from all types of industrial bodies manufacturing equipment ranging from that required for the winning of oil to that used in the distribution of the refined products. The Council maintains a close liaison with similar bodies, Government departments, etc., and keeps the member firms advised on important developments in the industry. One of its major functions is the provision of technical advice and in this connection various technical subjects such as corrosion, packings, jointings, valves, etc., are studied by committees or individuals and the results circulated to member firms. The Council also works in close liaison with the British Standards Institution and other organisations for the purpose of formulating suitable standards for equipment. This work has resulted in the introduction of some 30 standards for petroleum equipment. Recently, the Council issued figures showing the value of orders for materials and equipment placed in the United Kingdom during 1951 by the various oil companies. These figures, supplied by the Oil Companies Materials Secretariat, show that the total value of such orders is equivalent to almost 84,000,000*l*. and illustrate the remarkable development of the British petroleum equipment industry, particularly when it is appreciated that the pre-war comparative figure is in the neighbourhood of 9,000,000*l*. The equipment ordered was varied, ranging from geophysical and other exploratory apparatus through drilling rigs, etc., to boiler-house plant. The total figure covers both home and export orders, but it is understood that the expert figure for the first three periods of 1951 totalled 42,302,340*l*.

OBITUARY.

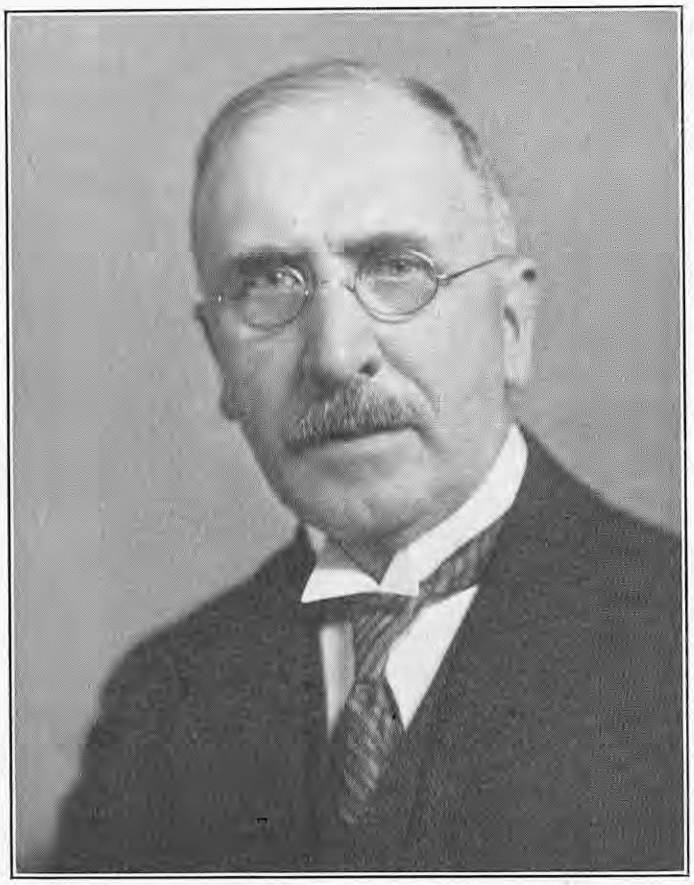
MR. S. S. COOK, F.R.S.

LITTLE more than a couple of months ago we had to record the death of Mr. W. H. Pilmour, the managing director and secretary of the Parsons Marine Steam Turbine Company, who had been connected with the company since its establishment more than 50 years ago. Now, we regret to report that the company have lost another director of long standing, and of international scientific repute, by the death on May 21, after a short illness, of Mr. S. S. Cook, F.R.S., at the age of 77. Like Mr. Pilmour, Mr. Cook had been with the older firm of C. A. Parsons and Company at their Heaton Works before the establishment of the Turbinia Works at Wallsend-on-Tyne, but it was in connection with the marine steam turbine that he was most widely known among engineers.

Stanley Smith Cook was born in Canterbury on January 25, 1875, and received his general education at the King's School in that city, which he attended from 1889 to 1893. In the latter year he went up to St. John's College, Cambridge, where he graduated B.A., being 7th Wrangler in the Mathematical Tripos in 1896, and obtaining first-class honours in the Engineering Tripos in the following year. He remained at Cambridge for a while after taking his degree, to study experimental electricity in the engineering laboratory, but in 1898 went to Newcastle-on-Tyne to serve an apprenticeship of three years with C. A. Parsons and Company. There he was brought into intimate contact with Parsons' famous collaborator, the late Dr. Gerald Stoney, F.R.S., to whose genius the development of the steam turbine owed almost as much as to Parsons himself; with the result that, after Cook had served only a year of his apprenticeship, he became Stoney's personal research assistant. He retained that position until 1903, when he was appointed an assistant designer on the staff of the Parsons Marine Steam Turbine Company, which had been formed in 1901 to take over from the original Marine Steam Turbine Company the right to use Parsons' marine-propulsion patents. With the new company, Cook was to spend the rest of his life. He served for seven years as assistant designer and was then appointed technical manager. In 1927 he was made a director, and was still a member of the board at the time of his death.

The mere chronicle of Cook's successive promotions in the firm to which he had devoted practically half a century of service, however, conveys no adequate impression of how valuable that service was, not only to the firm but to the development of marine propulsion, or of the versatility of his scientific genius. He represented, in fact, an exceptional combination of engineer, mathematician and scientist; and the problems that had to be solved in the course of applying the steam turbine to the propulsion of ships were sufficiently numerous and novel to provide ample scope for his abilities in all three fields, quite apart from the incidental investigations which came his way as the result of Parsons' excursions into such diverse studies as the design of searchlights and the artificial production of diamonds. When Cook went to Newcastle in 1898, most of the experimental work on the famous launch Turbinia had been completed, though she was still in occasional service for demonstration purposes; for example, she was taken to the Paris Exposition of 1900. She had served her purpose, however, and, when Cook was transferred from the Heaton works to Wallsend, the suitability of the steam turbine for shipboard use was no longer in doubt. There had been a temporary set-back in consequence of the loss of the destroyer Cobra, but the Clyde steamers King Edward and Queen Alexandra were in regular service, the Channel steamers Queen and Brighton were almost completed, and orders for other and larger turbine-driven vessels were being placed at a rapidly increasing rate. Marine-engine builders all over the country were taking out licences to construct the new type of machinery, and all of these firms relied, of necessity, upon the Parsons Marine Steam Turbine Company to provide the basic particulars of the designs. To compare some of the types of turbine blading then in use with those of the present day is to realise a few of the problems involved in developing an entirely new method of propulsion.

Cook had much to do with the design of blading, and with the strength considerations involved in producing rotors to revolve at speeds previously attained only by machines of much smaller size; but possibly some of his most prolonged researches were in connection with propeller cavitation. It was his work in this field which eventually brought him his Fellowship of the Royal Society; though it might be supposed, by anyone reading of the subject for the first time in Cook's Parsons Memorial Lecture of 1938, that all the work of finding a solution to that urgent problem had been done by Parsons himself. Like most large-scale investigations, of course, it required the close and sustained teamwork of a number of researchers, but it was Cook, we believe, who was responsible for much—in fact, for most—of the mathematical computation of the impact pressures set up by the collapse of cavities in water, caused by a fast-running propeller. Cook showed (and Lord Rayleigh later confirmed) that the pressures instantaneously caused by this water-hammer effect in a vortex cavity could reach hundreds of tons per square inch. His results were presented in a paper which, jointly with Sir Charles Parsons, he delivered to the Institution of Naval Architects in 1919. It was the first of three of which he was joint author, read before that Institution, all delivered within five years, the others dealing with marine-turbine gearing. This was another subject of which he had exceptional knowledge, having been intimately concerned with its development from the time of Parsons' first experiments with the tramp steamer Vespasian.



THE LATE MR. S. S. COOK, F.R.S.

Cook had been a member of the Institution of Naval Architects since 1909 and was a fairly regular attender at the Spring Meetings in London until recent years; but he joined the Institution of Mechanical Engineers only in 1939, following his delivery of the Parsons Memorial Lecture, to which reference has been made. On the occasion of the Institution's centenary, in 1947, he collaborated with Dr. T. W. F. Brown and Mr. F. W. Gardner in contributing a survey of "Steam and Gas Turbines for Marine Propulsion." He was also a member of the Institute of Metals, and a Fellow and Gold Medallist of the North East Coast Institution of Engineers and Shipbuilders, to which he had belonged for 40 years. In that institution he took a keen interest, being a member of the Council and of numerous committees.

THE CAMBRIDGE UNIVERSITY ENGINEERS' ASSOCIATION.—We have received from Mr. A. H. Chapman, honorary secretary of the Cambridge University Engineers' Association, a copy of the *Register* of the Association, containing the names of some 1,360 members. The objects of the Association, which was founded in 1929, are to keep Cambridge engineers in touch with each other and with the engineering department of the University, to which end a periodical *Bulletin* is issued and a reunion is held annually at Cambridge in July. Former Cambridge graduates in engineering who desire particulars may obtain them from Mr. Chapman at the Engineering Laboratory, Trumpington-street, Cambridge.

LETTERS TO THE EDITOR.

THE ECONOMICS OF FUEL AND POWER.

TO THE EDITOR OF ENGINEERING.

SIR,—I cannot allow your editorial of May 16 to go unchallenged. Being in no way connected with either the electricity or gas industries, but a mere consumer, I may possibly be allowed to make certain observations without being accused of bias. One may perhaps be pardoned for harbouring the suspicion that to quote a deputy of the British Electricity Authority on the subject of gas is hardly "considering the matter judicially," to quote your own expression.

You state that an improvement in national generating-plant efficiency cannot be expected by the employment of back-pressure turbines in large stations. Ignoring the recent installation of two such machines at Battersea, which is an illustration of this very nature, those who are advocating the greater employment of back-pressure machines have always emphasised that these should be installed in small stations situated in the centre of an urban or industrial area, and that large stations should not be built to the exclusion of all others. The only method of finding out whether the cost of heat distribution is "uneconomic" is to build one or two combined heat and power stations, lay distribution mains and see how much consumers are prepared to pay for the convenience. That was how the electricity and gas industries started; there appears to be no valid reason why the same degree of commercial risk should not be taken with heat distribution.

I confess I am unable to follow the arguments quoted by you about the efficiency of the gas industry. If my facts are correct, two tons of coal produce approximately 150 therms of gas and one ton of coke. Assuming that the efficiency of utilisation of the coke is the same as for coal, and taking your figure of 50 per cent. for the efficiency of utilisation of gas, we find that we should need to burn at least $1\frac{1}{2}$ tons of coal at 19 per cent. efficiency to produce the same heating value as gas, either by open grate or by a condensing power station. In other words, the use of gas for space heating gives a fuel saving of 25 per cent., ignoring altogether the question of by-products. As regards the cost of power for gas production, I believe it is true to say that, if the gas industry was thermally efficient, more than enough power could be produced by the industry itself, and that, so far from making a demand on the grid, the gas industry could supply power to the grid. As for the suggestion that the heat value of tar used for road-making should be charged against gas, one could adopt the same argument in respect of, for example, the heat value of the timber lost in the products of a furniture factory.

Another potent argument in favour of gas, which you do not mention, is that, for the same output of heat, the amount of capital investment required for plant is very much less, and there is not as great a demand on the type of highly skilled labour required for defence purposes.

The proposal to ban the use of electricity for space and water heating is based quite as much, if not more, on the fact that the electricity industry cannot meet peak demands by drawing from storage, as on the efficiency of utilisation. It is precisely during the "prohibited hours" that the average domestic consumer chiefly wants to use his space-heating appliances. By using gas he can do this with impunity, because he is drawing from storage. Why can we not recognise that electricity is a high-grade form of energy, eminently suitable for power, lighting and other specialised uses, instead of allowing it to compete in fields where low-grade heat is equally effective and more economical?

Yours truly,
H. M. PEACOCK,
M.I.Mech.E., M.Inst.F.

20, Kylestrome House,
Ebury-square,
London, S.W.1.
May 27, 1952.

HYDRAULIC LOCK.

TO THE EDITOR OF ENGINEERING.

SIR,—We find that our test records appear to provide answers to several of the queries raised in Dr. Sweeney's letter in your issue of May 16, on page 624, *ante*.

Relationship Between Locking Force Due to Dirt and (a) Oil Pressure, (b) Lap.—Plain piston with 0·0005 in. radial clearance, unguided, no filter, OM.35 oil. Examined under the microscope, the oil was found to contain dirt particles, per field of view at 100 magnification, as follows: a few pieces, measuring up to 5×10^{-3} in.; some pieces, measuring approximately 1 to 2×10^{-3} in.; and very many pieces measuring about $0{\cdot}1$ to $0{\cdot}2 \times 10^{-3}$ in.

Lb. per Sq. In.	Axial Force Required to Free Valve.		Time for Cessation of Oil Flow. Min.
	Lb.	Oz.	
0·01 in. lap.—			
200 ..	—	4	2
400 ..	—	13	2
600 ..	—	14	½
900 ..	6	0	1
0·1 in. lap.—			
200 ..	2	4	2
400 ..	1	6	3
600 ..	1	8	1¼
900 ..	3	8	1

The above tests were chosen from the available data because they give the desired direct comparison between locking force and oil pressure; in some other tests, the variation was more regular, but tests were confined to one value of lap. In these tests, the valve was unguided; therefore there would have been present some degree of eccentric locking. Later tests have shown eccentric locking has only about one-tenth of the value of lock due to dirt, or less.

At no time when dirt was present (i.e., when using unfiltered oil) did we find the valve to become free when oil pressure was released; in those cases when a locking test was shut down at night, the valve was found to be still stuck the following morning. If we omit the very high (possibly chance) value of locking force (6 lb.), the average value of axial force required to free the valve is 3·3 times as great for 0·1 in. lap as compared with 0·01 in. lap.

Effect of Surface Finish; Test (14), *on page* 510, *ante*.—To settle this point, Topograph recordings have been made of the surface finish (axial direction) of the plain and grooved pistons involved.

Plain Piston.	Grooved Piston.
Measured in two places. Mean reading 41 micro-in., H_{max}.	Measured in three places. Average reading 47 micro-in., H_{max}.

It would, therefore, seem quite fair to compare the grooved piston performance with that of the plain one.

Repeat Run with Plain Piston, Unguided, Using Felt Filter.—As the test apparatus is still available, a test on these lines is under consideration.

We are grateful to Dr. Sweeney for drawing attention to the above. But we may say that making a selection of data from the many tests carried out at Elswick, with a view to keeping the original account to a reasonable length, was not easy.

Yours faithfully,
J. E. C. STRINGER.

Elswick Works,
Newcastle-upon-Tyne, 4.
May 22, 1952.

LAST AVRO "ANSON" AIRCRAFT.—On Tuesday, May 27, the last Anson aircraft to be built by Messrs. A. V. Roe and Company, Limited, Greengate, Middleton, Manchester, was handed over to the Royal Air Force. Production of the Avro Anson, which was originally intended for coastal reconnaissance and later was used for a variety of training and transport duties, commenced in 1935. Altogether, 11,020 Anson aircraft have been constructed.

THE ROYAL SOCIETY'S CONVERSAZIONE.

THE Royal Society's annual conversazione was held at Burlington House, London, W.1, on Thursday, May 22, the Fellows and guests being received by the President, Dr. E. D. Adrian, O.M. In accordance with custom, a number of exhibits covering a wide range of scientific interest and significance were on view, few of them, however, relating directly to engineering. The physical sciences were well represented and there were also a number of exhibits associated with medicine, biology, zoology, plant pathology, and chemistry. During the evening, two films showing the feeding habits of species of amœbæ were exhibited. These had been taken by Dr. J. Comandon and Dr. P. de Fonbrune of the Institut Pasteur, Garches. An introductory talk on each film was given by Dr. T. Goodey, O.B.E., F.R.S., of the Rothamsted Experimental Station. The exhibit of most general scientific interest was undoubtedly the recently-discovered Chaucer manuscript "The Equatorie of the Planetis." Written in 1392, this work was found in the library of Peterhouse College, Cambridge, by Dr. D. J. Price of Christ's College, and its authenticity was established by modern scientific methods. In addition to the actual manuscript, the exhibit included a full-scale reconstruction of the planetary calculating instrument described, which had been made in the Cavendish Laboratory. Another exhibit from the past, also of considerable interest, was apparatus which had belonged to Charles Wheatstone, F.R.S., which included the first printing telegraph, invented by him in 1841. It was recently discovered and identified at King's College, London.

Members of the staff of University College, London, exhibited a flying-spot microscope which provided a novel method of resolving closely-adjacent particles. In this apparatus, light from a small screen illuminated in the same manner as a television-receiver screen was passed through a microscope in reverse, each instantaneous area of light on the source being reduced, thereby, to one of extremely small dimensions in the focal plane of the microscope, and correspondingly intensified. The specimen under observation was placed in the focal plane and the transmitted light scanned, as in a television camera, the scanning being in synchronism with the illumination of the screen. The picture obtained was displayed on an ordinary television receiver. When ultra-violet light was used as the source, greater contrast in the final picture, as well as enhanced resolution of low-contrast materials, was obtained. Such equipment has obvious value for demonstration purposes. Also among its potentialities is the ability to count, size and sort microscopic particles.

Dr. R. A. Smith of the Telecommunications Research Establishment, Malvern, exhibited an infra-red high-speed spectrometer by means of which short-lived substances could be identified by virtue of their heat radiation. The light emitted or absorbed by a substance formed in a transitory process, such as a flash, has long been used as a means to identify the substance, the method depending on the use of photo-electric detectors which have an extremely rapid response to light. The method is not, of course, limited in its application to light in the visible part of the spectrum but, in the case of infra-red and heat radiations, its use has been restricted owing to the lack, until recently, of detectors having the requisite sensitivity and speed of response. This want has now been overcome by the development of photo-conductive detectors which employ lead sulphide, selenide or telluride. The result has been a spectrometer which can display infra-red emission and absorption spectra on a cathode-ray tube at repetition rates up to 100 per second. In demonstrating the equipment, part of the prismatic spectrum of a hot source of radiation was caused to oscillate rapidly across the exit slit of the spectrometer and was focussed on the detector. The varying response was amplified and displayed on a large cathode-ray tube. The absorption spectra of samples of various materials were shown by placing the materials in the beam of radiation.

A rapid means of discovering crystal structure by optical means was shown by Dr. H. Lipson of the College of Technology, Manchester. The usual method of determining crystal structure is by the analysis of an X-ray diffraction pattern, a process which involves laborious computations of the diffraction patterns of hypothetical arrangements of atoms and the calculation of the form of the image produced by a given set of diffracted beams. In the optical method which was demonstrated, the work of computation was replaced by an experimental procedure in which a card, punctured in a pattern of small holes to represent a trial arrangement of atoms, was illuminated by a parallel beam of light in a tube. The Fraunhofer diffraction pattern which resulted was then observed at an eyepiece and compared with an X-ray diffraction pattern obtained previously from the substance under investigation. Similarly, when a card perforated according to the X-ray diffraction pattern was examined, the diffracted image gave an indication of the atomic structure which produced the pattern.

The propagation of a modulated high-frequency electromagnetic wave, along the outer surface of a single conducting wire of circular cross-section was demonstrated by Professor H. M. Barlow and Dr. A. L. Cullen, of University College, London. In this case, the conductor was copper and the frequency 10,000 megacycles per second. By employing a movable detector coupled to a loudspeaker and a cathode-ray oscilloscope to determine the field strength outside the wire, it was demonstrated that the power flow was practically confined to a region within a radius of a few centimetres from the wire. It was also shown that in the case of a similar wire embedded in a coating of material such as polythene, having a high dielectric constant, the energy flow was confined to a still narrower region surrounding the wire, and that energy losses at bends in the wire were appreciably reduced.

A somewhat remarkable physical property of nearly pure germanium, a metal which is well known on account of its unusual electrical properties, was demonstrated by means of a film of experiments made in the research laboratories of the General Electric Company, Limited. Normally, when a small piece of fusible metal is heated to its melting point on a base of refractory material, it assumes an approximately spherical form, which it retains on cooling. In the case of germanium, however, as soon as the source of heat is removed, the molten globule rapidly assumes the form of a slender circular cone terminating in a sharp point. The explanation of this occurrence is thought to be that nearly pure germanium, in the molten state, contains hardly any nuclei, such as impurities, at which crystallisation could begin, so that, when the globule cools, crystallisation begins only at the surface of the material on which the globule rests, and continues thereafter on the surface of the layer of solid germanium which has been formed. As crystallisation proceeds, the layer of solidified germanium builds up and lifts the remaining molten metal, which shrinks by reason of loss to the crystalline base. In consequence, the globule continues to shrink as it rises and the diameter of the base on which it rests contracts accordingly. Ultimately, when all the molten material has crystallised, the globule has shrunk to vanishing point and a sharp-pointed cone has been formed.

From the same laboratories, examples were shown of synthetic sapphire grown in the form of a rod in a photo-electrically controlled furnace. This is the form in which the sapphire is most suitable for its industrial applications in instruments. As the growth of the rod proceeds, the direction of the optic axis gradually changes and, when it becomes almost perpendicular to the direction of growth, characteristic changes occur in the surface geometry of the rod. Examples of synthetic ruby and crystals of titanium dioxide were also shown. The refractive index of the latter material is appreciably greater than that of diamond, which gives the crystal a brilliant appearance.

Dr. V. E. Cosslett and Mr. W. C. Nixon of the Cavendish Laboratory, Cambridge, exhibited an X-ray tube having a magnetic lens to focus the electron beam on an area less than 0·001 mm. in diameter. When a tube of this kind is employed and an object is placed close to the focus, an enlarged shadow-image is cast on a distant photographic plate. The resolution obtainable with the apparatus of the type shown approaches that of an optical microscope but is likely to be improved in the future. Owing to the great penetrating power of the X-rays, thicker objects than usual can be examined, and it is possible to see the internal details of specimens opaque to visible light. Furthermore, all of the object is in focus simultaneously, hence it is possible to make stereographic pairs of photographs which can be used to visualise the internal structure in its 3-dimensional form. Various biological specimens have already been photographed successfully.

The possibilities of "transistors," germanium triode 'valves," as alternatives to thermionic valves in radio communications, and electronic circuits in general, were demonstrated in an exhibit of a miniature radio link by Standard Telecommunications Laboratories, Limited. In the transmitter, transistors were used in the radio-frequency oscillator and audio-frequency modulator, all operating from a low-power dry battery. The radiation frequency was between 1 and 2 megacycles per second. Amplitude modulation was used in the transmitter, and the receiver consisted of a radio-frequency amplifier, detector and audio-amplifier, and an indicating device.

The transistor shows promise of being extremely reliable, and it is also small, light and robust and can operate at very low powers with high efficiency. In the field of telephony, its use may well revolutionise many existing techniques, and in installations such as electronic computers where very large numbers of thermionic valves are at present used, the saving in space, power consumption and replacement costs may be considerable if transistors are fitted. The chief problem still requiring solution is the extension of the signal frequency-range in which transitors can operate satisfactorily. The present upper limit is about 50 megacycles per second.

TEST TO DESTRUCTION OF PRESTRESSED CONCRETE BRIDGE.

SUPPLEMENTARY details relating to the testing to destruction of the prestressed concrete bridge at the South Bank exhibition site, which was the subject of an article on page 595, *ante*, are given in a report by the Cement and Concrete Association, 52, Grosvenor-gardens, London, S.W.1. After the bridge had been loaded to 100 per cent. overload, on the second day of the trials, it was unloaded again until only four blocks of kentledge, weighing 9 tons in all, remained near column *b* (see Fig. 2, on page 595, *ante*). To have removed this load would have necessitated re-siting the crane. On the third and final day, the bridge was gradually loaded until failure occurred. The operation was halted, however, when 100 per cent. overload had been reached and the bridge was left for $1\frac{1}{2}$ hours, after which the deflections were noted again.

Fig. 1.

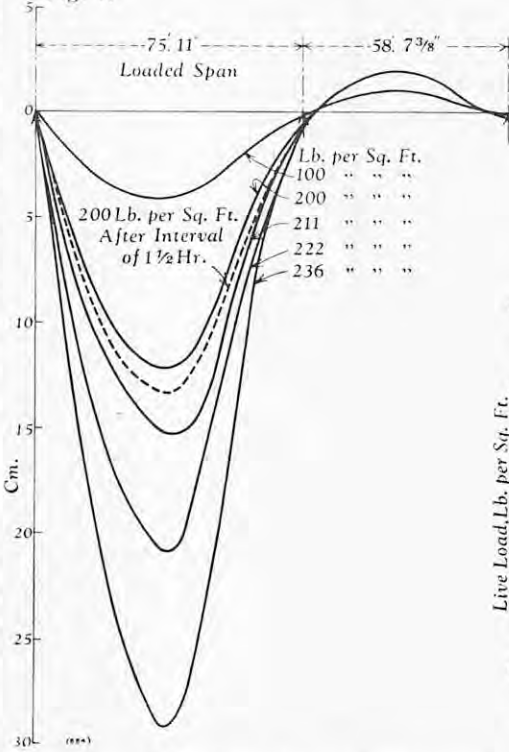
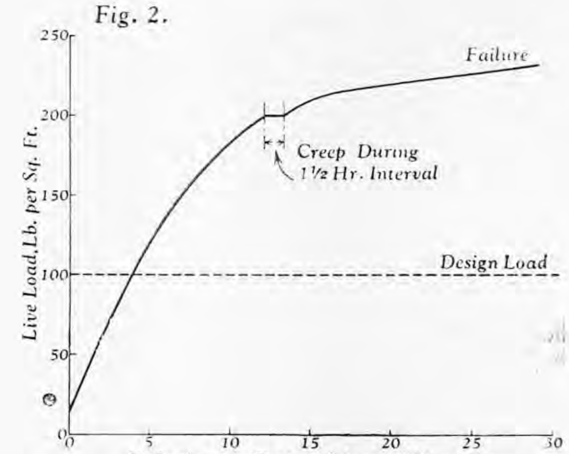


Fig. 2.



Gauge Stations.	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.
Unloading—												
50 per cent. overload ..	0·6	6·2	8·3	4·6	0·0	−1·4	−2·3	−1·9	−0·8	0·2	0·55	0·1
25 per cent. overload ..	0·75	5·5	7·4	4·05	0·0	−1·2	−2·06	−1·06	−0·7	0·2	0·55	0·1
Design load	0·7	4·4	5·9	3·25	0·0	−0·8	−1·5	−1·2	−0·5	0·2	0·45	0·15
9 tons near column *b* ..	0·5	0·6	0·9	0·65	0·2	0·3	0·3	0·4	0·25	—	—	—
Reload—												
106 lb. per square foot ..	0·25	3·15	4·1	2·3	0·2	−0·75	−1·05	−0·95	−0·4	0·05	0·15	0
124 lb. ,, ,, ..	0·4	4·3	5·4	3·0	0·2	−0·85	−1·15	−1·15	−0·5	0·15	0·3	0·1
146 lb. ,, ,, ..	0·5	5·1	6·6	3·7	0·2	−1·05	−1·4	−1·35	−0·6	0·2	0·4	0·15
175 lb. ,, ,, ..	0·7	6·8	9·0	5·0	0·25	−1·25	−1·7	−1·65	−0·8	0·25	0·5	0·25
200 lb. ,, ,, ..	0·9	9·30	12·25	6·75	0·25	−1·4	−1·95	−1·85	−0·9	0·3	0·6	0·25
200 lb. ,, ,, ..	1·1	9·9	13·4	7·35	0·4	−1·25	−1·85	−1·75	−0·8	0·6	—	—
210 lb. ,, ,, ..	1·1	11·10	15·25	8·45	0·4	−1·35	−2·0	−1·8	−1·0	0·6	0·75	0·3
222 lb. ,, ,, ..	1·25	—	20·9	10·8	0·4	−1·40	−2·05	−1·9	−1·0	0·6	0·8	0·4
236 lb. ,, ,, ..	1·40	20·80	29·2	15·5	0·35	−1·3	−2·0	−1·8	−0·9	—	0·8	0·4

The vertical displacements (in cm.) at the twelve stations indicated in Fig. 3, on page 595, *ante*, during the unloading period on the second day and the reloading on the third day, are given in the attached table, which is taken from the report. The loading has been expressed as an equivalent uniform loading by equating the calculated bending moment at the centre of the loaded span to the value appropriate to a freely-supported and uniformly-loaded span of 76 ft. The load for which the bridge was designed was 100 lb. per square foot. Deflection curves under various loadings on the final day are reproduced in Fig. 1, herewith, and the relation between load and deflection at the centre of the loaded span is shown in Fig. 2.

The report concludes as follows: "The structure carried a load of $84\frac{1}{2}$ tons, which was equivalent to 236 lb. per square foot uniformly distributed, and failed under a load of 88 tons (250 lb. per square foot). Failure appeared to occur almost simultaneously over the second support and near the middle of the loaded span by compression in the concrete. The end column remained vertical until pulled over by the collapsing span. There does not appear to have been any general failure of the steel cables, but a very noticeable feature after collapse was the absence of bond between steel and concrete due to the failure of the grout to penetrate through from the ends."

MAGNETIC NICKEL-IRON ALLOY.

Fig. 1. D.C. AND A.C. MAGNETISATION OF PERMALLOY "F" (THICKNESS 0·002")

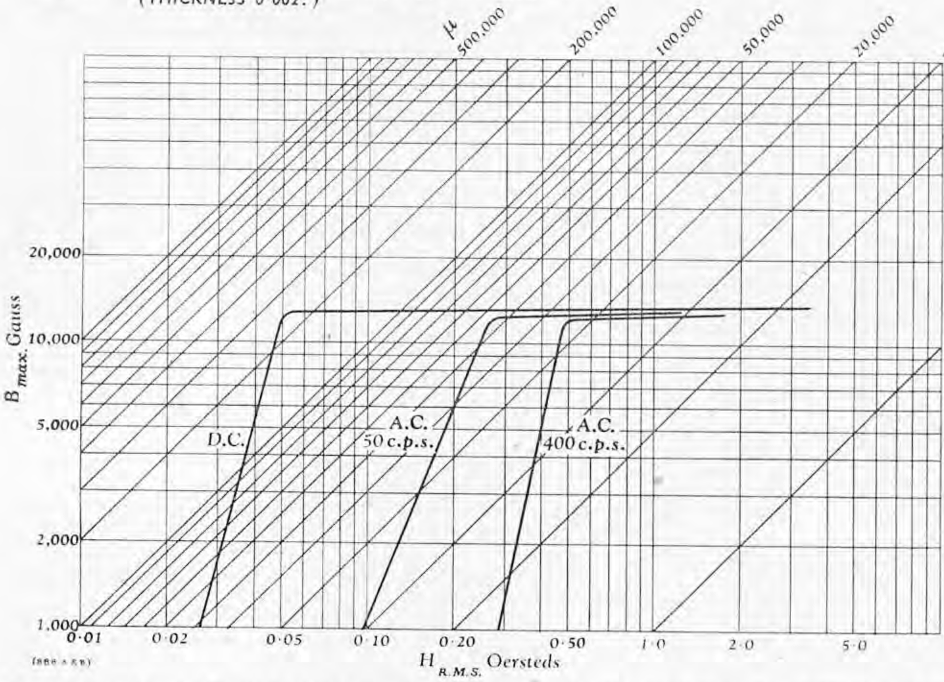
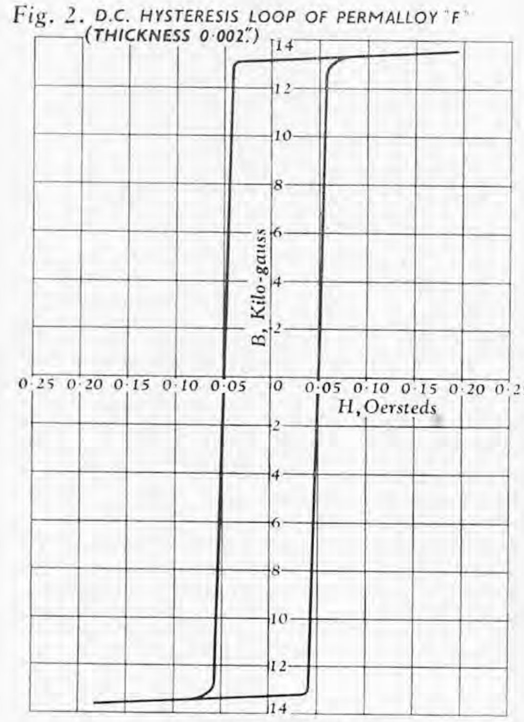


Fig. 2. D.C. HYSTERESIS LOOP OF PERMALLOY "F" (THICKNESS 0·002")



MAGNETIC NICKEL-IRON ALLOY.

A NEW material has recently been added to the range of magnetic alloys made by Standard Telephones and Cables, Limited, Connaught House, Aldwych, London, W.C.2. It is Permalloy "F," a nickel-iron alloy in which a very rectangular hysteresis loop and a low value of coercive force are obtained by the method of domain orientation. It is, therefore, suitable as a core material for all types of saturable reactor. Permalloy "F" is produced in the form of toroidal cores wound from thin tape, and these cores are supplied in the fully heat-treated condition ready for winding. In common with all magnetic materials which have high permeability, Permalloy "F" is somewhat strain-sensitive and needs to be handled with care during winding and other processing if its outstanding magnetic properties are to be fully retained. For some designs it may be advisable to place the core in a box before winding; this will serve both to avoid straining the core during winding and to prevent the penetration of coil-impregnating compounds into the core.

The magnetisation characteristics are shown in Fig. 1, from which it will be seen that a flux density of nearly 14,000 gauss may be obtained in magnetising fields of less than 0·1 oersted. Fig. 2 shows a direct-current hysteresis loop; from a maximum flux density of 13,500 gauss, the remanence is greater than 13,000 gauss, while the coercive force is less than 0·05 oersted, thus resulting in a hysteresis loss of only 210 ergs. The specific gravity of the alloy is 8·4, and the electrical resistivity is 26 microhms per centimetre cube. The core sizes which are proposed are as shown in the table. For very small cores for memory circuits and computers, sizes will be standardised as the need arises.

Outer Diameter, In.	Inner Diameter, In.	Height, In.	Thickness of Tape, in.
2·25	1·50	0·5	0·004 or 0·002
1·75	1·00	0·5	0·004 or 0·002
1·50	1·00	0·25	0·004 or 0·002
1·50	0·75	0·5	0·002
1·00	0·50	0·25	0·002

FRENCH AUTUMN METALLURGICAL MEETING.—The Société Française de Métallurgie is to hold its Journées Métallurgique d'Automne from October 20 to 25 at the Maison de la Chimie, 28 bis, Rue St. Dominique, Paris, 7e. The two main topics for discussion are defects and fractures observed in metals during service, and means of effecting economies in metals in short supply. A number of visits, including one to the new laboratories of the Institut de Recherches de la Sidérurgie (Irsid), at Saint-Germain-en-Laye, are to be arranged, and a banquet will also be held. British metallurgists are invited to attend and may obtain further particulars from the secretary of the Society at 25, Rue de Clichy, Paris (9e).

FORTHCOMING EXHIBITIONS AND CONFERENCES.

THIS list appears in the last issue of each month. Organisers are invited to send to the Editor particulars of forthcoming events.

WORLD EXHIBITION OF PHOTOGRAPHY AND SCIENTIFIC PHOTOGRAPHIC APPARATUS.—Thursday, May 15, to Thursday, July 31, at Lucerne. Details from the general secretary, Weltausstellung der Photographie, Reuss-Steg 11, Lucerne, Switzerland.

CANADIAN INTERNATIONAL TRADE FAIR.—Monday, June 2, to Friday, June 13, at Toronto. Apply to Miss M. A. Armstrong, Canadian Government Exhibition Commission, Canada House, Trafalgar-square, London, S.W.1. (Telephone: WHItehall 8701.)

MECHANICAL HANDLING EXHIBITION.—Wednesday, June 4, to Saturday, June 14, at Olympia, London, W.14. Exhibition organisers, Iliffe and Sons, Ltd., Dorset House, Stamford-street, London, S.E.1. (Telephone: WATerloo 3333.)

4TH INTERNATIONAL MECHANICAL ENGINEERING CONGRESS.—Wednesday, June 4, to Tuesday, June 10, at Stockholm. Further information obtainable from the British Engineers' Association, 32, Victoria-street, London, S.W.1. (Telephone: ABBey 2141.) See also page 497, *ante*.

INTERNATIONAL SAMPLES FAIR AND FIRST INTERNATIONAL PACKAGING EXHIBITION.—Saturday, June 7, to Sunday, June 22, at Padua, Italy. British section organised by Mr. F. C. Kerry, via Gazzera 25, Verona. *Agents:* Italian Chamber of Commerce, 652, Grand Buildings, Trafalgar-square, London, W.C.2. (Telephone: WHItehall 5521.)

FIFTH HYDRAULICS CONFERENCE.—Monday, Tuesday and Wednesday, June 9, 10 and 11, at Iowa City. Apply to the Iowa Institute of Hydraulic Research, State University of Iowa, Iowa City, U.S.A. See also page 341, *ante*.

20TH INTERNATIONAL SAMPLES FAIR.—Tuesday, June 10, to Monday, June 30, at Barcelona, Spain. *Agents:* Spanish Tourist Agency, 4, West Halkin-street, London, S.W.1. (Telephone: SLOane 6124.)

INSTITUTION OF HEATING AND VENTILATING ENGINEERS, SUMMER MEETING.—Saturday, June 14, to Tuesday, June 17, at the Palace Hotel, Torquay. Apply to the secretary of the Institution, 75, Eaton-place, London, S.W.1. (Telephone: SLOane 3158.)

CONFERENCE ON CIVIL ENGINEERING PROBLEMS IN THE COLONIES.—Monday, June 16, to Friday, June 20, at the Institution of Civil Engineers, Great George-street, Westminster, London, S.W.1. Details obtainable from the secretary of the Institution at the address given. (Telephone: WHItehall 4577.) See also page 339, *ante*.

INDUSTRIAL FINISHING EXPOSITION.—Monday, June 16, to Friday, June 20, at International Amphitheatre, 43rd and Halsted Streets, Chicago, Illinois, U.S.A. Sponsored by the American Electroplaters Society. Further details available from the secretary, Suite 580-84, 35, East Wacker-drive, Chicago, 1.

4TH INDUSTRIAL PHYSICS CONFERENCE.—Tuesday, June 24, to Saturday, June 28, at the Royal Technical College, Glasgow. Organised by the Institute of Physics. Apply to the secretary of the Institute, 47, Belgrave-square, London, S.W.1. (Telephone: SLOane 9806.) See also page 497, *ante*.

TRIESTE INTERNATIONAL TRADE FAIR.—Sunday, June 29, to Sunday, July 13, at Trieste. *Agents:* Italian Chamber of Commerce, 652, Grand Buildings, Trafalgar-square, London, W.C.2. (Telephone: WHItehall 5521.)

SECOND INTERNATIONAL CONFERENCE ON HOT DIP GALVANISING.—Monday, June 30, to Friday, July 4, at Düsseldorf. Organised by the Zinc Development Association, Lincoln House, Turl-street, Oxford. (Telephone: Oxford 47988.) See also page 655, *ante*.

ROYAL AGRICULTURAL SHOW.—Tuesday, July 1, to Friday, July 4, at Newton Abbot. Organised by the Royal Agricultural Society of England, 16, Bedford-square, London, W.C.1. (Telephone: MUSeum 5905.)

SYMPOSIUM ON CONCRETE SHELL ROOF CONSTRUCTION.—Wednesday, Thursday and Friday, July 2, 3 and 4, at the Royal Institute of British Architects, 66, Portland-place, London, W.1, and the Institution of Civil Engineers, Great George-street, London, S.W.1. Organised by the Cement and Concrete Association, 52, Grosvenor-gardens, Westminster, London, S.W.1. (Telephone: SLOane 5255.) See also page 649, *ante*.

WELDING DESIGN AND ENGINEERING SUMMER SCHOOL.—Wednesday, July 16, to Sunday, July 20; and Sunday, July 20, to Friday, July 25, at Ashorne Hill. Organised by the British Welding Research Association, 29, Park-crescent, London, W.1. (Telephone: LANgham 7485.)

INTERNATIONAL ASSOCIATION FOR BRIDGE AND STRUCTURAL ENGINEERING, FOURTH INTERNATIONAL CONGRESS.—Monday, August 25, to Friday, August 29, at Cambridge. For further information, apply to the secretary of the Association, Swiss Federal Institute of Technology, Zürich, Switzerland.

19TH NATIONAL RADIO AND TELEVISION EXHIBITION.—Tuesday, August 26, to Saturday, September 6, at Earl's Court, London, S.W.5. Organised by the Radio Industry Council. Apply to the secretary of the Council, 59, Russell-square, London, W.C.1. (Telephone: MUSeum 6901.)

FRANKFURT AUTUMN FAIR.—Sunday, August 31, to Thursday, September 4, at Frankfurt-on-Main. *Agents:* LEP Transport Ltd., Sunlight Wharf, Upper Thames-street, London, E.C.4. (Telephone: CENtral 5050.)

59TH ROYAL NETHERLANDS INDUSTRIES FAIR.—Tuesday, September 2, to Thursday, September 11, at Utrecht, Holland. *Agent:* Mr. W. Friedhoff, 10, Grosvenor-place, London, W.1. (Telephone: WELbeck 9971.)

FLYING DISPLAY AND EXHIBITION.—Tuesday, September 2, to Sunday, September 7, at Farnborough. Apply to the Society of British Aircraft Constructors, Ltd., 32, Savile-row, London, W.1. (Telephone: REGent 5215.)

WELSH INDUSTRIES FAIR.—Wednesday, September 10, to Saturday, September 20, at the New Pavilion, Sophia-gardens, Cardiff. Particulars from the offices of the Fair, 17, Windsor-place, Cardiff. (Tel.: Cardiff 23049.)

Swiss Fair, Lausanne.—Saturday, September 13, to Sunday, September 28, at Lausanne. For further information, apply to Comptoir Suisse, Place de la Riponne 5, Lausanne, Switzerland.

International Machine Tool Exhibition.—Wednesday, September 17, to Saturday, October 4, at Olympia, London, W.14. Organised by the Machine Tool Trades Association, Victoria House, Southampton-row, London, W.C.1. (Telephone: HOLborn 4667.) See also our issue of July 13, 1951, page 51.

Modern Building Plant Exhibition.—Thursday, September 18, to Wednesday, September 24, at the Sophia Gardens Field, Cardiff. For further information, apply to the Ministry of Works, Lambeth Bridge House, London, S.E.1. (Telephone: RELiance 7611.)

Aslib (Association of Special Libraries and Information Bureaux).—Friday, September 19, to Monday, September 22, Annual Conference at The Hayes, Swanwick, Derbyshire. Apply to the secretary of the Association, 4, Palace-gate, Kensington, London, W.8. (WEStern 6321.)

North-Western Business Efficiency Exhibition.—Monday, September 22, to Saturday, September 27, at St. George's Hall, Liverpool. Organised by the Office Appliance and Business Equipment Trades Association, 11-13, Dowgate-hill, Cannon-street, London, E.C.4. (Telephone: CENtral 7771.)

Symposium on Mineral Dressing.—Tuesday and Wednesday, September 23 and 24, at the Imperial College of Science and Technology, Prince Consort-road, South Kensington, London, S.W.7. Organised by the Institution of Mining and Metallurgy, Salisbury House, Finsbury-circus, London, E.C.2. (Telephone: MONarch 2096.) See also page 211, *ante.*

Commercial Motor Show.—Friday, September 26, to Saturday, October 4, at Earl's Court, London, S.W.5. Organised by the Society of Motor Manufacturers and Traders, Ltd., 148, Piccadilly, London, W.1. (Telephone: GROsvenor 4040.)

Fourth International Congress on Industrial Heat and Applied Thermodynamics.—Saturday, September 27, to Saturday, October 4, in Paris. Apply to the general secretary of the Congress, 2, Rue des Tanneries, Paris, 13e.

18th International Nautical Exhibition.—Saturday, September 27, to Sunday, October 12, in Paris. *Agents*: Home and Overseas Trade Fairs, 40, Gerrard-street, London, W.1. (Telephone: GERrard 5947)

Iron and Steel Exposition.—Tuesday, September 30, to Friday, October 3, at the Public Auditorium, Cleveland, Ohio, U.S.A. Organised by the Association of Iron and Steel Engineers. Apply to Mr. Albert W. Erickson, Junr., at the Association's offices, 1010, Empire Building, Pittsburgh 22, U.S.A. See also page 486, *ante.*

Engineering Industries Association, London Regional Display.—Tuesday and Wednesday, October 14 and 15, at the Horticultural Hall, Vincent-square, London, S.W.1. Apply to the secretary of the Association, 9, Seymour-street, Portman-square, London, W.1. (Telephone: WELbeck 2241.)

"The Model Engineer" Exhibition.—Monday, October 20, to Wednesday, October 29, at the New Horticultural Hall, Vincent-square, London, S.W.1. Apply to the offices of the Exhibition, Panton House, Haymarket, London, S.W.1. (Telephone: TRAfalgar 2862.)

Motor Show.—Wednesday, October 22, to Saturday, November 1, at Earl's Court, London, S.W.5. Organised by the Society of Motor Manufacturers and Traders, Ltd., 148, Piccadilly, London, W.1. (Telephone: GROsvenor 4040.)

27th International Cycle and Motor-Cycle Show.—Saturday, November 15, to Saturday, November 22, at Earl's Court, London, S.W.5. Organisers: British Cycle and Motor Cycle Manufacturers' and Traders' Union, Ltd., The Towers, Warwick-road, Coventry. (Telephone: Coventry 62511.)

Brewers' Exhibition.—Monday, November 24, to Friday, November 28, at Olympia, London, W.14. Particulars obtainable from the organisers, Trades Markets and Exhibitions, Ltd., 623, Grand Buildings, Trafalgar-square, London, W.C.2. (Telephone: WHItehall 1371.)

Smithfield Show and Agricultural Machinery Exhibition.—Monday, December 8, to Friday, December 12, at Earl's Court, London, S.W.5. Details obtainable from the Smithfield Show Joint Committee, 148, Piccadilly, London, W.1. (Telephone: GROsvenor 4040.)

Unemployment in North Wales.—It was reported to the North Wales Committee of the Welsh Board for Industry, meeting at Llangollen on May 22, that there were 7,282 unemployed in the area, an increase of 702 on the mid-March total.

LABOUR NOTES.

Comments that the short time and unemployment latterly being experienced in some sections of British industry did not in any way lessen the need for higher production are made in a leading article on Anglo-American industrial co-operation, which is contained in the May issue of *Man and Metal*, the monthly journal of the Iron and Steel Trades Confederation. It is stated that, as a matter of fact, these economic misfortunes intensified the need for larger outputs, because a nation, which depended for its life upon its ability to export its goods to the markets of the world, must face up to the growing competition of other nations. This was an economic fact from which there was no escape. In many of the nation's industries there was a great deal of room for improvement and there was certainly a place, the journal considers, for an organisation, such as the Anglo-American Council on Productivity, of which the principal task was to bring to the notice of backward firms the best industrial practice and methods, with a view to encouraging their wider adoption.

Of the Anglo-American Council on Productivity, the journal comments that its closure will bring to an end "one of the most imaginative and valuable experiments of its kind ever made." The Council, which was formed in the autumn of 1948, was composed of representatives of management and labour from both countries, and its purpose was to raise the level of British productivity by giving British firms an insight into American methods of productivity. It was not created, however, the journal points out, on the basis that Britain was the pupil and the United States the teacher, and, while it was realised that this country derived the greater advantage from the experiment, American industry gained something by the closer contact which the Council made possible with all levels of British industry. Americans were quick to appreciate this, and it was right that they should, since most of the basic inventions on which American industry was built originated in this country.

The most efficient plants in Britain were equal to the best in the United States, the journal continues, but that did not justify people here sitting back with an air of satisfaction and believing that they had nothing to learn from others. It was good to know that the experience gained during the operation of the Council would not be set aside and that it was the intention to establish a British Productivity Council, in which the Trades Union Congress had agreed to participate. The skill of British craftsmen and technicians was still second to none, but, the journal concludes, there could be no mistaking that the fight for Britain's economic independence as a nation would be won in the country's mines, fields and workshops, and, in so far as the British Productivity Council could bring this fact home to all, it would justify its existence.

Wage claims by the three principal railway trade unions were presented to the Railway Executive on May 23. They took the form of a joint demand for an all-round increase of 10 per cent. on salaries and wages and for payment at the rate of time and a half for work performed between noon and midnight on Saturdays. The unions' case was based mainly upon the advances which have taken place in the cost of living since the railwaymen were granted an increase of 8 per cent. on their earnings in November last, as the result of a recommendation by the Railway Staff National Tribunal. That concession added some 14,200,000*l.* to the industry's annual wage bill. The new claims, if granted in full, would benefit about 450,000 members of the three unions, employed in all grades of the railway service, at an estimated annual cost of 17,000,000*l.*

After the presentation of their case, the three unions concerned, the National Union of Railwaymen, the Associated Society of Locomotive Engineers and Firemen, and the Transport Salaried Staffs' Association, were informed by the Railway Executive that their representations would be carefully considered, and that a further meeting would be called at an early date, when the Executive would give its reply. The three unions are expected to lodge similar claims with other divisions of the British Transport Commission, including the London Transport, Road Haulage, and the Docks and Inland Waterways Executives, in the near future.

Suggestions that foremen and technicians were in need of substantial increases in their wages and salaries to compensate them for the increased cost of living were made by Mr. Harry G. Knight, the general secretary of the Association of Supervisory Staffs, Executives and Technicians, in a statement issued in London on Tuesday last, after a meeting of the union's executive council. He said that the union could not accept any form of wage stabilisation and that there was little doubt that the union's annual delegate conference, being held during the coming week-end, would authorise demands being put forward for wage and salary increases. They should be for such amounts as would meet not only the recent sharp rises in living costs, but would take into account also the increases that had lowered the standard of living of foremen and technicians since 1946.

There was an almost complete lack of incentives for foremen, Mr. Knight considered. British foremen were among the worst paid in the world. Indeed, their salaries were often less than the earnings of the men under their supervision. As an example of the trend of foremen's salaries during recent years, Mr. Knight mentioned that men in junior positions earning 348*l.* in 1946 now received 420*l.* a year, but, to maintain the 1946 relative value of their income, they should be given an increase of 72*l.* a year, which would raise their pay to 492*l.* a year. Men earning 388*l.* in 1946, now received 475*l.*, but needed 536*l.* to maintain their previous position. A first-class supervisor now receiving 680*l.*, should be paid 749*l.* In the United States, a junior foreman received 20 per cent. more than the men under his control, but, in Britain, it was doubtful if the difference averaged more than 2 per cent. The union was satisfied that production in this country could be increased by as much as one-third, if the earnings of British supervisors were to be raised to something approaching the levels obtaining in the United States.

Dismissal notices, it is understood, have been tendered by the National Coal Board to more than one thousand Italians who were due to take up employment in coal-mines in Britain, owing to the refusal of British miners to work with them. The men were brought to this country on the understanding that they would be given two years' work in British collieries and the British and Italian Governments are considering what compensation shall be given for the loss of this employment. The Italians have been receiving the surface rate of pay, 6*l.* 1*s.* 6*d.* a week, and the Board has expressed its intention of continuing this payment on a day-to-day basis to those men who have obtained other employment in Britain by the end of this month. These payments will be given until the men's new jobs become available but they will not generally be maintained after June 21.

The Board has announced that, as from the end of this month, it would commence the repatriation, at its own expense, of those Italians who have not found alternative employment, but that all such men would be paid at the full surface rate obtaining in British coal-mines, until their return to Italy. It may be recalled that the recruiting of the Italians was conducted with the approval of the National Union of Mineworkers in an attempt to overcome the man-power shortage in the coal-mining industry, and that the union's executive council undertook to use its best endeavours to secure the men's acceptance by the miners' lodges. Recruiting by the Board was stopped about three months ago, after the union's executive had expressed the view that there was no longer any hope of persuading the miners to receive any more Italians. The Italians given notice include those undergoing instruction in mining work in Yorkshire, Lancashire, South Wales and Scotland. Rather more than 1,200 Italians are at present employed in British collieries. These men are not affected and are expected to complete their contracts.

Suggestions that an entirely fresh approach to wage problems was needed were made by Mr. Frank Foulkes in his presidential address to the annual conference of the Electrical Trades Union, which opened at Eastbourne on Monday last. He expressed the view that there should be a vigorous opposition to any form of "wage freeze." Referring to the rejection in some quarters of industrial action for political purposes, Mr. Foulkes said that there was no firm line of demarcation between industrial and political motives. In fact, the fundamental basic principle of trade unionism was to safeguard and increase the living standards of its members and their families.

Trade unions should fight with all their industrial might against any attempt by any political party to introduce wage stabilisation. The requirements of the workpeople within an industry and the skill displayed by them should be the deciding factors in wage assessment. Unions' efforts to secure wage increases sufficient to offset the rapidly rising cost of living had become a major problem. There was no difference between nationalised industries and private firms in their approach to wage negotiations and, in these days of rapid increases in the cost of living, speedier negotiations were necessary in all branches of industry. Quicker decisions must be given if industrial strife was to be avoided.

CHEMICAL CAUSES OF WEAR.

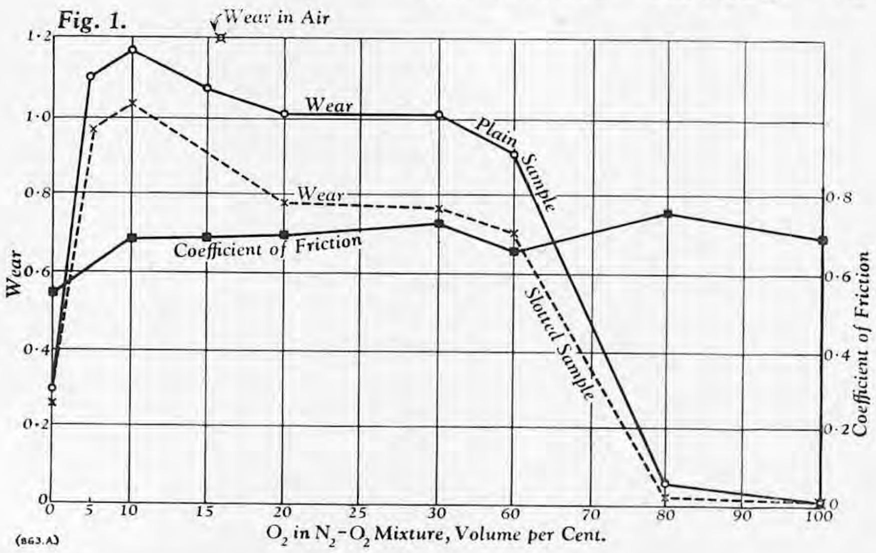


FIG. 2. × 265.

FIG. 3. × 260.

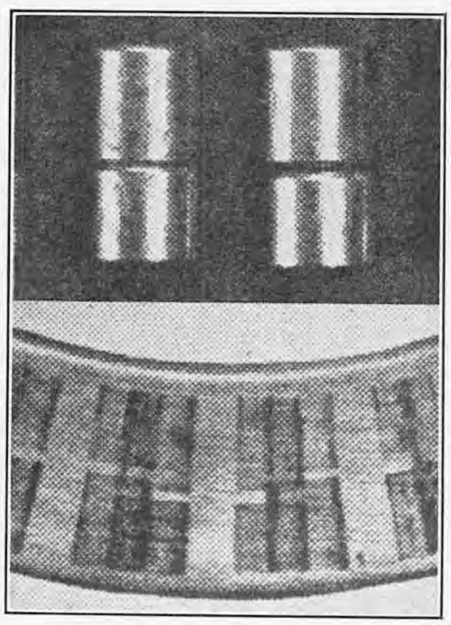


FIG. 4. × 265.

CHEMICAL CAUSES OF WEAR.*

By PROFESSOR J. J. BROEZE.

THE oldest conception of wear visualises it as a mechanical process in which two bodies, rubbing together under pressure, continually interlock the protuberances of their irregular surfaces and force them to shear off. In many cases, the process of wear can still be called purely mechanical; in many others, it may be termed physical, as when primarily thermal effects, due to the development of frictional heat, cause changes in the surfaces and sub-surfaces. A large percentage of wear cases are of a chemical nature; that is, the surface is attacked by some outside agent and subsequently detached. Three typical fields in which chemical causes of wear, of practical significance, have been identified are in circumstances of general lubrication, where there is chemical attack by the atmosphere; in engine and gear lubrication, with chemical attack by the lubricants; and in engine lubrication, with chemical attack by the combustion products.

I. *General Lubrication: Chemical Attack by the Atmosphere.*—This group encompasses widely divergent cases. There are, for instance, the dry rubbing experiments of Siebel and Kobitzsch,† of which those with a varying atmosphere, using steel on steel, are extremely interesting. Their test pieces were ring-shaped, one being slotted; they were rubbed co-axially at a velocity of 52 cm. per second and a unit pressure of 2 kg. per square centimetre. The results (see Fig. 1, herewith) show a variation of wear with oxygen content of the artificial atmosphere: the admixture of oxygen to nitrogen causes a strong increase in wear, which, however, reaches a maximum at about 10 per cent. oxygen. However, at high oxygen concentration, wear drops off sharply. Whereas, in nitrogen or at the lower oxygen contents, the steel wore in a pattern of strong surface deformation caused by metal-to-metal or adhesive forces (see Fig. 2, herewith), the higher oxygen concentrations caused complete oxidation of the rubbing surfaces and a sliding of oxide over oxide to an accompaniment of "hellish shrieking," as the authors report. Apparently, the hard oxide dust withstood abrasion—a curious effect, as we shall encounter cases where such oxide dust may cause rapid wear. Extended tests with an atmosphere of carbon dioxide resulted in no wear at all, the test pieces showing hardly any rubbing marks. (Fig. 3.) Whereas, with O_2, there was still surface flow, with CO_2 there was none at all. The lower coefficient of friction with CO_2, 0·15 as against 0·7 in the earlier tests, accords with that result. The very low rate of wear on CO_2 is apparently reflected in low rates of wear in CO_2 compressor cylinders; we shall find different results when discussing combustion gases.

A special category is that where very small movements occur, so-called "fretting."* This takes place between parts that fit just not tightly enough, as in an unsatisfactory shrink fit that allows some movement. This wear is oxidative and the symptoms of it are red-coloured patches on the mating surfaces (the Germans call it "bleeding"), but when the movement is limited it usually does not amount to much. It may be very serious, however, if the parts can follow up any looseness caused by the attack itself. The most widely-known case is "false Brinelling" (Fig. 4) in ball or roller bearings subjected to vibration.* Roller races are found grooved by the rollers, often to a considerable depth, each groove more or less following the contour of a roller. In contrast to real Brinelling, which is plastic indentation, in these cases there is no crystalline deformation, the material being carried away as oxide; although it is not certain that this oxide is a primary product, its presence as a lapping powder undoubtedly accelerates the process. The phenomenon can spoil bearings of standing machinery, and was first discovered on automobiles that had been transported by rail over long distances. It appears that such a form of attack is already possible when the relative movement is of the order of molecular distances. A case that came to my knowledge was that of steel plates inserted between connecting rods and bearings of marine Diesel engines, which lost up to 1 mm. in thickness, also without deformation. Here the atmosphere or the lubricant may have been corrosive even towards normally stressed material, but every feature pointed to a resemblance to the case mentioned above, and the limited movement due to looseness of bolts must have been the primary cause. It is a point to keep in mind when designing heavily stressed joints, because, for instance, lack of conformity between the deformations of the parts joined may introduce such fretting along the joint faces.

II. *Engine and Gear Lubrication: Chemical Attack by Lubricants.*—Hydrocarbon lubricants possess only a limited power of adhesion to metals and hence may be sheared off relatively easily, the result being local metal-to-metal contact. It is well known that polar substances may improve their adhesion by forming a stronger bond to the metal. Friction is then often less. The character of this adhesive force may be called physical, but there is no strict line of demarcation between these physical forces and those of chemical bond. Thus, chemical attack may take place, leading to the formation of metal soaps, and these may yield to shear stresses encountered under normal rubbing conditions and wear away rapidly. Such influences have been found by Williams† and others when using oleic acid as an additive to engine oil, the cylinder wear increasing 5 per cent. when oleic acid was used but decreasing when less than 2 per cent. was used. (Fig. 5.)

Such wear increases may occur with drastic effect in bearings, notably in those containing lead or cadmium, when the lubricating oil is subject to oxidation. This phenomenon became alarming when, about 1935, extraction processes produced lubricating oils of a highly paraffinic character which on oxidising, formed oil-soluble organic acids at temperatures over about 120 deg. C. At the same time, high crankcase temperatures, due to increased power, had prompted automobile manufacturers to change from tin-base white-metal bearings to lead and cadmium-alloy bearings, and the result was a most unfortunate clash.

* Paper presented to the Conference on Abrasion and Wear, held at Delft, Holland, on November 14 and 15, 1951.

† E. Siebel and R. Kobitzsch: "Verschleisser-scheinungen bei gleitender trockener Reibung." *Z.V.D.I,* 1941.

* M. Fink: "Wear Oxidation, a New Component of Wear." *Trans. Am. Soc. for Steel Treating,* 1930, page 1026. G. A. Tomlinson, P. L. Thorpe and H. J. Gough: "An Investigation of the Fretting Corrosion of Closely Fitting Surfaces." *Proc. I. Mech. E.,* vol. 141 (1939), page 223 and discussion, page 328; and vol. 142, page 401 (1939).

* J. O. Almen: "False Brinelling." *Automotive Industries,* vol. 77, page 226 (1937).

† C. G. Williams: *Collected Researches on Cylinder Wear.* Inst. of Automobile Eng. (1940.)

CHEMICAL CAUSES OF WEAR.

Similar havoc was wrought later in aircraft engines by synthetic lubricants. Significant improvements have been made since, notably the introduction of indium as an anti-corrosive "flash" coating diffused into cadmium-alloy bearings, and the use of aluminium alloys and silver alloys for heavy-duty engines. On the other hand, the development of oxidation-inhibiting additives for motor oils has proceeded rapidly, and is now accepted practice. All motor oils coming under the designation "heavy-duty" must undergo a high-temperature test in which only a certain amount of bearing wear is allowed (the L-4 test from the 2-104 B and Mil 2-104 specifications for motor oils in the United States), and in practically all cases this test is passed by additive-type oils.

A special kind of corrosive attack may occur on the journals (not the bearings) of marine engines, but only in certain cases may this be called wear: mostly, the wear is secondary wear of the white metal, due to the roughened shaft. More about these cases can be found in the report by Dr. W. J. Muller before the recent Internal Combustion Engine Congress (Paris, May, 1951).* In gear lubrication, wear caused by corrosion through the lubricant may take place, and, to a certain extent, is even intended to do so. It is well to pause here for a moment, because a protective principle is involved that has its application also elsewhere.

Of all the forms of wear, with the possible exception of false Brinelling, the most obnoxious is that of the thermal type, where local junctions result from the combination of pressure and frictional heat, and the subsequent ruptures roughen the surfaces. Such wear may assume a violent character, as the roughened surfaces decrease the chances for film formation and increase the intensity of local heat development, thus, in certain cases, leading from the milder form of scuffing via scoring to complete seizure. Even the plain journal bearing, which is now more often than not under the complete control of full film lubrication, was in the old days prone to such a catastrophic ending. But in the early 'thirties it became acute in automotive gear practice through the introduction of the offset axes of hypoid (bevel) gears for the back-axle drive. These gears were stronger and permitted a lower position of the drive shaft, but they suffered from higher rubbing velocities on the gear teeth and brought to the fore the problem of how to avoid scoring.† The oil industry sought the solution mainly in additives to the lubricating oils (so-called Extreme-Pressure oils, a name criticised by Blok in 1939, but still in use), which usually function by decomposing at the high local temperatures of the contact spots and reacting with the steel to form relatively low-melting (sulphur, chlorine, phosphorus) compounds. These protect the contact spots, probably by forming a temporary film, which, however, is subject to shearing-off, so that a certain amount of wear does still take place. It is noted in tests on the four-ball apparatus (Fig. 6), where similar conditions prevail, that, below the limiting conditions for seizure, most extreme-pressure lubricants already cause more or less rapid wear; but, since this rate of wear is usually of far less significance than the destructive scoring, it is often acceptable. The principle may be defined as that of guarding against a dangerous roughening type of wear by introducing wilfully another type which is more controllable. Beeck‡ reduced this to a fine art in some of his experiments. A review of the physics and chemistry involved was given during the Third World Petroleum Congress by Professor Hugel in his general lecture.

III. *Engine Lubrication: Chemical Attack by Combustion Products.*—Since practically all internal-combustion engines operate on hydrocarbons, or on organic compounds containing hydrogen and carbon, water and carbonic acid are always prominent among the combustion products. In actual practice, they may be supplemented by a host of other compounds, formed during combustion as a result either of side reactions at high temperatures, or of the presence of other elements in the fuel (notably sulphur), or of incomplete combustion. The latter is due to improper mixing of fuel and air or too low a temperature: along cooled metal surfaces there is always a danger that the reactions are chilled and left unfinished.

Under normal operating conditions, there will be no condensation of water in the cylinders, although the partial pressure of water vapour may be quite high: at the moment of combustion, there may be several atmospheres of water-vapour pressure, and, at the end of expansion, still half an atmosphere. However, the temperatures of the cylinder walls are normally high

* W. J. Muller: "Investigations on the Cause of Crankshaft Corrosion" (not yet published).

† J. O. Almen: "Surface Deterioration of Gear Teeth," in *Mechanical Wear*, edited by J. T. Burwell, jr., *Amer. Soc. for Metals*, 1950; and H. Blok, "Gear Lubricant: A Constructional Gear Material," *Ingenieur*, 1951, No. 39.

‡ O. Beeck: *Proc. Royal Soc. A*, vol. 177, pages 90 and 103 (1940).

Fig. 5.

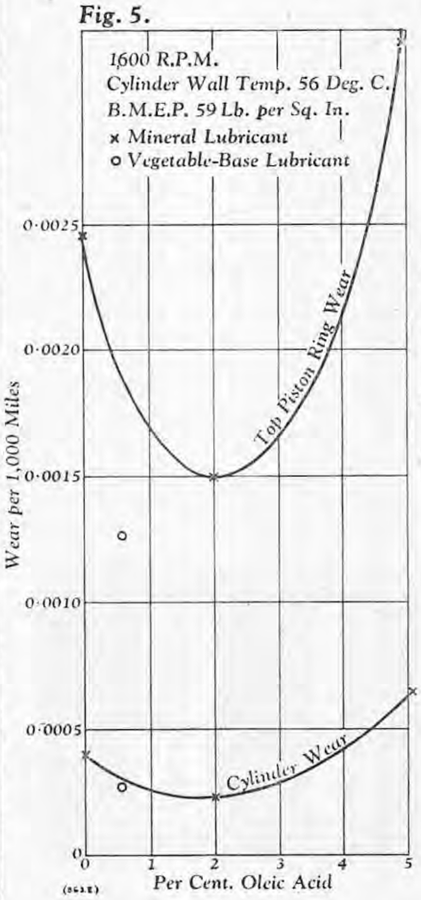


Fig. 6. WEAR DIAGRAM FOR HIGH LOADS ½" S.K.F. STEEL BALLS.

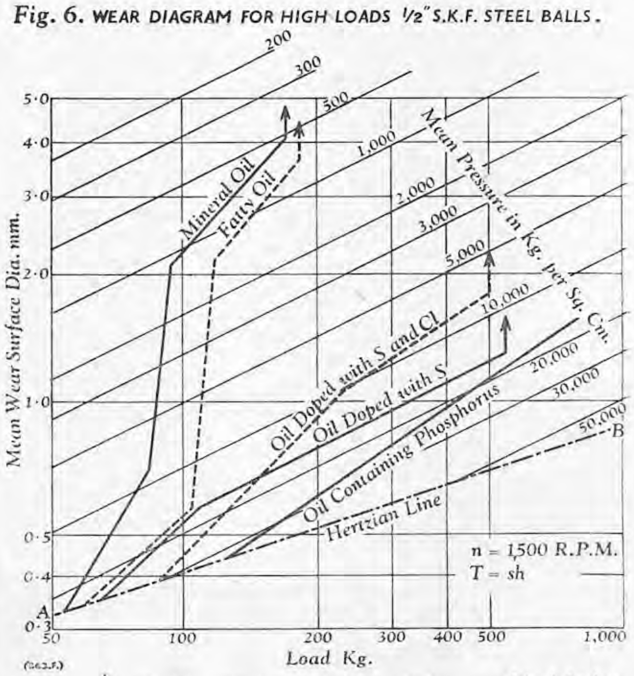
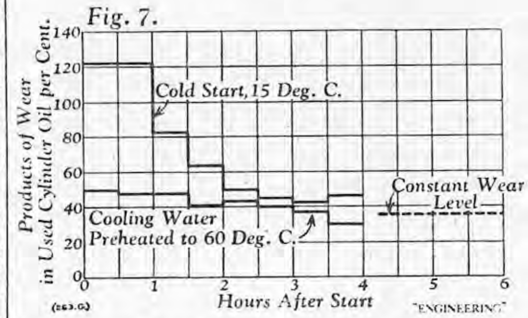


Fig. 7.



enough to avoid condensation, but during the warming-up period this is not so.

The extraordinary rate of wear sometimes met with in automobile engines has long been a puzzle. In the 'thirties, the investigations of Boerlage and Gravesteyn* and of Williams† turned the searchlight on condensation during the warming-up period. While not neglecting the effect of the delayed delivery of fresh oil to the cylinders after each start, Williams showed that prolonged running with cold cylinder walls also could cause excessive wear. The effect of sulphur in the fuel, which is particularly noticeable in Diesel engines, received attention in the same period and was ascribed to a similar process, in which it was found that SO_3 played a part. It has taken much longer to obtain some insight into the question of how exactly SO_3 can get there; most probably, metal and also oxidation products of fuel and lubricant act as promoters of the oxidation to the trioxide. At any rate, its presence explains why the Diesel engine, with its much drier combustion gases, should be susceptible to this attack: the dew point of H_2SO_4 is considerably higher than that of other possible acids or of water.

This part of the wear in engine cylinders is thus obviously caused by electrolytic corrosion and subsequent rubbing-off of the corroded layer. In special cases a somewhat different mechanism, more akin to corrosion fatigue and leading to roughening of the cylinder by pitting, has been found.

Of course, there are complications; for instance, scuffing or scoring tendencies may interact, in a positive or negative sense. There is concrete evidence of both. One cannot say that a complete picture can be given, but the recognition of the corrosive factor in cylinder (and piston-ring) wear has greatly improved insight into such problems, and has shown the way towards improvement. The better temperature control of modern automobile engines, as well as a significant part of the development of modern additive-type lubricating oils, are examples of the results, whereby the whole situation has been markedly improved.

The story would not be complete unless mention were made of some abnormal experiments in laboratory engines, involving the preliminary stages of auto-oxidation. There it has been experienced that such reacting gases are extraordinarily active, and excessive rates of wear have been met with. Undoubtedly, in these cases it has been peroxides and other extremely active compounds, possibly free radicals, that were responsible.

* G. D. Boerlage and B. J. J. Gravesteyn: "Cylinder Wear in Diesel Engines," *Motor Ship*, 1932, page 171.

† C. G. Williams: *Collected Researches on Cylinder Wear*. Inst. of Automobile Eng. (1940).

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.

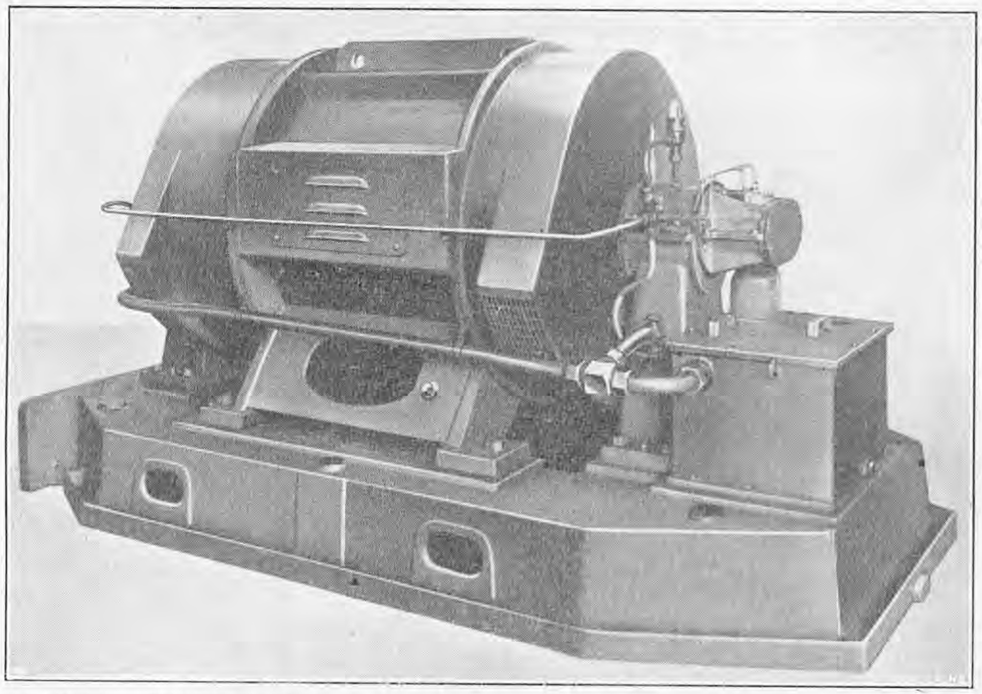
Stainless-Steel Hollow-ware.—A new specification, B.S. No. 1823, has been prepared to meet the need for the standardisation of small stainless-steel hollow-ware utensils for use in hospital operating theatres and wards. The range of sizes and dimensions of each type of utensil are specified and requirements for the quality of the material and of the finish are laid down. [Price 2s., postage included.]

Compressed-Asbestos Jointing for Petroleum Industry.—A further specification in the series prepared for the petroleum industry has now been issued. This, B.S. No. 1832, covers two grades of compressed-asbestos jointing, from $\frac{1}{64}$ in. up to, and including, $\frac{1}{8}$ in. in thickness. The two grades are grade G, which is intended for general low-duty purposes (mainly employed in marketing and transportation), and grade H, for higher-duty purposes (involving contact with oil and mainly used in refinery applications). The specification also contains full details regarding the physical properties and characteristics of the jointing, and tests for cohesion, tensile strength, and resistance to compression, to penetration by oil and water, and to ageing, are prescribed. A service test is laid down and clauses relating to sampling, re-testing, marking and inspection are included. [Price 2s. 6d., postage included.]

Nickel-Silver Strip and Foil for Telecommunication Industries.—A new specification, B.S. No. 1824, forms part of a series for nickel and nickel alloys in various forms prepared to meet the special requirements of the telecommunication industries and more particularly the telephone industry. The specification covers nickel-silver strip and foil; and the chemical compositions, temper grades, mechanical properties and tolerances in dimensions are laid down. The procedure to be adopted in selecting test pieces and the methods of carrying out the tests are specified. [Price 2s., postage included.]

MOTOR FOR BOILER-FEED PUMP.

METROPOLITAN-VICKERS ELECTRICAL COMPANY, LIMITED, MANCHESTER.



1,225-H.P. MOTOR FOR DRIVING BOILER-FEED PUMPS.

THE accompanying illustration shows a 1,225-h.p. squirrel-cage motor which has been designed by Metropolitan-Vickers Electrical Company, Limited, Trafford Park, Manchester, 17, for driving boiler feed pumps. It runs at 2,980 r.p.m. and is suitable for direct starting from a 3·3-kV supply. Two of these motors have been supplied to the Brunswick Wharf station* of the British Electricity Authority in the East End of London; six more are being built for this station and four are on order for the new power station at Brighton.†

As motors driving boiler-feed pumps have to run continuously for several months at a time, and as the speed is high and the rotor heavy, pedestal sleeve bearings are used. To ensure that these bearings are adequately lubricated and cooled, a constant-flow oil system is incorporated, through which filtered oil is circulated by a pump. This pump is geared to the main shaft and drives filtered oil through the bearings, whence it is returned to a tank mounted on the bedplate which acts both as a reservoir and a cooler. The bearings are also fitted with normal oil rings so that an adequate supply of oil is available during the starting period. These rings ensure that the bearings will not be damaged in the event of a failure in the oil-circulating system.

LAUNCHES AND TRIAL TRIPS.

S.S. "CAIRNDHU."—Single-screw cargo vessel, built by William Gray and Co., Ltd., West Hartlepool, for the Cairn Line of Steamships, Ltd., Newcastle-upon-Tyne. Second vessel of an order for two. Main dimensions: 419 ft. between perpendiculars by 60 ft. by 37 ft.; deadweight capacity, about 9,400 tons on a draught of 27 ft. Double-reduction steam turbines developing 4,650 s.h.p., constructed by the Parsons Marine Steam Turbine Co., Ltd., Wallsend-on-Tyne; and two Babcock and Wilcox oil-fired water-tube boilers, constructed by the shipbuilders. Service speed, 13 knots. Launch, April 9.

M.S. "EASDALE H."—Single-screw tank barge, built by Cook, Welton and Gemmell, Ltd., Beverley, Yorkshire, for John Harker, Ltd., Knottingley, Yorkshire, for service on inland waterways between the Humber and West Yorkshire. Third vessel of a series of three. Main dimensions: 132 ft. between perpendiculars by 17 ft. 6 in. by 7 ft. 9 in. Six cargo tanks having a total capacity of 275 tons. Six-cylinder oil engine working through reduction gearing and developing 120 b.h.p. at 900 r.p.m., constructed by Gleniffer Engines, Ltd., Glasgow. Launch, April 15.

M.S. "KOWHAI."—Single-screw cargo vessel, built and engined by Alexander Stephen and Sons, Ltd., Linthouse, Glasgow, for the New Zealand to Australia service of the Union Steam Ship Co. of New Zealand, Ltd., Wellington, New Zealand. Sixth vessel of a series for these owners. Main dimensions: 325 ft. by 50 ft. by 26 ft.; gross tonnage, 3,550; deadweight capacity, 5,300 tons on a draught of about 22 ft. 4 in. Stephen-Sulzer six-cylinder Diesel engine, developing 3,000 b.h.p. at 150 r.p.m., and a speed of 12 knots in service. Launch, April 23.

M.S. "SINGULARITY."—Single-screw cargo vessel, built by the Goole Shipbuilding and Repairing Co., Ltd., Goole, for F. T. Everard and Sons, Ltd., London, E.C.3. Main dimensions: 225 ft. by 37 ft. 10 in. by 16 ft.; deadweight capacity, 1,814 tons on a draught of about 15 ft. 8 in. Four-cylinder Diesel engine, developing 800 b.h.p. at 250 r.p.m., constructed by the Newbury Diesel Co., Ltd., Newbury, Berkshire. Speed, about 10¾ knots. Launch, April 23.

S.S. "STANLEY ANGWIN."—Twin-screw cable ship, built and engined by Swan, Hunter, and Wigham Richardson, Ltd., Newcastle-upon-Tyne, for Cable and Wireless, Ltd., London. Main dimensions: 315 ft. overall by 41 ft. by 25 ft. 9 in. to upper deck; deadweight capacity, about 2,200 tons on a draught of 19 ft.; gross tonnage, 2,550; coiling capacity, about 18,000 cub. ft., equal to 400 miles of deep-sea cable; operating range, 10,000 miles. Two triple-expansion steam engines, developing a total of 1,450 i.h.p. at 104 r.p.m., and two oil-fired multitubular Scotch boilers. Speed on trial exceeded 12 knots. Trial trip, May 7.

M.S. "IRISH COAST."—Twin-screw vessel carrying 242 first-class, and 146 third-class passengers, 348 cattle, motor cars and cargo, built and engined by Harland and Wolff, Ltd., Belfast, for the cross-channel services of Coast Lines, Ltd., London, E.C.3. Main dimensions: 320 ft. between perpendiculars by 51 ft. 6 in. by 19 ft.; gross tonnage, about 3,600. Two Harland-B. and W. ten-cylinder two-stroke trunk-piston Diesel engines. Launch, May 8.

S.S. "CAIRNGOWAN."—Single-screw cargo vessel, with accommodation for twelve passengers, built by William Gray and Co., Ltd., West Hartlepool, for the Cairn Line of Steamships, Ltd., Newcastle-upon-Tyne. First vessel of an order for two. Main dimensions: 419 ft. between perpendiculars by 60 ft. by 37 ft.; deadweight capacity, 9,200 tons on a draught of 27 ft. Double-reduction steam turbines, developing 4,650 s.h.p., constructed by Parsons Marine Steam Turbine Co., Ltd., Wallsend-on-Tyne; and two Babcock and Wilcox oil-fired water-tube boilers, constructed by the shipbuilders. Service speed, 13 knots. Trial trip, May 6 and 7.

M.S. "DUCHESS OF ATHENS."—Single-screw oil tanker, built by the Furness Shipbuilding Co., Ltd., Haverton Hill, County Durham, for the Trent Maritime Co., Ltd., London. Main dimensions: 525 ft. between perpendiculars by 71 ft. by 39 ft. 3 in.; deadweight capacity, 18,200 tons on a draught of 30 ft. 6 in.; oil-carrying capacity, 17,280 tons. Vickers-Doxford six-cylinder two-stroke single-acting oil engine, developing 6,600 b.h.p. at 115 r.p.m., constructed by Vickers-Armstrongs Ltd., Barrow-in-Furness. Speed, 15 knots. Launch, May 14.

* See ENGINEERING, vol. 171, page 788 (1951).

† *Ibid.*, vol. 171, page 724 (1951).

EXPLOSIONS IN ENGINE CRANKCASES.*

By JOHN LAMB, O.B.E., M.I.Mech.E.

(*Concluded from page 662.*)

A DEVICE which, it is claimed, will prevent an undesirable build-up of pressure in the event of an explosion, and at the same time close instantly, is shown in Fig. 11, on page 696. This device is called the "Lightning" safety valve, and, in slightly different form, has been used with good effect for many years in connection with the starting-air systems of marine Diesel engines.

The special features of this valve are that it can be designed to open at any predetermined pressure above atmospheric; it opens instantly and to its fullest extent without shock when the predetermined pressure is reached; and it closes immediately the excess pressure is released. Other good features possessed by this valve, when related to the release of excess pressure from crankcases, are that it will operate equally well when disposed vertically, horizontally, or at an angle, and that size does not affect its operation. The main advantage of this valve over spring-loaded relief valves is that whereas, in the latter, the load is progressively increased as the valve opens, the load on the "Lightning" valve is decreased. Actually, at the moment the valve begins to open about 90 per cent. of the load is thrown off, and it opens instantly to its fullest extent.

QUENCHING OF FLAME.

Having a positive means of preventing a serious build-up of pressure, as well as entry of air into the crankcase, it remains to find a method of making the released hot gases non-injurious to personnel and incapable of starting a fire. In most instances, the first gases to reach the open air will comprise an unburnt mixture of air and oil particles, followed by a similar mixture still in process of burning. The burning will continue, or, in other words, the flame will exist, until the whole of the inflammable mixture released has burnt or has been cooled to below its ignition temperature by contact with the surrounding air. The length of flame issuing from the crankcase exit will, therefore, depend upon two factors, namely, the point in the crankcase at which explosion begins, and the position of the exit. Assuming that the pressure wave travels toward the exit, the nearer the seat of the explosion is to the exit, the smaller will be the quantity of unburnt mixture expelled, and, consequently, the shorter will be the length of flame.

To ensure that every explosion that might occur in a multi-unit engine takes place near to an exit, so that the least possible quantity of unburnt mixture is expelled ahead of the burning gases, is impracticable. It would probably mean several exits on each crankcase door and at least two on each end of the crankcase. Even then there is no certainty that the excess pressure would be released through the nearest exit. Moreover, the greater the number of exits, the greater the risk to personnel of injury by burning. The dangers attending the expulsion of burning gases could be overcome by trunking the gases from the exits to a point clear of the engine room. The trunking would need to be of large size and free from bends if it were not to interfere with the free flow of the released gases. It would not be practicable to provide such trunking in a ship's engine room, and it would not be favoured even in installations where space is unlimited. It would seem, therefore, that prevention of injury by burning would result only if the released gases could be cooled as they left the crankcase exits. The following experiments were based upon this contention.

The chamber selected for the tests was a disused, but sound, Diesel-engine air-injection bottle having an internal diameter of 18¾ in. and a length of 12 ft. Air and gas oil were introduced and ignited, the excess pressure produced escaping through a "Lightning" relief valve of 6 in. diameter, connected at one end of the bottle. One end of the bottle was faced to take the relief valve, and the other end was closed except for an opening to take the 2-in. connection of a motor-driven fan, the purpose of which was to expel the combustion products after each explosion. A hole 1 in. in diameter was drilled tangentially near the fan end of the bottle for insertion of a compressed-air pipe, used to effect swirl and better mixing of the air and atomised oil inside the bottle. The test equipment is shown in Fig. 12, on page 696.

The principal aim was to produce pressure and flame adequate to test the relief valve and flame trap. To assimilate more exactly conditions in an engine crankcase the bottle should have been heated to about 140 deg. F. Heating arrangements were not provided, but it was found that, as the tests proceeded, the bottle quickly attained a sufficiently high temperature.

To ensure more positive ignition and to simplify the tests, it was decided to spray paraffin into the

* Paper presented at a meeting of the Institution of Mechanical Engineers, held in London on Friday, April 25, 1952. Abridged.

EXPLOSIONS IN ENGINE CRANKCASES.

Fig. 11. 12 IN. DIA. LIGHTNING SAFETY VALVE FOR CRANKCASES.

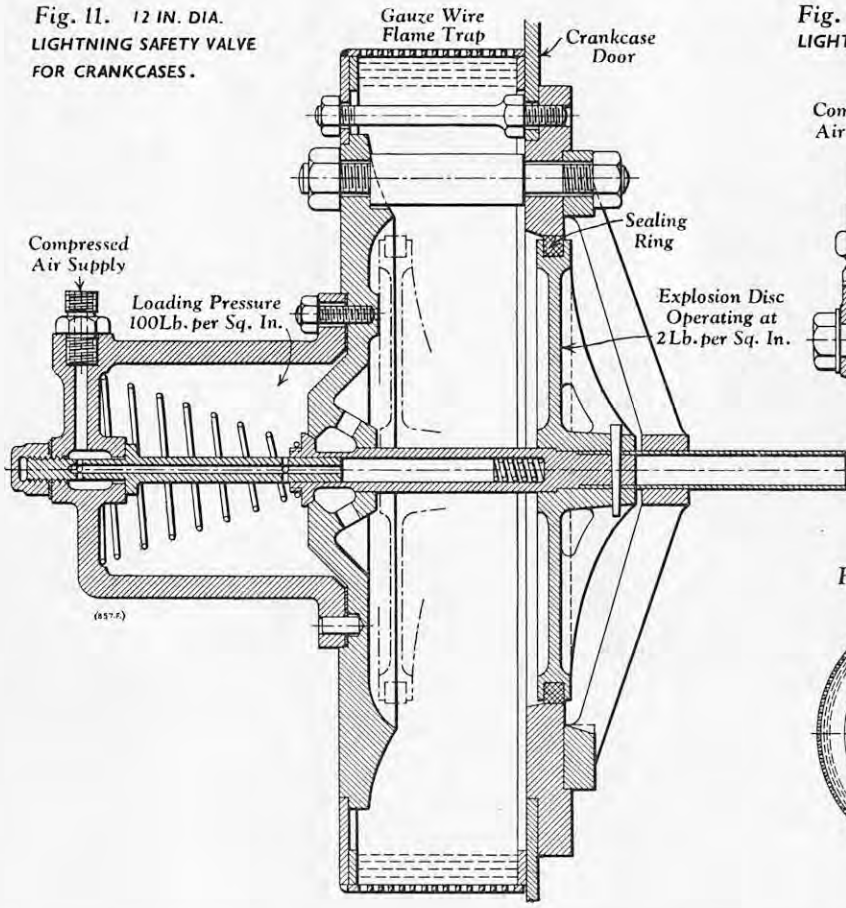


Fig. 13. MODIFIED LIGHTNING SAFETY VALVE.

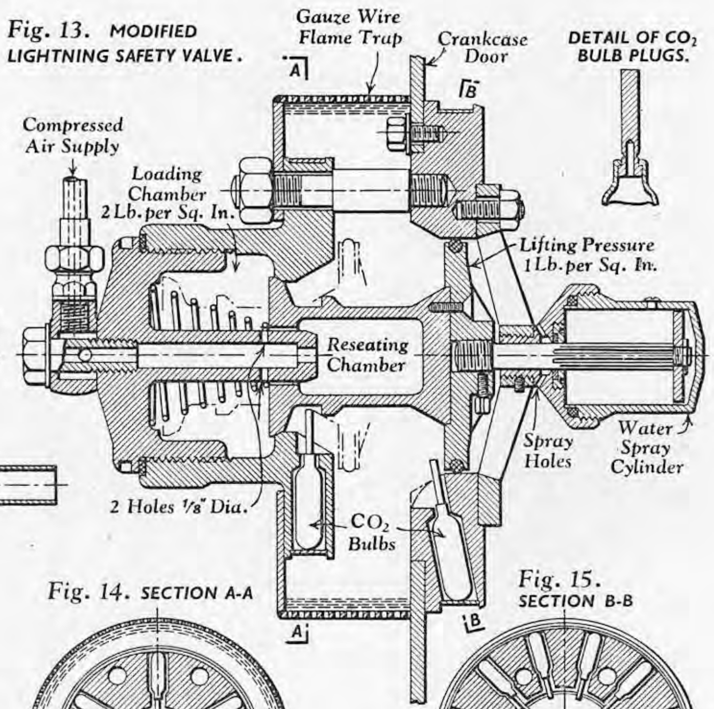


Fig. 14. SECTION A-A

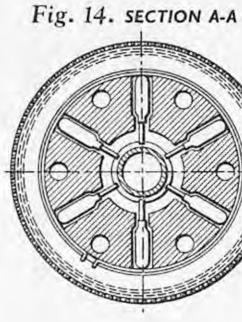
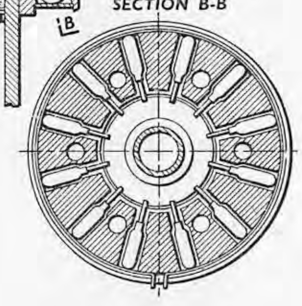


Fig. 15. SECTION B-B



bottle in a finely divided state and to ignite the mixture of air and oil particles by means of an electrically-heated wire. The spray forms produced by various types of Diesel-engine injector were examined, but found unsuitable owing to the required small spray angle and excessive penetration in air at atmospheric pressure. Better results were obtained with a continuous-flow swirl type of nozzle, as used in internal-combustion turbines, and a nozzle, was made from design data supplied by the Fuel Injection Section of the Shell Company's Thornton Research Centre. This nozzle produced a conical spray with an included angle of about 90 deg., adequate atomisation being obtained with 80 lb. per square inch injection pressure.

With paraffin, the flame issuing from the relief valve took the form of irregular tongues up to 18 in. long. With no air loading on the relief valve, ignition resulted in a series of three or four explosions at intervals of about one second. This was caused by the valve not being adjusted to prevent the inrush of air into the bottle after an explosion. This phenomenon was also apparent when no valve was fitted, and the bottle was open to the atmosphere.

As it was known that this particular form of valve was fully capable of preventing a build-up of pressure, efforts were concentrated upon finding means of reducing the temperature of the released gases, and it was decided to test first the effectiveness of the well-known cooling mediums, namely, wire gauze, carbon dioxide and water, and a "Lightning" valve was made as shown in Figs. 13, 14 and 15, herewith. The carbon dioxide was contained in a number of small bottle-shaped vessels situated in the path of the escaping gases, while the water sprayer was connected as shown. The wire gauze was the first to be tried and, in view of the encouraging results obtained during the initial tests, it was decided to pursue this line of investigation before applying either carbon dioxide or water. No. 40 mesh wire-gauze was cut and shaped to cover the relief-valve outlet-ports, and this alone was sufficient to extinguish a flame 18 in. long.

To get a rough idea of the quantity of heat extracted from the gases by this crude form of flame trap, wax candles were lashed in such a position that the gases released by the valve would impinge upon them. With no trap fitted, the exposed half of the candle melted so much that the string by which it was secured buried itself in the softened wax. With the flame trap fitted, the candle was as firm as before the test, indicating that the trap had reduced the temperature of the released gases by an appreciable amount. Efforts were then directed toward producing a more violent

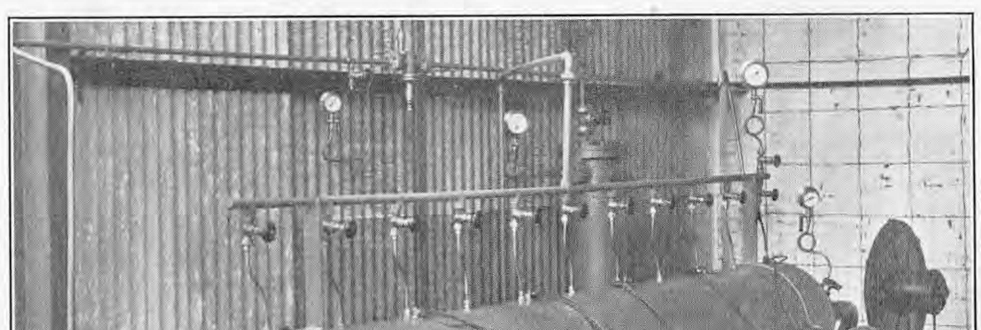


FIG. 12. EQUIPMENT USED FOR EXPLOSION TESTS.

explosion combined with a longer flame. A mixture of one part petrol and two parts gas oil was found most suitable. With the relief valve loaded and after the best method of injecting and igniting had been worked out, flames 15 ft. long could be produced at will. A series of tests to determine the most suitable form of flame trap were then carried out, after which endeavours were made to obtain a reasonably accurate assessment of the cooling effect.

The temperature-measuring tests were carried out with improvised apparatus, for which great accuracy is not claimed. The temperature-measuring elements were grids of fine platinum wire (0·002 and 0·004 in. diameter) consisting of ten 50-mm. spans supported on light Nichrome hooks attached to Tufnol frames. Photographs of the grid and its frame, and of its embodiment in a unit with protective shields, supports, and connecting cable are reproduced in Figs. 16 and 17.

The wire grid was placed in the path of the issuing gases and, by virtue of its low heat capacity and the high velocity of the gases, it more or less faithfully followed the gas temperature. It was connected as one arm of a Wheatstone bridge energised with alternating current; the other arms of the bridge are insensitive to temperature changes and are adjusted so that the bridge is balanced when the grid is at the

EXPLOSIONS IN ENGINE CRANKCASES.

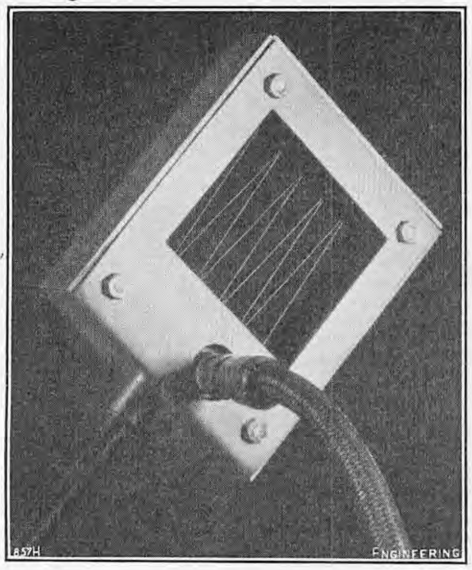


FIG. 16.

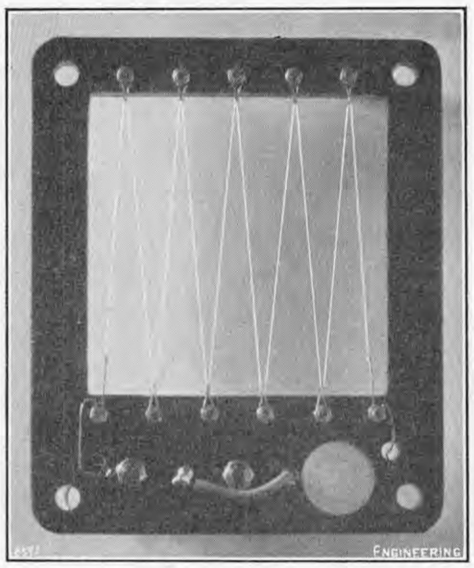


FIG. 17.

FIGS. 16 AND 17. GRID OF APPARATUS FOR MEASURING TEMPERATURE OF HIGH-VELOCITY GASES.

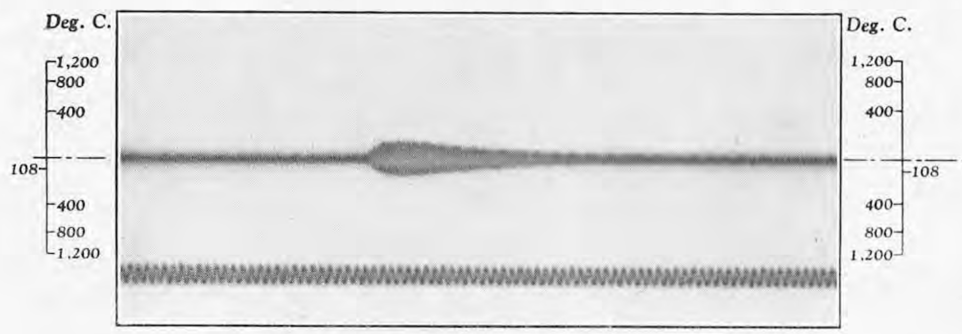


FIG. 18. WITH FLAME TRAP, 4 FT. 9 IN.

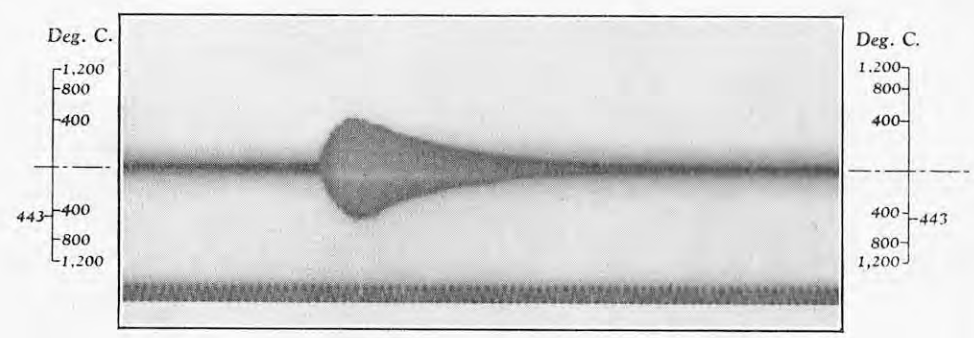


FIG. 19. WITH FLAME TRAP, 2 FT. 6 IN.

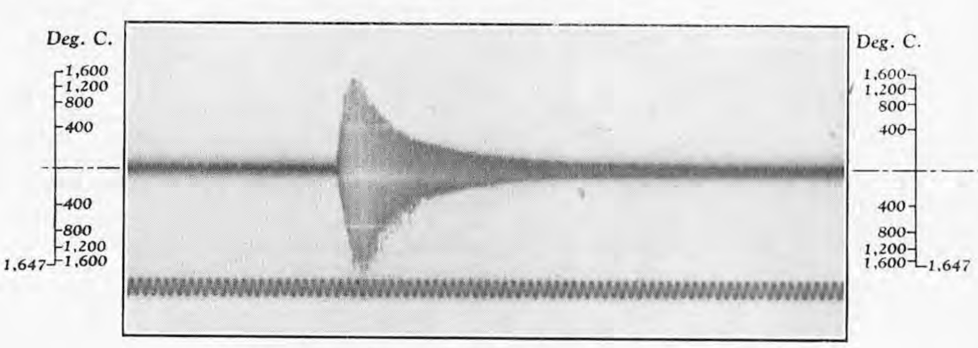
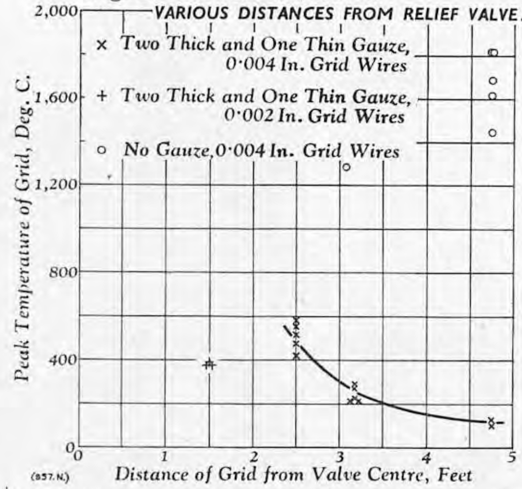


FIG. 20. WITHOUT FLAME TRAP, 4 FT. 9 IN.
FIGS. 18 TO 20. RECORDS OF GAS TEMPERATURES.

temperature of the surrounding air. When the hot gases raise the grid temperature, its electrical resistance increases, unbalances the bridge, and produces an alternating voltage from which the grid temperature can be calculated using the well-established relation between the electrical resistance of platinum and its temperature. The voltage is amplified and recorded by means of a cathode-ray oscillograph and moving-film camera.

Three typical records with the grids at 2 ft. 6 in. and 4 ft. 9 in. from the valve centre and with flame trap fitted, and at 4 ft. 9 in. without flame trap fitted, are shown in Figs. 18, 19 and 20, herewith. The central lines are traces of the stationary cathode-ray when the

Fig. 21. GAS TEMPERATURE AT VARIOUS DISTANCES FROM RELIEF VALVE.



bridge is balanced, and the out-of-balance alternating voltage swings the trace symmetrical to either side (the frequency is too high for individual excursions to be distinguished). The width of the trace is thus a measure of the out-of-balance voltage, and hence of the grid resistance and of the gas temperature. The sine-wave trace to one side of the record is a time-scale; 2/100 second elapses between successive peaks. The results of the test carried out are summarised in Fig. 21. There are some anomalies, but the effect of the flame trap in the tests at 4 ft. 9 in. from the valve centre is beyond question.

The principal uncertainty in interpreting these records lies in estimating the effect of the lag between grid and gas temperatures, which depends upon gas velocity. No allowance has been made for this in the graphical summary, and in the records with flame trap fitted it is probably not very important. It is believed that the peak gas velocity is of the order of 100 m. per second, and at 200 m. per second the time constant of the 0·004-in. wire will be in the region of 0·025 second. A considerable correction of the temperature recorded without flame trap is therefore probably necessary, but it would have the effect of increasing the estimated gas temperature and enhancing the apparent effect of the flame trap.

Numerous sizes and combinations of sizes of gauze were tried out, and it was found that unless the gauze was in close contact with the supporting frame, or, when a number of thicknesses were used, unless they were in close contact with each other, a red-hot patch was produced. This not only allowed the flame to pass, but weakened the gauze so much that when a second explosion occurred immediately, due to entry of air, the force of the explosion blew out the hot patch. The best results were obtained with a flame trap made up of two layers of thick gauze and three layers of thin gauze, the thick layers being on the inside and first to meet the issuing flame. The two inner layers were cut from 20-mesh gauze with wire of 0·02 in. diameter, clear area 36 per cent., and weight 0·56 lb. per square foot. The remaining layers were cut from 40-mesh gauze with wire of 0·01 in. diameter, clear area 36 per cent., and weight 0·30 lb. per square foot. The reason for locating innermost the gauze made of the thicker wire is because 0·02 in. diameter wire absorbs about 80 per cent. as much heat as 0·01 in. diameter wire, and because of its greater weight per unit area the temperature rise will be only about 50 per cent. of that of the thinner wire. The effect of this flame trap was to extinguish completely a flame 15 ft. long and to reduce the temperature of the gases issuing from the valve from 1,647 to 108 deg. C. at a distance of 4 ft. 9 in. from the centre of the valve.

Tests were then carried out to determine the resistance to the flow of gases caused by the wire-gauze flame trap. The pressure in the bottle was registered by an engine-cylinder pressure indicator screwed into a hole near the relief-valve end of the bottle. The indicator was fitted with a spring 16 lb. to the inch and, while the type of instrument used for the purpose might be criticised, it was considered satisfactory, as it was apparent during previous tests that the rate of pressure build-up was not particularly rapid and could be controlled by varying the points of injection and ignition, of which there were 24 and six, respectively.

The relief valve was designed to operate at a pressure of 1 lb. per square inch when loaded by air at 2 lb. per square inch. The reason why such a low loading pressure was used is that it was intended ultimately to fit this valve on an engine where a continuous supply of supercharge air at that pressure was available. It was found that, to produce a long flame, a low valve

STANDARD 2-6-2 TANK LOCOMOTIVE: BRITISH RAILWAYS.

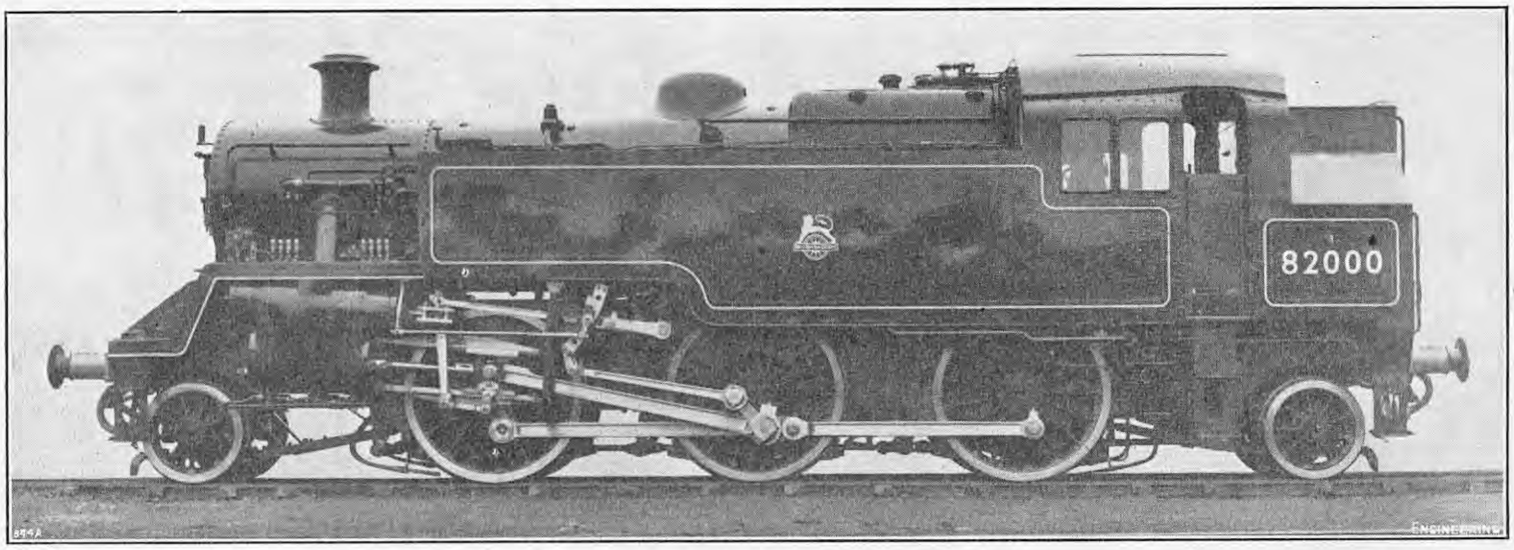
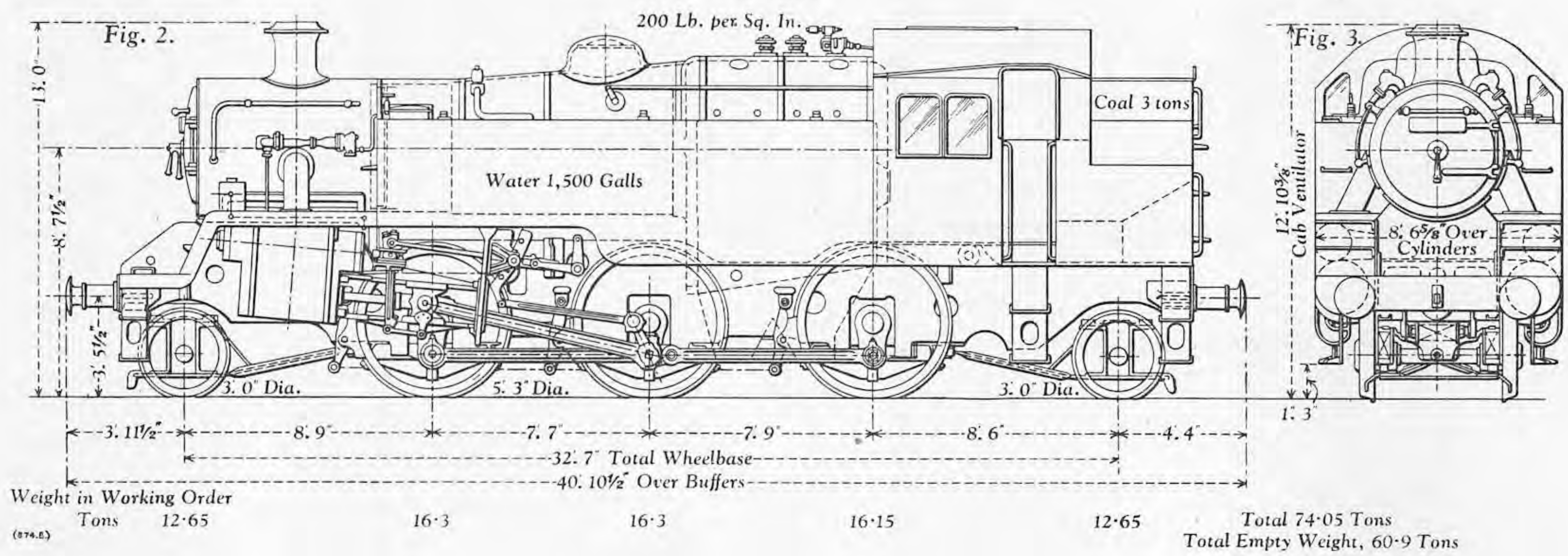


FIG. 1.



loading was required, and to obtain a measurable pressure in the bottle the relief-valve loading had to be increased. This was presumably due to the difference in time between ignition and release as a result of varying the load; the longer the opening of the relief valve was delayed, the greater was the proportion of fuel burnt inside the bottle, and, consequently, the shorter the issuing flame.

Tests were then made, first with and then without the flame trap in position. The first few explosions in the former group took place without the pressure indicator in position, and the loading on the relief valve progressively increased until, by visual inspection of the smoke issuing from the pressure indicator hole, it was apparent that a measurable pressure was being produced inside the bottle. It was then found that when the relief valve was loaded to 7·5 lb. and 10 lb. per square inch, the maximum explosion pressures were 3 lb. and 3·8 lb. per square inch, respectively.

The tests were repeated, but with the flame trap in position, and it was found that the trap had no discernible effect upon the explosion pressure. The clear area through the flame trap was 1·31 times the clear area through the relief valve. It was only when the wire gauze became dirty after several days in use that there was evidence of back pressure.

The pressures recorded may not have been absolutely correct, but the pressures obtained on a great number of occasions were sufficiently consistent to satisfy those present that the flame trap did not interfere to any material extent with the free flow of gases released by the relief valve. Moreover, with pressures of such a low order it is possible to detect any appreciable difference by observing the gases issuing from the pressure indicator hole. These tests concluded the first stage of this investigation. Next, it is proposed to erect an eight-cylinder 1,005-b.h.p. trunk-piston engine from the Diesel-electric ship Auris at Thornton Research Centre, and explosions will be produced in the crankcase while operating and at rest. It is hoped to obtain information regarding pressure waves when oil mist of varying density is ignited at different points.

2-6-2 TANK LOCOMOTIVES: BRITISH RAILWAYS.

THE sixth standard type* of steam locomotive to be introduced by the Railway Executive is a Class 3 2-6-2 tank engine. It has a tractive effort of 21,490 lb., compared with 25,100 lb. for the slightly larger (Class 4) 2-6-4 tank engine which appeared last year. The first of 20 which are to be built this year is shown in Fig. 1, after completion at Swindon Works. The first 10 are being allocated to the Western Region and the rest will go to the Southern Region. The engines are numbered 82000 to 82019 and have been designed and built under the direction of Mr. R. A. Riddles, C.B.E., M.I.Mech.E., member of the Railway Executive. The parent drawing office for the design of the new tank engines was at Swindon, but certain sections were designed at Brighton, Derby and Doncaster. Like both Class 4 types—tender and tank—the Class 3 tank locomotive has almost universal availability over main and secondary lines on British Railways. The cylinders are $17\frac{1}{2}$ in. in diameter by 26-in. stroke; the boiler pressure is 200 lb. per square inch; the coupled wheels are 5 ft. 3 in. in diameter; the weight of the engine in working order is 74·05 tons; and the adhesion factor is 5·08. The grate has an area of 20·35 sq. ft., and the heating surfaces are as follows: tubes, 932·9 sq. ft.; firebox, 118·4 sq. ft.; total evaporative, 1,051·3 sq. ft.; and superheater, 190·0 sq. ft. Other dimensions and weights are shown in Figs. 2 and 3.

The boiler, British Railways standard No. 6, follows closely the design of the former Great Western Railway's standard No. 2 boiler, which was used on the 5100, 6100, 8100 and 5600 classes. The steel and copper-flanged plates for the firebox are common to both designs, but the barrel is $5\frac{13}{16}$ in. shorter. It consists of two rings, the second of which is tapered, the outside diameter being 4 ft. 5 in. at the front and 5 ft. $0\frac{1}{2}$ in. at the firebox end. Both barrel rings are made from high-tensile steel plate, $\frac{1}{2}$ in. thick. The smokebox tubeplate is of the drumhead type, $\frac{5}{8}$ in. thick, and there are 18 large flue tubes $5\frac{1}{8}$ in. outside diameter and 7 s.w.g. thick, and 145 small tubes $1\frac{5}{8}$ in. in outside diameter and 12 s.w.g. thick. The superheater elements were supplied by the Superheater Company, Limited. The length between tubeplates is 10 ft. $10\frac{1}{2}$ in., and the free cross-sectional area through the flues is 3·08 sq. ft.

The firebox is of the Belpaire type, 7 ft. long at the bottom, with an outside width of 4 ft., giving the grate area of 20·35 sq. ft. The steel and copper wrapper plates of the outer and inner fireboxes, respectively, are $\frac{9}{16}$ in. thick. Both the throat-plate and back-plate are vertical, and the copper tubeplate is $\frac{7}{8}$ in. thick. All the firebox water-space stays are made of Monel metal, fitted with steel nuts inside the firebox, and the roof, longitudinal, and transverse stays are of steel. The lagging of the boiler and firebox consists of asbestos mattresses. A rocking grate and self-emptying ashpan are fitted, as many details as possible, and the controls, being similar to those on other classes of standard locomotives. The boiler mountings, regulator, clack valves and manifold are similar in design to those used on Classes 4 and 5 standard locomotives. The smokebox self-cleaning arrangement also follows closely these two classes. The blast pipe has a plain circular cap $4\frac{1}{2}$ in. in diameter, which contains the four nozzles of a Cardew blower. A single-note whistle is fitted.

The engine frame, as on existing standard locomotives, is adequately stayed both horizontally and vertically. Boiler-securing arrangements and springing, as well as the method of staying axlebox guides, are also rather similar to those obtaining on the other classes. Other similar design features include the axleboxes, axlebox guides, method of lubrication

* The first five standard types were described and illustrated in ENGINEERING as follows: 4-6-2 Class 7, vol. 171, pages 126 and 341 (1951); 4-6-0 Class 5, vol. 171, page 528 (1951); 4-6-0 Class 4, vol. 171, page 752, (1951); 2-6-4 Class 4 tank, vol. 172, page 138 (1951); and 4-6-2 Class 6, vol. 173, page 108 (1952).

NEEDLE-TYPE PYROMETER.

CAMBRIDGE INSTRUMENT CO., LTD., LONDON.

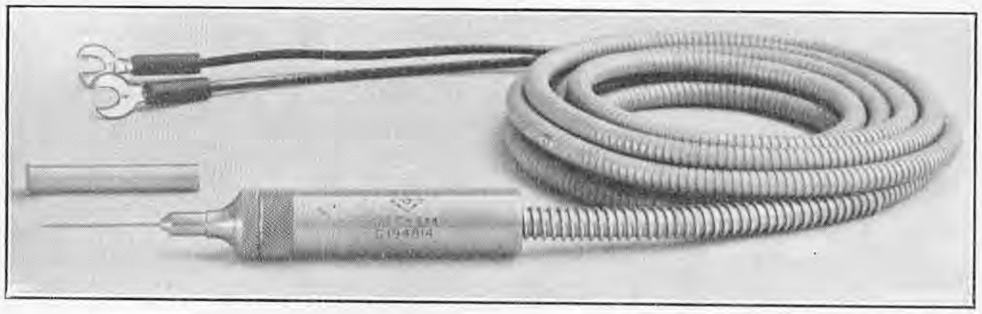


FIG. 1. PYROMETER AND LEADS.

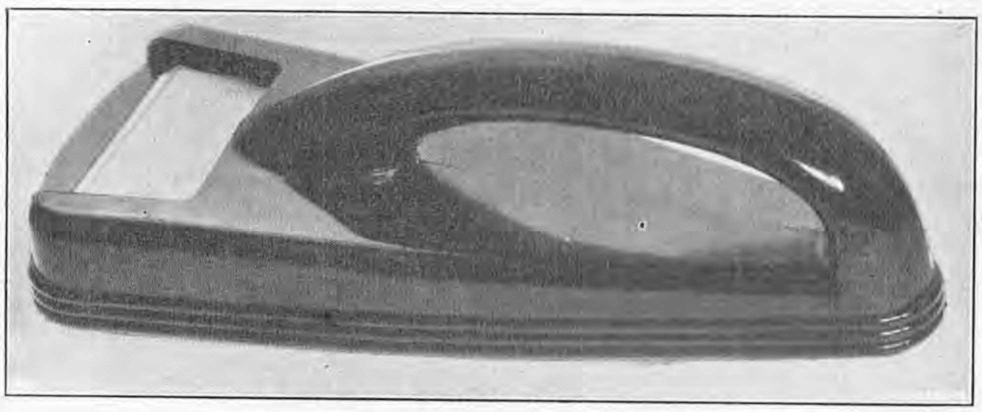


FIG. 2. HAND-PATTERN INDICATOR.

and cylinder-cock and sanding arrangements. The cab layout, of which a mock-up was made, follows as far as possible the design laid down as standard for tender engines. The two cylinders, which are fitted with cast-iron liners, are cast in steel from the pattern used for the former London Midland and Scottish Railway's Class 4F, 2-6-0 locomotives. Piston valves with a nominal diameter of 10 in. are provided, the rear head being $9\frac{7}{8}$ in. in diameter for ease of insertion and removal. They are operated by Walschaerts valve gear, giving a full-gear travel of $6\frac{29}{64}$ in., corresponding to a cut-off of 75 per cent. with a steam lap of $1\frac{1}{2}$ in. and lead of $\frac{1}{4}$ in. The return cranks are fitted with Skefko self-aligning ball bearings.

The motion has more in common with that of the Class 4 tank engine than with other standard locomotives as both have the two-bar "crocodile" type of crosshead, as well as the same method of reversing, using a sliding block in a slotted extension to the radius rod behind the motion plate. The leading pony truck is similar in all respects to that fitted to the Class 4 tank engine, the side play being controlled mainly by double helical springs, while the trailing truck is of the swing-link type. The method of transmitting the load to the axleboxes, and the side-play control retarding gear, are the same for both pony trucks. The tanks and bunker are of welded construction throughout, the former being carried at the leading end on the outside slide-bar bracket and at the trailing end on a frame bracket. Unlike the Class 4 tank engine, no water is carried under the bunker. The tanks have a water capacity of 1,500 gallons and the bunker a coal capacity of 3 tons. The braking proportion for the engine is 51·5 per cent. and the minimum radius of curve (with specified gauge widening) is $4\frac{1}{2}$ chains.

FACTORY FACILITIES IN NORTHERN IRELAND.—A pamphlet issued by the Industrial Development Division, Ministry of Commerce, Government of Northern Ireland, and entitled "Blueprint for Industry," explains the special facilities offered by the Government towards the establishment of new industrial undertakings in the six counties of the Province, namely Antrim, Armagh, Down, Fermanagh, Londonderry and Tyrone. Typical factories are shown and information on public finance, labour, local rates, housing, public utilities, transport and other matters of interest are included. Copies of the pamphlet and further particulars are obtainable from the secretary, Industrial Development Division, Ministry of Commerce, Chichester House, Chichester-street, Belfast.

NEEDLE-TYPE PYROMETER.

THERE are many occasions in industrial manufacturing processes when precise knowledge of the temperature below the surface of a plastic or semi-plastic material is important, success or failure of the process depending on the temperature not exceeding or falling below some definite value. An illustration is provided by rubber manufacture, when accelerators, fillers and synthetic rubber are used. In breaking down crude rubber prior to adding fillers, too high a temperature must be avoided and the temperature of the mixture of rubber and filler must be measured periodically in order to determine when accelerators may be added. It is important, also, to continue measuring the temperature afterwards in order to ensure that it does not reach a value at which scorching or pre-vulcanisation can occur. In extrusion processes in plastics manufacture, high pressures and friction may cause excessive heating and result in damaging temperatures being attained. In the case of certain celluloid products, variations in temperature may result in the celluloid becoming either too stiff or too pliable for the purpose in view. Other examples of a similar nature, when temperature is an important factor, are to be found in the food, pharmaceutical and chemical industries.

To meet the requirements of temperature measurement in these, and other, instances, the Cambridge Instrument Company, Limited, 13, Grosvenor-place, London, S.W.1, have produced the needle pyrometer illustrated in Fig. 1, above. It consists of a sensitive thermocouple mounted inside a hollow stainless-steel hypodermic needle approximately 1 in. long, which is fitted into an insulated handle. A metal cap is provided to cover the needle when the thermocouple is not in use. Connecting leads, surrounded by flexible steel armouring, run from the needle to an indicator, which may be the hand pattern illustrated in Fig. 2, herewith, or, alternatively, a bench or wall-type instrument. The indicators supplied with the thermocouple are calibrated to read temperature directly, ranges from 0 to 200 deg. C. or 50 to 400 deg. F. being available as standard. Needle thermocouples of lengths and diameters to suit special requirements can also be supplied.

CENTENARY OF DEPTFORD BELTING COMPANY.—A folder containing a brief illustrated account of the history of the firm, Preller's and Samson's Belting Co., Evelyn-street, Deptford, London, S.E.8, since its foundation in 1852, has recently been issued. Several interesting old illustrations are reproduced, together with a selection of letters testifying to the durability of the firm's belting.

SURVEY OF THE INTERNATIONAL SYMPOSIUM ON ABRASION AND WEAR.*

By DR. H. C. J. DE DECKER.

WE have tried to arrange this Symposium in such a way that some important knowledge about wear would be presented and that this knowledge would come from entirely different fields of research. The study of the general problem of wear will be facilitated, as far as we can see it, by making approaches to it from entirely different angles. In reviewing the several papers that have been presented, we can see at least three different possibilities for making a cross-section through the field of wear.

The first point of view that makes possible a cross-section is the type of material. In this cross-section, we see, for example, the following materials, one next to the other: carbon, hard metals, soft metals, plastics, fibres, paint and rubber. To begin with, we see an analogy between all these materials in the fact that wear is something that happens at the surface. There is also an analogy in the definition of wear, because the definition given by Blok really applies to all materials; this definition indicates wear as the undesirable migration of the material of a solid surface, essentially through the overstressing by mechanical forces, etc. It is also true that wear may be mainly a mechanical phenomenon, but that, in practically all cases, it is closely connected with chemical attack. Therefore, there is an important connection between corrosion of metals and ageing or weathering of rubber and plastics, on the one hand, and wear, on the other hand.

There is, however, an important difference in the rigidity or mobility of the entire bulk of the material, as distinguished from the surface. Through this difference, wear is influenced to a very different degree by the bulk of the material. In one case, we saw that fibrilisation of fibres is the cause that these wear not only at their surface, but throughout the entire fibre; in another case, we saw that pitting of a steel surface leaves the bulk of the steel object entirely unaffected.

Generally, we can say, perhaps, that the modulus and the dimensions of the wearing materials are determining factors for the degree in which wear penetrates below the surface. There is, for example, a great difference between wear of a certain plastic or rubber when it is subjected to abrasive action in the form of a massive block, or in the form of a thin layer on a hard base, or in the form of a cloth woven from threads.

The second point of view that enables us to make a cross-section is the division according to basic factors promoting wear. This cross-section shows the following basic factors:

1. Mechanical attack:
   (a) Impingement.
   (b) Impact pitting.
   (c) Interlocking.
   (d) Adhesion.
2. Chemical attack, including oxidation, ozone cracking, etc.
3. Fatigue phenomena.
4. Heating.

All these basic factors have this in common, that they can all contribute to the wear of all materials. It is also important to note that they rarely operate separately, because practically always more than one are operating. The complexity of wear phenomena and the difficulties in studying them are largely due to the fact that the basic factors are always operating in groups and not separately.

The differences between the basic factors are obvious. They are caused by different circumstances and they also depend on the type of material. We can easily see that oxygen and mechanical interlocking both will play an important part in wear of metals and rubber, but it is quite clear that their mutual interaction and their effect will be entirely different in both cases. I have had some difficulty in putting together the basic factors as they have been mentioned by various authors, and it is one of the advantages of this Symposium that we have had an opportunity to review all the basic factors that are thought of importance in various fields of this research, and that we had the opportunity to study differences and analogies.

There is still a third point of view, and the cross-section through our field that is emerging from this point of view is a series of factors counteracting wear. These are mainly the following:

1. Reduction of wearing forces:
   (a) Mechanical forces.
   (b) Chemical influences.
2. Choice of resisting materials:
   (a) Resisting mechanical forces.
   (b) Resisting chemical influences.
3. Surface finishing.

* Review of the papers presented at the International Symposium on Abrasion and Wear, held in Delft Holland, on November 14 and 15, 1951.

Both the reductions, 1(*a*) and 1(*b*), can be obtained by protective or lubricating coatings. The resistance against mechanical forces, 2(*a*), is not only a question of hardness or modulus, but often a question of tear strength and fatigue strength. It is remarkable that two entirely different materials like steel and rubber, having about the same tensile strength per true cross-section, but having an entirely different modulus and hardness, can take each other's place, according to circumstances, when a maximum wear resistance is needed.

As to chemical resistance, 2(*b*), most frequently the resistance to oxygen is most important; often, also, resistance to other compounds is necessary, for example, to acids. The surface finish (3) must be of a type that is least exposed to mechanical forces, i.e., it must be smooth. All these factors tend to diminish the destructive influence of wearing forces.

It seems to me that, especially through this review of factors which enable the reduction of wear, important gaps in our knowledge come to light. There may be a qualitative explanation of the fact that rubber is better than metals to resist the type of wear occurring in coal chutes or ball mills, and in car tyres. Still it is not entirely clear which one of the factors is most important in these cases. The small rate of wear of vulcanised-rubber carbon-black car tyres has not been fully explained; not even by Schallamach, Stiehler and Buist, who have worked so hard on the problem. It is still more difficult to explain the excellent suitability of relatively soft bearing metals, as Blok has indicated in his paper.

After having put before you three different cross-sections through the wear problem, all merging from this Symposium, I should like to draw your attention now to the possibility of characterising the wear properties of materials, for example, by simple quality indices or wear rating numbers.

It has been pointed out, especially by Buist, that the practical aim of wear testing is to predict or calculate long-term wear properties from relatively short tests, be they tests in the laboratory or in practice. If such predictions are possible, they would lead to some sort of wear rating numbers, as has been discussed by several of the authors at this Symposium (Blok, Salomon and others).

Now prediction is only possible when all the determining factors are fully known, and this is certainly not yet the case, owing to the complexity of wear phenomena. In order to arrive at any prediction of wear properties, and at such a simple and desirable thing as wear rating numbers, research on fundamentals of wear must be carried on. On the one side, we will need fundamental analysis of phenomena in the laboratory, such as Bowden, Schallamach, Salomon and Brunt have mentioned; on the other side, registration and evaluation of practical wear processes, as described for car tyres by Stiehler and Buist, is indispensable.

We frequently notice that there is much difficulty in arriving at the necessary relation between the testing of materials and fundamental knowledge. We notice the same difficulty in other fields, like applied mechanics and corrosion. In the ideal development of wear research, we will perhaps be able to distinguish the following five steps, leading to the quality numbers that I indicated as desirable:—

(*a*) Registration and evaluation of practical wear processes.

(*b*) Verification of rules and empirical formulae for the progress of wear.

(*c*) Research for elementary processes that are the basis of the rules and formulae in (*b*).

(*d*) Construction of a complete picture of wear from the elementary processes found.

(*e*) Introduction of wear rating numbers to characterise wear processes.

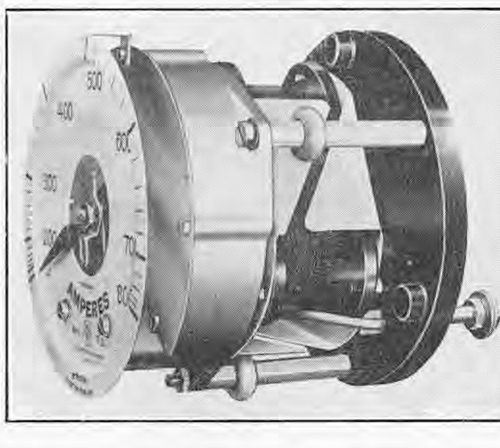
This development has been accomplished to a greater or lesser extent for various materials. Bowden has treated (*c*) and (*d*) for a wide variety of materials during friction. Blok has studied (*b*) and (*c*) for metal wear, mainly under mechanical forces. Broeze showed investigations covering (*a*), (*b*) and (*c*), and sometimes even (*d*) for certain cases of combined chemical and mechanical attack. Salomon studied (*c*) mainly for fibres and plastics. Brunt discussed (*b*) and (*c*) for paints, and even went as far as (*d*) for the case of abrasion by impact. For rubber car tyres, Stiehler presented a paper on (*a*); Buist on (*a*) and (*b*); Schallamach on (*c*). I may add here that the Rubber-Stichting is working on (*a*), (*b*) and (*c*); for (*c*), Schallamach is using microscopical methods, whereas the Rubber-Stichting is using macroscopical models in order to isolate one variable.

The problem of what we must see as the aggresive force in wear processes is, in my opinion, the biggest problem in wear research. Schallamach's needle, the four-ball apparatus used by Broeze and Blok, the falling carborundum particles studied by Brunt, and the bending tests on fibres as described by Salomon, are all trials to simplify the aggresive force in wear problems. This is the way to get some progress with the third step in our wear research, the finding of elementary processes at the basis of rules and formulae. We must realise that all the difficulties we already know from other fields of material research are present in wear research, and that, on top of that, there is the difficulty of defining the aggressive force.

You will understand, from what I have said, that I do not think it very useful to construct more or less arbitrary measuring apparatus for abrasion or wear. I think it is only useful to do measurements either in actual practice (including tests that are imitations of practice) or, on the other hand, on well-defined elementary processes. Any attempt to get to the last step without having made the other four steps is, in my opinion, senseless. In these circumstances, there is much work to do and I agree with Blok that here, as in many other fields, co-operation and team work is desirable. In this co-operation, the knowledge must be collected from research on entirely different materials if we do see wear problems, not as a specific problem of rubber or of steel or of fibres, but as a general problem of material research.

MOVING-IRON VOLTMETERS AND AMMETERS.

THE instrument shown in the accompanying illustration is one of a series of switchboard-pattern moving-iron voltmeters and ammeters recently introduced by Messrs. Crompton Parkinson, Limited, Crompton House, Aldwych, London, W.C.2. To produce a compact long-scale instrument at a reasonable cost, the firm concentrated on a design which has proved popular, namely, a flush-mounting pattern having a 4-in. dial. The scale is $6\frac{1}{2}$ in. long, and the face of the instrument is recessed so that the pointer rotates in the plane of the scale. Possible errors of reading arising from parallax are therefore obviated.



The movement is of the spring-controlled repulsion type with the addition of attraction elements which form part of the magnetic screens. The latter provide magnetic shielding against interference from external magnetic fields and also increase the efficiency of the movement. The moving part of the assembly is mounted on carbon-steel pivots which are hardened and polished and supported in synthetic-sapphire bearings, spring-mounted to protect the pivots from damage by vibration or shock. The movement is damped pneumatically by a vane in a dashpot which is an integral part of the frame of the movement. The frame is of tin-base alloy and is die-cast.

The movement, winding, dial and terminals are all mounted on a moulded plastic base which fits into a pressed-steel barrel, not shown in the illustration, having a square flange to which the die-cast aluminium-alloy front of the instrument is fixed. The window, of toughened glass, is bedded into a recess with a sealing compound and secured by a spring clip. The zero adjuster is in the centre of the window. The instruments are dust-proof and damp-proof. They may be attached from the front of the panel, if desired, and the main fixing screws are held in position by a brass locking ring.

The instruments are calibrated individually, each at a specified frequency or over a specified range of frequencies, and, in all cases, the error at any part of the scale within the effective range does not exceed 1 per cent. of the maximum indication. The effective range is from 20 to 100 per cent. of the latter. In the case of voltmeters, the necessary resistances are mounted on the back of the instrument and protected by a moulded plastic cover. Ranges available are from a minimum 0 to 30 volts to a maximum of 0 to 600 volts. For ammeters the minimum range is 0 to 1 ampere and the maximum 0 to 20 amperes. The instruments are normally finished in black enamel.

BOOKS RECEIVED.

Units and Standards of Measurement Employed at the National Physical Laboratory. II. Light. Photometry, Colorimetry and Radiometry. H.M. Stationery Office, Kingsway, London, W.C.2. [Price 6*d*. net.]

Ministry of Housing and Local Government Scottish Office. The Surface Water Year-Book of Great Britain, 1937-45. H.M. Stationery Office, Kingsway, London, W.C.2. [Price 17*s*. 6*d*. net.]

Second Seminar for European Sanitary Engineers. Rome, 11-17 November, 1951. United Nations World Health Organisation, Regional Office for Europe, Geneva, Switzerland.

Handbook of Heating, Ventilating and Air Conditioning. By JOHN PORGES. Third edition. George Newnes, Limited, Tower House, Southampton-street, London, W.C.2. [Price 25*s*. net.]

Water Engineer's Handbook, 1952. The Colliery Guardian Company, Limited, 30 and 31, Furnival-street, London, E.C.4. [Price 18*s*.]

Machine Design Drawing Room Problems. By PROFESSOR C. D. ALBERT. Fourth revised edition. John Wiley and Sons, Incorporated, 440, Fourth-avenue, New York 16, U.S.A. [Price 5 dols.]; and Chapman and Hall, Limited, 37, Essex-street, Strand, London, W.C.2. [Price 40*s*. net.]

Mechanics. Part I. Statics. By PROFESSOR J. L. MERIAM. John Wiley and Sons, Incorporated, 440, Fourth-avenue, New York 16, U.S.A. [Price 4 dols.]; and Chapman and Hall, Limited, 37, Essex-street, Strand, London, W.C.2. [Price 32*s*. net.]

Strength of Materials. By JOHN B. THIRLWELL. Macdonald and Company (Publishers), Limited, 16, Maddox-street, London, W.1. [Price 20*s*. net.]

Selection, Training, and Use of Personnel in Industrial Research. Proceedings of the Second Annual Conference on Industrial Research. June, 1951. Edited by DAVID B. HERTZ. King's Crown Press, 1145, Amsterdam-avenue, New York 27, U.S.A. [Price 4.50 dols.]; and King's Crown Press (Geoffrey Cumberlege), Amen House, Warwick-square, London, E.C.4. [Price 30*s*. net.]

The Story of Muskets. By FRED M. OSBORN. Thomas Nelson and Sons, Limited, 3, Henrietta-street, London, W.C.2. [Price 21*s*. net.]

The Rhymney Railway. By D. S. BARRIE. The Oakwood Press, Tanglewood, South Godstone, Surrey. [Price 6*s*. 6*d*. net.]

TRADE PUBLICATIONS.

Electric Vulcaniser for Cable Repairs.—A leaflet received from British Insulated Callender's Cables, Ltd., Norfolk-street, London, W.C.2 gives particulars of the electric vulcaniser which they have developed for the repair of cables. Heat and pressure for the repair are provided by copper tape wrapped around the repair, current being passed through the tape.

Heat Treatment of Tool Steels.—A pamphlet giving a brief summary of the firm's new South Midland heat-treatment department and the service provided for the heat-treatment of tool steels has been issued by Richd. W. Carr & Co., Ltd., Pluto Works, Wadsley Bridge, Sheffield, 6. The new department is at Bolton-street, Bordesley, Birmingham, 9.

Aluminium-Bronze Die Castings.—Fry's Diecastings Ltd., Midland Works, Brierley Hill-road, Wordsley, near Stourbridge, have sent us a copy of their pamphlet "Machining Aluminium Bronze Die Castings." This contains a description of the properties of aluminium bronze and notes on the turning and boring, drilling, reaming, tapping, milling and sawing of this alloy.

Rolling-Mill Installations.—A well-produced catalogue containing numerous reproductions of photographs of rolling-mill plants for aluminium and light alloys, copper and brass, and steel, installed by W. H. A. Robertson & Co., Ltd., Lynton Works, Bedford, at home and overseas, has been issued by this firm. The captions and descriptions are given in French and English.

Industrial Switchgear.—Full details of hand-operated air-break circuit-breakers of 200-amperes capacity, suitable for alternating-current at pressures up to 650 volts, as well as for direct-current, are contained in an illustrated leaflet No. K.110, recently published by the Belmos Co., Ltd., Bellshill, Lanarkshire. Leaflet No. K.120 describes direct-on contactor starters of which two models are available for 75 and 150 amperes, respectively, and for the same voltage range as that quoted above.

Marine Developments in Aluminium.—A reprint of a paper on "Marine Developments in Aluminium," read before the Institution of Engineers and Shipbuilders in Scotland in October, 1951, by Mr. J. Venus, of the Aluminium Development Association, has been sent to us by the Association, 33, Grosvenor-street, London, W.1. The use of aluminium for launches, deck-houses, trawler fish holds, and other purposes is described. Allusion is also made to the many applications of the metal and its alloys on the new American liner United States. The discussion on the paper is included.