

HYDRAULIC LOCK: ANOTHER EXPLANATION.

By J. E. C. STRINGER.

IN ENGINEERING of October 26 and November 9, 1951, Dr. D. C. Sweeney gave an account of his researches into hydraulic lock due to oil pressure forcing a piston against the side wall of the bore containing it. Dr. Sweeney's explanation of this nuisance was opportune, because hydraulic mechanisms are being used more than ever.

Quite independently, however, during the past two years, hydraulic lock has been studied in the Research Department of Vickers-Armstrongs Limited, Elswick, from a different approach, and sufficient work has been done to prove that an alternative and probably frequent cause of hydraulic lock is dirt in the oil used. This causes much more

Magnetism of the piston or body of the valve had no effect on the jamming.

Locking of piston-type control valves has been observed or described by many engineers, including those named in Dr. Sweeney's article, Ernst,* Richolt† (who also mentions that blocking of a filtering screen could take place at low temperatures, if a hydraulic oil contained more than 5 per cent. of water), and Conway.‡ It appeared at the outset that lock could be of at least two kinds, namely, that due to bending of the valve parts under pressure causing misalignment and mechanical jamming (a rotary control valve tested some three years ago by the author exhibited this kind of lock, which was removed by providing additional clearance); and that due to a piston valve moving over towards one side of its bore and being held there by the resulting pressure unbalance. The control valve described in this article had its piston centrally

tests. Oil OM.35 (Oil, Mineral, 35 Centistokes at 100 deg. F.: a light mineral oil as used in hydraulic servo-mechanisms) was drawn from a small header tank by a V.S.G. Mark XII aero-pump and delivered at any desired pressure up to 950 lb. per square inch to the control valve.

SEQUENCE OF EXPERIMENTS.

(1) Initial tests were made with 0.0005 in. radial clearance and 0.003 in. lap and an oil pressure of 950 lb. per square inch, the lap being set by pushing the piston along (with oil supply "on") by a micrometer screw until the oil flow suddenly decreased, and then giving 0.003 in. further movement of the piston.

(2) A fine brass wire-gauze filter of about 60 mesh was then fitted upstream of the control valve. Using reclaimed OM.35 oil, five runs were made; in each instance, the piston valve jammed in 2 to 3 minutes and all flow ceased in 5 to 6 minutes. On dismantling after each run, just a few isolated pieces of dirt could be seen near the control edges of the port in the valve body.

(3) Next, five layers of fine silk bolting cloth were added after the existing wire-gauze filter. Similar results were obtained, although, upon dismantling, no dirt at all could be seen in some cases.

(4) As the oil was reclaimed stock, and also because the header tank had been run without a cover, it was thought that the oil might have been excessively dirty or might have picked up contaminating particles from the workshop atmosphere. The tank was therefore drained and cleaned and refilled with new OM.35, a tank cover being fitted at the same time. No other change was made. Twelve runs were made, and in each case the valve jammed and the flow stopped in less than 1 minute. On dismantling the valve, no dirt was seen.

(5) Because it had been suggested that, under pressure, a water-in-oil emulsion might form crystalloid bodies of a size sufficient to jam in a fine clearance, the OM.35 was taken from the header tank, emulsified with 0.05 per cent. of water and returned to the header tank. The valve stuck and flow ceased as in the previous experiment, and in about the same time.

(6) The five layers of bolting cloth were then removed from the filter body and replaced by a single dense white felt disc, $\frac{3}{8}$ in. thick, having an active filtering area of about 1 sq. in. After ten consecutive runs of 12 minutes, the valve was still free and the oil flow continued. As no cooling was used, 12 minutes was the longest time that the rig could be run without overheating; the tests were shut down at 160 deg. F. tank oil temperature.

(7) The valve behaved very much as though the clearance had become silted with dirt, but up till now no silt had been found. It was suggested that, if there were any silt, it was washed away by the residual oil at the moment of splitting the valve body. Accordingly, a further run was made with the felt disc removed and the five layers of bolting cloth replaced in the filter body. The valve stuck and the oil flow almost ceased in 3 minutes. (On this occasion the lap was set larger, 0.01 in., and the rig was allowed to run a further 7 minutes, as it was desired only to prove the method). The assembly was degreased with trichlorethylene vapour before dismantling the valve body, and very appreciable amounts of dirt were at once discovered on the valve body and piston valve; see Figs. 3 and 4, page 510, which are one and a half times full size, also Figs. 5 and 6, which are 14 times full size. A repeat run was made with the lap reduced to 0.007 in. and a third run at 0.003 in. lap. In each case the valve stuck, the flow stopped and dirt was found.

(8) A drop of oil was applied to the silt residue

Fig. 1.

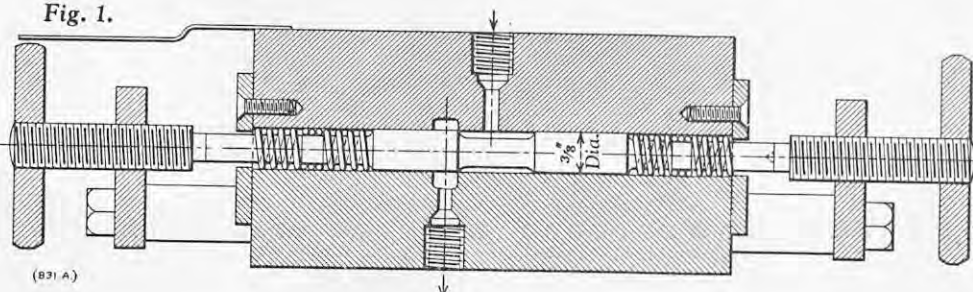
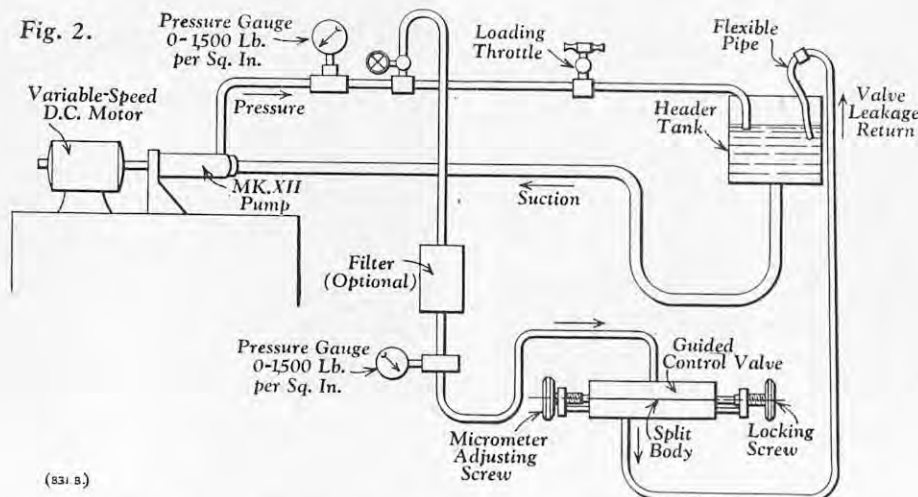


Fig. 2.



severe locking, the forces being about ten times as great as those reported by Dr. Sweeney. It appears that hydraulic fluid that is "clean" by accepted standards contains sufficient very fine particles of dirt to jam a control valve in a few minutes. The valve acts as a filter, and the leakage past the valve ceases as the valve locks.

The present article describes a series of experiments made with a felt filter of high filtering efficiency, using which no lock could be observed. The piston valve in the present experiments was ball-guided centrally in its body, with a clearance all round its periphery, so that eccentric locking of the type described by Dr. Sweeney could not occur. Lock was only observed when the felt filter was removed from the supply line. No oil tested was sufficiently clean to prevent locking; centrifuging the oil did not clean it sufficiently, nor did filtration through the finest Swiss-type silk bolting-cloth obtainable, which was grade S.21. Filtration through one layer of filter paper was only partly effective in preventing lock, and three layers of paper did not completely eliminate some degree of locking after an hour's run. A degreasing technique has been developed which gently removes the oil from the valve block and piston after the latter has locked, thus leaving the trapped dirt in the clearance for observation. (The valve block can be split down its centre-line for this purpose.)

guided in its bore to prevent jamming of this type. However, valves which did not bend and were guided centrally also locked. Dirt in the oil was a likely cause, but was not always found.

DESCRIPTION OF APPARATUS.

To examine what other causes of hydraulic lock might be, the demountable guided control valve shown in Fig. 1, herewith, was made. The principal feature is that the valve body is made in two pieces (the jointing faces being ground and lapped accurately flat before machining the bore) so that it may be split along the centre-line of the bore. Four taper dowel-pins, which are a drive fit in the upper half and a push fit in the lower half, provide an accurate register. The stems of the piston valve, each passing through a "nest" of 30 to 40 bearing balls, held in position with light springs, keep the piston valve accurately concentric in the bore. Fig. 2, herewith, shows the pipe circuit used in the

* Proc. National Conference on Industrial Hydraulics, by W. Ernst; note on "Commercial and Industrial Applications of Hydraulic Servo-mechanisms," vol. II, page 137 (Oct., 1948).

† Proc. of National Conference on Industrial Hydraulics; note by Robert Richolt on "Development of Constellation Hydraulic Systems," vol. III, page 193 (March, 1950).

‡ Fluid Pressure Mechanisms, by H. G. Conway; Sir Isaac Pitman and Sons, London, pages 57-58 (1949).

of experiment (7) and the silt immediately vanished.

(9) The largest particles trapped at the valve land were approximately $1 \text{ to } 1.5 \times 10^{-3}$ in. across.

(10) A triple filter was then tried: first, wire gauze; second, one layer of bolting cloth; and third, one layer of felt, $\frac{3}{8}$ in. thick. The pump speed was reduced from 1,100 r.p.m. in previous experiments to 600 r.p.m., which gave much less heating of the pump and therefore permitted longer runs to be made. No lock and no choking of the oil flow were observed in 20 minutes. On the left-hand side of Fig. 7, opposite, at a magnification of 1.5, larger pieces of dirt can be seen, caught on the wire gauze; and on the right-hand side, at the same magnification, are smaller dirt particles caught by the bolting cloth. Fig. 8, at 50-times magnification, shows a cross-section cut with a razor blade from the felt. Numerous fine particles of dirt are to be seen in the first 0.005 in. of the depth of the felt. Fig. 9, is a view, at 14-times magnification, of the dirt on the bolting cloth.

(11) When tested with a small pocket compass, the valve body and piston were found to be slightly magnetic. They were then de-magnetised, and using wire-gauze and bolting-cloth filters only, repeat runs were made; but lock and choking occurred as before.

(12) In conclusion, the rig was cleaned as follows: all steel pipes were scoured inside, the header tank was shot-blasted inside and enamelled with white cellulose, the copper pipes were degreased and cleaned in hot dilute nitric acid, and the pump was washed out with paraffin. This ensured that, as far as possible, no trace of dirt remained in the rig. Runs were then made, using the same filters as in experiment (3). Using new, and nominally clean, OM.35 oil, the valve jammed in a minute or two.

HYDRAULIC LOCK DUE TO DIRT.

The general behaviour of this valve follows the pattern of earlier cases of "hydraulic lock" or "stiction." Silting has been suggested many times as an explanation, but hitherto no silt has been observed. The degreasing technique showed that silt was there, and the way it vanished in a drop of oil provides sufficient explanation why it has not previously been seen. Silt also provides an adequate explanation of the fine scratches which are commonly observed on valve lands; and of the observation that valves stick more quickly when hot, and more slowly when the clearance is reduced. In these cases, the rate of silting depends on the rate of leakage of dirty oil.

It is well known that "dither" will prevent "stiction" indefinitely, and that relatively large particles then find their way past the valve. It is not known how large a particle can work its way through a fine clearance, but it is to be supposed that only a few are present at any instant while the valve is dithering, so that the drag on the valve will not be large. It is suggested that, when the valve silts, each particle, driven in by the oil pressure, acts like a minute wedge. Further work might profitably be done to find what size of particles may pass a given clearance with and without dither. This would be of assistance in designing filters.

ADDITIONAL TESTS AT ELSWICK.

The above tests formed the subject of a privately circulated report, issued in April, 1951. Following the publication of his article in *ENGINEERING*, we met Dr. Sweeney to compare notes. On all points, the views of the two parties were substantially similar; the two researches, having fundamentally different starting points, were complementary to each other. Following this conversation, it was decided to put in hand some further tests at Elswick to see if eccentric locking, as described by Dr. Sweeney, could be demonstrated with the Vickers-Armstrongs test rig.

EXPERIMENTS ON HYDRAULIC LOCK.

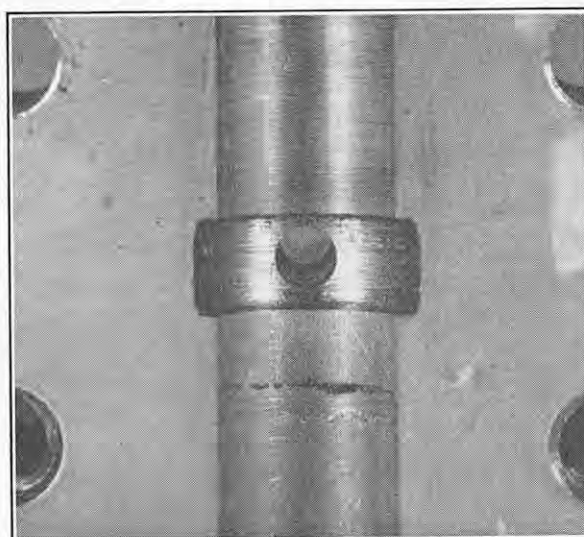


FIG. 3. DIRT ON LAND OF VALVE BODY. $\times 1.5$.

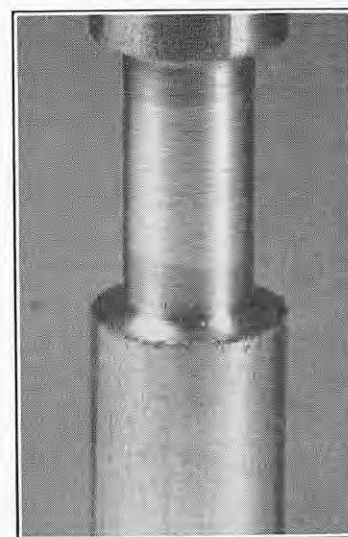


FIG. 4. DIRT ON EDGE OF PISTON VALVE. $\times 1.5$.

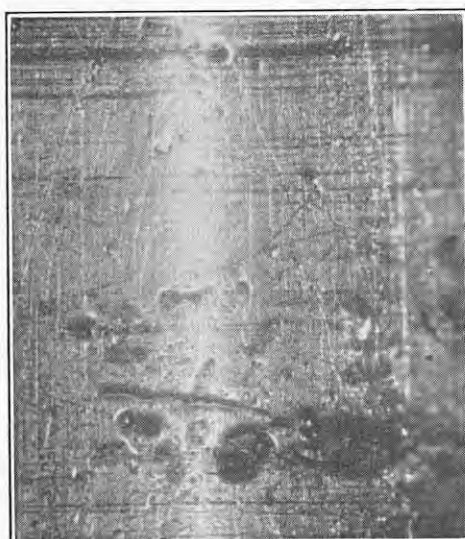


FIG. 5. PART OF DIRT SHOWN IN FIG. 3. $\times 14$.



FIG. 6. PART OF DIRT SHOWN IN FIG. 4. $\times 14$.

(13) A run was made with the felt filter in circuit and the guiding balls, etc., removed from the piston valve stems. The lap was set to 0.01 in. The axial force required to move the piston valve with zero oil pressure was about a quarter of an ounce. When pressure was applied, eccentric locking took place, varying in a regular manner with increase in pressure; i.e., at 100 lb. per square inch, the locking force was $\frac{1}{2}$ oz. and at 900 lb. per square inch, 8 oz.

(14) It has been suggested that the provision of a number of circumferential grooves in the lands of a piston should decrease the hydraulic lock. A run was made using a new piston valve (also unguided) of the same diameter, within 0.0001 in., but provided with grooves $\frac{1}{8}$ in. wide, pitched at $\frac{1}{16}$ -in. centres. Using the felt filter and 0.01-in. lap, eccentric locking again took place, varying from $1\frac{1}{2}$ oz. at 100 lb. per square inch to $3\frac{3}{4}$ oz. at 900 lb. per square inch. It should be noted that, compared with (13), the eccentric locking force was halved at the high pressure and almost doubled at the low pressure.

(15) Test (14) was repeated, keeping all the experimental conditions exactly the same. The eccentric locking force fell to between $\frac{1}{4}$ and $\frac{1}{2}$ oz. for the whole range of pressures, 100 to 900 lb. per square inch. We have no certain explanation of this, but it could indicate that, with continued running, the felt filter had cleaned the oil to the

point where the residual dirt particles were so small that either no particle was large enough to tilt the valve to initiate eccentric locking, or that the eccentric locking force was a function of the friction caused by dirt particles tying the surfaces of the valve and body together; it might even be something to do with the grooves.

(16) A test was made with the grooved piston in the guided condition, but with no filter in the circuit and a fresh charge of oil. The lap was 0.01 in. Silting and locking occurred, the locking force being 2 lb. at 200 lb. per square inch and 3 lb. at 900 lb. per square inch.

(17) A comparative test was made with the plain piston, guided, with 0.01-in. lap and no filter; it choked and silted. The locking force varied from $1\frac{1}{2}$ lb. at 200 lb. per square inch to 6 lb. at 900 lb. per square inch. Here again, grooving the piston halved the lock at the high pressure and about doubled the lock at low pressure; this anomaly is to be investigated further.

(18) Next, the plain piston, unguided, with 0.01-in. lap, was run with no filter. Choking and severe lock occurred, the force ranging from 4 oz. at 200 lb. per square inch to 6 lb. at 900 lb. per square inch.

(19) The grooved piston was then similarly tested. Choking and locking occurred, the force ranging from 12 oz. at 200 lb. per square inch to 4 lb. at 900 lb. per square inch.

EXPERIMENTS ON HYDRAULIC LOCK.

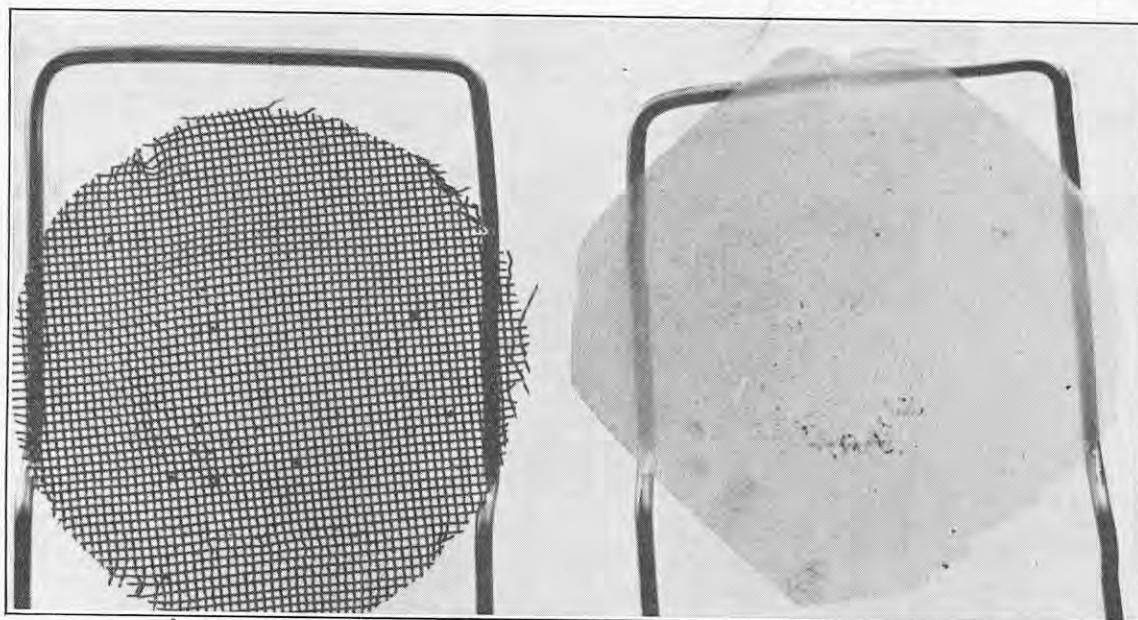


FIG. 7. LARGE DIRT PARTICLES CAUGHT ON 36 WIRE MESH, and FINER PARTICLES CAUGHT ON FINE SILK BOLTING CLOTH. $\times 1.5$.

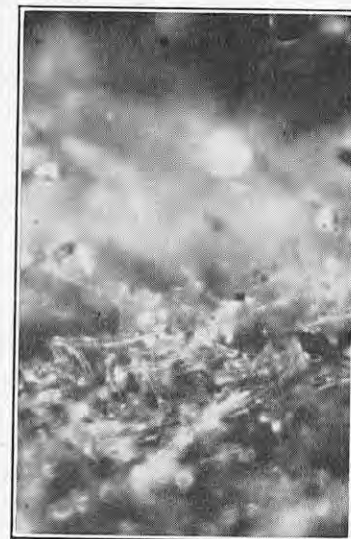


FIG. 8. VERY FINE PARTICLES IN FELT FILTER. $\times 50$.

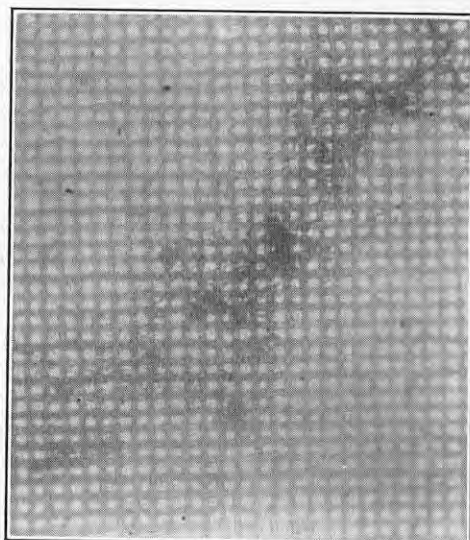


FIG. 9. FINE DIRT PARTICLES IN FINE SILK BOLTING CLOTH. $\times 14$.

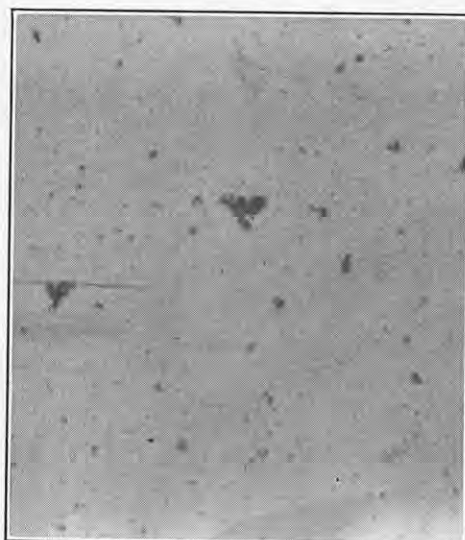


FIG. 10. AIR-BORNE GRIT, ETC., COLLECTED ON OILED GLASS SLIDE. $\times 50$.

(20) The plain piston was tested in the guided condition, with the felt filter. No choking occurred, and at all pressures the locking force was less than $\frac{1}{2}$ oz.

(21) The grooved piston was similarly tested. The results were identical with (20), confirming test (15).

(22) The plain piston, unguided, had already been tested with oil filtered through three layers of filter paper. Choking occurred in 45 minutes, and the locking force was 13 oz.

(23) The statement has also been made, in Dr. Sweeney's article, that "oiliness agents" added to an oil should decrease hydraulic lock. Two tests were made, using OM.35, to which had been added 5 per cent. of rape oil. In the first case, in which the plain piston was centrally guided and no filter was used (in one case, 0.01 in. lap), there was a striking decrease in the force required, from about 5 lb. to about 1 lb.; in another, with 0.1 in. lap, there was little or no decrease. No explanation has been found for this, and it is being further investigated.

DISCUSSION OF ADDITIONAL TESTS.

The additional tests have shown that eccentric locking can be demonstrated with the Vickers-

Armstrongs test rig. In both the guided and unguided condition, grooving the lands of the piston valve halved the locking force at high oil pressure, but doubled the low pressure value for both filtered and unfiltered oil. For the unfiltered oil, the maximum locking force was of the order of 3 lb. to 6 lb., but for the filtered oil it was only as many ounces. (Compare the locking force of 175 lb. on a 2-in. diameter piston valve at 1,000 lb. per square inch, which has been observed in another application.)

Two sorts of lock have been established. The greater, due to dirt, can be avoided by sufficiently filtering the fluid; the lesser, due to eccentricity, by guiding the valve. Both are known to be overcome by dither. It would also appear that the evidence obtained up to this stage in the research points to an extension of the above statement, namely, that when the oil is freed from dirt as completely as possible, even eccentric locking disappears.

It should be added that the nature of air-borne dirt in the shop was investigated by exposing horizontally an oiled glass slide for one day. Fig. 10, which is magnified 50 times, shows the kind of dirt caught. The size distribution appears to be much the same as in Fig. 9; in addition, there is an

exact colour match between many of the particles in the two figures, certain specks being a bright ruby red and others a distinctive orange. It would appear that this is evidence that some of the dirt causing lock was originally air-borne particles which settled in the header tank.

In the text, reference has been made to "reclaimed" oil. The reclaiming consisted in passing the oil through a Vickers centrifugal separator.

Acknowledgment is made to the manager of the Elswick Research Department of Vickers-Armstrongs Limited, Lt.-Cdr. J. R. D. Walker, R.N.V.R., who directed the work; and to the Admiralty, who financed the major part of the project, for permission to make this communication. Mr. A. W. Smith, of the Research Department, carried out the many tests involved.

LITERATURE.

Locomotives and Their Working, with a Section on Gas Turbine, Diesel and Electric Locomotives.

By C. R. H. SIMPSON, A.I.Loco.E., and F. BROWNE ROBERTS, M.B.E., A.M.I.Mech.E. Two vols. Virtue and Company, Limited, 24, Holborn, London, E.C.1. [Price 70s.]

THIS book, the authors state, is intended principally for enginemen, and a large proportion of it is so directed; but it will have a much wider appeal than that. It is a work which explains in full detail the why and wherefore of practically everything connected with the design and operation of railway locomotives, accomplishing this aim with a minimum of technical jargon; it is, in fact, a completely detailed guide to the locomotive engine. Formulae, in general, are avoided; but the proportions and interrelation of all the parts are given and the reasons adequately set out; even ratios, those primary governing factors in locomotive design, are introduced in such a way that the non-technical reader may not realise that he has absorbed them, though the book should still be found of interest by those who are well versed in the technicalities. There are some 250 excellent drawings, and many half-tone reproductions. The sectional perspective diagrams are especially clear and informative.

The division of the work groups related parts of the locomotive structure together, but also differentiates those chapters specially applicable to enginemen from those of more general interest; a convenient arrangement, though it leads inevitably to occasional duplication of explanations. With particular reference to their informative value, to enginemen and others concerned with operation, the chapters on "Distribution and Action of Steam in the Cylinders" and on "Valve Gears" are out-

standing; and the chapter on "Brakes" contains much information of modern developments which are of considerable interest, not only to enginemen. The interactions of the moving parts of locomotives are well set out and the various alternative means of accomplishing the desired results are adequately explained and illustrated. A good feature is that the authors give the current "trade names" of almost every part of a locomotive. There seems to be an error, however, in the description of the swing-link trucks shown in Figs. 36 and 37, on page 306; the suspensions there titled "single-pin" and "two-pin" are more generally described as "two-point" and "three-point," respectively. As an example of the full and up-to-date treatment given to all constructional features may be mentioned the illustrations of methods of fixing tubes in tubeplates, no fewer than ten methods—practically all those available—being shown; and another instance is the details given of steam-operated doors to a hopper-type ashpan.

There are a few minor points that invite criticism. One is the absence of any illustration of the once common four-bar arrangement of slide-bars and crosshead; and another is that, in the extensive description of fireboxes, most of the examples illustrated have the roofs flat and horizontal, poor features of long standing, but now seldom perpetrated. Further, the effects of the horizontal roof and the inclined roof, respectively, in their influence on the relation between the water-level as shown in the gauge-glass and the possibility of the roof becoming bare of water when the locomotive passes over the summit of an incline and commences to run down hill might be more explicitly stated for the guidance of enginemen. The book includes descriptions of the latest British and Colonial steam locomotives, an informative chapter on gas-turbine, Diesel, electric and fireless locomotives, and one dealing with the recently introduced standard types of British Railways.

THE INSTITUTE OF METALS.

(Continued from page 485.)

RESUMING our report of the annual general meeting of the Institute of Metals, held in London from Monday to Thursday, March 24 to 27, we have now to deal with programme "B" of Wednesday morning, March 26, namely, the scientific session held concurrently with programme "A," already reported in our columns, during which a symposium of seven papers on "Equipment for the Thermal Treatment of Non-Ferrous Metals and Alloys" was presented and discussed. The chairman for programme "B" was Professor F. C. Thompson.

HARDNESS AND STRENGTH OF METALS.

The first paper considered was upon the subject of "The Hardness and Strength of Metals," and was by Dr. T. Tabor, of the Department of Physical Chemistry of the University of Cambridge. He stated that his results had shown that indentation hardness measurements were essentially a measure of the elastic limit (or yield stress) of the metal under examination. For metals which did not work-harden appreciably, the hardness value for both the Brinell ball and the Vickers pyramidal indenter was approximately three times the yield stress. For metals which work-hardened appreciably, the indentation process itself produced an increase in the yield stress of the metal. With conical or pyramidal indenters the indentation was geometrically similar whatever its size, so that the work-hardening produced by the indentation was always geometrically the same. Consequently, the hardness value did not depend on the size of the indentation and was, therefore, independent of the load. For this reason the Vickers pyramid indenter gave a single value for the hardness of a metal. With spherical indenters, on the other hand, the shape of the indentation depended on the ratio $\frac{d}{D}$, where d was the chordal diameter of the indentation and D was the diameter of the ball. The larger the value of $\frac{d}{D}$, the greater the amount of work-hardening produced by the indentation and the

greater the resulting hardness value. For this reason, the Brinell hardness values depended on D , d and the load W .

CONSTITUTION AND PROPERTIES OF TITANIUM ALLOYS.

The next nine papers, all of which related to the constitution, properties and characteristics of titanium and titanium alloys, were presented jointly.

"Some Observations on the α - β Transformation in Titanium," by Dr. A. D. McQuillan, formerly of the Commonwealth Scientific and Industrial Research Organisation, Baillieu Laboratory, University of Melbourne, Australia, and now Senior Research Fellow, Department of Metallurgy, University of Birmingham, was the first paper of the series. The author stated that the α - β transformation had been studied on titanium prepared both by the van Arkel iodide process and by magnesium reduction. A new method, involving observations on the changes of hydrogen equilibrium pressure with temperature in very dilute solutions of hydrogen in the metal, had been used. It had been found that whereas the transformation in the van Arkel material occurred sharply at a single temperature, that in the magnesium-reduced material took place gradually over a temperature range of some 100 deg. C. This was due to the effects of impurities present in the titanium.

The second paper, also by Dr. A. D. McQuillan, was entitled "The Application of Hydrogen Equilibrium-Pressure Measurements to the Investigation of Titanium-Alloy Systems." The author described the method used in the investigation detailed in the previous paper, namely, that depending on the measurement of hydrogen pressures in equilibrium with a very dilute solution of hydrogen in the alloys. He stated that the method had been applied to a series of alloys in a limited region of the titanium-copper and titanium-iron systems. It was found that both copper and iron depressed the $\alpha \rightleftharpoons \beta$ transformation in titanium.

The third paper, on "The Constitution of Titanium-Rich Alloys of Iron and Titanium," was by Mr. H. W. Worner, who is in the Baillieu Laboratory, at Melbourne. In his paper, Mr. Worner stated that metallographic and X-ray methods had been employed to establish the general outline of the constitutional diagram. From the melting point of titanium, the liquidus and solidus fell steeply to an eutectic horizontal at 1,060 deg. C., the eutectic composition being at 29 atomic per cent. iron. This eutectic consisted of an intermetallic phase (FeTi) and a solid solution of iron in the high-temperature (β) form of titanium.

The fourth paper, entitled "The Titanium-Hydrogen System for Magnesium-Reduced Titanium," was again by Dr. A. D. McQuillan. He stated that, as an extension of recent work in which he had shown that the allotropic $\alpha \rightleftharpoons \beta$ transformation in titanium metal was much affected by the impurities present in material produced by the magnesium reduction of titanium chloride, the constitutional diagram of the titanium-hydrogen system had been studied using magnesium-reduced titanium. The results had been compared with those obtained for the same system when van Arkel titanium was employed. It had been found that the system, magnesium-reduced titanium and hydrogen, could not be treated as a simple binary system, but must be considered as a section through a multi-component system. The results obtained in the study of systems of magnesium-reduced titanium with other metals were likely to be affected in the same manner.

"A Provisional Constitutional Diagram of the Chromium-Titanium System" was the title of the fifth paper. It was by Mrs. M. K. McQuillan, who stated that she had studied the chromium-titanium system by quenching methods over the whole range of compositions. The general nature of the system had been established. At temperatures between 1,360 deg. and 1,400 deg. C., the elements appeared to be completely soluble in one another, but, on quenching, the solution broke up to form a compound, Cr_3Ti_2 , and a body-centred-cubic solid solution based on either the chromium or the β -titanium lattice. The β -titanium solution underwent a eutectoid transformation at low temperatures to form Cr_3Ti_2 and α -titanium.

The sixth paper in the series on titanium and its alloys was a contribution by Mr. N. Karlsson, of the University of Uppsala, Sweden, entitled "An X-Ray Study of the Phases in the Copper-Titanium System." The author stated that the general outline of the phase diagram of the copper-titanium system had been drawn from powder photographs. Four intermediate phases having the following approximate titanium atomic percentages had been found: β and β' , 21 to 25; γ , 50 to 53; δ , 45 to 50; and ϵ , 71 to 75. The structure of each phase had been determined. The β phase had an orthorhombic structure with the ideal composition Cu_2Ti . Both the γ and the δ phases had the ideal formula CuTi and had tetragonal symmetry and the ϵ phase, with the ideal composition CuTi_3 , also had tetragonal symmetry.

"The Structure and Some Properties of Titanium-Oxygen Alloys Containing 0-5 Atomic Per Cent. Oxygen" was the title of the seventh paper; it was by Mr. A. E. Jenkins and Mr. H. W. Worner, of the Baillieu Laboratory, University of Melbourne, Australia. The authors stated that it had been found that the impurities present in the commercial grade of titanium caused a marked broadening of the $\alpha \rightleftharpoons \beta$ transformation range. Work on the mechanical working and annealing of commercially-used alloys had indicated that it was possible to develop techniques for forging and swaging alloys containing as much as 3.5 atomic per cent. oxygen. Alloys containing more than 1.5 atomic per cent. oxygen could be hot-worked but were more or less brittle at normal temperatures. The room-temperature properties of alloys containing up to 1.5 atomic per cent. of oxygen were such as to suggest that these alloys might be of value in certain engineering applications. A particular feature of the alloys was that they possessed a comparatively high proof stress.

The eighth paper in the series, dealing with "Heat Treatment of Titanium-Rich Titanium-Iron Alloys," was by Mr. H. W. Worner. In it, he explained that he had made an exploratory investigation of the heat-treatment of titanium alloys containing from 2 to 9.5 weight per cent. of iron. It had been found that alloys containing from 2 to 6 per cent. of iron could be hardened appreciably by water-quenching than from the β -titanium-iron solid-solution region (at about 950 deg. C.). Some of the alloys which could be retained as β -solid solutions by water-quenching exhibited age-hardening effects when heated for a few hours in the range 220 to 450 deg. C. A problem encountered in the heat-treatment of all the alloys was the tendency for undesirably rapid grain growth to occur during heating in the β region. Moreover, it did not prove possible to refine the grain-size by heat-treatment alone. The most effective methods for grain refinement were hot working in the range 650 deg. to 800 deg. C., or cold working, both followed by a short anneal.

The ninth, and last, paper in the series on titanium and its alloys dealt with "The Effect of the Elements of the First Long Period in the $\alpha \rightleftharpoons \beta$ Transformation in Titanium." The author, Dr. A. D. McQuillan, stated that a systematic investigation of the effects of vanadium, chromium, manganese, nickel and cobalt on the $\alpha \rightleftharpoons \beta$ transformation in titanium had been made. The maximum quantity of each addition element used had been approximately 5 atomic per cent. It had been found that all these elements depressed the allotropic transformation, and that, with the exception of vanadium, they were not appreciably soluble in the low-temperature (α) form of titanium.

After consideration of the papers on titanium, the chairman adjourned the meeting for luncheon.

ALUMINIUM-MAGNESIUM ALLOYS.

The first three papers taken in the afternoon session of Programme "B," on March 26, were considered together as they were all concerned with Aluminium-Magnesium Alloys. The first was a communication from the British Non-Ferrous Metals Research Association, London, by Mr. E. C. W. Perryman and Mr. G. B. Brook on the "Mechanism of Precipitation in Aluminium-Magnesium Alloys." The authors stated that they had investigated the precipitation mechanism in commercial-purity aluminium—7 per cent. magnesium and high-purity

aluminium — 10 per cent. magnesium alloys by metallographic methods, and by hardness and X-ray measurements. The effect of 0.5 and 1 per cent. zinc on the rate of precipitation and hardening of the former alloy had also been studied. Precipitation took place first in the grain boundaries and then within the grains and, not until the latter process occurred, did hardening begin. The magnitude of the hardening was small, though it was increased both in rate and extent by the zinc additions. High degrees of supersaturation favoured the formation of a Widmanstätten structure. X-ray examination had shown that the precipitation in the aluminium — 7 per cent. magnesium alloy was of the continuous type at 200 deg. and 250 deg. C. At 125 deg. C. continuous and discontinuous precipitation took place together; continuous precipitation within the precipitated new solid solution then followed. The latter mode of precipitation had also been found in the aluminium — 10 per cent. magnesium alloy at temperatures up to and including 300 deg. C.

The second paper, which was entitled "Experiments on the Reaction of Aluminium-Magnesium Alloys with Steam," was also a communication from the British Non-Ferrous Metals Research Association. The author, Mr. A. J. Swain, stated that the reaction of aluminium-magnesium alloys, containing up to 25 per cent. of magnesium, with pure steam had been investigated over a range of temperatures from 450 deg. to 700 deg. C. A maximum reactivity, dependent on the composition, had been found at temperatures between 550 deg. and 625 deg. C. For the 10 per cent. magnesium alloy, which was widely used as a casting alloy, this maximum reaction rate occurred at a temperature within the solidus/liquidus range. This probably accounted for the fact that gas porosity caused by metal-mould reaction in sand castings of this alloy occurred mainly in the surface layers of the castings. No satisfactory explanation of these effects could be advanced at present.

The third paper, by Dr. C. Edeleanu, concerned work carried out in the Metallurgy Department in the University of Cambridge on "A Mechanism of Stress-Corrosion in Aluminium-Magnesium Alloys." The author stated that the attack on aluminium and aluminium-rich alloys, immersed in neutral chloride solutions, tended to become restricted to a limited area where the protective film of oxide which normally covered the metal became thinnest or weakest. In other words, the anodic reaction on aluminium was autocatalytic. This explained why corrosion, having started at one point, continued there in preference to any other points. On homogeneous alloys, corrosion caused scattered pits which could increase either in depth or in area; but in the case of alloys possessing a path of easy corrosion, the attack took the form of trenching and was confined to the tips of the cracks so formed. This latter type of corrosion led to great mechanical weakening, even though the actual rate of attack, per unit area, might not be very different in the two instances. From experiments carried out on aluminium—7 per cent. magnesium alloy, it was concluded that stress exerted no influence during the first stages of the process (the greater part of the life), but that corrosion played a vital role during the final rapid cracking.

AGEING OF ALUMINIUM-COPPER ALLOYS.

The last paper considered in Programme "B" on the afternoon of Wednesday, March 26, was by Dr. H. K. Hardy, of the Fulmer Research Institute and dealt with "The Ageing Characteristics of Binary Aluminium-Copper Alloys." The author stated that he had obtained hardness/ageing-time curves on aluminium alloys containing from 2 per cent. to 4.5 per cent. of copper at temperatures between 30 deg. and 240 deg. C. Ageing at 30 deg. C. had given an increase in hardness to a constant value. Ageing at 130 deg. C. caused an initial rise in hardness, which then remained at a constant value for a short time in alloys containing from 3.5 per cent. to 4.5 per cent. of copper. This was followed by a second rise to peak hardness. The time to attain this peak hardness was independent of composition in the range 3 per cent. to 4.5 per cent. of copper.

(To be continued.)

THE INSTITUTION OF NAVAL ARCHITECTS.

(Continued from page 488.)

WE continue below our report of the Spring Meeting of the Institution of Naval Architects, held in London on April 2 to 4. The proceedings at the opening session, on April 2, were dealt with last week. The session on the morning of April 3, when the chair was taken by Dr. S. F. Dorey, F.R.S., opened with Sir Wilfrid Ayre's paper on "Merchant Ship Design—A Thought for the Future."

MERCHANT SHIP DESIGN.

Sir Wilfrid Ayre's paper dealt mainly with the design of cargo vessels, and the directions in which it might be expected to develop. He introduced the subject with a "family tree" diagram in which were set out the main factors likely to affect that development and then proceeded to evaluate their respective influences. He did not think that design was likely to be affected greatly by any mere desire for change, but rather by economic changes such as the incidence of Government bulk buying, currency restrictions, national and international planning, etc., which might influence the types of cargoes to be carried, and the routes adopted. The resultant changes in design, however, must still be viewed in relation to capital expenditure and freight-earning capacity. The virtual disappearance of coal as a British export had reduced by many millions of tons per annum the volume of bulk cargoes, so that general-cargo ships were superseding the purely tramp class; but other types of bulk cargo—ores, bulk sugar, bauxite, edible oils, etc.—were stimulating the demand for "quasi single-purpose ships." Passenger travel in cargo ships—limited at present to 12 persons per ship—might well compete more seriously with the regular passenger liner services in future. Sea speeds would probably tend to increase, and might rise to 20 knots and more for the cargo-liner type. Air travel would probably gain in popularity, but it was clear, he considered, that there was still abundant space for both sea travel and air transport. For many years, it might be difficult to envisage the complete elimination of shipboard loading and discharging equipment, but he thought that it would come eventually in the case of vessels carrying general or package-type merchandise. The future of all of the many types of propelling machinery would be influenced by the trend of sea speed and by the ultimate ceiling of carrying capacities of merchant ships. The limit of horse-power per shaft was being extended, and might result in a revival of interest in the double-acting Diesel engine; but the possibilities of the gas turbine (and, more remotely, of atomic energy) might change the whole outlook for Diesel and steam-turbine propulsion. If the gas turbine was to be the next stage in propulsion, the controllable-pitch propeller might be more generally favoured than at present. It seemed inevitable that the placing of machinery aft would become more general, though, in large cargo vessels, the question of loaded trim would become important. If the use of light alloys were to extend, changes in shipyard practice and equipment might be necessary. Welding was firmly established, and its future would be seen in a logical development towards the goal of the all-welded ship. Shipyards on the Continent, and in the United States and Canada, were organised almost completely for welded construction, and, in the author's opinion, the adoption of welding must, in time, become equally general in British shipyards. Funnels might well disappear, masts or derrick posts being used instead to discharge exhaust fumes. Shapes of bows and stems might develop towards securing the greatest water-line length within the limits of overall ship dimensions. Because of the tendency to increase the height of the weather deck above the assigned load line, in order to obtain additional cubic capacity, sheer of profile might be reduced, or, preferably, eliminated altogether.

DISCUSSION.

Mr. J. Lenaghan, who opened the discussion, commented that, a few years ago, 10 knots was an

acceptable speed for tramps, whereas to-day it was 12 to 15 knots, and 10 years hence it might be 16 knots. Sir Wilfrid Ayre had stressed the need for the dual-purpose ship; Mr. Lenaghan, however, would like to see a dual-speed ship, which might be one result of the introduction of multiple Diesel engines. Multiple Diesel engines might not find unqualified favour in ships, but there seemed to be a future for them. Considering, for example, a tramp ship with four engines: in a good period, when freights were high, all four could be used, and when freights were low, the vessel could operate at a lower speed, using only two engines and less fuel. There were, of course, technical problems involved; it might be necessary to accept a less efficient hull and less efficiency in the top speed range, but that should not be a great deterrent. He was rather doubtful about the future of 12-passenger ships; carrying those passengers added considerably to costs, and it seemed doubtful whether there would not be a general desire to travel more quickly than could be done in a passenger-cargo vessel.

The present arrangements for cargo handling on board ships were possibly the cheapest equipment available, and to consider adding any other type of equipment was wrong; but he agreed with Sir Wilfrid that it was a matter for the port authorities, rather than for the ship designers, to consider. If port equipment was being used, he would like some brave shipowner to declare that he would not put winches and derricks on a ship, but would use the port facilities. He agreed that machinery aft was the thing for the cargo ship, and he wondered that it had not developed to a greater extent. He liked funnels, but thought that they would disappear, though there were many shipowners who liked to see colourful funnels. Space was valuable in ships. The tendency was towards single rooms for all the crew, but he did not see why there should not be a little more centralisation, e.g., two large mess spaces, one for the officers and one for the crew; that would probably save money. Why, also, was there not more use of mechanical ventilation in engine rooms?

Mr. J. D. Farmer, referring to the author's remarks about freezing fish at sea, said that various attempts had been made to commercialise that process, but, so far, difficulties in accommodation and handling had made it uneconomic and little real progress had been made. About 1928, two 6,000-ton to 10,000-ton ships were equipped with quick-freezing apparatus for dealing with halibut, brought to the factory ships by small catchers. The attempt failed because the large amount of fish brought in could not be marketed profitably in the required time, before the ships were due to sail again. Since the war, many schemes of freezing-factory ships had been discussed, but, apart from one or two comparatively small experimental plants, nothing had developed in the United Kingdom. There was no doubt that the quick freezing of fish, within hours of being caught, provided the best possible quality so long as the rest of the handling chain, right up to the consumer, was organised appropriately. Two large whale-meat freezing plants had been operating for a few years on vessels in the Antarctic, and had been very successful technically and commercially; but fish, to benefit from freezing, must be cooled from catching temperature to about -5 deg. F. in about two hours, which meant a large and expensive plant, of about 120 h.p. per ton per hour for all purposes. He was inclined to criticise the author's use of the term "air conditioning," a term generally accepted as applying only to comfort cooling; the significance of the word "conditioning" lay in the fact that it implied not only cooling, but also control of the moisture content. So far, in the carriage of perishable products, little attempt had been made to control the moisture content of the air. It was generally desirable to maintain the moisture content as high as possible, to avoid drying the cargo by evaporation, i.e., the air should be as nearly saturated as possible. On the other hand, for true "comfort" air-conditioning, the air should be cooled and also the moisture content reduced to lower than full saturation; in fact, the lowering of the moisture content was generally more important than the lowering of the temperature.

The two methods of carrying perishable fruits

were by ventilation by fresh air through uninsulated holds, the most recent vessels being equipped with high-efficiency reversible propeller-type fans fitting into the diameter of the cowls; or, secondly, in insulated holds by means of refrigerated air circulated in a closed circuit, using the same type of propeller fan. In a closed refrigerated air circuit, the same air was re-circulated continuously through the refrigerating air cooler and the cargo. With fruit, however, CO₂ and other gases were given off and it was necessary to inject fresh air, thereby rejecting an equal amount of cold air to keep down the concentration of undesirable impurities in the closed air circuit. For cargo maintained below freezing point, the same system was used as for fruit, namely, a closed air circuit in an insulated hold. Meat and other perishables carried at temperatures below freezing point, however, did not give off any harmful gas, and, therefore, they needed no injection of fresh air. Some fruit ships had been equipped with refrigeration, operating on a closed air circuit in non-insulated holds. These, however, were for special runs, where the water and atmospheric temperatures fell practically from the time the ship sailed in the loaded condition. The effect of the refrigeration was to hasten and enhance the natural cooling obtainable with forced ventilation. This had been found to be of considerable benefit for fruits loaded in such a stage of development as to be abnormally vigorous in their metabolic action. Such uninsulated refrigeration, however, could never contend economically with a temperature difference between inside and outside greater than about 10 deg. to 20 deg. F.

Professor E. V. Telfer quoted the author's statement that it was the world hunger for oil which had caused tankers of up to 60,000 tons to be contemplated. That, he considered, was not true; the world had always been hungry for oil. The idea of the 60,000-ton single ship sprang from an entirely different motive, namely, the realisation on the part of some shipowners that it was possible to have a 60,000-ton merchant ship. The principal cause of ship change, so far as both speed and size were concerned, was socialisation; speed as such could not be divorced from size as such. Neither could he agree with Sir Wilfrid's remark that, "In the case of purely deadweight carriers of similar dimensions, it is an academic statement that, as between a slow-speed ship and a ship having a sea speed, say, 50 per cent. faster, each having appropriate hull forms and engine power, the slow-speed ship could transport a greater aggregate of cargo in a given time than its speedier rival." A 10,000-ton ship of relatively low power, say, 1,500 h.p. maximum, which could do 10 knots, wallowed around the Atlantic at 7 knots. On the other hand, ships designed for 12 knots, and which gave possibly 12½ knots on trial, were maintaining respectable speeds under the same conditions, averaging about 11½ knots. Without any great change in design, those higher-powered ships were transporting much more cargo than the so-called low-speed ships. While it might have been possible in the early 1930's to have ships running at low speeds, it is not possible for British shipowners now to use that alternative economically, because socialisation pressure prevented them from reducing the wages of their crews in order to run economically at those low speeds. It was the on-cost that governed the matter. While Sir Wilfrid contemplated a possible return to low-freight conditions, such a return was impossible in the foreseeable future. So long as wages were going up all over the world, naval architects should continue to devote themselves to the development of the higher-speed ships.

Professor Telfer agreed very definitely with Sir Wilfrid in his rather startling statement that "Deadweight or bulk carriers in the future, helped by still further research in model tank work, are likely to have much fuller forms, as conveniently expressed by block coefficient, than is current practice to-day." Sir Wilfrid was pointing to greater block coefficients as something which would take place in the normal march of progress, and he was right. The real skill of the naval architect required an improved ship with increased block coefficient, and that was not impossible. Sir Wilfrid referred to the Canadian Great Lakes vessels as

providing an example of somewhat unique naval architecture. The Wilfrid Sykes had 7,000 h.p. and a speed of 16 knots; the block coefficient of that vessel was no less than 0.875, and the form was an extremely economical one. The Great Lakes were showing naval architects the way, and Sir Wilfrid was drawing the attention of the experiment tanks to a complete reversal of their present methods of designing.

Mr. J. M. Murray observed that, at the end of the paper, Sir Wilfrid indicated that he did not like the modern funnel. Mr. Murray agreed with him, but there were different opinions on that point, as was illustrated by the "Strombus" funnel, which had found favour in France. It was like an aeroplane wing on the deck, with a streamlined section, and it seemed to serve very well. According to the French, not only was it an efficient funnel, but it was a most aesthetic form, which was not his own view. With regard to sea speed, and the amount of cargo which could be transported by a fast ship as against a slow one, in a paper on petroleum tankers, read before the American Society of Marine Engineers and Architects in 1948, it was shown that, for a voyage of 2,000 miles, a 16-knot ship transported more cargo, in ton-miles per year, than a 12-knot ship; but when the length of the voyage was increased to 8,000 miles, there was little difference in the amount of cargo transported. In some cases, there might be a reduction. Calculations had been made to show that, in a period of low freights, the slower ship was the more economical, and in a period of high freights the reverse followed; but there was little doubt that, irrespective of such considerations, the modern tendency was towards increased speed of cargo ships, a development which had repercussions on matters such as the design of the structure. That led to the point that the modern cargo ship, as Sir Wilfrid stated, was now generally designed for the carriage of cargoes of low specific gravity, and, on account of the finer form and often the greater length of machinery space required, it had been found necessary to seek capacity by fitting a long forecastle. That arrangement appeared to be preferred to a further increase in the height of the shelter 'tween decks, and the design was one which appears to be gaining ground. It had the disadvantage that, by tending to concentrate cargo towards the ends of the ship, the main longitudinal stresses were increased. There was a much greater hogging moment than in the normal ship, which led to some difficulty with regard to the structure. Thus a trend in one direction might have unfortunate repercussions in others.

Mr. W. Muckle said that he would submit in writing some comments concerning sea speed; he did not agree with some of the remarks made in the discussion. Coming to the use of aluminium alloys in ships, he suggested that the figure which Sir Wilfrid gave, a saving of 50 per cent. in weight, was a conservative one; something like 60 per cent. saving in weight was possible in the superstructures of ships. It might appear that there was not much difference between the two figures; but, when using a very costly material, it would have an appreciable effect on the economics of the proposition. The main future for aluminium alloys in ships—the immediate future—was in the passenger type of ship, and, in those circumstances, in some of the larger ships, the introduction of these materials was an economic proposition. Good progress had been made with the welding of those materials, and he thought that, with the lighter weight to be handled, a greater degree of pre-fabrication could be carried on in the shipyards. Sir Wilfrid had hinted that the aluminium alloys might be used unpainted. Personally, he would like to see them painted, because he would not like to see a ship looking like an old tin can. He agreed that streamlining was taken to excess.

Captain J. P. Thomson thought that not enough progress was being made in adopting modern types of machinery. For instance, in the tanker, the old plunger pump was accepted as being the perfect pump, whereas there were more satisfactory types of pump on the market. The rotary pump was far better than the plunger pump. Sir Wilfrid had referred to dual-purpose ships. Some experience of such ships was gained during the war, but it was

remarkable that so few of them existed to-day. They all went back to their specialised trades. One of the first tank landing craft was a shallow tanker, and it did a very good job. With regard to the twelve-passenger cargo ship: accommodation for 12 passengers occupied space which would carry 120 tons, and would probably cost, during a year, 1,200l. in port dues. If all the accommodation was occupied during the whole year, well and good, but tankers so fitted often had only one or two passengers, or none at all. As to fuel consumptions, it always seemed to him beneficial to travel at higher speed, no matter what the route. During the years of depression, he commanded big tankers having a sea-going speed of about 10 knots. The question arose, whether to lay up the ships or keep them at sea, and it was decided to keep them at sea. The consumption of oil was 40 tons per day at 10 knots; at eight knots, the consumption was about 24 tons per day. That was a small economy, but the lower speed enabled the company to keep the ships at sea. To lay them up was not economic from the point of view of maintenance. He drew attention to recent reports on the gas-turbine machinery of the tanker Auris, and the saving in weight of machinery compared with the ordinary type. That gas turbine took the ship at 7.3 knots on a voyage of some 4,000 miles, which was a very creditable performance. In his opinion, more would be heard about that work in the future.

Mr. Norman M. Hunter regretted that Sir Wilfrid was rather pessimistic about the progress of welding in this country, which really began the construction of ships by welding, and was still leading the world. More than 50 years ago, the firm with which he was connected sent completely welded ships, without a single rivet in their construction, across the Atlantic, and they had been building all-welded ships ever since. Cinematograph films were sent across, showing the fabrication by welding. Now, welding was practised to a very great degree in every shipyard in the country. It was time that people realised that, because it is a great pity to see in Sir Wilfrid's paper the statement that "time will, and indeed must, see the general adoption of welding here to no less extent than in shipyards in these countries"—on the Continent and in the United States and in Canada. Those were the countries which learned the game from Britain.

Sir Wilfrid Ayre, thanking the speakers who had taken part in the discussion, intimated that he would reply to their comments in writing.

(To be continued.)

THE ROCKWELL MACHINE-TOOL COMPANY.

SOME 18 months ago, the Rockwell Machine Tool Company, Limited, moved into their present premises at the Welsh Harp, Edgware-road, London, N.W.2, comprising two modern buildings—one an office and the other a showroom for the display of machine tools for which the company are agents. This showroom has recently been considerably extended and now occupies a total floor area of 12,500 sq. ft. The new extension, which we have been given an opportunity to inspect, is 150 ft. long by approximately 40 ft. wide. The insulated roof is provided with a considerable area of Perspex window space giving ample daylight illumination, while artificial lighting is supplied by numerous fluorescent-light tubes. In view of the fact that machines are constantly moved in and out, the floor is of hard and dust-free Granolithic concrete. A five-ton overhead electric travelling crane runs through the length of the showroom and on through continuous hinged shutter-type doors at the end. This enables machine tools to be taken directly from motor lorries into the showroom. Further to facilitate the movement of machines the unloading bay is provided with a 12½-ton gantry fitted with a 10-ton electric pulley block. In addition, a powerful fork-lift truck is available in the showroom. For demonstration purposes, electric wall plugs are provided enabling any machine on view to be operated independently. The showroom is heated by an oil-fired hot-water system, controlled by thermostats and time switches, enabling a constant temperature to be maintained. A small air-conditioned cinema opens out of the main showroom.

RAILWAY WHEEL MILL: MESSRS. STEEL, PEECH AND TOZER.

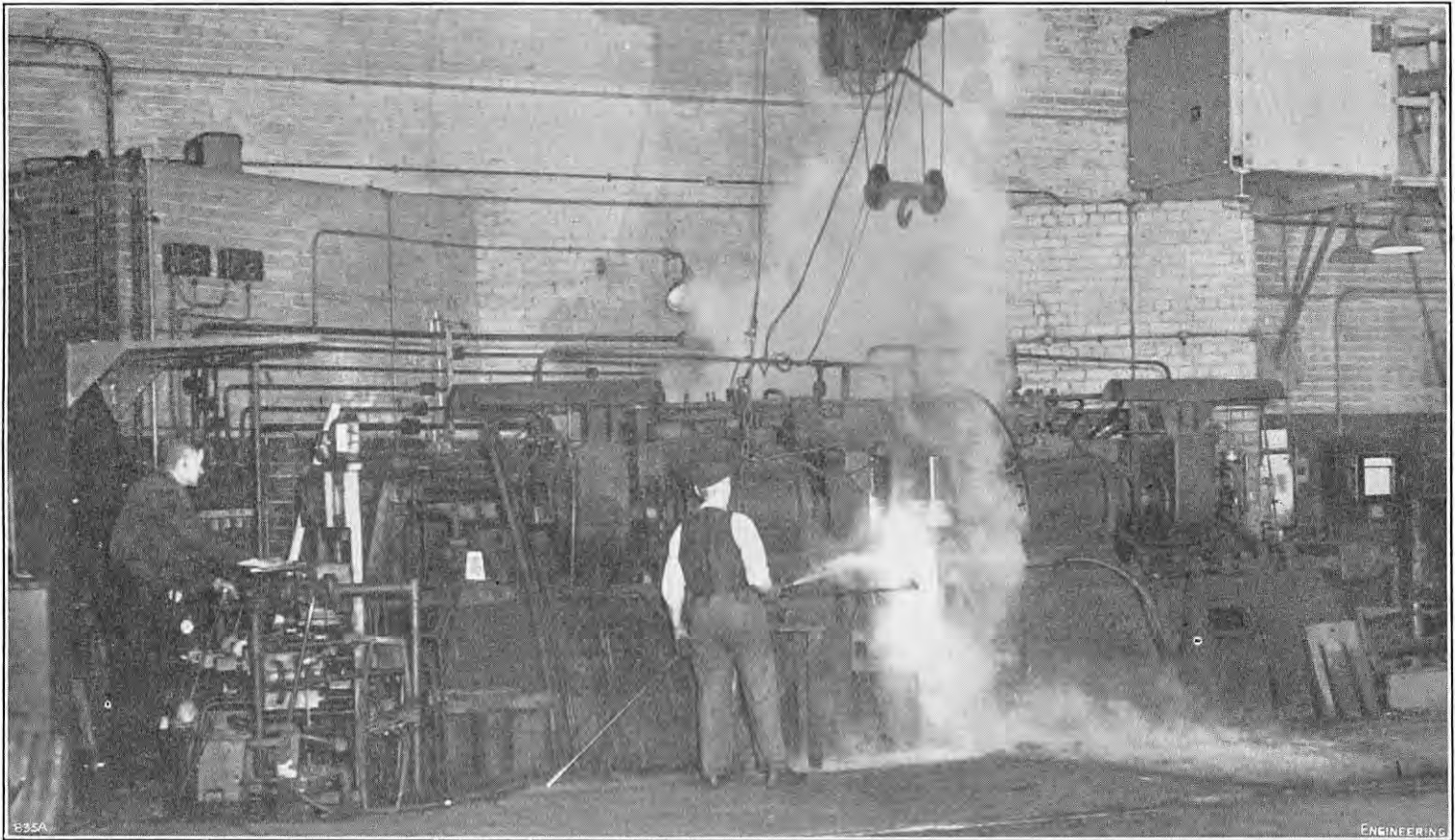
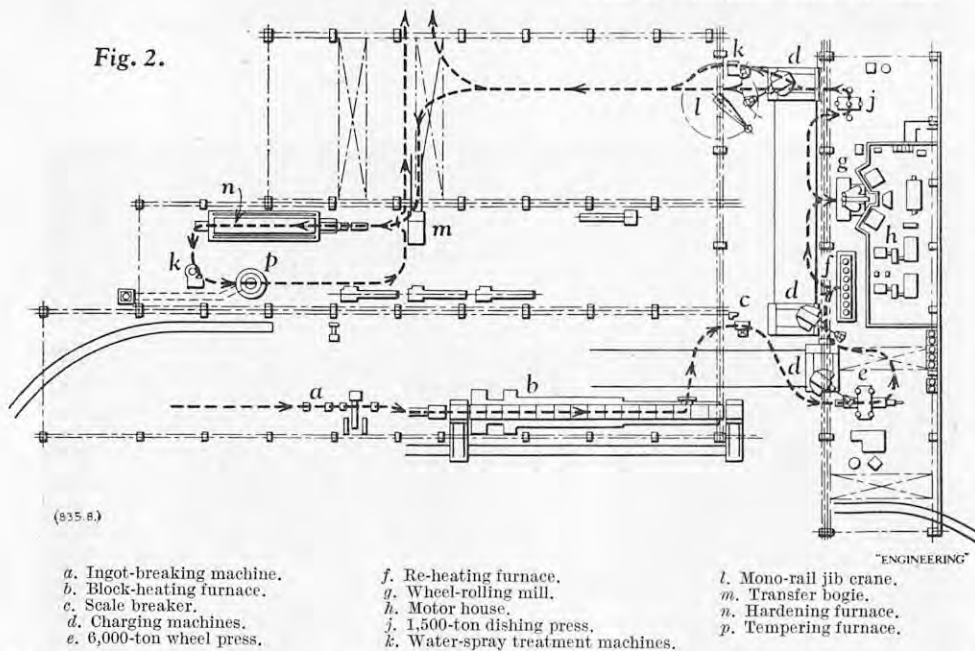


FIG. 1. GENERAL VIEW OF MILL.



RAILWAY WHEEL MILL OF MESSRS. STEEL, PEECH AND TOZER, SHEFFIELD.

For many years, one of the principal activities of Messrs. Steel, Peech and Tozer, Ickles Works, Sheffield—who are a branch of the United Steel Companies, Limited—has been the production of railway wheels, tyres, axles and springs. Over a long period of time, the methods of production, as in the case of many steelworks processes, might have been described as “traditional,” and greatly dependent on the skill of individual workmen; but the exceptional demands of the post-war years, apart from the developments in technique which normally take place, have pointed to the advisability of including these departments in the extensive programme of modernisation that has been in progress. How thoroughly this policy is being

carried out is well exemplified by the wheel mill which we describe and illustrate below.

A general view of the wheel mill is given in Fig. 1, herewith, and an outline diagram in Fig. 2. Figs. 3 and 4, on page 516, and Figs. 5 and 6, on page 524, show the principal items of its mechanical equipment. The mill, which is situated at the company's Ickles Works, covers an area of about three-quarters of an acre and can maintain an output of 180 to 200 solid wheels or discs per shift. The processes are substantially the same for both solid wheels and discs, and references to “wheels,” in the following description, may be taken, therefore, to cover discs also. The sequence of operations, very briefly, is that the ingots, as received from the melting shop, are broken into blocks which are heated in a bogie-type gas-fired furnace for forging in a 6,000-ton press. They are then reheated before being placed in the mill, where each wheel blank is rolled to the correct finished

diameter and thickness. A charging machine transfers the rolled blank to a 1,500-ton dishing press, where the boss is pressed into its final position in relation to the plane of the tread. After reheating the wheel to 850 deg. C., the rim is sprayed with water to harden the tread. It is then ready for inspection and machining.

The ingots, as received from the melting shop, are laid out in rows and inspected for surface defects. Each ingot is then marked for breaking, by burning a series of nicks round about a third of its circumference. The thickness of the blocks depends, of course, on the size of the wheels to be made, and is set by means of an adjustable template. The ingot-breaker, indicated at *a* in Fig. 2, and illustrated in Fig. 6, on page 524, is, in effect, a shearing machine, in which the ingot is sheared by a heavy crosshead, mounted on anti-friction rollers, between two pairs of hard steel breaking blocks. The crosshead is actuated by an eccentric keyed on to the high-tensile steel shaft of the machine, which is driven by an induction motor of 100 h.p., running at 970 r.p.m. The drive is by belt from the motor to a large flywheel, and thence through reduction gears to the shaft. A hand-operated clutch is provided for engaging the crosshead, and is designed so that the machine always stops in the middle of a stroke; thus it is not possible for it to stop with the crosshead in contact with an ingot. The breaking blocks are adjustable in height by means of screw-actuated wedges.

After breaking, the blanks are lifted clear by a magnetic crane and are inspected again, any surface defects observed being burned out with a descaling torch. The wheel blocks are then transferred on a conveyor into the heating furnace (*b*, in Fig. 2), which is of the continuous counterflow type, and are heated to a uniform temperature of about 1,200 deg. C. The heating takes from five to seven hours. The furnace comprises a preheating zone long enough to take nine bogies, a heating and soaking zone which will hold four bogies, and a cooling zone which accommodates two bogies. Each bogie normally carries nine blocks and, as 13 of the 15 bogies are carrying a charge at any given time, the effective capacity of the furnace is 117 blocks. There are two bogie transfer cars, one at each end.

The bogies are propelled through the furnace by an electrically-operated double rack pusher, which has a stroke of 9 ft. 6 in. and can exert a thrust of 20 tons. It is driven by a direct-current motor of 30 h.p. For control of the temperature, four platinum-platinum/rhodium thermocouples are used in conjunction with multi-coloured dot temperature recorders.

At the exit end of the furnace, a charging machine lifts each block from the bogie and inserts it in a descaling machine of the whirling-chain type, indicated at *c*, Fig. 2. This removes the scale from the top and bottom of the block, which is then transferred by another charging machine to the 6,000-ton Davy and United forging press (*e* in Fig. 2), illustrated in Fig. 3. The press is of the single-cylinder vertical four-column type, operated by two sets of hydraulic pumps and equipped with an air-loaded hydraulic accumulator and a hydraulic intensifier. The pumps are of the three-throw horizontal type, with rams $4\frac{1}{2}$ in. in diameter and 15 in. stroke, and are driven at 120 r.p.m. by 600-h.p. electric motors. The pumps have a theoretical delivery of 280 gallons a minute against a working head of 3,000 lb. per square inch. They are driven through a double-helical single-reduction gear, the speed of the motors being 720 r.p.m. Fig. 5, on page 524, shows the pumping plant.

The accumulator, which will maintain a steady pressure of 3,000 lb. per square inch, has a useful water capacity of 300 gallons and a total volume (air and water) of 520 cub. ft. It has two water bottles and five air bottles, and the control gear is designed to by-pass the water delivered by the pumps according to the position of the level in the accumulator, the pumps running continuously. A safety control cuts out the pumps at the high level and shuts the accumulator stop valve at the low level if the normal control instruments fail to act. The low-pressure ram of the vertical intensifier is operated through valves by the fluid from the air accumulator at a maximum pressure of 3,000 lb. per square inch and acts on a high-pressure ram which raises the pressure to 6,000 lb. per square inch and is in communication with the main cylinder of the press.

The press is specially designed for forging wheels and is provided with hydraulic gear to move the slabbing and finishing anvils in and out. The swinging holder for the top slabbing tool, also hydraulically operated, is pivoted on one of the columns. The mechanical handling gear for the wheel blanks consists of two gripping arms with forked fingers at the ends, working in the space between the press columns, one at each side. The movement of the press crosshead lifts the gripped blank; and, as the gear is attached to the crosshead, the fingers grip the work at a suitable height, whatever its size. The fingers also serve to centre the blank under the press.

In operation, the block is placed on the slabbing anvil, which is then moved under the press. The top slabbing tool is then swung into position under the press, and a light squeeze is given to the block to break the scale, which is blown clear by compressed air. The block is pressed into a blank in a ring hanging from the top slabbing tool. The tool is then lifted, press crosshead ejecting the blank from the ring into the forming die, which has been brought into position by the sliding table. The slabbing tool is swung away and, with the partly formed blank within the forming die, the press crosshead, carrying the top forming tool, makes the final pressing stroke with the full power of 6,000 tons. The forged wheel is then punched, and a crane removes it for transfer to the reheating furnace (*f* in Fig. 2). At this stage it has the shape of a wheel, but is thicker, and smaller in diameter than the finished product.

A second charging machine places the forging in the reheating furnace, which is fired with coke-oven gas at a pressure of 5 lb. per square inch and a calorific value of 500 B.Th.U. per cubic foot, and can heat 30 or more blanks an hour (depending on their size and weight) from 1,100 to 1,250 deg. C. From the furnace, the forging is transferred to the wheel rolling mill (*g* in Fig. 2), where it is rolled to the correct finished diameter and thickness, and the tread and rim are formed.

The wheel mill, which is of the vertical type, can

RAILWAY WHEEL MILL.

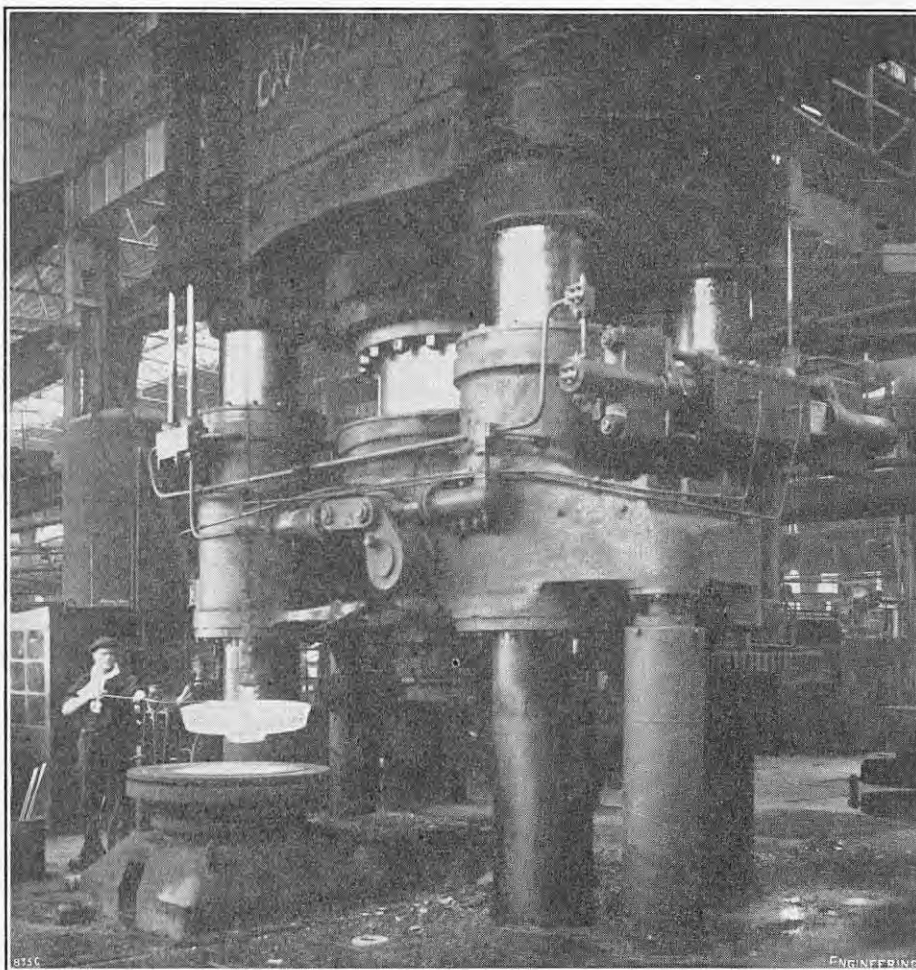


FIG. 3. 6,000-TON WHEEL FORGING PRESS.

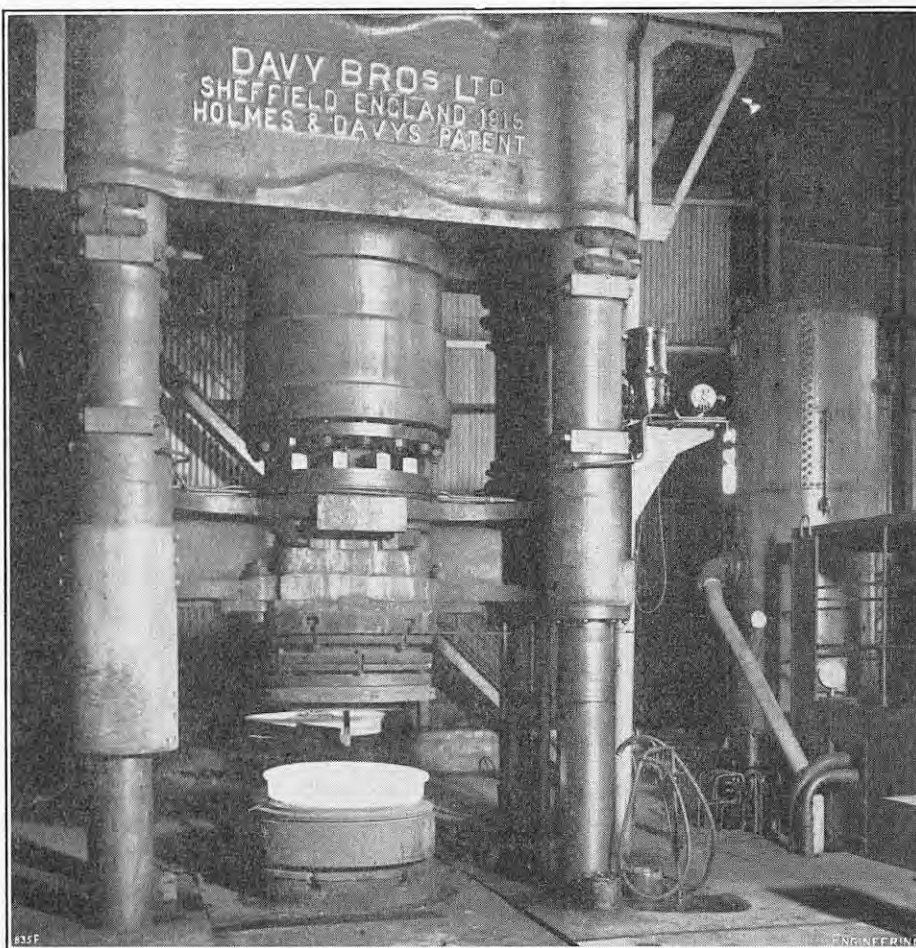


FIG. 4. 1,500-TON DISHING PRESS.

produce solid wheels from 18 in. to 4 ft. in diameter and up to $7\frac{1}{2}$ in. width of face. It can also roll gearwheels up to $6\frac{1}{2}$ in. wide on the rim. It has five rolls—namely, two web rolls, two side or edging rolls, and one back or tread roll—and is driven through the web roll assembly by means of a variable-speed electric motor of 500 h.p., the speeds of which range up to 130 r.p.m. Each web roll is moved towards or from the centre line of the mill by a ram having an extended tail rod which is screwed and fitted with nuts to limit the forward and return strokes. The tread roll is provided with a similar ram and locking nuts. The wheel is located and supported by a mandrel through the bore. Two brackets, which can be adjusted with liners, support the mandrel, upon which the wheel rotates while it is being rolled. Water is sprayed on to the wheel as it is rolled, to ensure that no scale is rolled into it. As it is essential that the web rolls should move in and out at a uniform rate, the separate pumps which deliver to the web-roll rams are fitted with metering valves which control the flow and accurately adjust the movement of the rams.

When the operation of rolling is completed, the wheel is picked up by a third charging machine and transferred to the dishing press (*j* in Fig. 2), in which the boss is pressed into the correct position to give the desired conical shape to the finished wheel. This press, which is illustrated in Fig. 4, on page 516, is an ordinary forging press of conventional type, designed to apply a total pressure of 1,500 tons. It is operated from the hydraulic pumps and air-loaded accumulator which also operate the 6,000-ton press, previously described, and has a sliding table to bring the wheel into the centre line of the press crosshead. After dishing, the wheel is stamped with an identification number, and is conveyed on a transfer bogie to the heat-treatment furnaces (*n* and *p* in Fig. 2).

The heat treatment given depends upon the customer's specification, but most of the wheels produced are rim-sprayed. In this process, the wheel is heated to a temperature of about 850 deg. C. in a walking-beam furnace and is placed on a revolving table (*k*, Fig. 2) which spins it for a predetermined time at a constant speed. As the wheel revolves, the rim is sprayed with water by a number of jets, fixed round the circumference of the table, thus hardening the tread. No water is allowed to strike the web of the wheel, as this might cause local hard spots.

The walking-beam furnace (*n*, Fig. 2) is fired by 28 low-pressure Eddy Ray burners, using coke-oven gas. The hearth consists of a bogie, lined with firebrick, running on cast-iron turned rollers which are flanged on one side for guidance. It is built of longitudinal joists, carrying a platform of mild-steel plates and angles, and is caused to rise and fall by a double-acting cylinder and ram, operating a rod which actuates the lifters. The complete cycle of movements—up, forward, down and return—is repeated about three times in a minute. The charging and discharging doors are electrically operated and automatically controlled. After undergoing the heat-treatment process, the wheels are ready for inspection and machining.

Various references have been made to the charging machines which are used to handle the wheel forgings. There are three of these machines, which are of the Wellman-Smith-Owen Company's 25-cwt. ground type and are indicated by the letter *d* in Fig. 2. The span of the machine which transfers the blocks from the furnace to the 6,000-ton press is 17 ft., and that of the wheel-handling machines is 20 ft. The slewing radii, from the centre of the

grips to the pins, are 17 ft. and 18 ft., respectively, and the driving speed is 400 ft. per minute. The trolley runs on an underframe which is carried on four runner wheels, 1 ft. 9 in. in diameter, mounted on fixed axles, two of these wheels being driven. The trolley wheels are supported on through axles and all are driven. The roller path and centre-pin bracket are mounted on the trolley frame, the revolving part of the machine turning on cast-steel rollers. A ball bearing takes the vertical load and locates the machine about the centre pin. The operator's platform is carried on the slewing frame and is so designed that the driver always has a clear view of his load. Gripping of the blocks is effected by a motor-driven gear, operating through a fluid coupling which enables the load to be taken up gradually and stalls at the maximum pressure. The cast-steel charging bar which carries the grips can rotate through 360 deg. and is located and secured in a locking frame, pivoted on brackets which form the front of the slewing frame. The charging bar is raised and lowered by a motor through a worm reduction gear and cranks.

STANDARD ELECTRIC MOTORS.

A RANGE of totally-enclosed fan-cooled squirrel-cage induction motors with outputs ranging from 1 to 20 h.p. and speeds depending on the number of poles (as shown in the Table below) has been introduced by the English Electric Company, Limited, Queen's House, Kingsway, London, W.C.2. These motors comply, as regards dimensions and "preferred" outputs and speeds, with the draft British Standard Specification CN(ELE)6814, and, with the exception of the 1-h.p. four-pole motor, the dimensions also correspond with the conditions laid down in the American N.E.M.A. standard MGI-1949. For a given frame size, however, the outputs have been increased, so that they accord more closely with generally-accepted practice in this country; the shaft dimensions have been correspondingly adjusted.

The type of enclosure employed makes it possible for the new motors to be used, in the majority of cases, instead of the existing protected, screen-protected, drop-proof, louver-ventilated, single- and double-pipe ventilated, splash-proof and straight totally-enclosed types. Their construction is such that they are capable of withstanding the most arduous duties. The stators are of one-piece iron construction with integral feet and terminal box bases. All the working surfaces are machined in order to ensure correct alignment of the fitted parts. The stator cores are built up of high-grade alloy stampings, which are welded together and machined to fine limits on both the external and internal diameters. The slots are insulated with press board—with mica and black-varnished cambric backing. The windings consist of copper wire, which is covered with synthetic resin. The assembled and wound stator is impregnated in an automatic continuous oven and the resulting tropically-insulated unit is pressed and keyed into the stator frame.

The rotor is pressure die-cast. Its core is built up of stampings made from alloy similar to that used on the stator and it has aluminium-alloy bars and end-rings with integrally-cast fan blades. The end shields are of cast iron and are accurately machined so as to give protection to the working parts and to maintain correct alignment under the heaviest loads. The shaft, which is of 4 per cent. carbon steel with a tensile strength of 38 to 42 tons per square inch, is fitted with metric bearings. Easy access to the terminals is obtainable through a diagonally split box which is usually on the right-hand side of the motor when looking towards the non-driving end. The cable entry then points vertically downwards. The box can, however, be turned into three other positions, 90 deg. apart, and the stator can be reversed when the terminal box is required on the left-hand side of the machine.

The method of ventilation employed has been developed so that the motors may be used in dusty situations without the air being contaminated.

INCREASED PRODUCTIVITY IN BRITISH DROP-FORGING.*

ALTHOUGH the report of the drop-forging team—the third productivity team to visit America—did not have the wide interest of that of the first one, on steel-founding, it was an outstanding contribution to the technical literature of the industry. Apart from the excellent circulars regularly sent to member firms by the National Association of Drop Forgers and Stampers, there is little written about drop-forging in Britain. The report provided a most valuable guide to modern drop-forging methods. Eight thousand copies of the report, which was published on May 2, 1950, were sold and distributed, and it is now out of print. It pointed to the same general factors in aiding the achievement of high productivity in America as the steel-founding report. The team cited a few American technical developments which they thought valuable, and they were interested in the new Ceo hammer. But their main comment was that the way the plant is used in America differs from that in this country, and that the degree of utilisation of machines, particularly the hammers, is very often greater than in Britain. The Association has looked into various technical points mentioned in the report, while individual firms have concentrated on increasing their hammer utilisation.

The Association is investigating how far it would be possible and of value to collect figures of productivity from its member firms from which to make some assessment of the rate of increase of productivity in the industry and to enable comparison to be made between an individual firm's figures and an industry average. At the present time, most firms are suffering from an acute shortage of steel bars and billets. Until this steel shortage limited output, there had been some increase in productivity in the industry since 1949; but it is difficult to compute how much. The examples given are not homogeneous or comparable, one with another; for the type and weight of stampings produced by different companies vary so much. No satisfactory method has yet been evolved of correlating productivity in different firms.

Among individual firms, the Blackheath Stamping Company, Limited; the Deritend Stamping Company, Limited; the English Steel Corporation, Limited; Messrs. Garringtons, Limited; Messrs. B. and S. Massey, Limited; Messrs. Mitchell, Shackleton and Company, Limited; Messrs. George Morgan, Limited; Smethwick Drop Forgings, Limited; Messrs. Smith-Clayton Forge, Limited; Messrs. Smith's Stamping Works (Coventry), Limited; the Stampings Alliance, Limited, and Messrs. A. J. Vaughan (Mitre Works), Limited, can cite examples of increased productivity. The Blackheath Stamping Company now work only five days a week instead of five and a half, resulting in a week of 40 hours instead of 44, but the weekly output has not dropped. By reorganisation of the hammer-team and hammer layout this company has increased the output of some of its hammers by 100 per cent. per hammer-hour since the war. The Deritend Stamping Company achieved an output from its mass-producing hammers $3\frac{1}{2}$ times higher in the early part of 1951 than in 1946, in spite of decreasing the working week from 44 hours to 40 hours; in the latter part of 1951 the steel shortage interfered. The English Steel Corporation has increased the output of its hammers and presses in the last five years by an average of about 50 per cent. Messrs. Garringtons, Limited, have maintained close contact with America. At this company, production per machine-hour (including both the Darlaston and Bromsgrove works) had increased to six times the 1938 figure by 1950, and in the same period production a man-year had more than doubled. The present rate of production per hour of certain forgings shows an increase of 100 per cent. over pre-war. Messrs. Mitchell, Shackleton and Company, Limited, have increased its output from their upsetting machines from between 60 tons and 70 tons in 1949 to 130 tons or 135 tons in 1951. Messrs. George Morgan, Limited, have increased the weight of forgings produced a hammer-hour from 153 lb. in 1949 (it was 132 lb. in 1947) to 181 lb. in 1951, an increase in hammer utilisation of 18 per cent. since the team's visit. At Stampings Alliance, Limited, the average weight of good forgings produced per stamp working hour increased during the period 1945 to 1951 by 50 per cent.

There has been an increase in output per man-hour (hammermen only) at Messrs. George Morgan, Limited, of 40 per cent. since 1949. Messrs. B. and S. Massey, Limited, have increased the output in a 44-hour week of various staple jobs by amounts ranging from 45 to 90 per cent.; average tonnage output has increased from 0.21 tons an hour (all workers) in 1949

* Report, entitled "Utilizing the Hammer," on the value of the visit of a productivity team from the British drop-forging industry to the United States in 1949. Issued (for Press circulation only) by the Anglo-American Council on Productivity, 21, Tothill-street, London, S.W.1. Abridged.

OUTPUTS AND SPEEDS OF BRITISH STANDARD MOTORS.

Frame Size.	2-Pole.		4-Pole.		6-Pole.		8-Pole.	
	H.P.	Speed, r.p.m.	H.P.	Speed, r.p.m.	H.P.	Speed, r.p.m.	H.P.	Speed, r.p.m.
B. 183 ..	1½	2,860	1	1,425	¾	930	—	—
B. 203 ..	2	2,845	1½	1,415	1	945	—	715
B. 204 ..	3	2,870	2	1,430	1½	945	—	715
B. 204 ..	5	2,870	3	1,430	2	950	1	715
B. 225 ..	7½	2,885	5	1,445	3	960	2	720
B. 254 ..	10	2,885	7½	1,450	5	960	3	720
B. 284 ..	15	2,900	10	1,455	7½	965	5	720
B. 324 ..	20	2,910	15	1,465	10	975	7½	730
B. 326 ..	25	2,920	20	1,470	15	975	10	730

to 0.33 tons an hour at the end of 1951. At Stampings Alliance, Limited, the average weight of forgings produced per man-hour (all employees, excluding staff) increased from 1945 to 1951 by 19 per cent. Total output of the firm in this period increased by 27 per cent. The output a man-hour of Messrs. A. J. Vaughan (Mitre Works), Limited, has risen from 15.47 lb. in 1949 to 19.04 lb. a man-hour in the first half of 1951. Messrs. Garringtons, Limited, also report a direct comparison in output with 28 identical forgings made on similar plant in America, and claim a rate of output between 5 and 48 per cent. higher for 12 items, and equivalent rates for a further seven forgings. Total output of the firm has increased from 1949 to 1951 by 75 per cent. The English Steel Corporation has increased its output per shift for finished tons of stampings in the period 1946/47 to 1951/52 from 0.67 tons to 1.12 tons on light friction-lift stamps; from 1.5 tons to 1.85 tons on heavy friction-lift stamps (5, 6 and 7-ton); and from 1.4 tons to 2.1 tons on upsetting presses. Smethwick Drop Forgings, Limited, has increased the output by weight of good forgings per man per week (including all employees) at the Kidderminster works from 550 lb. in 1945 to 1,200 lb. in 1950; at Kidderminster it has concentrated on board hammers. At Smith-Clayton Forge, Limited, there has been an increase of 32.8 per cent. in output by weight per man-year (all workers included) from the year ending July, 1949, to the half-year July-December, 1951. The output by weight per man-year was 13.1 tons in 1947/48, 13.4 tons in 1948/49, 15 tons in 1949/50, 16.5 tons in 1950/51, and 17.8 tons in the latter half of 1951. At Smith's Stampings Works (Coventry), Limited, the output by weight per man-year increased by 29.7 per cent. from the year 1948/49 to the year 1950/51; output was 11.8 tons per man-year in 1948/49, 13.8 tons per man-year in 1949/50, and 15.3 tons per man-year in 1950/51. Messrs. Smith-Clayton Forge, Limited, have also concentrated on fuel economy; whereas, in 1946, 523 therms of gas were used in the heating of 182 tons of drop-forgings, in 1950 only 267 therms were used for heating 336 tons, and in 1951 some 280 therms for heating 350 tons.

The British drop-forging industry only came into its own during the first World War. The industry grew as a consequence of the rise of the automobile industry, to which some 70 per cent. of drop-forgings still go. The trade association was formed in 1918. Demand for drop-forgings dropped in the early 1920's, but drop-forgings increasingly replaced iron castings for small repetition jobs. The second World War was a period of unprecedented activity. Large expansions were undertaken with Government aid, and two of the most productive of present-day units, Messrs. Garringtons' forge at Broomsgrove, and Smethwick Drop Forgings' works at Kidderminster, arose directly or indirectly as a result. After 1945, a period of reorganisation was essential in order to assimilate the developments made during the war, when cost was no object. The team's visit in the summer of 1949 occurred in the middle of this post-war reorganisation, and its influence has been to hasten the process and encourage even fuller criticism of old methods. Now, increased demand for rearmament and the shortage of steel bars and billets have interfered with the smoothness of the steady increase in the efficiency of the industry. After the report was published in the summer of 1950, meetings were held in Birmingham (the main centre of the industry), Sheffield and Glasgow, with the team present in each case. Members of the team have visited many firms both in and outside the Association. Three members of the team took part in a course of six lectures at the Birmingham Central Technical College.

A memorandum was issued by the Association in January, 1951, in which the main recommendations of the report were considered in detail by expert committees of the Association. The Association emphasised the importance of maximum machine utilisation and specialisation in production. A number of the technical recommendations of the report were accepted, such as the need for research in furnace design and in methods for shearing steel billets; and the Association recognised the advantage of using three-dimensional models for planning alterations in layout. The memorandum was widely discussed in the industry. Technical Conventions largely devoted to the report were held in 1950 and 1951. The first conference of foremen to be held in the drop-forging industry took place in the spring of 1951, and it was largely devoted to the report. A second foremen's conference was held at the beginning of February, 1952; lectures were given on foremanship and a visit was made to a die-block manufacturer. The report was widely commented upon in the Press, particularly in *ENGINEERING** and in the official journal of the Association, *Metal Treatment and Drop Forging*. The team has held re-unions since it returned from the United States; on each of these occasions it has paid a visit to a drop-

forging works and has also had a session to discuss development arising out of the report.

The National Association of Drop Forgers and Stampers, whose technical officer was the secretary of the team, has not only been intimately concerned with the dissemination of the report but also has committees on furnace design and other matters, and has instituted research in a number of subjects suggested by the team. The most ambitious research inaugurated has been that on furnace design and usage. The team reported that: "The adoption by British drop forges of larger and better furnaces is a matter for urgent attention." The co-operation of Powell Duffryn Technical Services was obtained and a long-term investigation is in progress. The operation of the furnaces in a dozen forges was first investigated; about half a dozen different types of burner are now being studied and two experimental oil-fired furnaces have been set aside for experiment by George Morgan, Limited, and by Smith's Stampings Works (Coventry), Limited, at their own cost. The investigation has been a little delayed because of the slow delivery of furnace measuring instruments. A questionnaire was sent out to member firms asking for oil consumption figures and details of the furnaces used and 25 replies were received. Another similar investigation is planned for the summer of 1952.

Powell Duffryn Technical Services have now presented an interim report on furnace design and usage. Often the basic shape and design have led to inefficiency; poor insulation and the use of a counterblast have often limited the furnace's heat efficiency. In British forges, furnaces are usually home-made and looked upon as perishable items. Improvements could be made especially in atomisation of the fuel and waste-heat recovery; about 45 per cent. of heat from the oil is often wasted. Since, as the team reported, the required increase in hammer utilisation necessitates the use of larger furnaces, and since American forges commonly employ a larger furnace for a given output fuel economy is essential. The final report is expected early in 1953. The analysis of the questionnaire on oil consumption shows that, for the most efficient furnace, oil costs one-third of what it costs in the least efficient; the larger forges with more furnaces tend to be the less efficient and the batch-type furnace tends to be more efficient than the more common slot-type furnace.

Committees were also set up on mechanical handling, clipping tools, inspection, die-block specification and the technical aspects of die standardisation. A number of members of the team have played a valuable part in these committees. A report was issued in March, 1951, on mechanical handling of bar and billet steel and of forgings during and after the stamping process. Members were encouraged to make better use of space above the floor, and to make more use of small conveyors, which could often be home-made gadgets of one kind and another. A special exhibition of mechanical handling appliances suitable for forges was staged at Smethwick Drop Forgings, Limited, in 1950. A valuable technical pamphlet was issued in April, 1951, on "Tools for Clipping Drop Forgings." The team commented on the greater use of split clipping beds in the United States in order to allow for easier adjustments. A survey was made of present usage, and much of the pamphlet critically discusses the various methods of clipping in operation in the industry. Experiments made by members both for cold clipping and hot clipping were reported on. The committee recommended the use of high-quality steel and segmented clipping beds for long runs.

Other research contracts may be placed by the Association with universities and technical consultants after the research on furnace design is completed. A large number of inquiries has been received by the Association since 1950 about technical processes in use in America. The Association is undertaking a greater amount of research than ever before, largely on subjects suggested by the team's report. The team also made long-term recommendations on training. Training has been discussed by a special committee of the Association on which two members of the team sit. The Staffordshire County Technical College at Wednesbury has already instituted a course on die-sinking for young workers. In new extensions being made to the college a small model forge is probably going to be set up, equipped with a pneumatic forging hammer and a 6-cwt. drop stamp; short courses for drop-forging workers will then also be given. The Bilston College of Further Education has arranged a general educational course for young workers in the iron and steel trades, including drop-forging. Some of the larger companies in the industry have their own scheme for training boys for drop-forging. The industry has had difficulty in importing certain American equipment, such as Ceco air-lift or steam-lift gravity drop hammers, horizontal upset forging machines, vertical forging presses, specialised die-sinking plant, Buffalo shears for cold cropping billets, and die-burrs, because of import restrictions.

THE LIME GROVE TELEVISION STUDIOS OF THE BRITISH BROADCASTING CORPORATION.

THE premises of the British Broadcasting Corporation at Lime Grove, Hammersmith, London, were acquired early in 1950 to meet the expanding demands of the television service and have since been modified to accommodate five studios, three of which are now in regular use.

One of these studios, which is used for the children's programme, has an area of 2,800 sq. ft. and is equipped with vision apparatus, manufactured by Electric and Musical Industries, Limited, Hayes, Middlesex. This equipment was used for televising the Olympic Games in 1948 and has since been constantly employed for other outside broadcasts. It consists of three studio cameras, containing C.P.S. Emitron tubes, each of which has a three-lens turret, allowing viewing angles of 38.5 deg., 24 deg., and 16 deg. to be selected, as required by the producers. Two of these cameras are mounted on Vinten "Pathfinder" crane dollies and one on a De Brie rolling tripod. In addition, there is a "telecine" channel for inserting film sequences in the productions. The sound installation is composed of six studio microphones, four gramophone outputs and a film sound channel. Two microphone booms are used on the studio floor. The normal lighting load is about 100 kW. This enables an incident light value of between 100 and 130 ft. candles to be obtained, which is adequate for the average set. Under these conditions the approximate peak white brightness reflected from the scene is some 70 to 80 foot-lamberts.

The vision control rooms for this studio, one of which is shown in Fig. 1, opposite, are arranged so that the mixing control desks and picture monitors give the production team a frontal view through the window, instead of the usual side view. The producer, his secretary and the vision mixer sit at a desk immediately in front of the studio windows, while the senior engineer is at a second desk, which is mounted on a dais and contains monitoring equipment. A close-up view of this equipment is given in Fig. 2. The monitors can be speedily removed for servicing and above them are small spot lights so focused as to throw a good general light on documents on the desk, while leaving the other sections relatively dark. The double-glazed windows between the control rooms and the studio are tinted glass to prevent eye strain.

To simplify operation, the vision mixing equipment, which forms part of the control gear associated with the studio cameras, is installed in a separate apparatus room, but is remotely controlled from the vision control room. "Cuts" from one camera to another can thus be simply made by pressing the appropriate button. The outputs of two cameras can also be superimposed, the degree of superimposition being pre-set on one camera independently of the other and adjusted and checked on a pre-view monitor screen. The picture produced by this camera is then brought into the transmission chain by pressing a superimposition key, which automatically releases the camera formerly on transmission. A view in the apparatus room showing the camera control units and vision mixer in the centre, with the control unit for the telecine channel on the extreme left, is given in Fig. 3.

Originally, this studio was very sound absorbent, all the walls and the ceiling being covered with rock wool. To improve the sound quality, this material was subsequently removed from the main piers on both sides and from part of the ceiling, and the areas re-covered with hard board. Tests showed that as a result the reverberation time was increased by about 30 per cent. There has also been an appreciable acoustic livening. The studio is equipped with a ventilation plant consisting of air washing, heating and de-humidifying sections, of which some details are given below.

Of the other two studios now in use, one has an area of 5,400 sq. ft. and is primarily used for the production of drama. It is equipped with three E.M.I. cameras and six microphones and the total lighting power available is 120 kW. To reduce the noise, the original floor was removed and screeded with concrete. This concrete was then laid with wood blocks and covered with linoleum. The new floor is virtually silent but is slightly resilient, which is an advantage for certain classes of production. The third studio has an area of 6,000 sq. ft. and is equipped with vision apparatus manufactured by Messrs. Pye, Limited, Cambridge. This consists of four cameras, using Photicon pick-up tubes with a spare camera channel. Each camera is fitted with a four-lens turret allowing viewing angles of 37 deg., 28 deg., 19 deg. and 10 deg. to be employed. Two of these cameras are mounted on De Brie rolling tripods, one on a Vinten "Pathfinder" crane dolly, and the fourth on a Vinten crane power-operated dolly. There is also a telecine channel. The sound apparatus in this studio consists of six microphones, four gramophone outputs and one film sound channel for use with the telecine equipment. Spare amplifiers in any

* See vol. 169, page 508 (1950).

LIME GROVE TELEVISION STUDIOS.

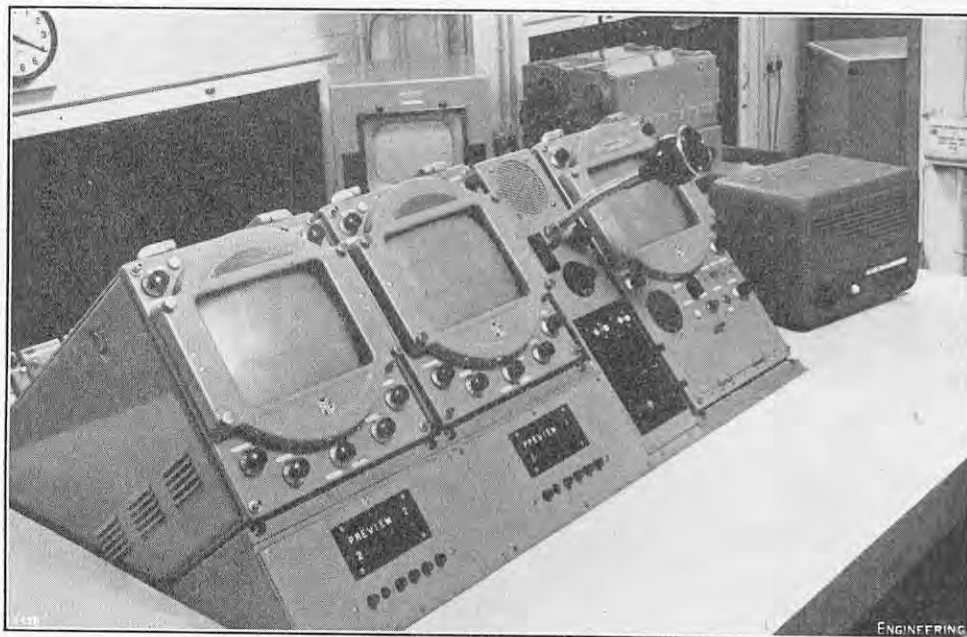


FIG. 1. VISION CONTROL ROOM.

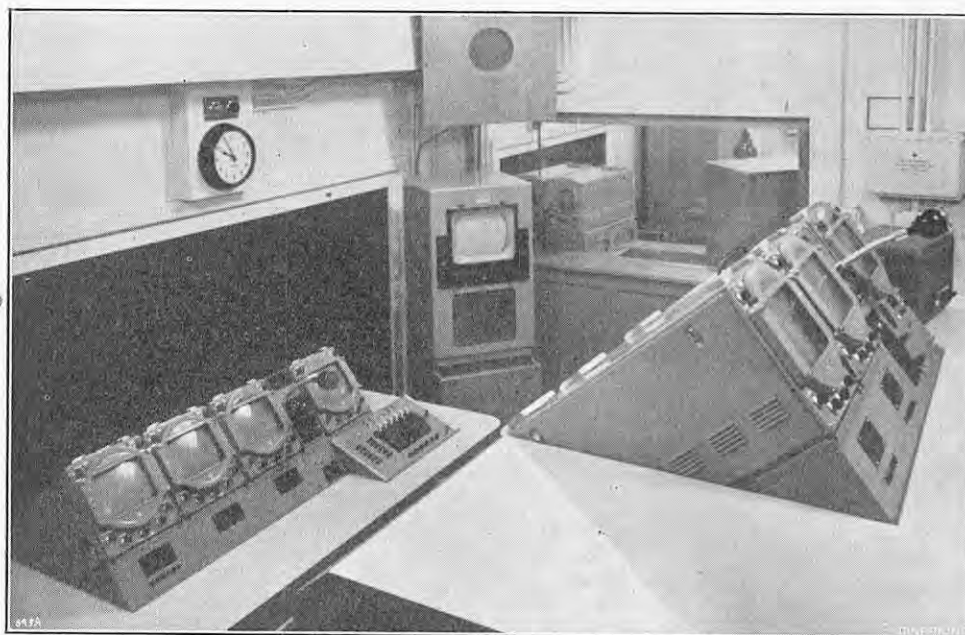


FIG. 2. ENGINEER'S MONITORING DESK.

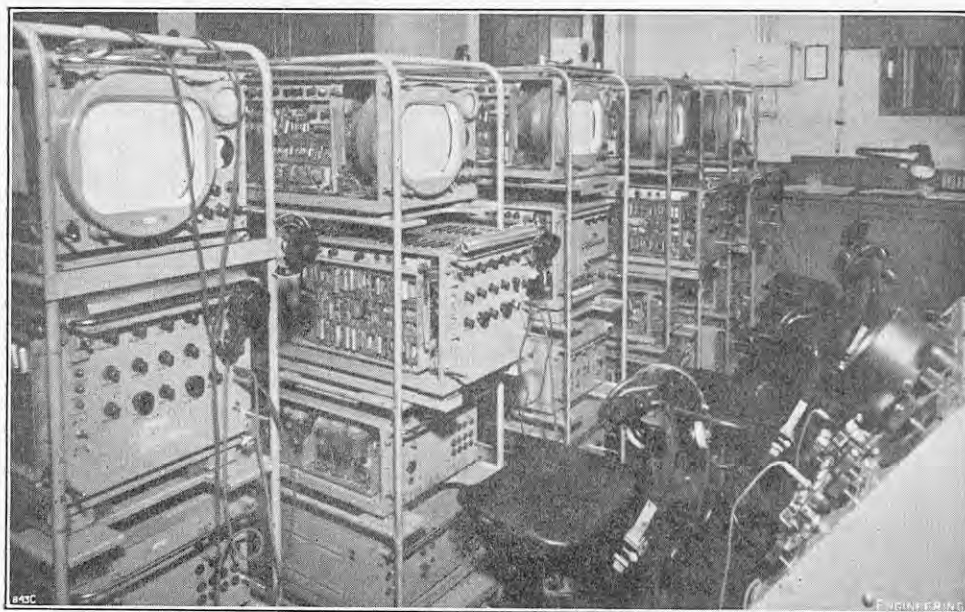


FIG. 3. APPARATUS ROOM.

channel can be brought into action immediately by throwing a key, and the echo on the microphone outputs can be varied by rotary switches on the control desk.

There are separate sound and vision control rooms for this studio. These rooms are separated by a glass window, which can be opened or closed by a motor, thus enabling the sound and vision groups of the production team to work as a single unit or separately. About 250 kW of lighting are available, giving from 130 to 200 foot-candles on normal settings, while the average peak white brightness reflected from the scenes is between 100 and 170 foot lamberts. The studio is equipped with air-conditioning plant, which, like that mentioned above, was manufactured by the Carrier Engineering Company, Limited, London, S.W.1. It consists of a pre-heater over which fresh air is drawn. After being cleaned, this air is then passed through cooling coils, which are supplied with chilled water from a refrigeration plant, and then through the main heater battery, which is fed with steam at 50 lb. per square inch. Two delivery fans, each with an output of 150,000 cub. ft. per minute, then pass the air to a cork-insulated ring duct in the studio, from which it is extracted by two similar fans. The air flow is controlled by 23 groups of louvres, each group being fitted with an air-operated damper. These dampers are operated from a central control panel so that the air can be delivered over the whole floor area or concentrated over any portion. The chilled water for the cooler is obtained from a steam-driven absorption refrigeration system. This plant has a capacity of 150 tons per hour and is completely automatic in operation, control being effected by thermostats which operate motor-driven valves in the chilled-water and steam supply lines.

The sound and vision outputs from the studio in use are transmitted to banks of relays in a lines termination room. These relays can be operated either locally or from the studio vision control room of any studio, interlocks being provided so that not more than one studio can be connected at a time to Alexandra Palace and the other television transmitters at Sutton Coldfield, Holme Moss and Kirk O'Shotts. The necessary power supplies for operating the studios are obtained from the British Electricity Authority at 6.6 kW through duplicate three-phase feeders. This supply is stepped down to 415 volts in 1,500 kVA transformers, the secondaries of which are connected to the motors of four 125-kW and two 250-kW motor generators. The generators of these sets supply direct-current at 115 volts.

As regards future developments, it is hoped to provide three 35-mm. telefilm recording channels by the end of the present year. At a later date a further studio, equipped with four Marconi Image Orthicon camera channels, will be brought into service, thus adding a further 4,800 sq. ft. to the production area. This will be followed by a central telecine suite, comprising seven 35-mm. and five 16-mm. channels. There will also be a new central presentation suite, which will include a continuity studio equipped with two Pye Photicon cameras for announcements. New central control and apparatus rooms will replace those at Alexandra Palace, and there will also be separate control room for rehearsals, as well as a quality checking room. At a still later date the fifth and largest studio, which has a floor area of 9,600 sq. ft., will be equipped.

BUILDING MAINTENANCE LICENCES FOR MACHINERY INSTALLATION.—The Ministry of Works draw attention to an extra facility now provided by annual maintenance licences. Arrangements can now be made for these licences to cover minor works of alteration consequent on the installation of new machinery and on the transfer of machinery from one factory to another, besides (as hitherto) on transfers in the same factory. Current licences will be amended on application to the Ministry's Regional Licensing Officers.

STANDARD METHOD FOR DIMENSIONING AERO-ENGINE COMPRESSOR BLADES.—In order to expedite the production of compressor blades for aircraft gas turbines, the Engine Standardisation Panel of the Society of British Aircraft Constructors has issued a specification for a dimensioning system, entitled "A Standard Method of Dimensioning Compressor Blades," which lays down the minimum information which must be given by the blade drawings, and how the various dimensions should be set out. It defines the method of specifying tolerances for the blade profile, the blade thickness, the position of the datum point from which the measurements are set out, the angular displacement of the blades, the leading-edge position, and the surface smoothness. Hitherto, each engine company has been using its own methods of dimensioning, and consequently the aluminium-forging companies producing the forgings have had to interpret different layouts for each type of engine. The lack of standardisation in specifying tolerances has also slowed down the inspection of blades by officials of the Aeronautical Inspection Directorate. The wide use of subcontracting also renders a high degree of standardisation desirable.

TWIN-ENGINED DIESEL TRAINS.

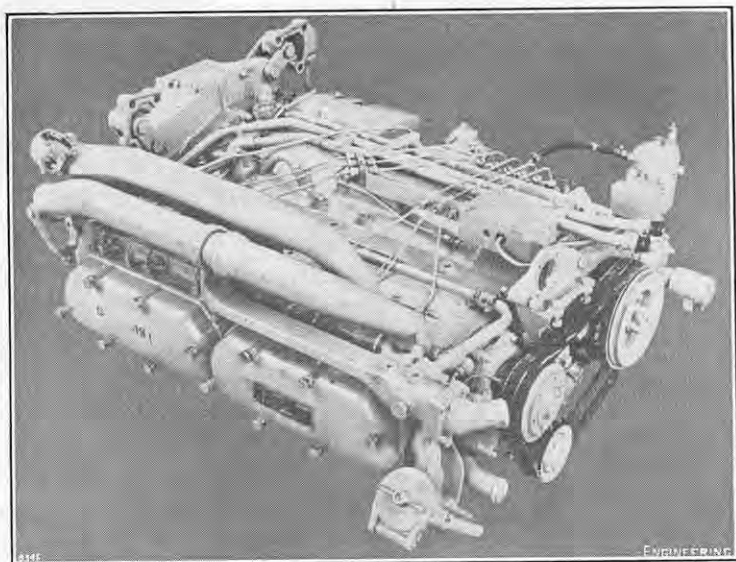


FIG. 1. LEFT SIDE OF LEYLAND 125-H.P. HORIZONTAL DIESEL ENGINE.

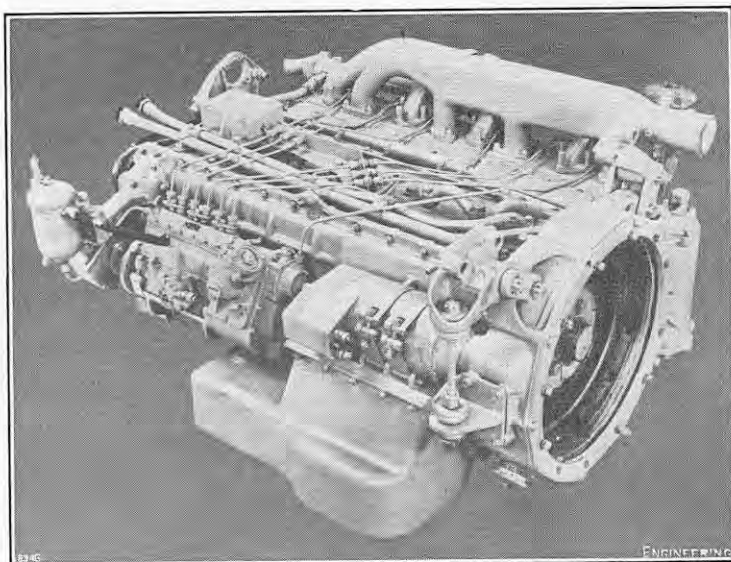


FIG. 2. RIGHT SIDE OF ENGINE.

Fig. 3.

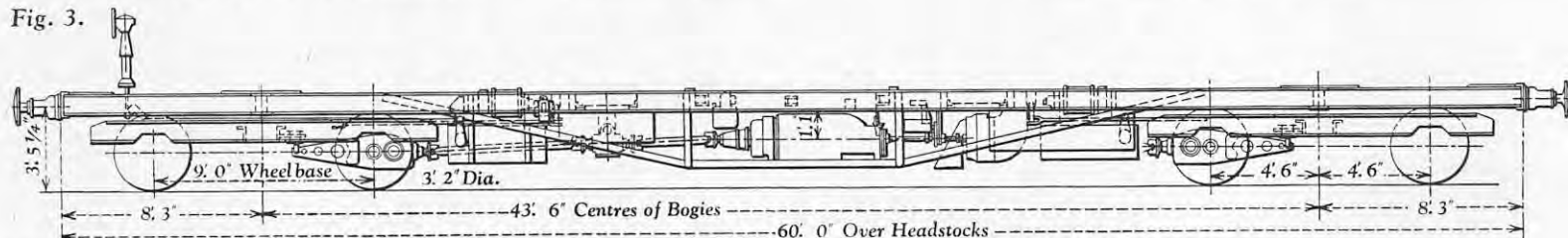
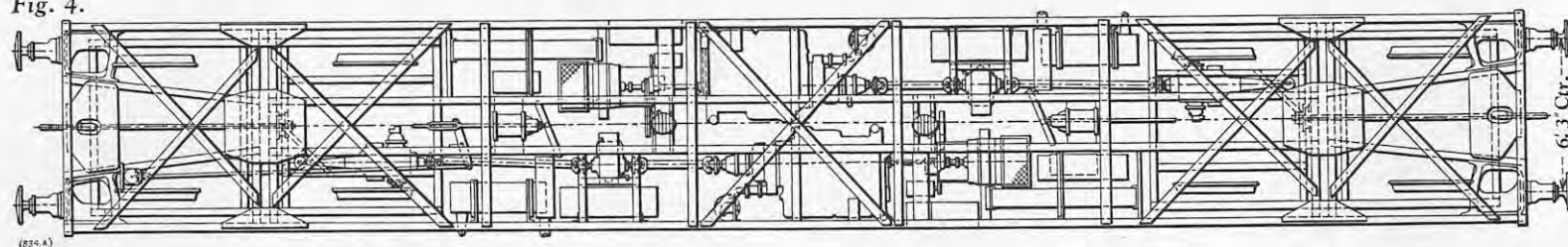


Fig. 4.



MULTI-ENGINED DIESEL TRAINS FOR ULSTER.

THE use of multiple Diesel engines for passenger trains has been carried a stage farther by Leyland Motors, Limited, Leyland, Lancashire, Messrs. Walker Brothers (Wigan), Limited, and the Engineering Department of the Ulster Transport Authority, and has resulted in the perfecting of control gear capable of synchronising and controlling the power output of eight Leyland flat Diesel engines (Figs. 1 and 2, above), giving a total output of 1,000 h.p. and capable of propelling a train of six to eight coaches, weighing 185 to 225 tons, at 73 miles per hour over average rail track formation. This development is thought to be the first application of the use of multi-powered units to such an extent in rail traction. The method of controls allows the driver to stop or start each engine and gives visual indication while the train is travelling as to whether each engine is running or stopped.

The first of the six-coach trains is composed of converted centre-corridor bogie carriages, and comprises four twin-engined coaches and two non-powered intermediate coaches. All the power plant is accommodated in the underframes, leaving the entire floor area free for seating, etc.; there is only one driver's control position in each powered coach. The general arrangement of the underframes is shown in Figs. 3 and 4, above, and in Fig. 9, on Plate XX. Various combinations of trains can be arranged; two powered coaches form the smallest unit.

Two Leyland 125-h.p. horizontal Diesel engines are used for each powered coach, the transmission units being the products of Messrs. Walker Brothers and Leyland Motors, Limited. The two flexibly-suspended engines are arranged symmetrically on each side of the longitudinal centre-line, each engine driving the inside axle of one bogie. Provision is made for the removal of the engine through valances for overhaul (Fig. 5). The drive from each engine is taken through a Lysholm Smith (Leyland) torque converter and short universally-jointed propeller shaft to an auxiliary gearbox, and thence by a similar propeller shaft to the final

drive on the axle. The final drive is of the double-reduction and reverse type and comprises a bevel pinion in constant mesh with two bevel gears. The bevel gears have internal spur teeth. The layshaft incorporates a spur pinion, the teeth of which mesh with one or the other set of internal teeth of the bevel gears, and so determine the direction of rotation. Also in constant mesh with the spur pinion is a second spur gear pressed on to the driving axle. Each radiator is divided into three sections, one each for engine cooling water, engine oil, and torque-converter fluid.

All the controls are electro-pneumatically operated, the current being supplied by two 24-volt 222-ampere-hour batteries. The controls comprise engine speed control, clutch control, and forward and reverse control. The engine speed is controlled by small air cylinders. Each engine has its own speed control unit, which gives four engine speeds in addition to the normal idling speed. One group of four magnet valves supplies the air for the two control units in each powered coach. The clutch is controlled by an air cylinder built on to the torque converter. Three clutch positions are obtainable, namely, neutral, converter drive and direct drive. Air is admitted through two magnet valves adjacent to each converter. In order that the speed of the train may exceed the speed of the engines when necessary, two free-wheels are incorporated in the torque converters, one for the converter drive and one for direct drive. Forward or reverse direction of the train is obtained by air-actuated pistons in cylinders mounted on each final-drive housing, the pistons operating the forward-and-reverse sliding pinions. The flow of compressed air is controlled by two electro-pneumatic valves, and two switches are fitted to cut off the feed to the electro-pneumatic valve when the layshaft spur pinion is fully engaged with the internal spur teeth. These are also arranged in a circuit to give the driver a clear indication by indicator lamps that the sliding pinions have been properly positioned for the desired direction. In the event of a forward-and-reverse sliding pinion creeping out of gear, air is automatically re-applied to restore it to the correct position. Fig. 10, on Plate XX, shows the auxiliary

gearbox; Fig. 11 shows the final drive and Fig. 8 the general arrangement.

If the oil pressure of an engine should drop below a predetermined figure, or if the water level in the radiator header tank should fall below safety level, that particular engine is automatically stopped by an isolating switch and its clutch returned to neutral. The driver will have warning of this by indicator lamp. The starter of the engine cannot be re-engaged until the fault has been rectified. The advantage of this device is that, should the trouble occur while the train is in motion, the driver can continue to his destination on the remaining seven engines.

The driver's controls (except brake controls) were made by Sharp Control Gear, Limited, 24, Redditch-road, Birmingham, 30, and consist of electric switches which operate the various magnet valves throughout the train. The switches are grouped together on a control table in each powered coach. The engine speed control is operated by the driver's left hand and gives four engine speeds, in addition to idling. The "dead-man's" device is incorporated in this unit. Should the driver unconsciously release the handle, all the engines are returned to idling speed, the clutches are returned to neutral, and, after a five-seconds delay, the brakes are automatically applied. The return of the clutches into neutral prevents the stalling of the engines. The clutch control has five positions, i.e. "handle off," "neutral," "converter drive," "direct drive" and a "test" position. Only in the neutral position is it possible to start the engines or change the direction of the train. The "test" position is provided for the maintenance staff. The direction control has two positions only, i.e. forward and reverse.

Shunting controls are provided at each side of the driver's cab. They consist of engine-speed controllers which give two speeds only and are operative only in converter drive. The feed to all the controls is effected by an interlocking control switch on the table. Movement of the handle to the left or right selects either battery in that powered coach to feed the control system, and by removing the handle in that position the control switches in all other driver's compartments

TWIN-ENGINE DIESEL RAILCAR.

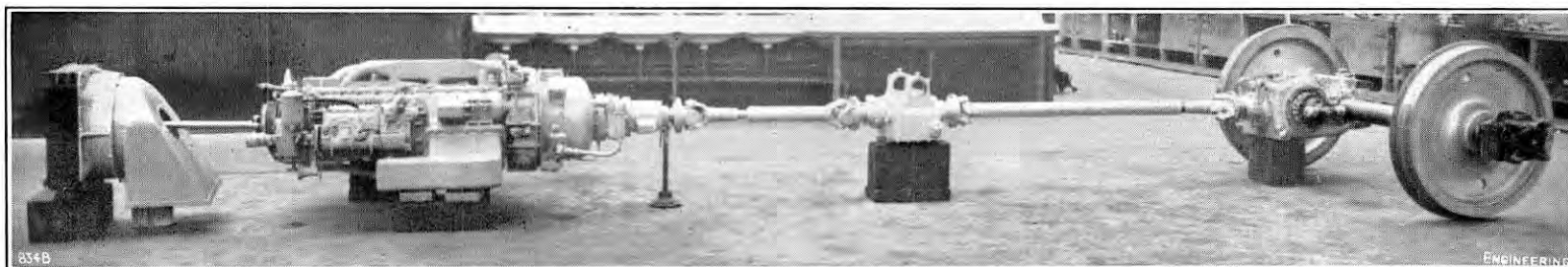
(For Description, see Page 520.)

FIG. 8. ARRANGEMENT OF POWER AND TRANSMISSION UNITS.

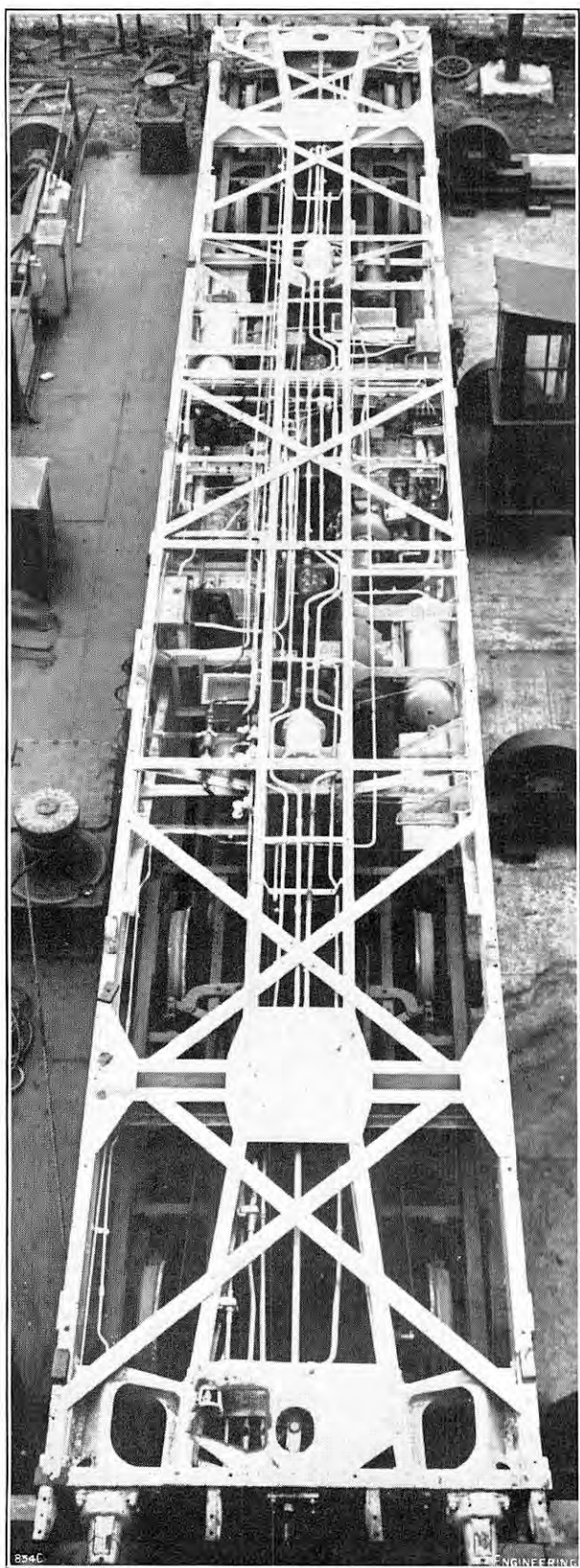


FIG. 9. RAILCAR CHASSIS.

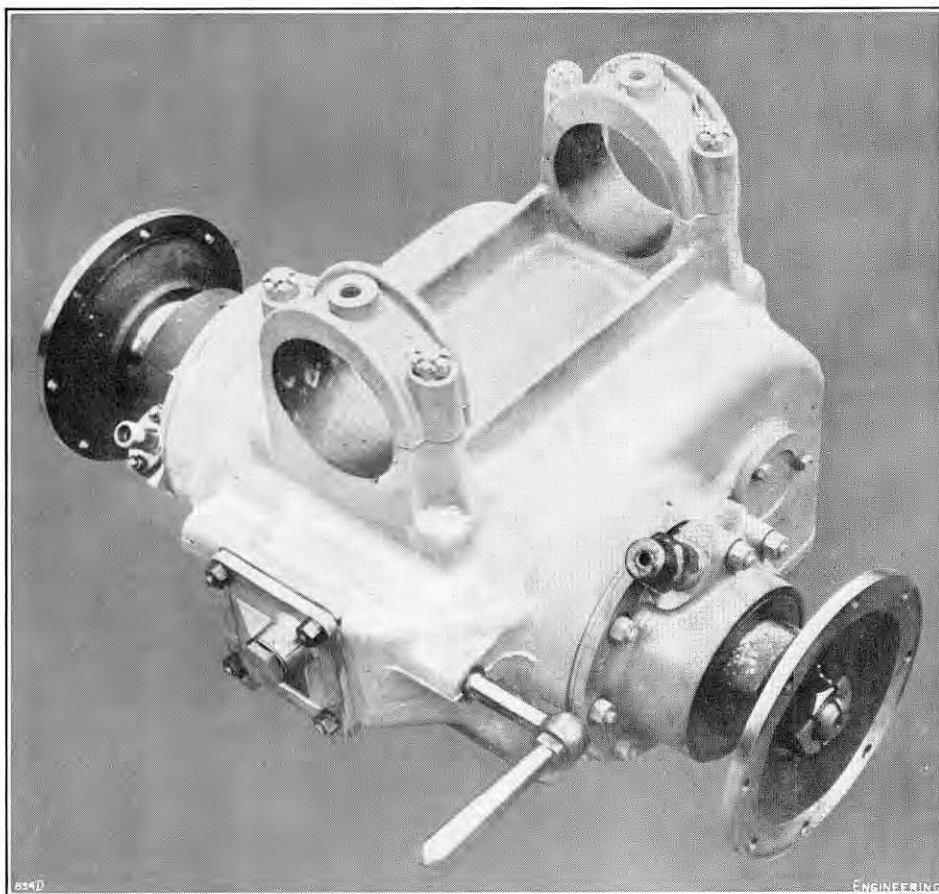


FIG. 10. AUXILIARY GEARBOX, WITH HANDLE FOR HIGH AND LOW GEARS.

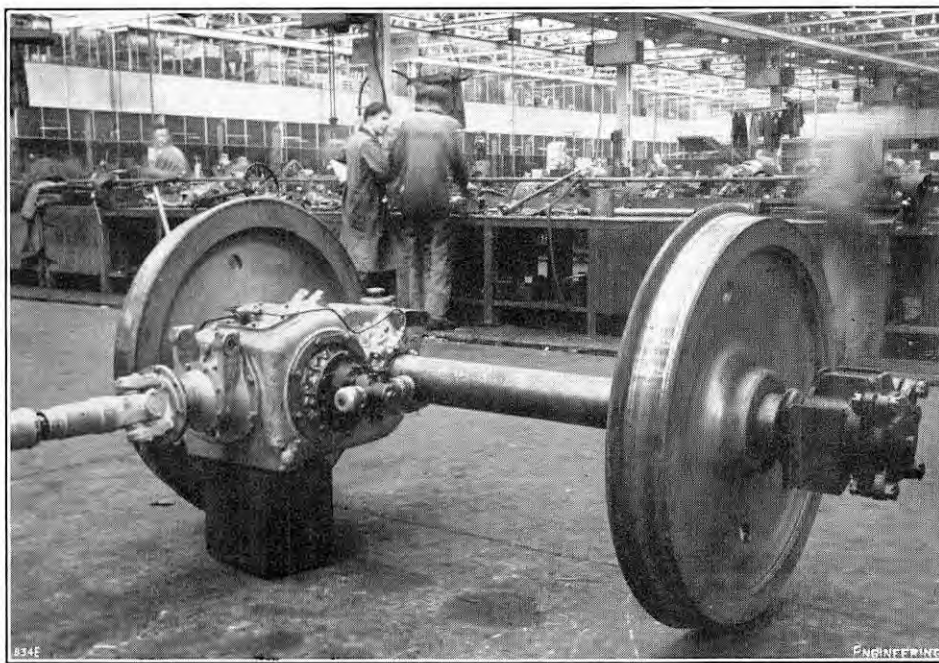


FIG. 11. DOUBLE-REDUCTION FINAL DRIVE.

TWIN-ENGINED DIESEL TRAINS.

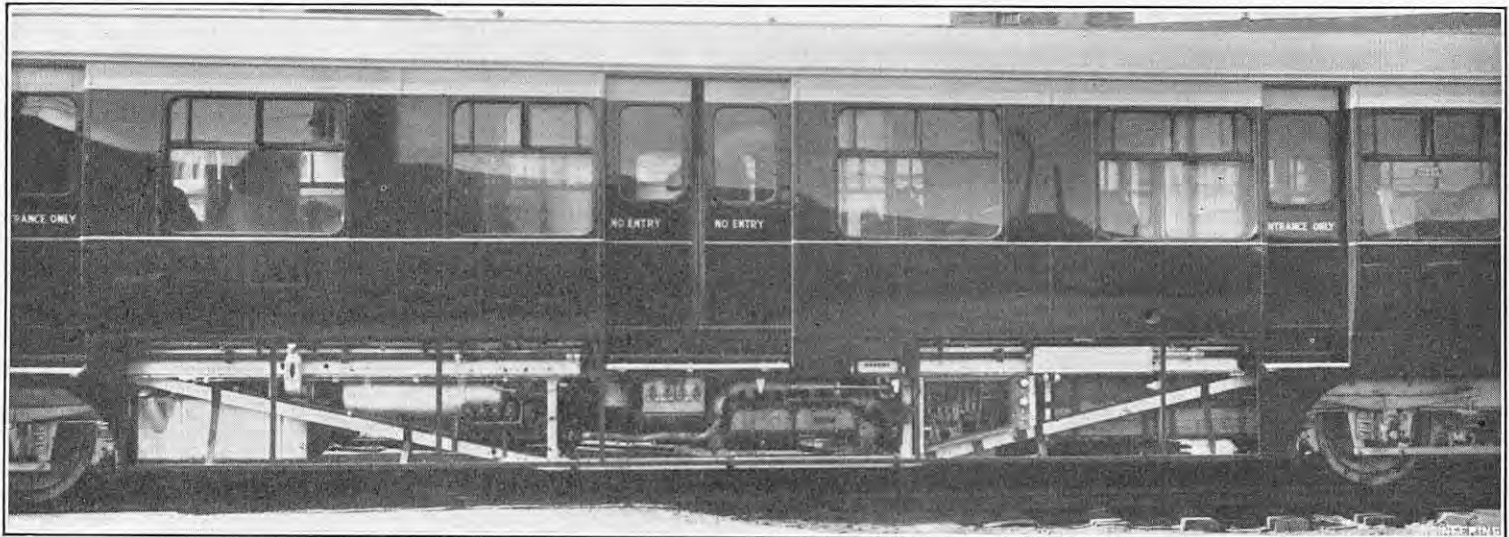


FIG. 5. CAR WITH VALANCE REMOVED, SHOWING ENGINE AND CONTROL BOX.

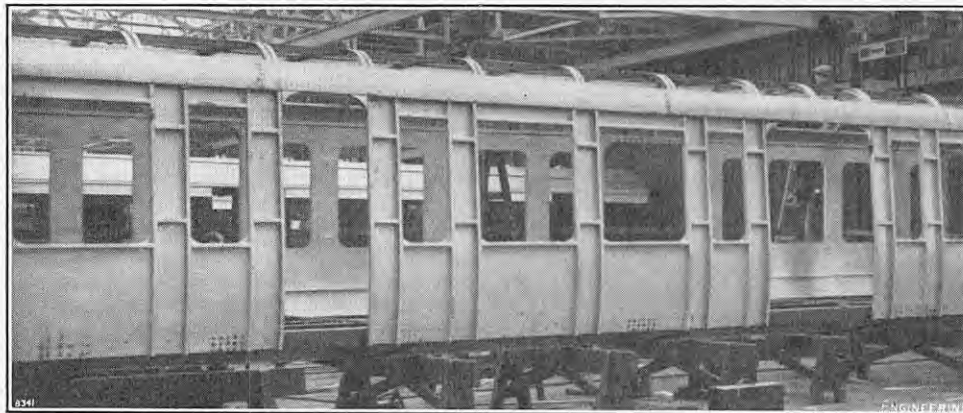


FIG. 6. LIGHTWEIGHT CAR UNDER CONSTRUCTION.

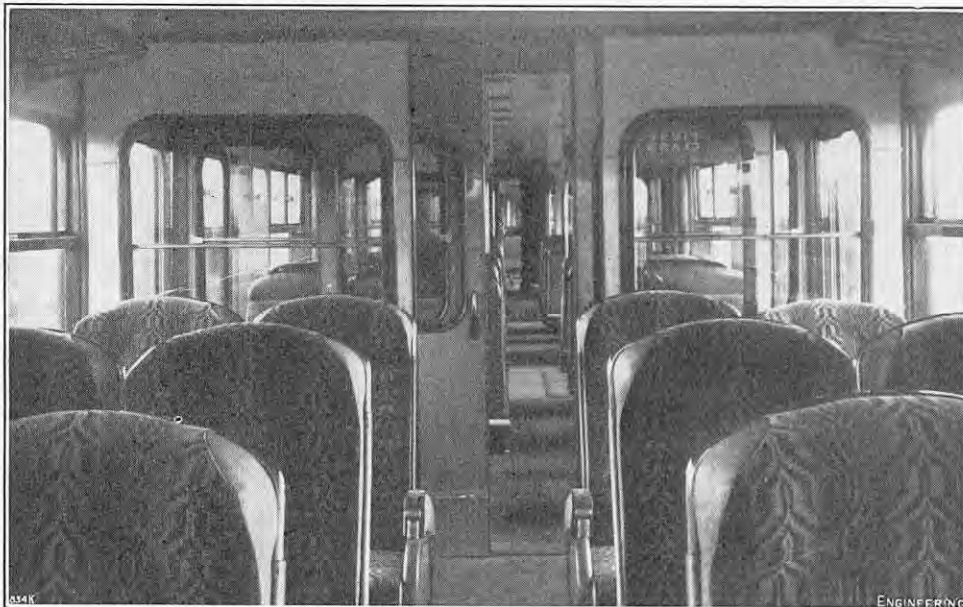


FIG. 7. FIRST-CLASS COMPARTMENT.

in the train are locked and no unauthorised person can interfere with them.

The brake system is the Westinghouse straight air brake on which is superimposed electro-pneumatic application equipment to give simultaneous application throughout the train. An emergency brake, controlled by the driver's brake valve, operates on a reduction of pressure in the emergency pipe. Emergency brake applications can also be made from the engine speed controller.

The powered coaches are heated by the engine cooling water in two separate open-circuit systems, each engine supplying heat to one-half of the coach. When an engine reaches its normal running tempera-

ture the thermostat opens and the hot water is pumped through gilled tubes along the sides of the coach. If the water temperature on the return is too high, another thermostat opens and allows it to pass through the radiator before finally returning to the engine. The non-powered intermediate coaches are heated by means of a hot-water gravity system. In the centre of each coach a magazine type of hot-water boiler is installed; it is fired with either coke or anthracite.

The total seating accommodation in the first six-coach train is 48 first-class and 346 standard-class seats, but in the lightweight steel trains accommodation will be provided for 32 and 430 first-class and standard-class passengers, respectively. Fig. 7, herewith, shows the

interior of a first-class compartment. The outside sliding doors (shown in Fig. 5, above) are operated by long-stroke air cylinders mounted in spherical bearings above each doorway, two such cylinders being employed for the double doors. Low-pressure air for operating these is obtained from the braking system.

A number of the vehicles for the remaining trains are being constructed in lightweight steel of integral design. The manufacture and prefabrication of the assemblies are being carried out by Messrs. Metal Sections, Limited, Oldbury, and the erection, installation of equipment, etc., are being carried out in the Authority's workshops. Fig. 6, above, shows a lightweight vehicle under construction. In order to save weight and thus give better performance, it has become necessary to design railcars and railway coaches in such a way that the body structure shall be load-carrying. The loads are in the form of end loads or buffing shock, and the vertical loads are the sum of the passengers, structure and equipment. These lightweight coaches are therefore of "integral design," i.e., the entire body has been designed as a load-carrying structure. The presence of windows and doorways necessitated the transference of stress from the body side girders to the load-carrying roof members, which are suitably stiffened over the doorways. The base of the body structure has two main longitudinals, 12 in. deep, made from $\frac{3}{8}$ in. plates built into H-sections by the addition of 14 s.w.g. cold-rolled angles at either side, top and bottom. These longitudinals run between the bogie centre members, from which diagonals of similar construction run out to the headstocks.

The bogie centre members are formed from two folded channels plated top and bottom to form one unit and reinforced to carry the bogie centre and side friction blocks. Cross-members constructed in the same manner as the longitudinals, but with plates and top-hat sections above and below the H-section, intersect the longitudinals at four places and connect the side-soles together. The side-soles are made from $\frac{1}{2}$ in. steel formed into channels 6 in. deep and the cross-members are tapered at the outer ends to suit the depth. Corrugated 16 s.w.g. steel flooring is riveted to the top of the base members, and the floor will be covered with an ample thickness of cork. The interior design of the coaches is similar to those comprising the first six-coach train already described, with slight alterations in the sizes of compartments and positions of the doorways. The body pillars, light rails and cant-rails are of a special 14-s.w.g. channel section. The bottom of the pillars, and the 14-s.w.g. truss panels which are continuous from doorway to doorway and extend downwards from the waist rails, are riveted to the side-soles. The roof sections, built with 16-s.w.g. car-lines and Z-section purlins, are fastened to the cant-rails with angles. Continuous truss panels on the outside and truss panels above the doorways on the inside are riveted to the cant-rails, the car-lines and the first roof purlin, which is a channel section similar to the pillars. This method of construction, together with the roof panels, which are solidly riveted to the roof sections, provide the body structure with the necessary stability. The framework of all interior partitions, sliding doors and door pocket screens is made from light-gauge square steel tubes. All exterior panels are of 16-s.w.g. aluminium alloy and are pop-riveted to the structure, with the exception of the roof panels which, as stated before, are solid riveted.

NOTES FROM THE INDUSTRIAL CENTRES.

SCOTLAND.

MECHANICAL ENGINEERING RESEARCH.—Mr. T. C. Crawhall, assistant director of the Mechanical Engineering Research Laboratory at East Kilbride, outlining the progress of the development of this venture in an address to the Incorporated Plant Engineers in Glasgow on April 15, said that the Engineering Division of the National Physical Laboratory, at Teddington, had ceased to exist as such, the bulk of the staff and equipment having been transferred to Scotland. The team working on engineering metrology were in the process of moving north, but that doing research on the creep of metals would remain at Teddington for probably two years, pending the erection of a special building. Until the new laboratories for hydraulic machinery and heat-transfer research, the first of their kind in the country, were built, a limited amount of work in these fields was shortly to begin in the available space at East Kilbride.

"ATOMIC" OR "NUCLEAR" BOMB?—Sir Lawrence Bragg, Cavendish Professor of Experimental Physics, Cambridge University, giving the 1952 Keith Lecture in Edinburgh on April 2 pointed out that "atomic" energy and "atomic" bomb were really misnomers, and pleaded for the word "nuclear" to be substituted.

MEMORIAL TO J. L. BAIRD.—A bronze plaque to the memory of John Logie Baird, pioneer of television, set in the wall of the house in Helensburgh where he was born, was unveiled on April 15 by the Provost of Helensburgh, Mr. W. B. Lever. Mr. Lever pointed out that the house was the first in Helensburgh to be fitted with electricity, Baird having run a dynamo by means of a tap in the kitchen sink. It was also the first in the town to have a telephone, Baird having rigged up a line across the road to a friend's home.

BALLOON FOR COSMIC-RAY RESEARCH.—Photographic equipment from a cosmic-ray balloon, launched on April 8 from a site in Ayrshire by Professor C. F. Powell and a team of research physicists from Bristol University, was found in Berwickshire on April 10. The balloon is believed to have reached a height of 96,000 ft.

GASHOLDER TO BE BUILT AT NEWTON-ON-AYR.—A new gasholder of 3,000,000 cub. ft. capacity is to be constructed at Newton-on-Ayr to serve Ayr and Prestwick. The estimated cost is 155,000l., and work is expected to commence in 1954. The height of the gasholder will be restricted to 165 ft. on account of its proximity to the Prestwick and Heathfield airfields.

AGRICULTURAL-MACHINERY FACTORIES AT EAST KILBRIDE.—An official of the East Kilbride Development Corporation said on April 17 that the John Deere agricultural-machinery factories in the new town would be ready before the end of next year if the building work, which Scottish Industrial Estates, Ltd., had been authorised to start as soon as the company were ready, were put in hand at once. The work would be speeded up to compensate for the delay of three months caused by steel shortage.

SALE OF OLD PADDLE FERRY STEAMER.—The sale of the 28-year-old paddle steamer Sir William High has been recommended by the Dundee Harbour Board Tay Ferries Committee. The vessel has not been in use for the past six months—since the new Diesel ferry Scots-craig went into service—and, moreover, there is another vessel available.

COAL EXPORTS.—Scottish coal exports declined during March, to 51,936 tons, as compared with 57,146 tons in the corresponding month last year, the first set-back since shipments began to expand in November, 1951. The principal reduction occurred in consignments to Eire, which declined to 5,959 tons, as compared with 10,510 tons in March, 1951. The total exports for the first three months of this year aggregated 135,102 tons against 135,116 tons in the corresponding quarter of 1951.

CLEVELAND AND THE NORTHERN COUNTIES.

REORGANISATION SCHEME AT A WALLSEND SHIPYARD.—Swan, Hunter, and Wigham Richardson, Ltd., the Wallsend shipbuilders, are about to commence work on an important berth-reorganising scheme which will permit them to cope more easily with the construction of vessels of 30,000 tons and upwards. Four existing shipbuilding berths will be replaced by two large berths and the work will take two years to carry out. At the

company's Wallsend and Walker yards there is a total of about 550,000 gross tons of shipping on order, half of which consists of tankers.

INDUSTRIAL PROSPECTS ON THE NORTH-EAST COAST.—The annual report of the Newcastle-on-Tyne and Gateshead Chamber of Commerce states that North-East Coast shipbuilding and engineering firms have been fully employed and that during 1951 substantial orders were received for ships and machinery. Towards the end of the year, however, the steel position began to cause anxiety and, with the emphasis on export and rearmament work, those firms which specialise in the home market have been adversely affected. The report adds that it is difficult to forecast the future position. Every industry has to face rises in costs of labour, transport, coal and electricity, all of which make the export trade more difficult.

CRITICISMS OF B.I.F. PUBLICITY.—A British Industries Fair supplement of the *Board of Trade Journal* has aroused criticism in the North-East for its failure to mention that area. The supplement dealt with regional contributions to the Fair and the "Northern Section" dealt only with Yorkshire and Lancashire. Northumberland, Durham and Cumber-land were not mentioned.

DEVELOPMENT CHARGES ON INDUSTRY.—The Rural Council of Alston, Cumberland, which recently passed a resolution urging the removal of development charges on industry, has been informed that this matter is being considered by the Government. In a letter to Mr. R. Donald Scott, the local Member of Parliament, the Minister of Housing and Local Government stated that, although the development charge is not popular with industrialists, there is no evidence that it is having a serious effect on the productive capacity of industry.

LANCASHIRE AND SOUTH YORKSHIRE.

CHROMIUM STEELS.—The shortage of alloying elements has necessitated a revision of the types of steel which Sheffield steelmakers manufacture. Some stainless steels are being made without the use of nickel, which is needed for the rearmament programme, and there has been a switch to "straight" chromium steels for many products. It is recorded that the average monthly production of straight chromium steel by Samuel Fox & Co., Ltd., Stocksbridge, rose from 8.8 per cent. of the total stainless-steel production in 1949 to about 26 per cent. in the last few months of 1951.

EXPORT COAL.—Recent increases from deep mines in the coalfields of the area have resulted in an increase in the export allocations. Yorkshire miners returned to work very satisfactorily after the Easter holidays; the average attendance on the Wednesday after Easter was 80 to 85 per cent., while at some Doncaster pits it was as high as 90 per cent. This was a marked improvement on the record of Easter last year.

"CENTURION" TANK VISITS SHEFFIELD.—Nine Sheffield steel and engineering works have had a "courtesy" visit from a Centurion tank and its crew of Korean veterans to afford Sheffield workpeople an opportunity of seeing how their products are utilised in modern warfare. A detachment of nine men and an officer, as well as distinguished military visitors, were equally interested in seeing how Sheffield makes the armour plate, gun turrets, bogie wheels and many other components of a Centurion. The visits to works were preceded by a civic reception.

SHEFFIELD AIRPORT BAN.—The Commercial Aviation Committee of the Sheffield Chamber of Commerce has recommended the Chamber to support the Sheffield City Council in its fight against the ban imposed upon the setting up of an airport at Redmires, Sheffield. Local M.P.s have been asked to co-operate. It is claimed that the lack of airfield facilities has compelled some overseas businessmen to cut Sheffield out of their itineraries.

THE MIDLANDS.

RIVER POLLUTION.—Mr. D. H. A. Price, chief chemist to the Severn River Board, addressing a joint meeting of the Institute of Sewage Purification and the Institute of Water Engineers in Birmingham on April 17, said that river pollution in the Midlands at present was worse than in any other part of the country. He instanced the river Avon, which, he said, was now so bad that Coventry had to seek water elsewhere. Mr. Price said that, bad as the situation was, it was likely to become more difficult in the future. The demand for water was increasing and the time was coming when increased supplies would have to be taken from the rivers. The prevention of pollution therefore became of greater importance as time went on, and managements should give special attention to the question of discharging wastes into rivers.

ANOTHER MUNICIPAL SCRAP COLLECTION.—The sanitary department of Dudley (Worcestershire) town council have recently arranged canvassing visits to 1,200 houses in the borough, and 14 tons of assorted scrap, mainly steel and cast iron, have been collected. There are 16,000 properties in the town, and it is expected that the target figure of 100 tons will be reached.

PEDESTRIAN-CONTROLLED TRAFFIC LIGHTS.—Pedestrian-controlled traffic lights, which will be the first in the Black Country, are to be installed at three points on the Birmingham-Wolverhampton trunk road. The road, which was opened in 1927 to enable traffic to by-pass the thickly-populated centre of the Black Country, has since been so built up that the accident rate has become severe. The divisional road engineer of the Ministry of Transport, Mr. J. E. Cardell, announcing the new development at Oldbury, through the outskirts of which the road passes, said that two of the existing traffic lights at road crossings would be converted from automatic time control to vehicle actuation.

FIRES IN PRE-FABRICATED HOUSES.—Three fires which have occurred recently in pre-fabricated houses on the Birmingham Corporation Maypole Estate have led to a demand for an inquiry into the cause, which is at present unknown. In addition, the residents of the estate are seeking an explanation for the rapid spread of the fires. One house was practically destroyed within seven minutes of the outbreak. A suggestion that the cause of the fires was faulty electric wiring has already been investigated by the Midlands Electricity Board, who checked the wiring of twenty similar houses on the estate. The investigation produced no evidence that the wiring was at fault.

SOUTH-WEST ENGLAND AND SOUTH WALES.

WELSH IRON AND STEEL PRODUCTION.—In March the production of steel in Wales was the highest since November, 1951, when it reached an all-time record. The output of steel ingots and castings was on a weekly average of 72,210 tons, only 40 tons below the average for November, and it compared with the February figure of 69,930 tons and with 68,180 tons in the corresponding month of last year. The weekly average output of pig iron rose from 23,560 tons in February to 26,860 tons in March. It was 26,040 tons in March, 1951.

POST-EASTER HOLIDAY COLLIERY ACTIVITY.—In spite of the holidays, miners at 79 of the 159 South Wales pits worked the voluntary Saturday shift on the day following Good Friday. This brought the production for the week up to 480,052 tons of saleable coal. This, although it showed a substantial drop from the previous "bull" week's output of 510,778 tons, was 34,000 tons higher than the output for the corresponding week of last year. Post-holiday absenteeism also showed a slight improvement. The average absenteeism, throughout the coalfield on the day work was resumed, was 22 per cent., compared with 23½ per cent. on the corresponding day last year, and with 30 per cent. at Christmas.

OPENCAST COAL SCHEMES AT BLAENAVON.—No further opencast coal schemes are in mind at present for Blaenavon, a representative of the Ministry of Fuel and Power has stated. He added, however, that, should a suitable area be proved, the coal would have to be recovered in the national interests.

ITALIANS IN TIN-PLATE WORKS.—A deputation from the Welsh Plate and Sheet Manufacturers' Association has returned to Swansea after a fortnight's visit to Milan where they recruited 192 more Italian workers for the tin-plate industry. These will increase the number of Italians employed in South Wales and Monmouthshire tin-plate works to 700.

DIESEL-ENGINE FACTORY, PEMBROKE.—The Pembroke County Council have announced that licences required for a new engineering factory have been granted after some delay. The factory is to be used for producing a two-stroke Diesel engine now required by the Admiralty under the defence programme. About 90 per cent. of the labour force needed for the factory will be drawn from local sources.

BRISTOL COALFIELD RE-OPENED.—Mr. H. Lyn Jones, M.C., deputy chairman of the South Western Division of the National Coal Board, formally started the work on the re-opening of the Bristol coalfield on April 21, on the site chosen for a new mine at Harry Stoke, near Filton. The Board some time ago sanctioned the construction of a number of mines in this area, at an estimated cost of some 216,000l. and an annual output of from 90,000 to 100,000 tons of coal is expected to result from this project, beginning in 1954. At one time there were 17 collieries in the district round Bristol but they were all closed about 50 years ago, because geological faults made the working of the seams uneconomic.

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.

INSTITUTE OF PRODUCTION ENGINEERS.—Sheffield Section: Monday, April 28, 6.30 p.m., Royal Victoria Station Hotel, Sheffield. "Fuel: Design for Economy," by Mr. D. H. Hayes. **Luton Section:** Tuesday, April 29, 7.15 p.m., Staff Canteen, W. H. Allen, Sons & Co., Ltd., Queen's Engineering Works, Bedford. "Electric Welding in General Engineering," by Mr. R. T. Rolfe and Mr. A. Holmes. **Shrewsbury Section:** Wednesday, April 30, 7.30 p.m., Walker Technical College, Oakengates, Salop. "Pressed Metals," by Mr. J. M. Phillips. **Nottingham Section:** Wednesday, May 7, 7 p.m., Victoria Station Hotel, Milton-street, Nottingham. "Social Science as Applied to Industry," by Mr. F. A. Wells. **Norwich Section:** Wednesday, May 7, 7.30 p.m., Norwich City College, St. George's-street, Norwich. "Advance of Industrial Heat Treatment," by Mr. J. McHenry.

INSTITUTE OF PACKAGING.—Midland Area: Monday, April 28, 6.30 p.m., Imperial Hotel, Birmingham. Joint Meeting with the INSTITUTE OF EXPORT. Open Discussion. **Southern Area:** Thursday, May 1, 6 p.m., Waldorf Hotel, Aldwych, London, W.C.2. "Glass Containers," by Mr. E. J. Gooding. **Northern Area:** Monday, May 12, 6.30 p.m., Old Nag's Head Hotel, Manchester. "Multi-wall Paper Sacks," by Mr. G. M. Hobday.

ILLUMINATING ENGINEERING SOCIETY.—Leeds Centre: Monday, April 28, 7 p.m., Lighting Service Bureau, 24, Aire-street, Leeds, 1. Annual General Meeting. **Leicester Centre:** Thursday, May 8, 6.30 p.m., Offices of East Midlands Electricity Board, Charles-street, Leicester. Annual General Meeting.

JUNIOR INSTITUTION OF ENGINEERS.—Sheffield Section: Monday, April 28, 7.30 p.m., Co-operative Educational Centre, 201, Napier-street, Sheffield, 11. Various short lectures. **Midland Section:** Wednesday, May 7, 7 p.m., James Watt Memorial Institute, Birmingham. "Sintered Oil Retaining Bushes and Bearings," by Mr. A. E. Mapstone.

INCORPORATED PLANT ENGINEERS.—West and East Yorkshire Branch: Monday, April 28, 7.30 p.m., The University, Leeds. "How a Technical Knowledge of Timber Can Help a Maintenance Engineer," by Mr. John Jowett. **London Branch:** Tuesday, May 6, 7 p.m., Royal Society of Arts, John Adam-street, Adelphi, W.C.2. "The Manufacture of Nylon Stockings," by Mr. H. J. Hall. **East Lancashire Branch:** Tuesday, May 6, 7.15 p.m., Engineers' Club, Albert-square, Manchester. Open Meeting. **Newcastle-on-Tyne Branch:** Thursday, May 8, 7.30 p.m., Roadway House, Oxford-street, Newcastle-upon-Tyne. "The Use of Low-Grade Fuel in Shell-Type Boilers," by Dr. E. G. Ritchie.

INSTITUTE OF ROAD TRANSPORT ENGINEERS.—Scottish Centre: Monday, April 28, 8 p.m., North British Hotel, Edinburgh. Annual General Meeting. **South Wales Group:** Friday, May 9, 7 p.m., South Wales Institute of Engineers, Park-place, Cardiff. "Chassis Frame Construction and Repair," by Mr. C. F. Cunningham.

INSTITUTE OF REFRIGERATION.—Tuesday, April 29, 5.30 p.m., Institution of Mechanical Engineers, Storey's-gate, St. James's Park, S.W.1. "Plastics from the Viewpoint of the Refrigeration Industry," by Dr. V. E. Yarsley.

INSTITUTION OF CIVIL ENGINEERS.—Yorkshire Association: Friday, May 2, 7 p.m., Royal Victoria Station Hotel, Sheffield. Annual General Meeting. "Preparing for and Surfacing of Roads," by Mr. S. M. Lovell. **Midlands Association:** Thursday, May 8, 6 p.m., James Watt Memorial Institute, Birmingham. Annual General Meeting.

INSTITUTION OF STRUCTURAL ENGINEERS.—Midland Counties Branch: Tuesday, April 29, 6 p.m., James Watt Memorial Institute, Birmingham. Annual General Meeting. **Lancashire and Cheshire Branch:** Tuesday, April 29, 6.30 p.m., College of Technology, Manchester. "Plasticity and Structural Design," by Professor J. A. L. Matheson.

INSTITUTION OF HEATING AND VENTILATING ENGINEERS.—Scottish Branch: Tuesday, April 29, 6.30 p.m., Engineering Centre, 351, Sauchiehall-street, Glasgow, C.2. "A Review of Current Research in Heating and Ventilating," by Mr. N. S. Billington.

SOCIETY OF INSTRUMENT TECHNOLOGY.—Tuesday, April 29, 7 p.m., Royal Society of Hygiene and Tropical Medicine, Manson House, 26, Portland-place, W.1. "Why the Human Operator?" by Dr. W. E. Hick.

INSTITUTION OF CHEMICAL ENGINEERS.—South Wales Graduates' and Students' Section: Tuesday, April 29, 7 p.m., University College of South Wales and Monmouthshire, Museum-avenue, Cathays Park, Cardiff. Annual General Meeting. "The Application of Planned Maintenance in Chemical Industries," by Mr. R. K. B. Lyne.

INSTITUTION OF NAVAL ARCHITECTS and INSTITUTE OF MARINE ENGINEERS.—Southern Junior Branch: Tues-

day, April 29, 7.30 p.m., Polygon Hotel, Southampton. "Rolling of Ships," by Professor A. J. Sims.

INSTITUTION OF WORKS MANAGERS.—West Yorkshire Branch: Tuesday, April 29, 7.30 p.m., Collinson's Café, Huddersfield. Annual General Meeting.

IRON AND STEEL INSTITUTE.—Annual General Meeting, Wednesday, April 30, Royal Institution, Albemarle-street, W.1, 9.45 a.m., Formal Business; 11.45 a.m., Hatfield Memorial Lecture on "The Flow of Metals," by Professor E. N. da C. Andrade. Wednesday, April 30, 2.30 p.m., and Thursday, May 1, 10 a.m. and 2.15 p.m., 4, Grosvenor-gardens, Westminster, S.W.1. Various Papers and Discussions. For further particulars see page 502, ante.

ROYAL SOCIETY OF ARTS.—Wednesday, April 30, 2.30 p.m., John Adam-street, Adelphi, W.C.2. "Amenities in Factory Design," by Mr. Walter R. Bennett.

INSTITUTE OF BRITISH FOUNDRYMEN.—London Branch: Wednesday, April 30, 7 p.m., Waldorf Hotel, Aldwych, W.C.2. Annual General Meeting. "Surface Finish and Design Sands," by Mr. F. Roy Pell.

BRITISH INSTITUTION OF RADIO ENGINEERS.—North-Western Section: Wednesday, April 30, 7.15 p.m., College of Technology, Manchester. "Very High Frequency Broadcasting: The Case for Amplitude Modulation," by Mr. J. R. Brinkley. **London Section:** Wednesday, May 7, 6.30 p.m., London School of Hygiene and Tropical Medicine, Keppel-street, W.C.1. "An Aerial Analogue Computer," by Dr. W. Saraga, Mr. D. T. Hadley and Mr. F. Moss.

INSTITUTION OF ELECTRICAL ENGINEERS.—Southern Centre: Wednesday, April 30, 7.30 p.m., R.A.E. Technical College, Farnborough. Open Meeting. Wednesday, May 7, 6.30 p.m., Royal Beach Hotel, Portsmouth. "Technical Colleges and Education for the Electrical Industry," by Dr. H. L. Haslegrave. **South Midland Centre:** Monday, May 5, 6 p.m., James Watt Memorial Institute, Birmingham. "Railway Electrification in Great Britain," by Mr. C. M. Cock. **Measurements Section:** Tuesday, May 6, 5.30 p.m., Savoy-place, Victoria-embankment, W.C.2. "The Electricity Division of the National Physical Laboratory," by Mr. R. S. J. Spilsbury. **North-Western Centre:** Tuesday, May 6, 6.15 p.m., Engineers' Club, Manchester. Annual General Meeting. "The Design of High-Speed Salient-Pole Alternating-Current Generators for Water-Power Plants," by Mr. E. M. Johnson and Mr. C. P. Holder. **North Midland Centre:** Tuesday, May 6, 6.30 p.m., Offices of the British Electricity Authority, 1, Whitehall-road, Leeds, 1. Annual General Meeting.

INSTITUTION OF LOCOMOTIVE ENGINEERS and INSTITUTE OF FUEL.—Thursday, May 1, 5.30 p.m., Institution of Mechanical Engineers, Storey's-gate, St. James's Park, S.W.1. Joint Meeting. "The Railways and Coal," by Mr. R. G. Jarvis.

LEEDS METALLURGICAL SOCIETY.—Thursday, May 1, 7 p.m., Chemistry Department, The University, Leeds, 2. Annual General Meeting. Various papers by junior members.

INSTITUTION OF MECHANICAL ENGINEERS.—Friday, May 2, 5.30 p.m., Storey's-gate, St. James's Park, S.W.1. (i) "Dust and Fume in Industry," by Mr. R. Ashman. (ii) "Filter Efficiency and Standardisation of Test Dust," by Dr. H. Heywood. **London Graduates' Section: Tuesday, May 6, 6.30 p.m., Storey's-gate, St. James's Park, S.W.1. "Industrial Health Engineering," by Mr. R. J. Sherwood.**

INSTITUTE OF FUEL.—South Wales Section: Friday, May 2, 6 p.m., South Wales Institute of Engineers, Park-place, Cardiff. Annual General Meeting. **Midland Students' Section:** Monday, May 5, 7.30 p.m., The University, Edmund-street, Birmingham. Annual General Meeting and Film Evening.

ROAD ENGINEERING DIVISION: Tuesday, April 29, 5.30 p.m., Great George Street, S.W.1. "Mechanical Surfacing of Roads," by Mr. S. M. Lovell, Mr. E. W. W. Richards and Mr. T. U. Wilson.

ASSOCIATION OF SUPERVISING ELECTRICAL ENGINEERS.—Nottingham Branch: Friday, May 2, 7.30 p.m., Electricity Showrooms, Smithy-row, Nottingham. Film Evening. **Liverpool Branch:** Friday, May 2, 8 p.m., Liverpool Engineering Society, 9, The Temple, 24, Dale-street, Liverpool. Various short lectures.

INSTITUTE OF ECONOMIC ENGINEERING.—Glasgow Branch: Saturday, May 3, 10.30 a.m., The Christian Institute, 70, Bothwell-street, Glasgow. Open-Discussion Meeting. **London Branch:** Thursday, May 8, 7 p.m., The George Hotel, Church-lane, Kingsbury, N.W.9. "Material Handling as a Factor of Efficiency," by Mr. J. R. Smart. **Manchester Branch:** Friday, May 9, 7 p.m., Engineers' Club, Albert-square, Manchester. "Production Control as a Management Tool," by Mr. W. J. Worsdale.

CHEMICAL ENGINEERING GROUP.—Tuesday, May 6, 5.30 p.m., Geological Society's Apartments, Burlington House, Piccadilly, W.1. "Chemical Engineering and Atomic Energy," by Mr. C. M. Nicholls and Mr. A. S. White.

PERSONAL.

Mr. H. G. HERRINGTON, managing director of High Duty Alloys Ltd., Slough, has been elected President of the Aluminium Development Association, 33, Grosvenor-street, London, W.1, for the year 1952-53, in succession to Mr. AUSTYN REYNOLDS. The new vice-president is Mr. R. D. HAMER, a vice-president and director of Aluminium Laboratories Ltd. Mr. G. W. LACEY, sales director, British Aluminium Co. Ltd., has been elected chairman of the executive committee.

LT.-COLONEL THOMAS EUSTACE SMITH, joint managing director, Smith's Dock Co. Ltd., has been elected President of the North East Coast Institution of Engineers and Shipbuilders, Bolbec Hall, Newcastle-upon-Tyne, 1, for the session 1952-53.

Mr. W. F. RANDALL, B.Sc., A.R.S.M., M.I.E.E., F.I.M., director of the Telegraph Construction and Maintenance Co. Ltd., Telcon Works, Greenwich, London, S.E.10, at the invitation of the British Iron and Steel Research Association, is to act as chairman of the newly-formed conjoint committee of B.I.S.R.A. and the British Electrical and Allied Industries Research Association on electrical sheet.

PROFESSOR SIR LEONARD BAIRSTOW, F.R.S., formerly Zaharoff Professor of Aviation, Imperial College of Science and Technology, London; PROFESSOR R. G. H. CLEMENTS, formerly Professor of Highway Engineering, Imperial College; PROFESSOR J. T. HEWITT, F.R.S., Professor Emeritus of Chemistry, Queen Mary College, London; and PROFESSOR R. S. HUTTON, member of the governing body of Imperial College and of the delegacy of the City and Guilds College, and formerly chairman of the Council of the City and Guilds of London Institute, have been elected to honorary fellowships of Imperial College.

PROFESSOR C. K. INGOLD, D.Sc., Ph.D., F.R.S., has been elected President of the Chemical Society, Burlington House, London, W.1. SIR ERIC RIDEAL, M.B.E., M.A., D.Sc., F.R.S., who retires from the office of President, becomes a vice-president.

Mr. D. L. McCARDEL, area general manager, West Ayr, is leaving the service of the Scottish Division of the National Coal Board at the end of May to take up another appointment. Before the nationalisation of the coal industry, Mr. McCardel was general manager of Bairds and Dalmellington, Ltd., Glasgow.

With the merger between HORSELEY BRIDGE AND THOMAS PIGGOTT LTD., Tipton, Staffordshire, and CARTER-HORSELEY (ENGINEERS) LTD., Mr. J. V. SHEPHERD, the chairman, and Mr. VINCENT SENIOR, joint managing director of Carter-Horseley, have joined the board of the parent company, Horseley Bridge and Thomas Piggott Ltd., Mr. Sheffield as deputy-chairman. Mr. J. W. BAILLIE, joint managing director, has resigned from the board of Carter-Horseley, but continues as managing director of the parent company.

Mr. G. S. CAUSON and Mr. A. E. NICOL, who have been in the employ, in various positions, of the Hackbridge and Hewitt Electric Co. Ltd., for nearly 25 years, have been appointed directors of the company.

Mr. W. D. CUTLER, who has been one of the representatives of Foundry Services Ltd., Long Acre, Nechells, Birmingham, 7, in the Lancashire area for the past two years, is moving, early next month, to Italy to become the firm's resident technical representative there. He will work in close co-operation with the firm's agent, DITTA A. CESANA, Via San Marco, 50, Milan. Mr. R. A. BLINCOE, 9, Gainsborough-drive, Rochdale, Lancashire, is taking over Mr. Cutler's present area. Foundry Services Ltd., in association with their agents, FIRMA HUGO WACHENFELD, are forming a manufacturing company in Germany.

Mr. ERIC FLINTHAM, technical service manager of the Quasi-Arc Co. Ltd., Bilston, has been elected chairman of the Wolverhampton branch of the Institute of Welding.

F. J. EDWARDS LTD., 359-361, Euston-road, London, N.W.1, are shortly to open a new warehouse covering an area of more than 100,000 sq. ft. at Park-street, Islington, London, N.1.

On and after April 28, the address of the London office of JAMES HOWDEN & CO. LTD., and JAMES HOWDEN & CO. (LAND) LTD., will be 15, Grosvenor-place, Westminster, London, S.W.1. (Telephone: SLOane 0611.) (Telegrams: Preheating Knights London.)

INSLEY (LONDON) LTD., 119, Oxford-street, London, W.1, have been appointed agents in the United Kingdom for the ball and roller bearings manufactured by the KAYDON ENGINEERING CORPORATION, Muskegon, Michigan, U.S.A.

On page 399, ante, we announced that Mr. W. M. B. FURNISS had been appointed a member of the Midland Regional Board for Industry. We stated that Mr. W. M. B. FURNISS is chairman of the Electric Construction Co. Ltd., Wolverhampton. Our information, however, was incorrect; he is assistant managing director of the firm. The chairman and managing director is Mr. W. M. FURNISS.

RAILWAY WHEEL MILL: MESSRS. STEEL, PEECH AND TOZER.

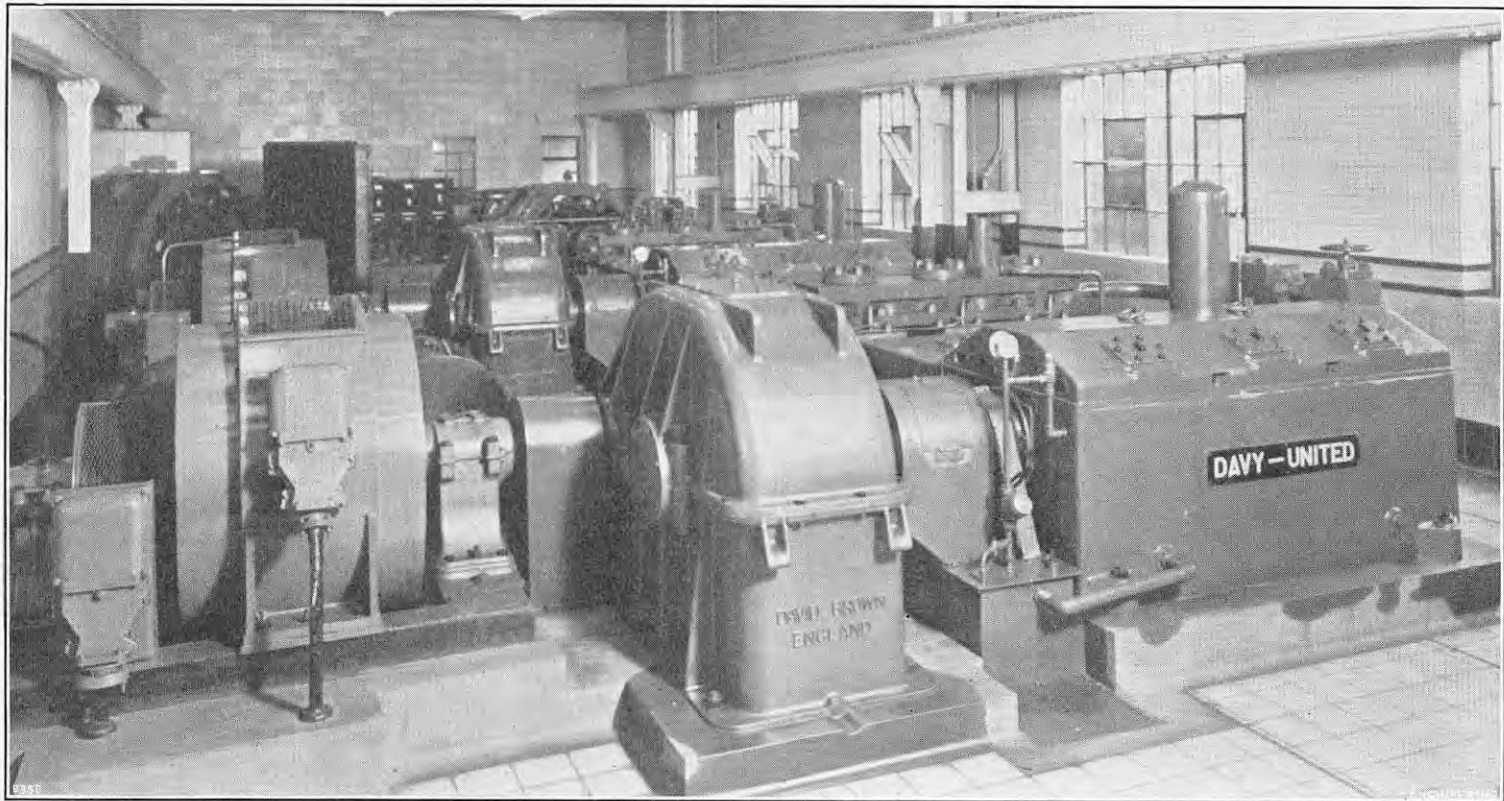
(For Description, see Page 515.)

FIG. 5. HYDRAULIC PUMPS AND MOTORS.

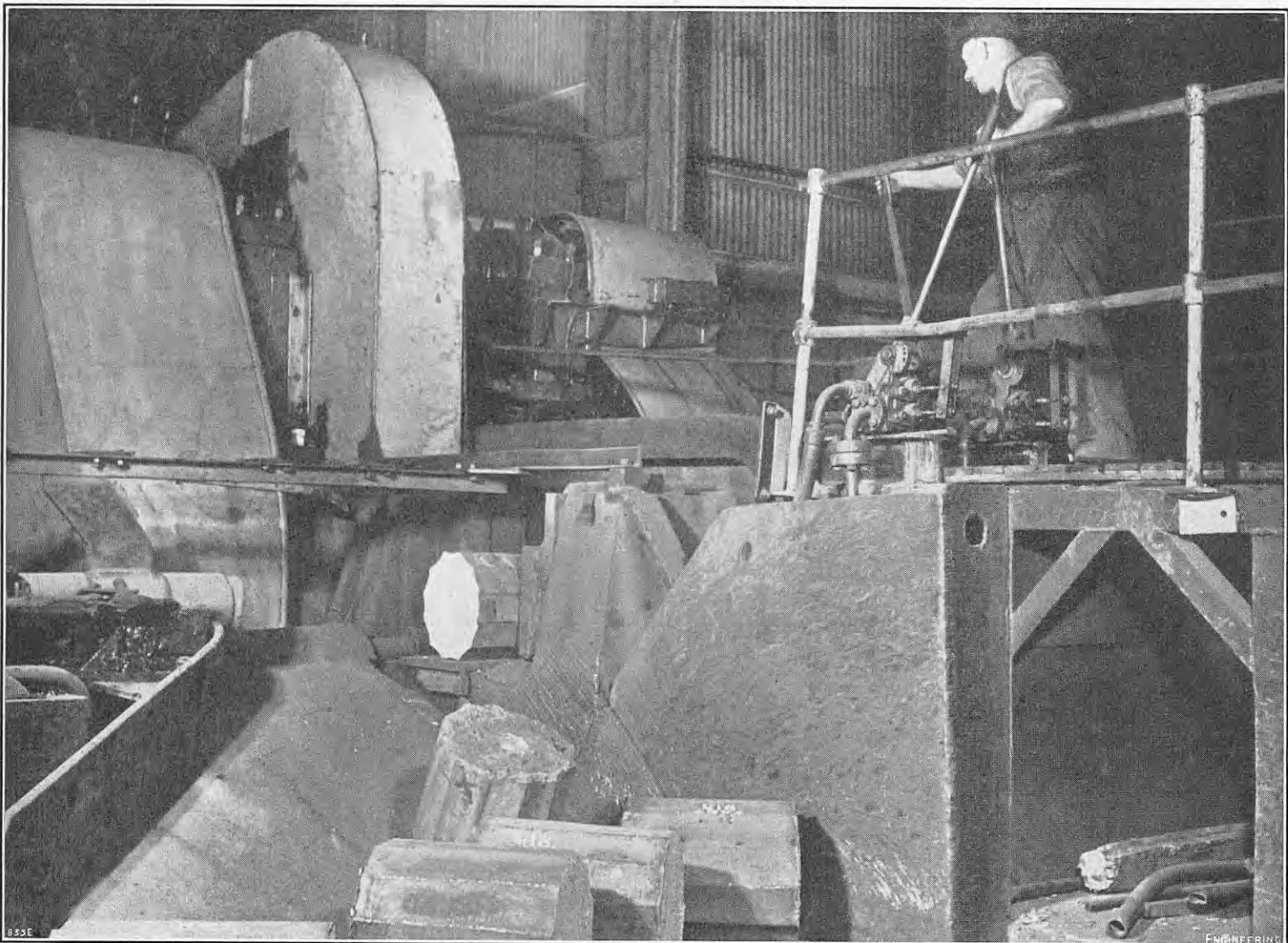


FIG. 6. INGOT-BREAKING MACHINE.

ENGINEERING

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

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

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SUBSCRIPTIONS.

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ADVERTISEMENT RATES.

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

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

TIME FOR RECEIPT OF ADVERTISEMENTS.

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

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

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

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No. 4500.

WOOD PRESERVATION.

FROM among the very many different kinds of wood, one or other type finds application in a wide variety of industries. The range available to furniture makers and builders is considerable and has been added to in recent years by the extensive importation of Colonial timbers, particularly from West Africa, which were previously unknown to commerce. It is stated in the latest report* of the Forest Products Research Board that "the testing and evaluation of these new woods . . . remains the largest project engaging all the technical sections of the Laboratory." Possibly some of the new species may ultimately find application in various branches of engineering, but many tests and much experience will be necessary before previously-unknown timbers could be extensively adopted for railway sleepers, transmission poles or piles.

The problem presented by the decay of timber is not the same for all types of engineering structure. Breakdown of the louveres in water-cooling towers is due to fungi, but deterioration of timber structures exposed to sea-water is due to attack by marine organisms, particularly *Limnoria* and *Teredo*. Preservation against this latter type of attack is only briefly mentioned in the present Forest Products Report, but the results of detailed studies, carried on over many years, are given in a recent report† published by the Institution of Civil Engineers. The first edition of this report was published in 1947 and the main difference between that and the new edition is that particulars of a series of tests carried out at Singapore have now been included. The

* Report of the Forest Products Research Board, with the Report of the Director of Forest Products Research for the Year 1950. H.M. Stationery Office. [Price 3s. net.]

† Deterioration of Structures of Timber, Metal and Concrete Exposed to the Action of Sea-Water. Second edition. By J. Bryan, M.Eng. The Institution of Civil Engineers, Great George Street, Westminster, London, S.W.1. [Price 5s., post free.]

general conclusion reached, as the result of tests first begun in 1921, and covering both home and tropical waters is that "the most satisfactory preservative so far found for the protection of timber is ordinary coal-tar creosote." It is added, however, that the Singapore tests indicate that Celcure might be equally effective. Celcure is a proprietary preservative; it contains potassium dichromate, copper sulphate and chromium acetate.

Although the Forest Products Report does not go into detail about marine timbers, it mentions that the Officer in Charge of the Wood Preservation Section of the Laboratory, through the generosity of the Economic Co-operation Administration, made a tour extending over three months in the United States and Canada to study the wood-preservation industries in those countries. The officer, Mr. N. A. Richardson, has prepared a valuable report* from which much may be learned about American wood-preserving practice. He also read a paper at the First Annual Convention of the British Wood Preserving Association, held at Cambridge in June, 1951. These two documents should be studied by all who are concerned with industrial applications of timber. In connection with the question of structures exposed to the action of sea-water, American practice favours coal-tar creosote as a preservative, but with the important difference from much British practice that round piling is always used. Round timber has a thick outer band of sapwood which is completely penetrated by the creosote. When timber is squared much or all of this sapwood is cut away and if a resistant timber, such as Douglas fir, is used, adequate penetration is difficult to attain. The use of squared timber in British practice seems to be based partly on aesthetic considerations and partly because it facilitates the arrangement of bracing connections. This matter of the longer life likely to be obtained from round piles is mentioned in the Institution of Civil Engineer's report.

Possibly the most extensive use of timber in engineering practice is for transmission-line and telegraph poles. The Forest Product Report states that a large number of redwood poles used for electricity transmission lines, which were creosoted early in 1930, are exhibiting premature decay. It is suggested that the trouble may be due to inadequate initial treatment and that many were possibly creosoted either green, or without sufficient seasoning. At the request of the Electrical Research Association, the Laboratory is to investigate methods of treating the poles *in situ* in order to prolong their life. Mr. Richardson's report does not appear to give much information on this matter; he recalls that Dr. T. E. Snyder, of the Bureau of Entomology and Plant Quarantine of the United States Department of Agriculture, stated that "the only satisfactory method of dealing with timbers *in situ* was to fumigate with hydrocyanic acid"; but the precise bearing of this remark on the case of transmission poles is not clear. The Detroit Edison Electric Company, which has 500,000 poles in use, has developed a portable X-ray plant for the detection of internal decay in poles; the cost of the method is about twice that of visual inspection, but internal decay is difficult to assess by the latter method.

Clearly, the most satisfactory way of ensuring long life for transmission-line and telegraph poles is adequate pre-treatment. One of the general conclusions of the Institution of Civil Engineers' report is that, in the case of Douglas fir, satisfactory protection can normally only be attained by incising the timber first and then subjecting it to a long pressure treatment. This conclusion may be

* Detailed Reports of Visits made to Research Laboratories and Wood Preserving Firms in the U.S.A. and Canada from 29th March to 7th July, 1950. By N. A. Richardson, B.Sc., A.R.I.C. Forest Products Research Laboratory, Princes Risborough, Aylesbury, Bucks.

accepted without reserve, but Mr. Richardson suggests that it is not always acted on in this country. He states that "it is not sufficiently realised in Great Britain that such treatments cannot be hurried or carried out in a short time; they frequently necessitate a treating period of 36 to 48 hours even with incised material." In the United States, as here, creosote is the preservative most commonly used for poles.

Although there are a number of proprietary wood preservatives available, coal-tar creosote is by far the most widely used material. In 1949, more than 94 per cent. of all timber preserved in the United States was treated with either creosote or creosote mixtures. A survey of preservative practice on American railways showed that all were using creosote or creosote mixtures for sleepers and considerable adverse criticism has been directed against the use of water-borne preservatives as practised to some extent in this country. Apart from the question of decay, it was considered that creosote-coal tar mixtures were effective in reducing the incidence of splitting or other mechanical degrade. It had been found that coating the exposed surfaces of sleepers in the track with bituminous or coal-tar preparations was effective in reducing splitting of hardwood sleepers. Nothing is said in the Forest Products Report about the use of water-borne preservatives for sleepers, and it is stated that "all the methods of creosoting tested have been adequate for preserving the sleeper against fungal decay"; but it is added that "ultimate life will be determined by mechanical breakdown and not by decay." In this connection, the remark that "heavy splitting, which is the prominent cause of fracture, can be greatly reduced by incising," again emphasises the importance of securing adequate penetration in the initial creosoting of the timber. The report adds that there appears to be little, or no difference between the performance of home-grown Scots pine, and Douglas fir, and imported Baltic redwood. The latter is the timber most used for railway sleepers in Great Britain.

The Forest Products Report deals with many matters other than preservation. Some are hardly of concern to engineering industries, but boat builders will be interested in the brief reference to tests being carried out with stems, chines and keels made of composite wood. To a considerable extent the successful use of built-up timber parts depends on the properties and durability of the adhesive. Some information is given on this matter and it is stated that weather-proof adhesives such as phenolics, resorcinols and melamines, have proved virtually indestructible by weather, micro-organisms, hot and cold water and dry heat. They are more durable than the wood itself. Moisture-resisting adhesives, such as phenolic flues and casein, are satisfactory in less exacting conditions, but starch and polyvinyl emulsions suitable for use as interior adhesives fail under the action of water of dampness.

The entomology section of the report is largely concerned with the treatment of insect-infected wood with D.D.T. spray and other materials. It contains, however, some account of preliminary experiments undertaken to determine the effect of ultrasonics on insect-infected wood. The results obtained were not very promising. The use of low-voltage and radio-frequency heating for glue setting represent two other applications of modern physical methods which are becoming well established. It is stated that low-voltage heating has advantages when the glue lies close to the surface, as in veneering. A final matter of engineering interest which may be mentioned concerns the use of wood in association with metals. "When in a moist condition, all woods acquire the properties of electrolytes" and if, for instance, aluminium is attached to wood by steel or brass screws and moisture is present, corrosion of the aluminium will occur.

BRITISH ELECTRICAL MANUFACTURING.

SOME day, a thesis will be written on the philosophy of jubilees. It will include a discussion, and perhaps an explanation, of the reason why existence for 50 years, whether it be of individuals or corporate bodies, is regarded as a special occasion for celebration; and may describe, not without a touch of humorous cynicism, why some of those which qualify are chosen and some are neglected. It may also comment in the same vein on the forms, appropriate and inappropriate, which such recognition takes. Fortunately, perhaps, we are engineers rather than philosophers, and our principal task is therefore to record and not to speculate. In pursuance of that task, we therefore note with gratification that the British Electrical and Allied Manufacturers Association is now celebrating the fiftieth year of its existence; and express the hope that when, in another 50 years' time, the centenary of its establishment arrives, it will be possible to record progress equal to that exhibited during the period that has just ended.

Electrical engineers are probably generally familiar with the history of this energetic body. It was founded as the National Electrical Manufacturers Association in February, 1902, by a representative meeting of "electrical supply houses and manufacturers . . . for the better protection of their financial and general interests," and it assumed its present title nine years later. That such an association was urgently required, if the British electrical manufacturing industry was to be rescued from oblivion, was clear in view of the hampering effect of British legislation and of the active encouragement given to foreign firms by their Governments. The task which it set itself was difficult of performance, not the least because co-operation had to be attained without removing the stimulus of healthy competition. Nevertheless, progress was made at an accelerating rate and with the gradually increasing strength of the Association there went a growing usefulness, not only to the electrical industry but to the country as a whole.

Much of what has been done in the course of years is written in the annual reports of the Association, the latest of which, for the year ended March 31, 1952, was presented at the annual general meeting held yesterday. This, as might be expected, discloses a year of achievement in the face of great anxieties and difficulties, a fact which in itself is a proof of the usefulness of the body. This may be illustrated by referring shortly to some salient facts. During 1951, the value of British electrical exports amounted to just over 189½ million, an increase of more than 30½ million, or 20 per cent., over that of the previous year, and, incidentally, constituting a record. This high level, it is not going too far to say, has been reached in spite of world conditions and the more domestic problems which confront the firms concerned; and indicates the prime importance of electrical manufacture as a factor in the growth of world economy. In this connection, it may be pointed out that the two major sources of electrical exports at the present time are the United Kingdom and the United States, which between them account for more than 62 per cent. of the total. The Commonwealth countries form the main market for British exports, and this, as is rightly pointed out, is an important factor in the development of this particular example of the comity of nations. It is particularly gratifying to learn that there was considerable expansion in the supply of goods to Canada; and that the value of these reached nearly 7½ millions, or more than half as much again as in 1950. European countries, such as the Netherlands, Belgium and the Scandinavian countries, were also

important customers; and the level of business with the South American continent was maintained, in spite of the fact that trade with the Argentine decreased. Unfortunately, the immediate outlook is not altogether bright, owing to political action both in this country and elsewhere. It can, however, be said that the electrical industry is in a position to go forward as far and as quickly as it is allowed.

At home, the picture is also made up of both light and shade. As a result of the planning and re-organisation for greater production carried out by the manufacturers of generating plant some years ago, more new sets were brought into commission during the year under review than ever before, and the periods of repair were shortened. The demand for electricity, however, continues to rise, and, unless it is met, the increase in productivity which is so desirable for the nation's prosperity and security will be checked. Emphasis has therefore been laid and must continue to be laid on the need for sufficient capital to be forthcoming to provide the necessary equipment, since it is this shortage, and not the inability of manufacturers to produce plant, which is the main cause of the present difficulties. It is to be hoped that these arguments, the cogency of which should be clear to all, will result in those who control these matters correcting the errors of their past.

Dealing still with the darker side of the picture, shortages of materials, it is correctly recorded, have in particular had disturbing effects on the manufacturers' drive for greater output. In fact, many of the materials required, including copper, zinc and their alloys, have become increasingly difficult to obtain in adequate quantities with the result that plant and equipment production is being hampered. The curtailment by various means of the sales of the lighter apparatus in the home market also requires substantial easement, since without an assured and reasonable level of production it will be impossible for manufacturers of domestic electrical appliances to maintain, let alone to extend, their hold on the export markets. Another cloud, which, though at present small, might assume harmful dimensions for the industry, has arisen as the result of threatened fuel shortages. This threat has stimulated much debate and propaganda on the relative efficiencies of solid fuel and electrical appliances, in the course of which the latter have been charged with the crime of waste. To counteract this, we are glad to see, a fact-finding panel has been set up by the Joint Committee of the Association and the British Electricity Authority to collate data on the fuel economy and efficiency of electrical appliances. The report of this body will, we feel sure, do much to combat the arguments of those who ignore the fact that domestic solid-fuel appliances, not to speak of gasworks and steam locomotives, consume high-grade fuel, while power stations use coal which could not be employed for many other purposes and certainly not on the domestic grate. The whole question of the right utilisation of fuel resources is so important that any decisions which are reached should only be based on the incontrovertible evidence.

In dealing with the main activities of the Association we have only left ourselves space to refer quite briefly to the other work in which it is engaged. During the year under review this has included much deliberation by joint committees of the Association, the British Electrical Authority and the Area Boards with a view to easing bottlenecks of all kinds; with the Institution of Electrical Engineers on model general forms of contract conditions; and with a number of international bodies on such subjects as irrigation and drainage, standards, electric heating, and safety requirements. The Association has also operated in close co-operation with a number of other bodies to their mutual benefit.

NOTES.

THE WORLD'S SHIPBUILDING.

THAT the activity of the shipyards of Great Britain and Northern Ireland is maintained at the high level which has now continued for several years past is indicated by the fact that the steamers and motorships under construction in this country on March 31 totalled 356 vessels, making together 2,270,621 gross tons. This figure, it is pointed out, in the shipbuilding returns of Lloyd's Register of Shipping for the quarter ended March 31, represents an increase of 61,609 tons over the total for December 31, 1951. Of the 356 ships in hand at the end of March last, 96, aggregating 596,875 tons, were afloat and being fitted out while the remaining 260, totalling 1,673,746 tons, had still to be launched. The progress made in the shipyards of this country during the March quarter is indicated by the fact that 56 ships comprising 324,831 tons were commenced, 62 vessels totalling 327,141 tons were launched, and 55 ships aggregating 267,511 tons were completed. The shipping under construction in British shipyards for registration abroad or for sale amounted to 98 vessels totalling 716,853 tons. This figure is greater by 21,934 tons than that on December 31, 1951, and represents 31.6 per cent. of the total tonnage which is being built in this country. The oil tankers of 1,000 tons and upwards under construction in the United Kingdom total 109 ships, making together 1,285,060 tons, an increase of 45,563 tons as compared with the December quarter. This is the highest figure ever recorded for this country and this also applies to the oil-tanker percentage of the total tonnage under construction, which is 56.6 per cent. The steamers and motorships under construction on March 31 in shipyards abroad totalled 868 vessels, making together 3,409,947 tons, which represents an increase of 124,894 tons over the total for December 31, 1951. As has been the case for a number of years past, figures are not available for China, Poland and Russia. The leading foreign shipbuilding country is the United States, which had 662,892 tons of shipping under construction on March 31; Germany came second, with 432,676 tons, France was third with 425,300 tons, Japan fourth with 394,195 tons, Sweden fifth with 308,616 tons, and Holland sixth with 303,600 tons. The oil tankers of 1,000 tons and upwards under construction overseas totalled 111 ships, making together 1,208,608 tons, which figure is greater by 112,707 tons than the December total. Oil tankers represent 35.4 per cent. of the total tonnage being built abroad, as compared with 33.4 per cent. on December 31, 1951.

THE DIESEL ENGINE USERS ASSOCIATION.

Some interesting information regarding the use of Diesel engines in naval vessels was given by Vice-Admiral (E) Sir Denis C. Maxwell, K.C.B., C.B.E., Engineer-in-Chief of the Fleet, when speaking at the annual luncheon of the Diesel Engine Users Association, held in London on Thursday, April 17. Sir Denis was replying to the toast of "The Guests," proposed by the President, Mr. Gerald B. Fox, and after he had stressed the need for reliability and durability in naval machinery, pointed out that these needs had led to restrictions in the number of engines in use and to the prolonged testing of prototype models before their adoption for service. He then reviewed briefly the history of the Diesel engine as applied to the Navy, and stated that, by 1904, the horse-power of Diesel machinery in Admiralty possession was 225,000. By 1945, this figure had risen to 2,200,000, almost ten times as great, but the post-war "run-down" had reduced the current figure to 780,000. Over 400 different types, however, were in use at the height of the last war and in view of the complicated nature and large number of spares needed to cover such a vast range, it was decided to adopt a policy of standardisation. Sir Denis then gave details of the four new ranges which the Admiralty had decided to adopt, and explained how they would be used in carrying out the rearmament programme which, when completed, would bring the total horse-power in use at least back to the war-time peak. They would be used, he said, in such vessels

as minesweepers and frigates, and arrangements had been made for various firms to undertake their production. Turning to the subject of gas turbines, Sir Denis said that the experience gained from M.A.B. 2009 had encouraged the Admiralty to build two new prototype boats powered by large turbines of a similar type for operation in conjunction with Diesel engines. For other applications where good economy was necessary at low powers, the Admiralty had two somewhat complex engines of 6,000 h.p. under development. Sir Denis concluded by remarking that although the Admiralty were convinced that the gas turbine had a great future, there was still a long way to go and many difficulties to be overcome.

BEILBY MEMORIAL AWARDS.

The administration of the Sir George Beilby Memorial Fund, representing the Institute of Metals, the Royal Institute of Chemistry and the Society of Chemical Industry, have decided to make two awards, each of 100 guineas, from the Fund for 1951. One award has been made to Dr. Kenneth Henderson Jack, M.Sc.(Dunelm), F.R.I.C., in recognition of his experimental contributions to the study of interstitial alloys, especially in the iron-nitrogen and iron-carbon-nitrogen systems. The other award has been made to Dr. William Arnold Wood, F.Inst.P., in recognition of his experimental contributions to the knowledge of the mechanism of the deformation of metals. Dr. Jack graduated in 1939 at King's College, Newcastle-upon-Tyne, Durham University, with first-class honours in chemistry and later obtained the Ph.D.(Cantab.) degree. In 1945, he joined the British Iron and Steel Research Association and, continuing to work at Newcastle, carried out chemical and structural investigations on the iron-nitrogen and other systems. This research was extended from 1947 until 1949 at the crystallographic laboratory, Cavendish Laboratory, Cambridge. Recent work of Dr. Jack and his associates is concerned with the cobalt-carbon-nitrogen system and with the ageing of nitrogen pyrites. Dr. W. A. Wood joined the National Physical Laboratory in 1928 after graduating with first-class honours in the Physics School, University of Manchester. In 1935, he was seconded to work with Dr. H. J. Gough, F.R.S., on the structural changes produced by the fatigue stressing of metals, and, for his part in these researches, was awarded the D.Sc. degree by his University. In 1947, he was appointed senior research fellow, with the status of Associate Professor, in the Metallurgy Research Department of the University of Melbourne. It may be recalled, in conclusion, that awards from the Beilby Memorial Fund are made to British investigators for distinguished work in such fields as fuel economy, chemical engineering and metallurgy in which Sir George Beilby's special interests lay.

A TECHNICAL INFORMATION SERVICE.

One of the largest sources of technical information—and one that is untapped by potentially interested persons—consists of the great number of technical reports, emanating mostly from Government and industrial research organisations, which are distributed on a limited basis but are not published in the normal way. This difficulty is now being partly overcome by the Technical Information and Documents Unit (T.I.D.U.) of the Department of Scientific and Industrial Research. T.I.D.U. now incorporates the D.S.I.R. Headquarters Technical Information Service, and its services, freely available to anyone who has a specialised technical inquiry, include the distribution of original copies or photographed copies of such "semi-published" reports; the distribution of summaries of selected fields of these reports; guiding inquirers to sources of specialised information; answering inquiries for which no suitable specialised source exists; seeking technical information from foreign countries; providing a reading room, which includes personal attention to technical inquiries; and making available copies of German industrial documents. The T.I.D.U. offices are at Cunard Building, 15, Regent-street, London, S.W.1 (telephone: WHITEhall 9788). The Unit has grown from the organisation that was established at the end of the war to deal with the reports which

were prepared by teams after visits to German industrial firms, but its scope is now much broader, as indicated above. T.I.D.U.'s bulletin, *Unanswered Questions*, is circulated widely, and normally contains technical queries to which answers are sought on behalf of clients. The March issue of this bulletin (No. 7) is devoted to an explanation of T.I.D.U.'s services, as explained in this note. Copies are available, without charge, from the above address.

LETTERS TO THE EDITOR.

EXPERIMENTAL PEAT-FIRED CLOSED-CYCLE GAS TURBINE.

TO THE EDITOR OF ENGINEERING.

SIR,—With reference to the article on the "Experimental Peat-Fired Closed-Cycle Gas Turbine," on page 8, *ante*, it might be of interest to you that, at the dedication of the Carl Engler and Hans Bunte Institute for mineral oil and coal research at Karlsruhe, a novel process for the dehydration of peat was reported (see *Erdöl u. Kohle*, vol. 4, pages 677-8 (1951)). In this process, water (100 per cent. or more) is added to peat and the mixture heated to 250-260 deg. At these temperatures, the colloidal nature of peat, which is responsible for the high water content, is irreversibly destroyed and a decarboxylation and dehydration takes place under evolution of oxygen in the form of CO₂ and water. This process converts peat into a peat-coal equivalent to ordinary coal. The heat evolved in the exothermic reactions more than balances the heat expended for raising the temperature of the peat-water mixture to 250 deg. Further heating up to 300 deg. gives rise to the formation of N-free generator gas and provides a possible cheap source of H for hydrogenation. At 300-325 deg., gaseous hydrocarbons, principally methane and ethane, are formed. Beyond these temperatures, a direct hydrogenation to liquid and solid hydrocarbons takes place.

Very truly yours,

RICHARD WIEBE,
Head, Motor Fuels Evaluation Division,
Northern Regional Research Laboratory,
United States Department of Agriculture,
Bureau of Agricultural and Industrial
Chemistry,
Peoria 5, Illinois, U.S.A.
April 7, 1952.

JOSEPH DAY, INVENTOR OF THE CRANKCASE-COMPRESSION ENGINE.

TO THE EDITOR OF ENGINEERING.

SIR,—I am anxious to obtain for exhibition and record purposes a portrait photograph and biographical details of Joseph Day, who, in 1891, invented the crankcase-compression type of two-stroke internal-combustion engine.

I have spent considerable time and trouble in trying to locate any of his relatives who might be able to supply this information, but without success, and I should be obliged, therefore, if you would insert this letter in the hope that knowledge of the Science Museum's requirements may reach any persons who may be able to help.

Yours truly,

C. F. CAUNTER,
Assistant Keeper.

The Science Museum,
South Kensington,
London, S.W.7.
April 8, 1952.

THE CAROLINE HASLETT TRUST: TRAVELLING EXHIBITIONS.—The Caroline Haslett Trust invite applications for a travelling exhibition covering a period of one to three months from women holding the Diploma of Electrical Housecraft of the Electrical Association for Women. The exhibition will entitle the holder to study some aspect of domestic electricity in another country. Application forms, which should be returned by May 15, may be obtained from the Trust, Electrical Association for Women, 35, Grosvenor-place, London, S.W.1.

OBITUARY.

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

It is with profound regret that we record the death of Sir Charles Inglis, Emeritus Professor of Mechanical Sciences in the University of Cambridge and a past-President of the Institution of Civil Engineers. Professor Inglis, who was 76 years of age, survived by only 18 days the death of Lady Inglis, whose share and interest in his professional and other activities was greater, perhaps, than was commonly realised.

Charles Edward Inglis was of Scottish descent and was born on July 31, 1875. He was educated at Cheltenham College—of which he was, for more than 20 years before his death, a member of the College Council—and there obtained, in 1894, a scholarship at King's College, Cambridge, where he spent the next four years. He graduated as B.A. after gaining a first class in the Mechanical Sciences, and, in 1898, began a pupilage of two years in the office of Sir John Wolfe Barry, the consulting engineer who was responsible, *inter alia*, for the design of the Tower Bridge, London. He spent two years with Sir John Wolfe Barry, partly on dock and railway design, partly as an assistant engineer on the construction of the Whitechapel and Bow Railway, and, towards the end of his pupilage, on Parliamentary work. He had, however, an original and inquiring mind, which led him to investigate a subject—that of mechanical vibrations and their effects—which, when he took it up, had attracted comparatively little attention. He made that study his own to an extent that, in due course, influenced greatly the trend of his professional life and activities. His work in this field brought him a Fellowship of King's College and an appointment as lecturer in the Faculty of Mechanical Science at Cambridge University of which eventually he was to become the head.

When Inglis returned to Cambridge in 1901, on completion of his pupilage, his first appointment there was as an assistant to Sir James Alfred Ewing in the Engineering School. Two years later, however, Ewing left Cambridge, at the request of the Admiralty, to take up the newly-created post of Director of Naval Education and was succeeded as Professor by Bertram Hopkinson, who held the chair of Mechanism and Applied Mechanics (as it was then called) until his untimely death in 1918 as a result of an aeroplane accident. Under Hopkinson, Inglis was appointed to a lectureship in engineering, and it seems possible that it was to Hopkinson that he owed the inspiration to concentrate on the study of vibrations. Certainly, he was closely concerned with Hopkinson's own investigations of the subject, the elements of which were set out in a pamphlet, published by the Cambridge University Press in 1910, as the first in their series

of *Engineering Tracts*, under the title of "Vibrations of Systems having One Degree of Freedom"; and it was from this period, approximately, that Inglis' more active interest in it dated.

At the outbreak of war in 1914, Inglis was able to make an immediate and valuable contribution to military engineering; for, in connection with the work of the Royal Engineers unit which formed part of the Officers' Training Corps at the University, he had devised a light tubular bridge, readily transportable and easy to erect, which the War Office adopted and quickly put into production. In September, 1914, therefore, Inglis received a commission in the Royal Engineers, and, from 1916 to 1919, was in charge of the department responsible

for the design and supply of military bridges. For this work he received the O.B.E. On being demobilised, with the rank of Major, he returned once more to Cambridge, this time as the successor of Hopkinson in what then became the chair of Mechanical Sciences.

His work on bridges was not finished, however; indeed, the more important part, arising out of the appointment of the Bridge Stress Committee in 1923 by the Privy Council, was still to come. It led him in a number of other directions, the nature of which is reflected in the titles of many of his papers delivered to the Institution of Civil Engineers in particular, but to various other institutions in addition; examples are his papers to the Civils on "The Theory of the Transverse Oscillations of Girders," "Impact in Railway Bridges," "Crippling

Loads of Compression Members" and "The Analytical Determination of Shear and Torsion Stresses." The Bridge Stress Committee reported in 1928, but Inglis's interest had been permanently widened by then to include railways and their mechanical as well as structural problems; in particular, the motions of locomotive wheels on the track and the stresses to which they may give rise.

To list his numerous papers to the institutions of which he was an active member, however, is quite impracticable within the limits of a brief memoir; the most that can be done is to indicate the more important of his lectures and addresses. In 1919, he gave a paper on "Portable Military Bridges" before the British Association at Bournemouth, in which the evolution and use of the Inglis bridge was described in great detail; it was reprinted in *ENGINEERING* in that year, in our 108th volume. His presidential address to the Institution of Civil Engineers in 1941, on "University Education of Engineers," reprinted in our 152nd volume, departed notably from the usual trend of discourses on that subject by discussing the requirements—and not only the academic qualifications—that he considered to be essential in university teaching staffs, some of whose shortcomings he emphasised with considerable candour. His Thomas Hawksley Lecture to the Institution of Mechanical Engineers in 1943, on "Gyroscopic Principles and Applications," will be long remembered by those who were so fortunate as to hear it; not only as a masterly exposition, accompanied by most effective demonstrations, but as an astonishing feat of memory, for he used not a single note, yet deviated hardly a word from the printed text which was made available to his audience as they left the hall. His James Forrest Lecture, given to the Institution of Civil Engineers in the following year, dealt with mechanical vibrations, and was equally memorable.

Sir Charles Inglis, who received his knighthood in 1945, was a Fellow of the Royal Society; a past-President of the Institution of Water Engineers as well as of the Institution of Civil Engineers; and, at various periods, a member of Council of the Institution of Naval Architects (to which Institution he deli-

vered a paper on the balancing of marine engines as long ago as 1911) and of the Institution of Structural Engineers; and a Fellow and Vice-Provost of King's College, Cambridge. The University of Edinburgh conferred upon him the honorary degree of LL.D., and he was an honorary member of the Institution of Mechanical Engineers and the Institution of Structural Engineers. To all the eminent engineers of his day he was an accepted authority in various departments of their profession. To many more, not all so eminent, he was a familiar figure, respected for his character and his gift of lucid presentation. While it may be questioned whether he had the innate engineering instinct of either Ewing or Hopkinson—he was primarily a mathematician—without doubt he was a worthy successor to them, whose status will survive the test of time.



Photo. Lafayette Ltd.

THE LATE PROFESSOR SIR CHARLES E. INGLIS.

MEASURING VARIATION IN DIAMETER OF WIRE.

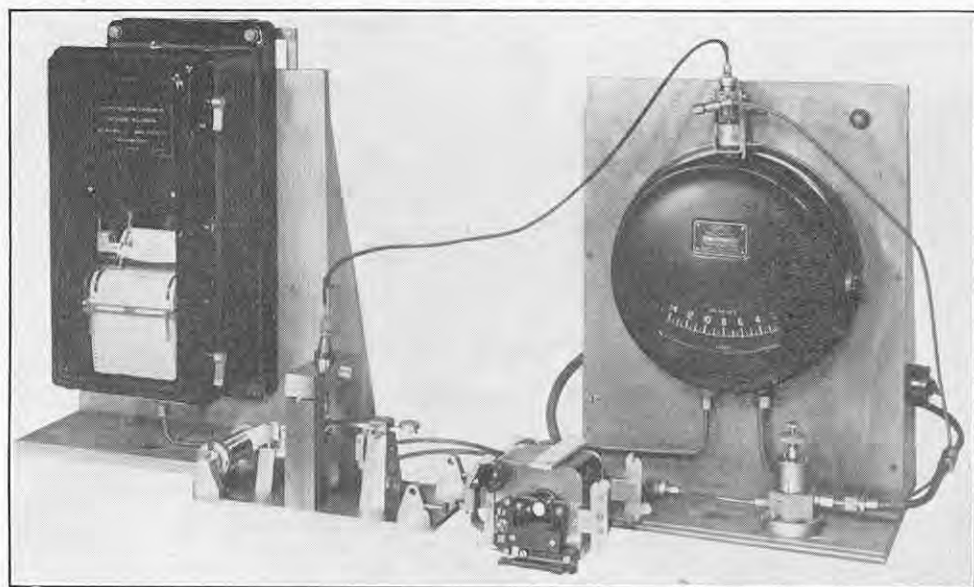


FIG. 1. SENSITIVE COMPARATOR.

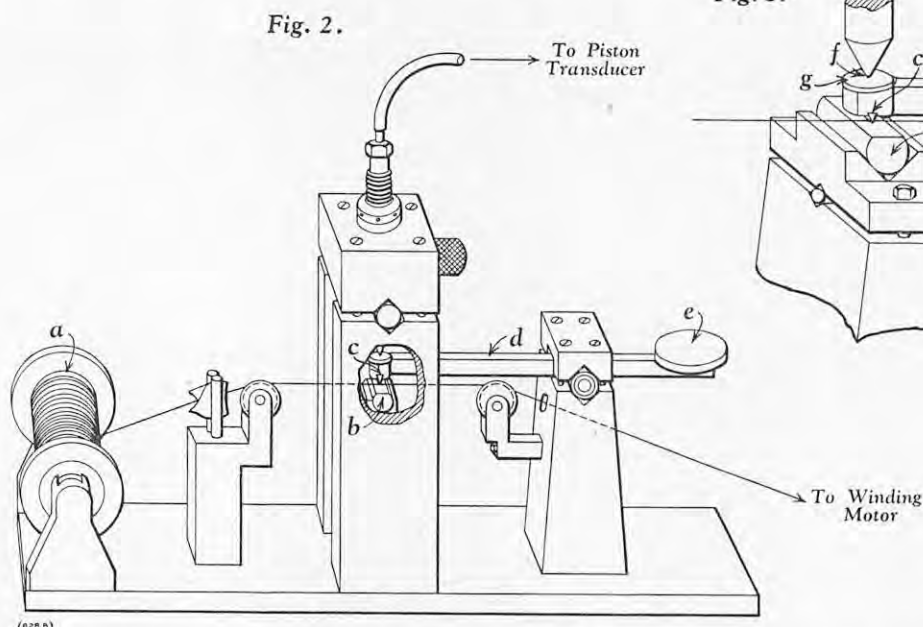
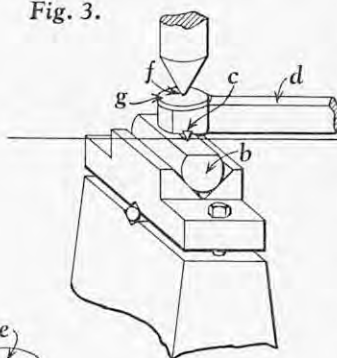


Fig. 3.



SENSITIVE COMPARATOR FOR MEASURING VARIATION IN DIAMETER OF WIRES.*

By J. C. EVANS, B.Sc., Ph.D., R. S. MARRINER and I. G. MORGAN.

THIS article describes a sensitive comparator suitable for measuring the variation in diameter of wires down to No. 50 s.w.g. (0.001 in.). When local readings are wanted, the comparator may be fitted with a dial indicator; alternatively, it can be fitted with an amplifier and recorder so as to provide a continuous record of the variation as the wire is drawn through the measuring head. Only the latter form is discussed here. The comparator is not considered to be suitable for direct inclusion in the production line; nevertheless, it can have a useful function in the laboratory by demonstrating the magnitude and nature of the variation in the product, so providing data for a deeper study of the manufacturing processes.

The comparator, which is illustrated in Fig. 1, on this page, is of the pneumatic type and is a development from instruments previously designed at the National Physical Laboratory and described in earlier publications.† An earlier design had been found

* Communication from the National Physical Laboratory. Abridged. The work was carried out as part of the research programme of the Laboratory, and is published by permission of the Director.

† "Continuous Pneumatic Gauging of Material in Thread or Wire Form," by J. C. Evans, M. Graneek, and H. G. Loe; *Trans. Soc. Instrum. Tech.*, vol. 2, page 34 (1950). British Prov. Pat. No. 28719/49, cog. 1471/50. "Pneumatic Comparator of High Sensitivity," by M. Graneek and J. C. Evans; *Machinery*, vol. 79, page 33 (1951).

suitable for the continuous measurement of the area of cross-section of wires down to No. 36 s.w.g. (0.008 in. approximately) when used with a measuring head comprising two apertures through which the wire was drawn. Records showing full details of the variation of cross-section could be obtained for wire speeds up to 20 ft. per minute for No. 36 s.w.g. wire, higher speeds being permissible for the larger wires. But attempts to measure by this technique a No. 49 s.w.g. enamelled wire, using a pair of over-size diamond wire-drawing dies in the measuring head, were unsuccessful. With so fine a wire and aperture, the air flow is so much reduced that the readings of the comparator are seriously affected by the presence in any part of the apparatus of the smallest air leakage. This fundamental limitation to the use of an aperture as measuring head prompted the development of the alternative technique described below.

The principal components of the comparator and their general arrangement are shown in Fig. 1. The measuring head is novel, but the piston transducer and the pneumatic amplifier remain as in the earlier designs and are fully described in the papers mentioned, which also discuss the underlying theory of the pneumatic principles used. The pressure recorder uses charts having rectilinear co-ordinates, but it could be replaced, with some saving in cost, by one designed for circular charts. The comparator is operated through a reducing valve from the ordinary compressed-air line, the precision regulator being adjusted to supply air at a constant pressure of the order of 15 lb. per square inch to the piston transducer.

The piston transducer is shown in schematic form in Fig. 4, on page 530. It comprises a hollow double piston which is a sliding fit (radial clearance about 0.0001 in.) in a cylinder of $\frac{1}{8}$ -in. bore and $1\frac{1}{2}$ -in. overall length. The air entering at *u* flows upwards through

the piston to a control orifice *v* in a detachable plate screwed to the top of the piston, whence it passes to the upper part of the cylinder and then through small-bore flexible tubing to the measuring head. The piston is loaded by means of a compression spring *s*, the degree of compression of which can be set initially by means of the zero adjusting screw *y*. A mild-steel rod *z* screwed into the lower end of the piston serves to transmit any displacement of the piston to the pneumatic amplifier through a suitable linkage embodied in the latter instrument. To reduce friction between piston and cylinder, a "dither" is impressed on the piston by the solenoid *l* fed with alternating current through a half-wave rectifier.

The pneumatic amplifier, which is supplied with air at a pressure of about 17 lb. per square inch, converts displacements communicated to it by the piston into proportional-output pressure changes which are registered by the pressure recorder. The full range of output pressure from the amplifier is 2 to 15 lb. per square inch and corresponds to a piston displacement of $\frac{1}{8}$ in.; within this range, the output pressure is proportional to displacement to within ± 1 per cent. of the maximum pressure, i.e., ± 0.15 lb. per square inch.

The measuring head is shown diagrammatically in Figs. 2 and 3, on this page. The wire is unreeled from the spool *a* by means of a small motor. It passes over a fixed lower anvil *b* and under an upper anvil *c* which is attached to a gravity-controlled lever *d* pivoting on a pair of miniature ball bearings. Two rollers, each having a circumferential groove, serve to guide the wire to and from the anvils. The air supply to the measuring head is taken to the fixed jet *f* (Fig. 3). A flat disc *g* attached to the lever *d* restricts the flow of air from this jet, the degree of restriction depending on the separation of the anvils, i.e., on the diameter of the portion of wire between them.

It will be seen then that, as the wire is unreeled from the spool, variation in its diameter varies the rate of escape of air from the jet *f*. This, in turn, varies the pressure in the upper part of the piston transducer and so alters the force on the piston; the resulting displacement of the piston changes the output pressure from the pneumatic motion transmitter. Under correct operating conditions, the output pressure changes are proportional to the variation of diameter, so that the record traced by the pressure recorder represents the variation of diameter along the wire. The conditions which must be satisfied in order to obtain this proportionality and the factors which determine the sensitivity of the comparator are discussed in an appendix.

The general shape of the measuring anvils may be gathered from Fig. 3. The flat on the lower anvil is about 0.2 in. wide, and the radius of the bearing edge of the upper anvil is about 0.004 in. The lower anvil is mounted in a platform provided with adjustments which enable the two anvils to be made parallel to one another. The parallelism is tested by inserting a wire of uniform diameter between the anvils, first at the near end and then at the far end, and observing whether any change of reading is shown by the pressure recorder. The force to which the wire is subjected during measurement may be reduced indefinitely by adjustment of the weight *e*; in the measurements described in the next section the force was 0.15 oz. weight. This force is sufficient to bring the wire into contact with the lower anvil so as to ensure that the diameter of the wire is being gauged. While it must, of course, compress the wire to some extent, repeated measurements on the same piece of wire have demonstrated that no permanent strain is produced. For a given wire, the reduction in diameter due to compression will remain sensibly constant, so that the variation charted by the recorder may be taken as correct.

PERFORMANCE OF COMPARATOR.

To illustrate the performance of the comparator, an account will be given of measurements which have been made on a No. 49 s.w.g. enamelled copper wire of mean overall diameter 0.0019 in. It is not suggested that these results are typical of fine enamelled wires, but they are suitable for demonstrating the accuracy with which the comparator records quite sudden changes in diameter. Figs. 5, 6 and 7, on page 530, are reproductions of parts of the actual records obtained when the wire was drawn through the measuring head. In Fig. 5 the speed of unreeling was 0.05 in. per minute and the chart speed was 5 in. per minute. It will be seen that, over the length of wire illustrated ($\frac{1}{8}$ in.) a range of variation of diameter of just over 0.0003 in. was displayed. This kind of variation was found over long lengths of the wire, and the wavelength of the variation, between 0.03 and 0.04 in., persisted.

Fig. 6 shows a repeated record for a $\frac{1}{8}$ -in. length of wire which was fed through the measuring head twice. The same speeds of unreeling and recording as in Fig. 5 were used, with the second recording displaced lengthwise for ease of comparison. The motor speed

COMPARATOR FOR MEASURING VARIATION IN DIAMETER OF WIRE.

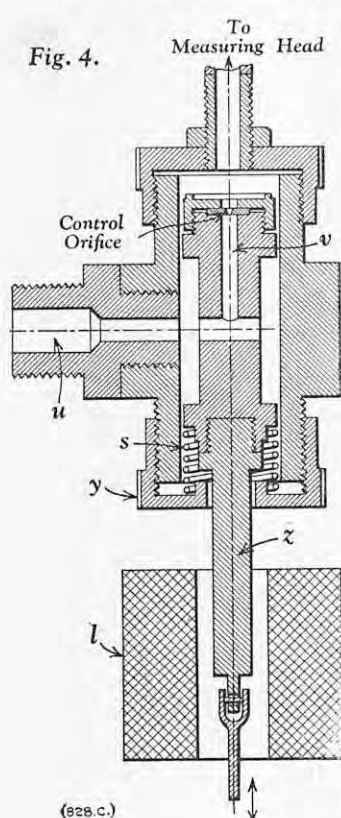


Fig. 5.

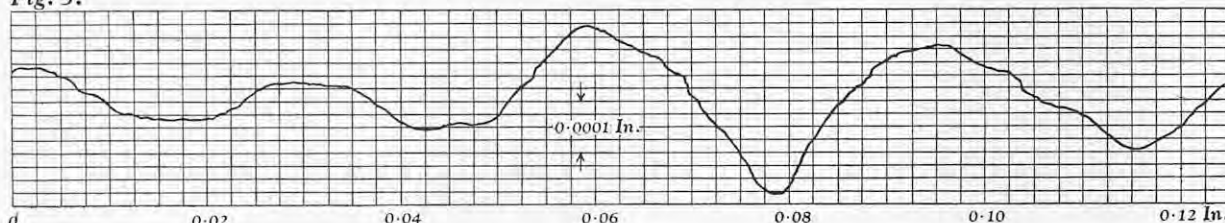


Fig. 6.

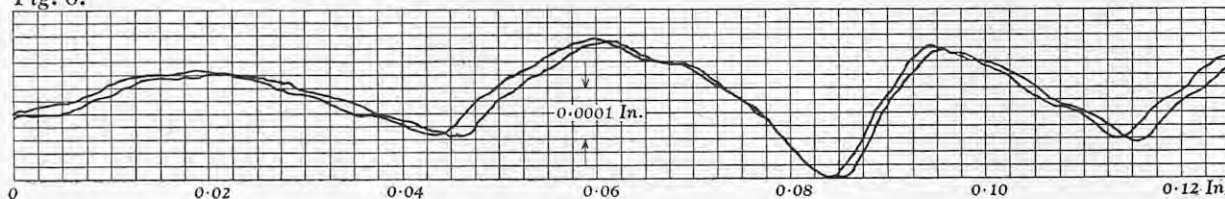
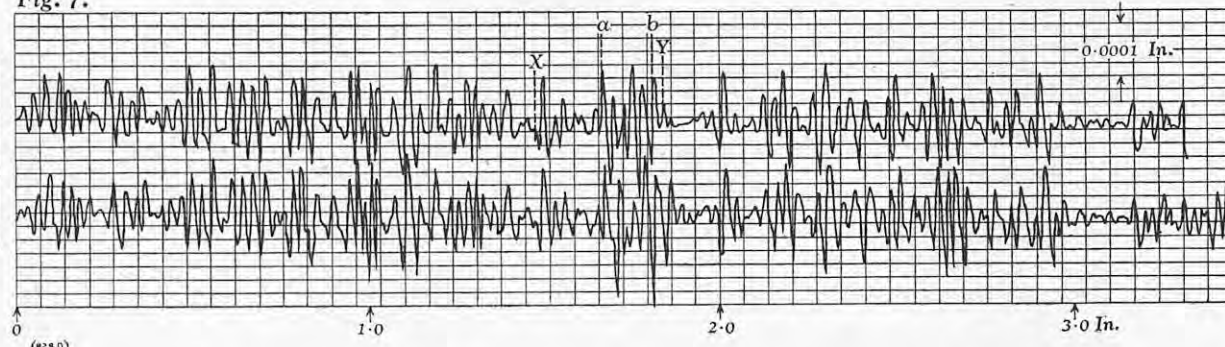


Fig. 7.



varied slightly during the runs so that the displacement is not constant. It will be seen that the two records agree in the diameter measurements to within ± 0.00002 in. Fig. 7 shows repeated records for a 34-in. length of wire when the speed of unreeling was 3 in. per minute and the chart speed 11 in. per minute. In this case the second recording has been displaced laterally, and it will be seen that the two records show good agreement.

In order to ascertain the effect of speed of measurement on the recorded amplitude of the variation of diameter, the portion of wire corresponding to the part of the record X-Y in Fig. 7 was run through again at a speed of 0.05 in. per minute (chart speed 5 in. per minute). Comparison of the two records showed a faithful repetition of form, but the maximum amplitude at the faster speed was about 20 per cent. less than that at the slower speed. The record in Fig. 5 corresponds to the part a-b in Fig. 7. It will be clear then that the general nature of the variation of diameter can be obtained at the higher speed, but if an accurate assessment of the magnitude of the variation is required the lower speed should be used.

It will be appreciated that if the wire under measurement is not circular in section and it twists during its passage through the measuring head, both variation in section and variation along the length will contribute to the record obtained. In this event, repetition such as is shown in Fig. 6 will not be realised. It was considered to be worthwhile to examine the No. 49-s.w.g. enamelled wire by projection at a magnification of $\times 400$, and this showed that, ± 0.0002 in., variations of diameter corresponding closely to those in the comparator records occurred along the length of wire.

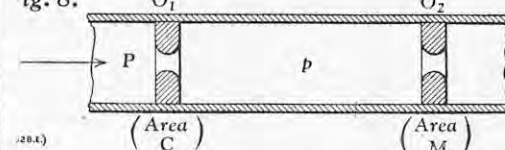
CONCLUSION.

The instrument described is intended solely for measuring variation of diameter and not for determining the mean size. The latter may be obtained by taking several readings along a length of the wire by means of a bench micrometer fitted with a large drum micrometer and a fiducial indicator, and associating these values with the variation shown on the record. If it is desired to make a more accurate determination of the diameter at any local point, the technique described by Rolt and Taylerson* can be employed.

The chart in the pressure recorder can be calibrated by raising the jet *f* and inserting slip gauges between it and the disc *g*, the wire being removed so that the two anvils are in contact. In this way, a displacement of the pen of 0.5 in. was found to correspond to a diameter change of 0.0001 in., showing the overall magnification to be 5,000:1.

* "An Experimental Machine for Measuring Fine Wire," by F. H. Rolt and C. O. Taylerson, *J. Sci. Instr.*, vol. 9, page 259 (1932).

Fig. 8.



APPENDIX.

In Fig. 8, the orifice *O*₁ represents the control orifice in the piston transducer, and the second orifice *O*₂ represents the escapement between the jet and disc in the measuring head. *P* is the constant-pressure input to the transducer, and *p*, the pressure between *O*₁ and *O*₂, is the downward pressure on the piston. Both are referred to atmospheric pressure as datum.

Let *C* be the effective area of escapement at the control orifice and let *M* be that at the measuring head. It has been shown experimentally† that, within the range $0.4 < \frac{p}{P} < 0.9$, the following relationship holds

$$\frac{p}{P} = 1.10 - 0.50 \frac{M}{C} \quad (1)$$

For linear operation, *p* must be confined within this range and this corresponds to confining *M* so that

$$1.4 > \frac{M}{C} > 0.4 \quad (2)$$

The sensitivity of the comparator will, in the first place, depend on the value of *C*, since, from equation (1),

$$\frac{dp}{dM} = -0.50 \frac{P}{C} \quad (3)$$

For maximum sensitivity, *C* must have the minimum value compatible with equation (2). If *M*_{max} represents the maximum value of *M*, corresponding to the minimum diameter of the wire, the optimum value for *C* is

$$C = 0.71 M_{\max} \quad (4)$$

Let *r* = radius of orifice in jet, *x* = distance of disc from jet when the diameter of the portion of wire between the anvils is *D*, then

$$M = 2\pi k r x \quad (5)$$

where *k* is a factor relating the effective area to the actual area of escapement from the jet. When the working range is correctly chosen, *k* is sensibly constant.†

Let *L* = minimum separation of disc from jet, i.e., separation when wire has its maximum diameter, *L* + Δ = maximum separation of disc from jet, i.e., Δ is the total range of variation of *D*, and *L* = *n* Δ , then

† Graneek and Evans, *ibid.*

$$M_{\min} = 2\pi k r L = 2\pi k r n \Delta$$

$$M_{\max} = 2\pi k r (L + \Delta) = 2\pi k r (n + 1) \Delta$$

and for maximum sensitivity

$$C = 0.71 \times 2\pi k r (n + 1) \Delta \quad (6)$$

From equation (5) $\frac{dM}{dx} = 2\pi k r$, and since $\frac{dx}{dD} = -1$,

$$\frac{dp}{dD} = \frac{dp}{dM} \times \frac{dM}{dx} \times \frac{dx}{dD}$$

$$= -0.50 \frac{P}{0.71 \times 2\pi k r (n + 1) \Delta} \times 2\pi k r \times (-1)$$

$$\text{i.e., } \frac{dp}{dD} = 0.70 \frac{P}{(n + 1) \Delta} \quad (7)$$

For a change δD in the diameter of the wire, the change δp in the pressure acting on the piston is, therefore, given by

$$\delta p = 0.70 \frac{P}{(n + 1) \Delta} \delta D \quad (7a)$$

Let *A* = area of piston, and *S* = spring constant of the spring *s*, then, if δl is the corresponding displacement of the piston, $\delta p = S \delta l$.

Let *l* = input displacement to pneumatic motion transmitter which gives the full range of output pressure (i.e., 2 to 15 lb. per square inch), and λ = corresponding linear displacement of the pen of the recorder.

$$\text{Then } \frac{\delta \lambda}{\lambda} = \frac{\delta l}{l}$$

$$\text{and so } \delta \lambda = \frac{\lambda}{l} \delta l = \frac{\lambda}{l} \frac{A}{s} \delta p$$

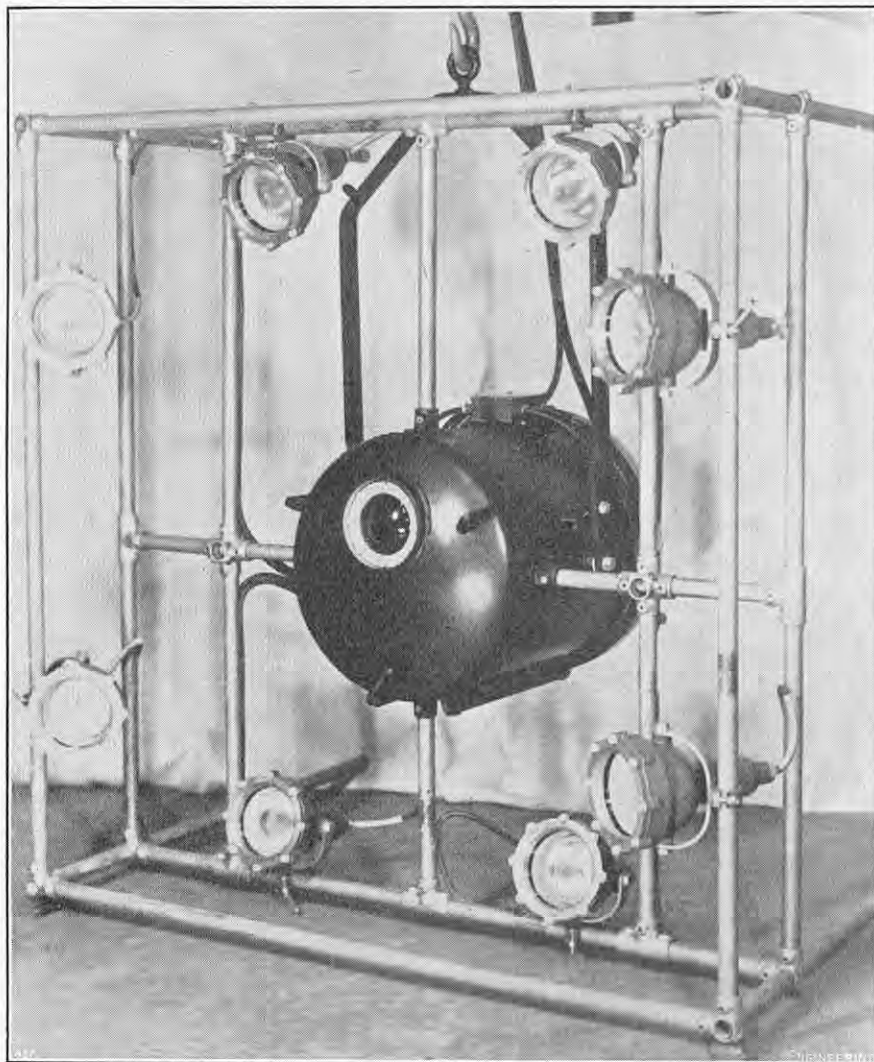
$$\text{i.e., using (7a), } \delta \lambda = \frac{\lambda A}{l s (n + 1) \Delta} 0.70 P \delta D$$

The overall magnification is therefore given by

$$\frac{\delta \lambda}{\delta D} = 0.70 \frac{\lambda A P}{l s (n + 1) \Delta} \quad (8)$$

Equation (8) sums up conveniently the influence on the sensitivity of the various factors concerned. In particular, it shows that the sensitivity is directly proportional to the operating pressure *P* and, though independent of the actual diameter *D*, it is inversely proportional to the range of variation of diameter which must be accommodated. The equation has been deduced on the assumption that the control orifice has been correctly selected to give the maximum sensitivity. The required effective area of escapement at the control orifice is given by equation (6). This equation cannot, however, be used to determine precisely the size of control orifice required because the relationship between effective and actual areas of escapement is not known. Nevertheless, experience has shown that with *k* made unity, the equation will indicate the required size with good results.

UNDERWATER TELEVISION EQUIPMENT.



UNDERWATER TELEVISION.

ALTHOUGH the possibilities of underwater television had been realised for some time and attempts had been made to employ it previously, it was its use for the identification of the wreck of H.M. submarine Affray, which sank with 75 officers and men in the English Channel on April 17, 1951, that first brought it to the notice of the public. For several weeks, the sunken submarine could not be located and when the wreck was subsequently found in Hurd Deep at a depth of 280 ft. the sea and weather conditions were extremely difficult for normal diving work so that it could not be identified with certainty. It was, however, subsequently identified with the aid of somewhat hurriedly constructed underwater television apparatus* which enabled its nameplate to be seen on the screen of a receiver on board the Admiralty diving ship Reclaim. It is not suggested that underwater television is of much use in locating a submerged wreck, but it is of great help in identifying and examining one and might be used to assist with salvage operations, having the obvious advantages that it can be used at great depths in conditions which would render the usual diving operations impracticable, and can remain under water for a much longer period than a diver could in any circumstances. In shallow water, underwater television equipment can be used for inspecting dock gates, ships' hulls below the waterline and other submarine structures without the use of divers or dry docks.

In view of these and other possible applications, Messrs. Marconi's Wireless Telegraph Company, Limited, of Chelmsford, Essex, in co-operation with Messrs. Siebe, Gorman and Company, Limited, of Tolworth, Surbiton, have designed and constructed the equipment illustrated on this page. It consists of a tubular framework, in the centre of which is mounted a cylindrical watertight chamber surrounded by eight 150-watt tungsten-filament reflectored spotlight lamps. The lamps are enclosed in watertight fittings which are mounted on trunnions clamped to the tubular framework so that their positions can be adjusted as desired; the lamps can be controlled in pairs from the surface.

The cylindrical chamber can be tilted to any convenient angle in the vertical plane. The rear end of the chamber is closed by a circular plate secured by bolts and made watertight by a rubber joint. Attached to the rear plate inside the chamber is a Marconi television camera of the type used by the British Broadcasting Corporation for outside television broadcasts. The principal component of the camera is the Image Orthicon pick-up tube, the mosaic of which receives the image formed by a lens which "sees" through an opening in the front end of the cylinder clearly visible in the illustration. The opening is closed by a special lens designed to correct for the different refractive indices of air and water and to avoid the distortion which would be caused if the opening were closed by a thick flat glass plate.

The electrical output from the Image Orthicon, after suitable amplification, is supplied through a multiple flexible cable, which passes through a gland in the cylinder, to a television receiver on the attendant surface ship from which the camera and framework are suspended. The cable is of special design and construction and can be used at depths of over 1,000 ft. In addition to the usual controls, the receiver is provided with means for adjusting the focus of the lens, which forms the image on the Image Orthicon, and also for varying the aperture of this lens by an iris diaphragm in accordance with the intensity of illumination on the object being televised. The focusing arrangements, it may be noted, enable the size and distance of an object to be estimated with reasonable accuracy. Other controls that should be mentioned are an inclinometer mounted on the camera which enables its angular position to be determined at any time, a compass to show the orientation, and an indicator which gives warning immediately if any water should leak into the cylinder. If this should happen, the camera would have to be brought to the surface to prevent damage to the electronic equipment.

At a recent demonstration, the equipment was used in a tank containing about 18 ft. depth of water, which was by no means clear, but the work of a "frog-man," wearing Siebe-Gorman self-contained breathing apparatus, could be clearly seen on the screen; even the lettering on a cigarette packet held by the diver could be read easily. It may be of interest to mention that

good pictures can be obtained with this apparatus at depths up to about 80 ft. without artificial light in certain conditions. It is considered, in fact, that artificial illumination is of little value when the water is clear and not too deep. Another point of interest is that tungsten-filament lamps appear to give better results than either sodium or mercury-vapour lamps. Under test conditions, most of the applications mentioned above have been found to be satisfactory, but others are possible and might prove helpful to engineers in solving some of their problems.

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.

LEONARDO DA VINCI QUINCENTENARY EXHIBITION.—From Thursday, March 6, to about the end of May. In the Diploma Gallery, Royal Academy, Piccadilly, London, W.1. See also page 307, *ante*.

LIÈGE INTERNATIONAL FAIR.—Saturday, April 26, to Sunday, May 11, at Liège. Apply to the Fair secretariat, 17, Boulevard d'Avory, Liège.

TELEVISION CONVENTION.—Monday, April 28, to Saturday, May 3, at Savoy-place, Victoria-embankment, London, W.C.2. Organised by the Radio Section of the Institution of Electrical Engineers. Apply to the secretary of the Institution at the address given above. (Telephone: TEMple Bar 7676.) See also our issue of September 21, 1951, page 371.

INTERNATIONAL FOUNDRY CONGRESS AND SHOW.—Thursday, May 1, to Wednesday, May 7, at Atlantic City, New Jersey, U.S.A. Organised by the American Foundrymen's Society, 616, South Michigan-avenue, Chicago 5, Illinois, U.S.A.

INTERNATIONAL AGRICULTURAL FAIR.—Thursday, May 1, to Wednesday, May 7, at Utrecht. Organised by the Royal Netherlands Industries Fair International, Utrecht, Holland. Agent: Mr. W. Freidhoff, 10, Gloucester-place, London, W.1. (Telephone: WELbeck 9971.)

CHEMICAL WORKS SAFETY CONFERENCE.—Friday, May 2, to Sunday, May 4, at the Palace Hotel, Buxton, Derbyshire. Organised by the Association of British Chemical Manufacturers. For further details, apply to the secretary of the Association, 166, Piccadilly, W.1. (Telephone: REGent 4126.)

BRITISH INDUSTRIES FAIR.—Monday, May 5, to Friday, May 16, at Earl's Court, London, S.W.5, and Olympia, London, W.14; and Castle Bromwich, Birmingham. Particulars from the director, British Industries Fair, Board of Trade, Lacon House, Theobald's-road, London, W.C.1. (Telephone: CHAncery 4411); or the general manager, British Industries Fair, 95, New-street, Birmingham, 2. (Telephone: MIDland 5021.)

INTERNATIONAL EXHIBITION OF ELECTRICAL APPLIANCES.—Tuesday, May 13, to Tuesday, May 27, at Bologna. Apply to the Ente Autonomo Fiera di Bologna, via Farina 6, Bologna.

INTERNATIONAL ROAD FEDERATION, WORLD MEETING.—Tuesday, May 13, to Friday, May 16, at Washington. Apply to the secretary of the Federation, 550, Washington Building, Washington, D.C., U.S.A.; or to the London office at 18, South-street, W.1.

SWEDISH INDUSTRIES FAIR.—Saturday, May 17, to Sunday, May 25, at Gothenburg. Agents: John E. Buck and Co., 47, Brewer-street, London, W.1. (Telephone: GERrard 7576.)

GERMAN EXHIBITION OF CHEMICAL APPARATUS.—Sunday, May 18, to Sunday, May 25, at Frankfurt-on-Main. Organisers: Dechema Deutsche Gesellschaft für Chemisches Apparatewesen E.V., Frankfurt.

ELECTRICAL ASSOCIATION FOR WOMEN, 27TH ANNUAL CONFERENCE.—Monday, May 19, to Saturday, May 24, at Scarborough. Apply to the director, the Electrical Association for Women, 35, Grosvenor-place, London, S.W.1. (Telephone: SLOane 0401.)

ELECTRONICS COURSE AT HARWELL.—Monday, May 19, to Friday, May 23. Applications to the Electronics Division, Atomic Energy Research Establishment, Harwell, Didcot, Berkshire. See also page 169, *ante*.

INSTITUTION OF ILLUMINATING ENGINEERS, SUMMER MEETING.—Tuesday, May 20, to Friday, May 23, at Eastbourne. Particulars from the secretary of the Institution, 32, Victoria-street, London, S.W.1. (Telephone: ABBey 5215.)

INCORPORATED PLANT ENGINEERS.—Wednesday, Thursday and Friday, May 21, 22 and 23, at the Grand Hotel, Harrogate. Fifth annual conference, on "The Scope of the Works Engineer." Apply to the secretary of the Institution, 48, Drury-lane, Solihull, Birmingham.

HEATING, VENTILATING AND AIR CONDITIONING, INTERNATIONAL MEETING.—Tuesday, May 27, to Thurs-

* See ENGINEERING, vol. 172, page 765 (1951).

day, May 29, at 7, Rue La Pérouse, Paris, 16e. Organised by the Institut Technique du Bâtiment et des Travaux Publics, 28, Boulevard Raspail, Paris, 8e.

CONFERENCE ON PREVENTIVE MAINTENANCE.—Wednesday, May 28, at Melton Mowbray. Organised by the Production Engineering Research Association of Great Britain, Staveley Lodge, Melton Mowbray, Leicestershire. (Telephone: Melton Mowbray 535.)

INTERNATIONAL HIGH TENSION CONFERENCE.—Wednesday, May 28, to Saturday, June 7, at the Fondation Berthelot, 28, Rue Saint Dominique, Paris. Apply to Mr. R. A. McMahon, secretary, British National Committee, Thorncroft Manor, Dorking-road, Leatherhead, Surrey. (Telephone: Leatherhead 3423.)

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. Apply to the 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*.

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*.

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*.

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.)

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.

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.

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 our issue of February 15, page 211.

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*.

LABOUR NOTES.

EXECUTIVE officials of the 38 organisations affiliated to the Confederation of Shipbuilding and Engineering Unions unanimously decided at a national conference in London, on Friday last, to accept the wage proposals put forward at the meeting of the Confederation's executive council on April 3. This will involve immediate demands being made to the Engineering and Allied Employers' National Federation and the Shipbuilding Employers' Federation for "substantial" wage increases to employees in these two industries. It is understood that claims have already been submitted and that negotiations may be expected to commence towards the end of May or early in June. In the preliminary stages, proposals for increases for adult male manual employees and for women engaged on men's work will be considered, and, if these result in concessions, proportionate increases will probably be granted to juveniles and other women employees shortly afterwards. Negotiations between the Confederation and the Shipbuilding Employers' Federation are likely to follow closely the course of events in the engineering industry.

Some of the 200 trade-union leaders present at last Friday's conference were in favour of putting forward a demand for a specific sum, but it was decided not to mention any definite amount until negotiations on the claims began, on the ground that further increases in the cost of living may well be expected during the next few weeks. Recent estimates of the total number of employees in the two industries likely to be affected by these claims is three millions, and they may reasonably be expected to add at least another 100,000,000. to the national wage bill.

According to an announcement in last week's issue of the *Railway Review*, the journal of the National Union of Railwaymen, the union is to present a claim at an early date for pay increases on behalf of its 400,000 members in the employ of the various Executives of the British Transport Commission. The executive council of the N.U.R. is arranging for a meeting in the middle of next week with the Associated Society of Locomotive Engineers and Firemen and the Transport Salaried Staffs' Association, when endeavours will be made to decide upon a joint wage policy applicable to all three unions. Coalminers, agricultural employees, tram and bus operatives, firemen, and shop assistants, are among other sections of employees on whose behalf wage claims have been made recently or are due to be submitted shortly, mainly on the ground that the cost of living is rising. In all, some 6,500,000 workpeople affiliated to the Trades Union Congress are concerned in these claims.

The national executive council of the Chemical Workers' Union decided at its quarterly meeting, held on April 19 and 20, that demands should be presented to the employers' organisation in the near future for substantial increases in the wages of all persons employed in the industry. A resolution strongly criticising the Government's economy proposals was also passed, according to a statement issued at the close of the meeting.

Engineering apprentices have received further substantial increases to their pay as a result of an agreement negotiated between the Engineering and Allied Employers' National Federation and the Confederation of Shipbuilding and Engineering Unions on April 17. The increases, which vary from 5s. 6d. a week for a lad 15 years old to 11s. a week for a youth aged 20, will take effect on Monday next. Young employees in the industry benefited proportionately from the general wage increase granted to engineering workpeople in November, 1951. An apprentice aged 20, for example, received an additional 6s. 2½d. a week under the agreement of that date. Early this year, however, the Confederation submitted a separate claim for an additional increase of 20s. a week for all junior engineering employees, on the ground that the services of these young persons to the engineering industry entitled them to higher remuneration. It was in support of this claim that several thousand young engineering employees in Glasgow, Edinburgh, Manchester and Sheffield took part in an unofficial strike last month.

Starting with an increase of 5s. 6d. a week for boys aged 15 and 6s. 3d. for those aged 16, the new agreement gives lads of 17 years 7s. 4d., lads of 18 years 8s. 3d., youths of 19 years 10s. 1d. and those of 20 years 11s. a week more. Including the young people employed by firms directly affiliated to the Federation and those in the service of firms having wage rates which conform to Federation levels, nearly 150,000 boys and youths, in all, are expected to benefit. The cost of the increase will amount to about three million pounds in a full year. A parallel claim, for an all-round increase of 20s. a week, was submitted by the

Confederation to the Shipbuilding Employers' Federation last month in respect of some 18,000 to 20,000 boys and apprentices in the shipbuilding and ship-repairing industries. A meeting between representatives of these bodies to discuss this claim is expected to take place very soon.

A wage claim presented by six trade unions which cater for employees in retail shops owned by co-operative societies has resulted in an award by the National Co-operative Conciliation Board of increases varying between 2s. 6d. and 7s. a week. According to an announcement made on April 17, men, aged 21 and over, will receive 7s. a week extra, and women, aged 21 and over, 5s. a week extra. Men aged between 18 and 20 will get 5s., women aged between 18 and 20 will receive 3s. 6d., while youths under 18 years old and girls in the same age group will obtain increases of 3s. 6d. and 2s. 6d., respectively. The new rates, which do not affect restaurant and café employees, came into force last Monday. Some 280,000 persons employed at about 1,100 co-operative retail shops will benefit from the award. It arose out of a claim for an increase of 10s. a week, regarding which the two sides of the industry were unable to agree. Special interest attaches to this award, in view of the resolutions passed at the annual conference of the Union of Shop, Distributive and Allied Workers at Margate during the Easter week-end, reported on page 502, *ante*. The union decided then that fresh demands for substantial wage increases should be presented on behalf of all its members, notwithstanding that a number of previous claims were not finally settled.

Some particulars of recent steps taken by both sides in connection with the controversy between Durham County Council and a number of professional organisations, which has arisen owing to the Council's closed-shop policy, were made known on Monday last, when a report on the problem by the Council's emergency committee was rejected at a meeting of the labour group of the Council. A deputation from the joint committee, which the organisations set up some weeks ago, met members of the Council's emergency committee earlier this month, to explain the objections of the parent bodies to the closed-shop policy. The joint committee also gave its reasons for requesting that the Council should withdraw the policy completely before April 30, and that the Council should give an undertaking that none of its professional employees would be subject to compulsory membership of a professional body in any manner, direct or indirect.

As a result of the meeting between the Council's emergency committee and the representatives of the professional organisations' joint committee, the emergency committee recommended to the labour group of the Council that, in future, professional persons in the Council's service should not be required to make their applications for extended sick pay through a trade union or other professional body. The emergency committee suggested that each profession should select one person to represent it and that applications for sick pay, and for similar benefits, should be made to the Council by professional employees through those representatives. A meeting of the full Council was held on Wednesday last, at which it was reported that the requests of the joint committee would be declined. It may be recalled that, as stated on page 376, *ante*, the joint committee comprises representatives of the Engineers' Guild, the British Medical Association, the British Dental Association, the National Union of Teachers, the Royal College of Midwives, and the Royal College of Nursing.

A stoppage of work by some 300 workpeople employed by Messrs. J. Samuel White & Co., Ltd., at their shipbuilding works at Cowes, Isle of Wight, commenced on April 17, as the result of a wage dispute. District officials of the Amalgamated Engineering Union, to which the strikers belong, had presented claims for increased wages and had, subsequently, rejected as unsatisfactory an offer by the company. In its turn, the company found itself unable to accept counter proposals put forward on behalf of the employees. At the time of going to press, the strike had not been recognised as official by the union.

Tables showing how the proportion of older persons in the United Kingdom has increased are among a mass of statistical information contained in the *Annual Abstract of Statistics, 1938-1950* (H.M. Stationery Office, price 21s. net), published last Monday. Between the years 1871 and 1950, the total population increased by 85 per cent., but the number of persons aged 65 and over increased by more than 300 per cent., from 1,334,000 (730,000 women and 604,000 men) in 1871, to 5,431,000 (3,160,000 women and 2,271,000 men) in 1950. Expenditure on alcohol rose from 719,000,000l. in 1949 to 724,000,000l. in 1950, and, on tobacco, from 764,000,000l. in 1949 to 778,000,000l. in 1950.

MECHANICS OF CAVITATION.

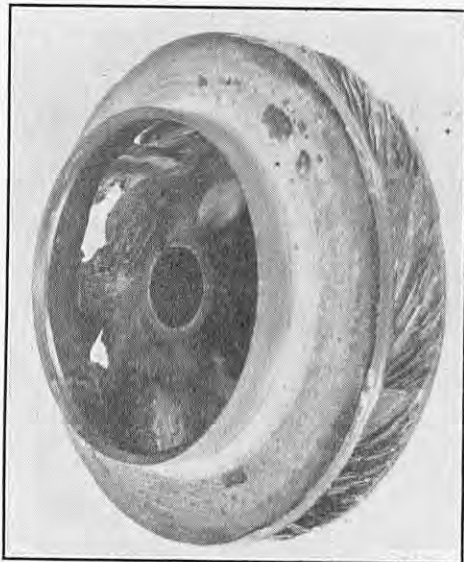


FIG. 1. CAVITATION DAMAGE TO SMALL PUMP IMPELLER.

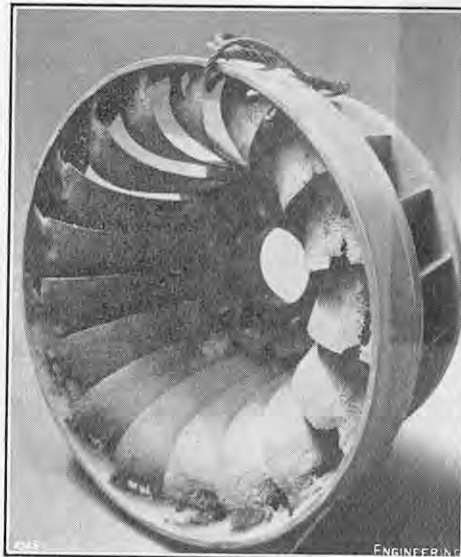


FIG. 2. CAVITATION DAMAGE TO FRANCIS TURBINE RUNNER.

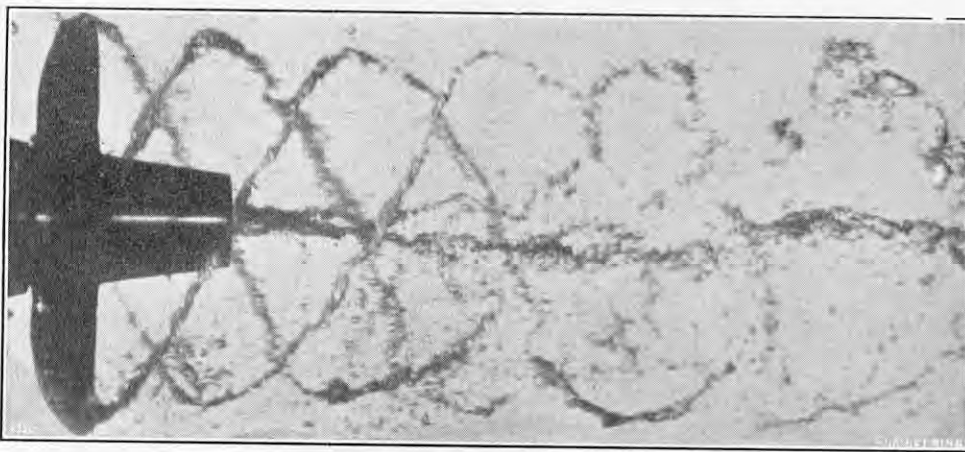


FIG. 3. TIP CAVITATION ON MODEL PROPELLER.

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

By PROFESSOR ROBERT T. KNAPP, Ph.D.†

CAVITATION is one hydraulic phenomenon in which the effects are predominantly undesirable and often destructive. It is true that in a few applications its characteristics are deliberately employed for a constructive purpose; for example, as the means of limiting the capacity of special centrifugal pumps. However, in the majority of cases the inception and growth of cavitation set an upper limit on the performance of hydraulic equipment and prevent the engineer from doing many useful things. The bad effects of cavitation are numerous. One of the most commonly recognised and economically significant effects is the damage that it does to hydraulic structures and machines. Indeed, cavitation damage is so common and so serious that many people think of it as the phenomenon itself rather than as an effect of which the cavitation is the cause.

EFFECTS OF CAVITATION.

Cavitation Damage.—Engineering journals contain many descriptions of the destructive effect of cavitation damage. The civil engineer encounters it in hydraulic structures. A single flood, which passes over the spillway or through the outlet works of a dam, may leave in its wake cavitation damage that will cost thousands of pounds to repair. Under such conditions many cubic yards of concrete may be removed in an incredibly short time. Needle valves, spillway gates, and seats have been badly damaged as the result of cavitation. In the machinery field, damage to hydraulic turbines

is common. Here the affected area is usually found near the discharge end of the runner passages and in the draft tube, as well as in the relief valve and associated energy dissipation devices. Similar cavitation damage may occur in the impellers of centrifugal pumps, particularly in large units. Figs. 1 and 2, herewith, show two examples of very severe cavitation damage: a small pump impeller and a Francis turbine runner, respectively.

With large pump or turbine installations the plant designer is constantly urged to keep the initial cost as low as possible. This tends to maintain to a minimum the margin of safety against cavitation. Unfortunately, the present knowledge of the factors controlling cavitation is still incomplete. The result is that all too frequently the designed margin of safety is found to be insufficient when the plant is put in operation. On the other hand, in some installations it may even be economically sound to design deliberately for operation with a limited amount of cavitation, on the basis that the necessary annual repairs may be less expensive than the cost of ensuring cavitation-free operation. Marine propellers are another type of hydraulic machine in which cavitation damage is commonly encountered. This is particularly true of high-speed ships. Some of the fast liners have the reputation of requiring major repairs to the propellers or even their replacement between each round trip.

This is by no means an exhaustive list of hydraulic equipment in which cavitation damage may occur. Such a list would be practically endless and would include all sorts of auxiliary equipment such as meters, valves and fittings.

Effects of Cavitation on Performance Characteristics.—Although cavitation damage is one of the most spectacular and easily identified of the deleterious effects of cavitation, it is by no means the only one. Of at least equal—and possibly greater—importance is the effect of cavitation on the performance characteristics of hydraulic equipment. Broadly speaking, it can be said that hydraulic equipment consists of combinations of surfaces or passages which guide and constrain

liquids to flow in specified directions at desired speeds. One effect of cavitation on such a surface or passage is to alter both the effective size of the passage and the direction of the guidance. There are very few cases indeed in which the flow under cavitating conditions conforms more closely to the designer's original intention than does the non-cavitating flow. In general, the flow pattern is degraded. The changes in direction are less than those specified, and the resistance to flow is increased. In centrifugal pumps these effects generally result in loss in head and often a simultaneous increase in power consumption. In hydraulic turbines the power output is lowered. In both cases the efficiency is reduced. Similarly, on ships' propellers, cavitation causes a reduction of the thrust and efficiency, and hence, of the speed of the ship. Fig. 3, herewith, is an example of tip cavitation on a model propeller. Cavitation on fins and rudders of surface and underwater craft causes loss of control and decrease of stabilising effect.

The economic losses resulting from these decreases in performance and efficiency are numerous. Unfortunately, they are not as well recognised as those resulting from cavitation damage. Cavitation damage can cause a shut-down of a piece of equipment and necessitate immediate repair or replacement. It is easy to evaluate both the loss due to the shut-downs and the cost of repair. The events are isolated and conspicuous; hence the charges against them are clearly defined. The economic loss caused by the decrease in performance is less spectacular but much more insidious. Except in rare cases in which the amount of vibration or instability in operation is intolerable, the presence of cavitation interferes comparatively little with the operation of the machine. However, the economic loss due to the degradation of the performance accumulates every hour that the machine is in operation. Few comparative figures are available, but it is safe to say that the economic loss due to this decreased performance is many times that chargeable to cavitation damage. For example, the loss of 1 per cent. of the efficiency of a 10,000-kW turbine would be equivalent to a loss of about 1,000% per year, assuming the load factor to be relatively high. The existence of cavitation might easily cause a drop in efficiency or output of 3 per cent. Thus, the yearly bill against cavitation for such a machine would be 3,000%, in addition to the actual cost of repairs and the loss of revenue due to the out-of-service time.

Vibration and Noise.—The production of vibration in all types of hydraulic equipment is another effect resulting from cavitation. The cavitation process is an unsteady one and is usually associated with relatively large hydrodynamic forces. This produces vibration of the equipment in which the cavitation is occurring. The amplitude of the vibration may range from very small to large enough to cause major damage or even destruction. The cavitation process is essentially noisy. The importance of this noise varies tremendously with the use of the equipment. A given amount of cavitation noise in hydraulic machines in a large power house may be hardly detectable above the general noise level, which averages about 100 decibels. The same amount of noise produced by a cavitating propeller on a submarine may destroy completely the usefulness of the vessel.

This enumeration of the many deleterious effects of cavitation is intended to emphasise the importance of the phenomenon and the need for enough knowledge concerning it to enable the engineer to eliminate or at least control it.

DEFINITION OF CAVITATION.

It has probably been noted that no attempt has been made as yet to describe or define cavitation. This is the normal state of affairs in this field since, even to engineers and scientists, cavitation is generally thought of and discussed in terms of its effects rather than in terms of the mechanics of the phenomenon. There is no intention to imply that little work has been done in this field. On the contrary, much time and effort have been spent in studying cavitation and its effects. Nevertheless, comparatively little definitive laboratory evidence has been accumulated concerning the detailed mechanics of the cavitation process. Some of the major reasons for this situation are: the relatively high speed at which the phenomenon occurs creates major technical difficulties for the experimenter, particularly with respect to quantitative measurements; it is becoming recognised that the characteristics of cavitation depend not only upon the hydrodynamics of the flow, but also on the physical properties of the liquid; the extreme economic seriousness of cavitation damage has placed great emphasis on the development of empirical methods of eliminating or controlling it. In the opinion of the author, this economic pressure has had the effect of diverting considerable effort from the direct study of the cavitation phenomenon. It is also his opinion that it is necessary to have a sound understanding of the mechanics of cavitation on at least a semi-quantitative

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

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basis before significant progress can be made in developing rational design methods of controlling or eliminating it and of increasing the allowable performance limits of hydraulic machines and hydrodynamic processes.

It is now time to turn from consideration of the effects of cavitation to examination of the phenomenon itself. From the engineer's point of view, cavitation may be defined as the formation and collapse of cavities in a stream of flowing liquid which results from pressure changes within the stream caused by changes in the velocity of flow. A cavity may be expected to form at every point in the liquid where the local pressure is reduced to that of the vapour pressure of the liquid at the temperature of the stream. Collapse of such a cavity will start when the pressure in the surrounding liquid becomes greater than the vapour pressure, as, for example, if the cavity is transported by the liquid into a region of higher local pressure.

The formation of cavities is closely related to boiling. However, as far as the mechanics of the process is concerned, it is not necessary that the cavities be vapour-filled. They might conceivably contain nothing or they might contain a gas, such as air, presumably at low pressure. One major difference between cavitation and boiling should be noted. In the boiling process heat is being added continuously to a liquid which is maintained at the vapour pressure in equilibrium with the existing temperature. Bubbles must form to absorb the added heat. If they did not form, the temperature of the liquid would increase. Thus boiling is essentially a thermodynamic process. In the cavitation process the thermodynamic condition is one of constant total heat, that is, no heat is added or taken away from the system. Usually the liquid is cold water or a similar fluid of low vapour pressure. Thus the pressure at which the cavities form is only slightly above absolute zero. If the cavity did not form and if the velocity level of the entire system were slightly increased, the local pressure would drop below absolute zero, that is, the liquid would have to sustain a tension. If a tension could not be sustained, the liquid would "break," thus forming a cavity. This cavity would then fill with vapour by evaporation of the adjacent liquid layer. During the cavity growth, the pressure would be slightly lower than the vapour pressure, as the heat of vaporisation must come from the cooling of the surrounding liquid layer. Since the filling of the cavity is a secondary process, it will be seen that as far as the liquid is concerned, there is little difference between an empty cavity and one that is vapour-filled.

EXPERIMENTAL INVESTIGATIONS.

Several different types of equipment have been developed for the study of the cavitation process.* Most of these fall into one of the following three classes: equipment for studying single cavities; Venturi-type flow channels; and water tunnels.

Single-Cavity Equipment.—Single-cavity equipment is used to study only the collapse phase of cavitation. Reduced to its bare essentials, it consists of a closed container completely filled with liquid, provided with windows to permit observation and measurement. A diaphragm or bellows forms one part of the container. When this is extended mechanically, the added volume must appear in the form of a cavity. The experiment consists in releasing the diaphragm and observing the subsequent behaviour of the cavity. According to the definition just given, this cannot be considered true cavitation, since the changes in pressure are not caused by changes in the velocity of the flow. Indeed, there is no general flow in the experiment. The only liquid movement is associated with the change in volume of the cavity. The experimenter reasons that the method of cavity formation is unimportant, since he is concerned only with the collapse, and since at the beginning of the collapse the cavity is motionless with respect to the liquid. He considers that the pressure changes are the important factors, and that beyond producing these pressure changes the velocity of the fluid has nothing to do with the behaviour of the cavity.

There are several advantages of this type of equipment: the size and location of the cavity are under the control of the experimenter, the system pressure or even the rate of change in pressure can be made whatever is desired, and there is no flow velocity to interfere with the measurements. In addition, the equipment is comparatively inexpensive and small, and the cost of operation is negligible. The principal disadvantage is that the phenomenon under study is not true cavitation, but a simulation of it. Therefore, the validity of the results will be questioned until it can be proved

* This lecture is limited to an examination of experimental findings concerning the mechanics of cavitation and their design implications. The mechanics of cavitation damage and the relative resistance of materials to such damage will not be considered; hence, no description will be given of such well-known equipment as the magnetostriction apparatus.

MECHANICS OF CAVITATION.

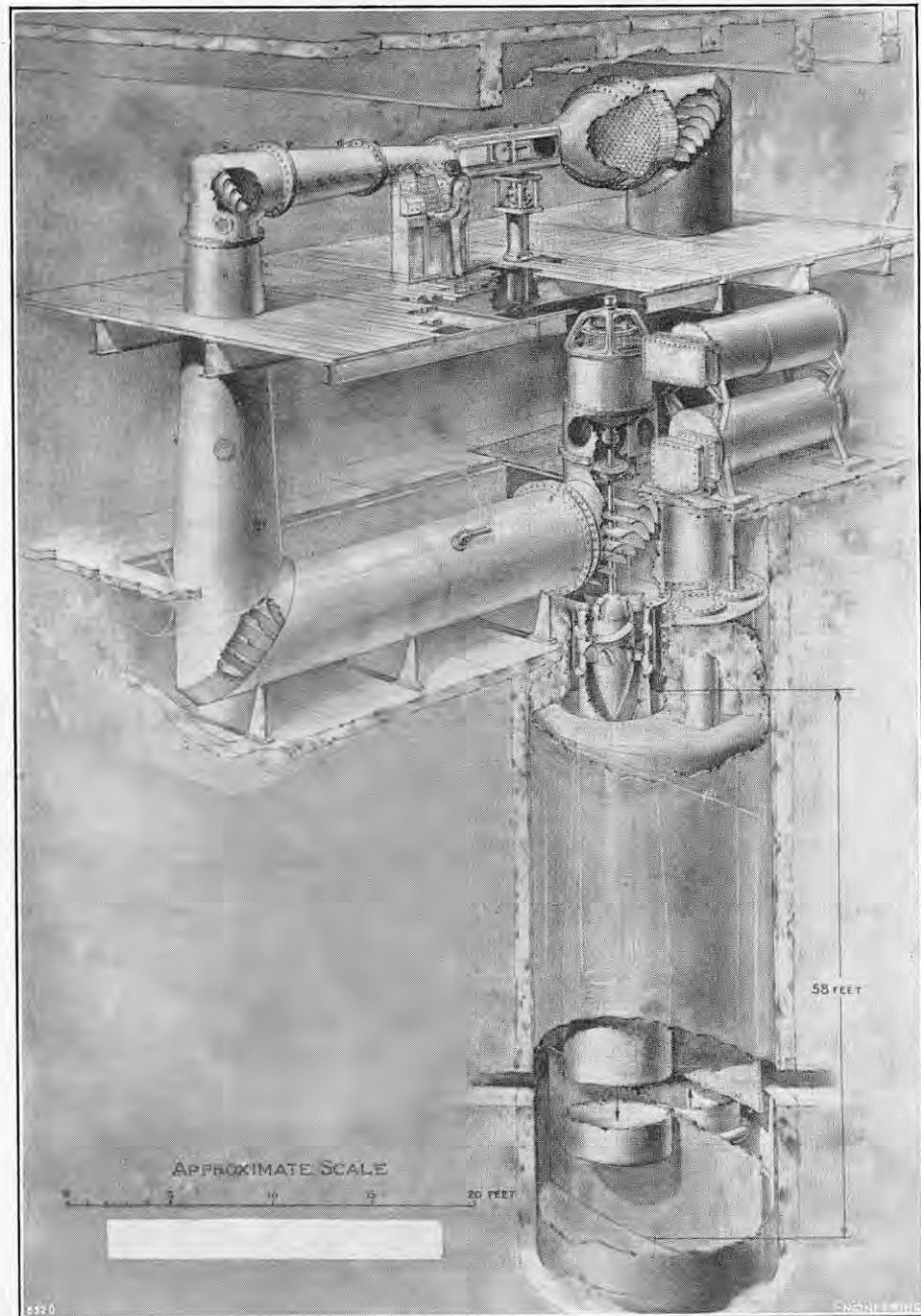


FIG. 4. HIGH-SPEED WATER TUNNEL AT CALIFORNIA INSTITUTE OF TECHNOLOGY.

definitely that the actual and simulated conditions are equivalent. It is probable that the greatest value of this type of experiment is to serve as a preliminary step to the actual experimental programme on true cavitation.

The Venturi Tube.—One of the simplest pieces of equipment that can be used to produce cavitation is the Venturi tube. The liquid is accelerated from the entrance of the tube to the throat. This produces the necessary drop in pressure for the development of a cavity. As the flow leaves the throat and enters the diffuser, deceleration begins, and the consequent increase in the pressure establishes the necessary conditions for cavity collapse. Furthermore, by controlling the system pressure it is possible to change the pressure level in the experimental section without affecting the velocity; thus cavitation can be induced or inhibited at will. Venturi tubes have been used to demonstrate cavitation in the classroom laboratory for many years. Research equipment using the same principle has also been constructed. In such equipment there is no question as to whether or not the real cavitation phenomenon is being studied. Furthermore, by in-setting specimens of different materials in the walls, it is possible to study relative resistance to cavitation damage.

Experience has shown, however, that this type of equipment has inherent limitations. Many of them stem from the fact that the cavitation takes place on the channel walls. This means that the wall configuration determines the location and type of the cavitation.

If it is desired to alter either, a major change in the equipment is necessary. In addition, since, for convenience, the Venturi tube is usually made symmetrical, the extent of the cavitation zone is relatively large compared to the size of the equipment. Therefore, if heavy cavitation is induced, the hydraulic properties of the flow circuit are modified seriously by the decrease in effective cross-section and increase in flow resistance caused by the presence of the cavitation voids. This situation has all the elements required to produce instability, that is, the increase in the resistance and decrease in effective cross-section caused by the cavitation alter the flow, which generally results in a decrease in velocity and an increase in pressure. This, in turn, reacts on the cavitation, tending to reduce it, thus eliminating part of the added resistance and constriction. Consequently, the flow accelerates, the cavitation zone grows, and the cycle restarts. The magnitude and frequency of the pulsations established by these conditions will be determined by the overall characteristics of the system, but they may well be so severe as to make observations impossible.

The Water Tunnel.—The third type of equipment, the water tunnel, appears at first sight to be only a large Venturi tube. The main distinction seems to be that the water tunnel has a longer constant-diameter section at the throat. This is quite true. However, this simple change makes possible a completely different type of use. This constant-diameter section is christened the "working section" and various types of objects are supported in it for test. These test objects

MECHANICS OF CAVITATION.

Fig. 5. MAIN TUNNEL CIRCUIT.

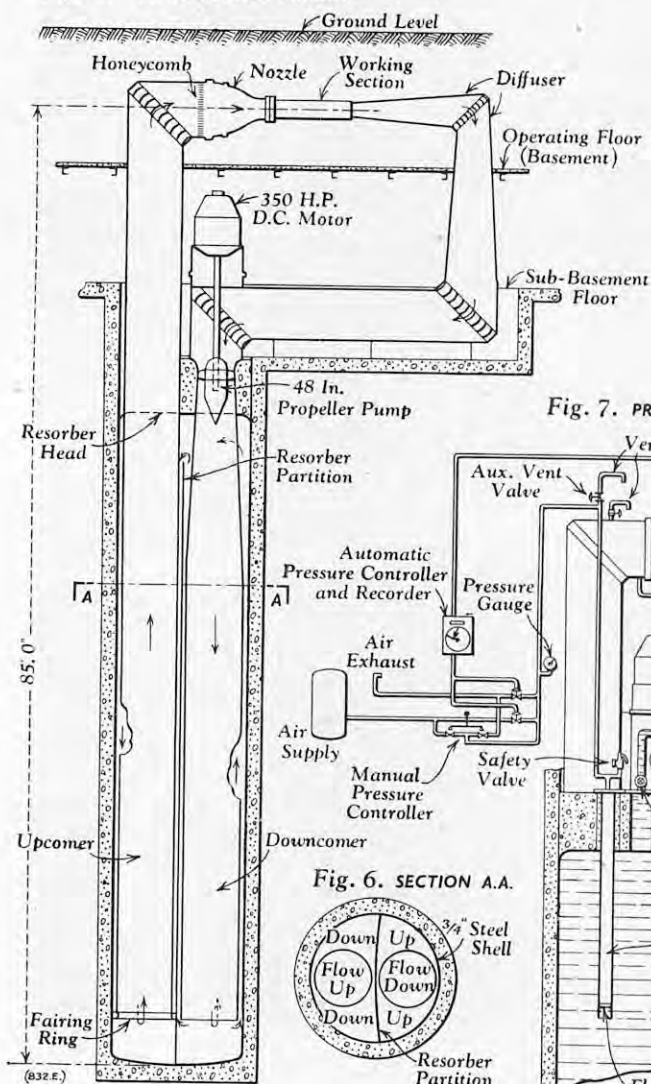


Fig. 6. SECTION A.A.

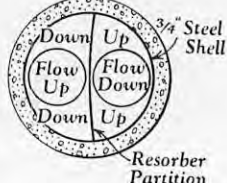


Fig. 7. PRESSURE CONTROL UNIT.

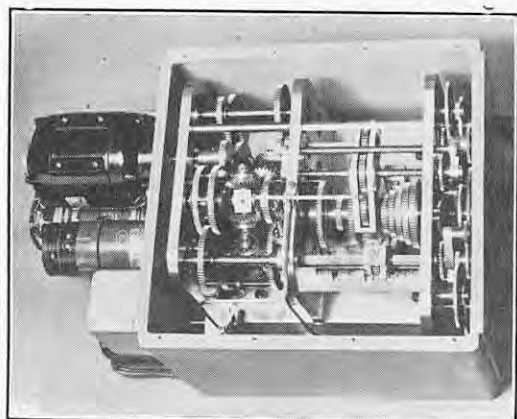
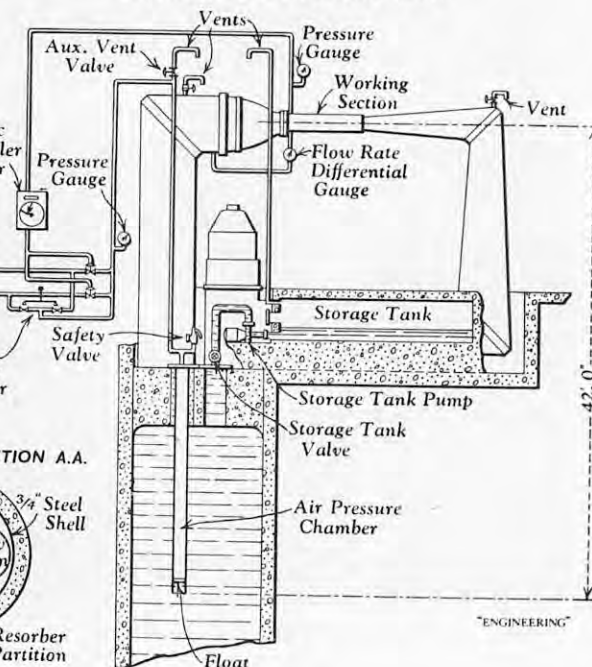


FIG. 8.



FIG. 9.

FIGS. 8 AND 9. SPEED CONTROL UNIT, OPEN AND CLOSED.

are made quite small as compared to the cross-section of the working area. In operation, the pressure in the working section is reduced only enough to produce cavitation on the test object, but not enough to produce it on the tunnel walls. Thus the relative amount of cavitation always remains small and has little or no effect on the characteristics of the flow circuit.

The elimination by the water tunnel of the disadvantages of the Venturi-tube test-equipment is not achieved without some sacrifice. The principal disadvantage of the tunnel is the relatively large increase in size and the consequent increase in cost of construction and operation. For example, consider a Venturi tube which is 2 in. in diameter at the throat. Since the cavitation occurs on the walls, the characteristic size of the test is the full diameter of the tunnel, i.e. 2 in. Assume that, at the maximum throat velocity, it requires a 5-h.p. motor to drive the circulating pump. Now compare this with a water tunnel of the proper

size to test objects of diameter 2 in. with a reasonably low amount of interference from the walls of the tunnel. This will require a working section about 14 in. in diameter. If this is to be operated at the same velocity as the 2-in. tube, it will require about 48 times as much flow. If the two pieces of equipment have the same efficiency, the tunnel will require an input of 240 h.p. as compared with the 5 h.p. needed for the tube. Fortunately, a water tunnel is a versatile piece of equipment which can be used for many purposes other than the study of cavitation.

High-Speed Water Tunnel of the California Institute of Technology.—Most of the experimental results to be discussed were obtained from tests carried out in the Hydrodynamics Laboratory of the California Institute of Technology, principally in the high-speed water tunnel, which is illustrated in Fig. 4, opposite. Since water tunnels and the associated equipment used in cavitation tests are not very common, they will be

described briefly. The two principal types of problem for which the tunnel was designed are: the determination of hydrodynamic forces on moving underwater bodies, and the investigation of various aspects of the cavitation phenomenon. The essential components of the tunnel are as follows: a working section in which the test object may be mounted and observed, a circulating system consisting basically of a propeller-type pump and piping by which the flow of water may be maintained through the working section; an air-content control system which maintains any desired concentration of dissolved air; an absorption system which forces back into solution any air that may come out of the water during the cavitation test, thus maintaining the total air content undisturbed; a cooling system which removes the energy added by the circulating pump and thus maintains a constant temperature; a control system which maintains the pressure and velocity in the working section at any desired set of values; and a force-and-moment balance by means of which a test object may be supported in different positions in the flowing stream and measurements made of the hydrodynamic forces acting upon it.

The working section of the tunnel is 14 in. in diameter and has a usable length of 4 ft. It may be operated at any desired velocity up to 100 ft. per second and at any pressure from vapour pressure to 100 lb. per square inch. A "closed" type of working section is used, because this design reduces the energy loss, increases the stability of the flow, and has other operating advantages. The working section has windows on both sides and the top, to facilitate visual observation and optical measurements. These windows are made of methymethacrolate plastic (Perspex, Lucite). The inside surface is cylindrical and is carefully fitted to match exactly the walls of the working section. The outer surfaces are plane, to reduce the optical distortion which would otherwise result from looking into a cylinder of water. The effectiveness ratio, i.e., the ratio of the amount of kinetic energy in the flow that passes through the working section in unit time to the power input, is about 5 : 1.

The working section is on the upper level, to the right of the operator. Figs. 5 and 6, herewith, show sections of the tunnel, on which the flow circuit can be traced. The 48-in. propeller pump discharges vertically downward into the diffuser and pipe that carries the flow to the bottom of the absorption tank. Here the water reverses and flows upward, passing over the central partition and down again to the bottom of the absorption tank. There it enters the vertical pipe that carries it to the vaned elbow at the working-section level. The flow leaves the elbow in a horizontal direction, passes through a honeycomb and a settling, or quieting, section, and thence through the nozzle into the working section. Screens may be inserted into the settling section to control the turbulence. The nozzle has an area reduction ratio of about 18:1, which results in a uniform velocity distribution and a thin boundary layer at the upstream end of the working section. Below the working section the flow enters the horizontal diffuser, in which the velocity is reduced to about one-third of that in the working section before it reaches the vaned elbow. Here the flow turns downward into a second diffuser, and then passes through two more vaned elbows and a horizontal run of piping to the inlet of the propeller pump. In a system of this design the pump operates under particularly advantageous conditions. The inlet pressure is high because the pump is located at the maximum available distance below the working section, and the velocity is the minimum, since the diffusion has been completed. Furthermore, as the propeller rotates in the horizontal plane, the pressure is the same on all of the blades. This is not so for a horizontal-shaft installation. The resorber, named for its function of resorbing any free air bubbles, accomplishes its purpose by providing a container in which the water is maintained for a relatively long time at a pressure which is considerably above atmospheric pressure under all conditions of operation.

A good pressure-control system is essential for cavitation studies. Fig. 7, on this page, shows the system used in this tunnel. Since the tunnel is closed and completely filled, the pressure of the working section may be controlled by control of the pressure at any point in the system. In this tunnel the control point is a small air chamber in which the water level is approximately 40 ft. below the centre-line of the working section. Owing to this difference in elevations, the air pressure in the control chamber is above atmospheric pressure at all times, even when the working-section pressure approaches the vapour pressure.

The speed-control system operates by holding constant the speed of the motor which drives the 48-in. pump. It is essentially a mechanical speed-matching system, in which the speed of the drive-motor is constantly compared to that of a standard synchronous motor operating from a controlled-frequency power source. Even a minute difference in speed is

MECHANICS OF CAVITATION.

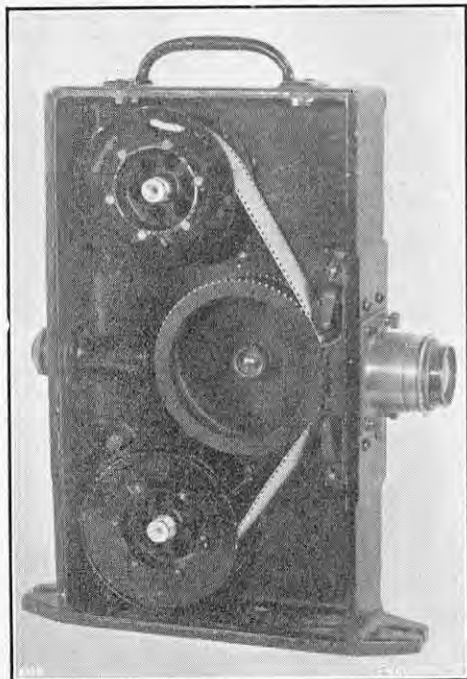


FIG. 10. HIGH-SPEED MOTION-PICTURE CAMERA.

automatically corrected so that the average speed of the drive motor is maintained at exactly the set value. The speed control unit, shown in Figs. 8 and 9, on page 535, contains a gear cluster with three selector gears which provide 1,000 steps of speed control.

High-speed Motion-picture Photography.—The tool selected to record the physical details of the cavitation phenomenon is high-speed motion-picture photography. Motion pictures taken at one speed and projected at another can be considered as performing the function of either a time telescope or microscope. With this concept, the ratio of magnification is the ratio of the picture-taking speed to the projecting speed. For example, if pictures of a given phenomenon are taken at relatively long intervals and then projected at the normal cinema speed of 16 frames per second, the times are apparently shortened in a manner comparable to that in which distances are apparently shortened when observed through a telescope. Conversely, motion pictures taken at a high speed and projected at a much lower speed serve as a time microscope.

Equipment such as this is needed to change the time scale for exactly the same reason that telescopes and microscopes are needed to change the length scale. In the Hydrodynamics Laboratory, pictures of cavitation have been taken at rates varying from 64 to 20,000 frames per second. When these are projected at the normal viewing rate of 16 frames per second, time magnifications of from 4:1 to 1,250:1 are secured.

Photographic Equipment.—Photographic equipment used in this study is of the multi-flash type. The pioneering development in this field was carried out by Professor Harold E. Edgerton and his associates at the Massachusetts Institute of Technology. The system consists of a simple camera in which the recording film moves through the focal plane at a high constant speed. The camera has no mechanical shutter. The required illumination is provided by synchronised flash lamps, which also act as the camera shutter. The camera is the standard General Radio instrument (shown in Fig. 10, above), adapted for use with a series of lenses of varying focal lengths. The commutator provided on the film drum to synchronise the flashes with the film travel is not used; instead, the pulsing of the flash lamps is controlled by an oscillator. The Laboratory has carried out considerable work to increase the flash rate of the lamps. The original equipment operated satisfactorily at 3,000 flashes per second. This limitation was found to be in the control circuit. To increase the maximum picture-taking rate, the Laboratory developed a system in which several control circuits are synchronised through a multi-phase oscillator to discharge their energy pulses in rotation through a single lamp. With this system, the flash rate is that of a single control circuit multiplied by the number of circuits involved. So far, a maximum of six circuits has been used and pictures have been taken at the rate of 30,000 flashes per second.

In the use of such a combined camera and flash-lamp system, the characteristics of the flash lamps exert a controlling influence on the work that can be done.

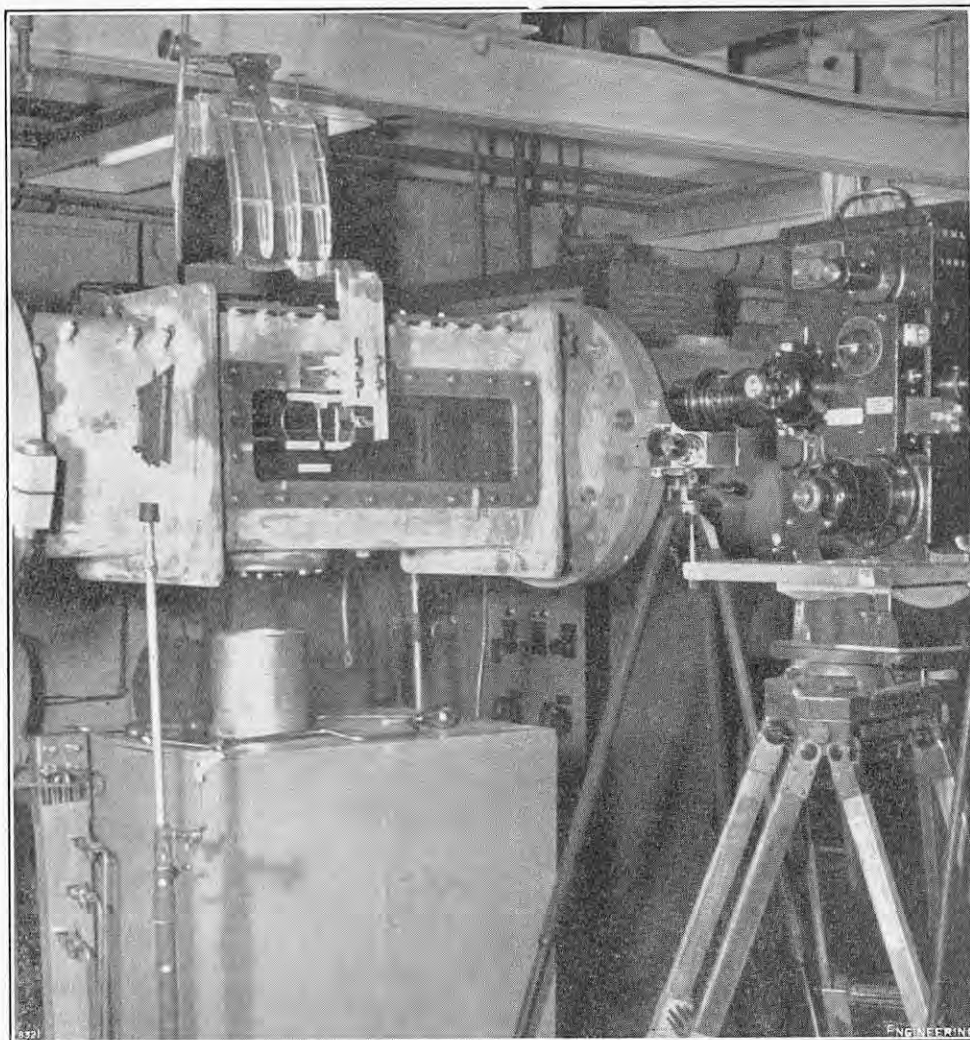


FIG. 11. TUNNEL WORKING SECTION WITH HIGH-SPEED PHOTOGRAPHIC EQUIPMENT.

The most important characteristics of the flash lamp are the effective duration and the brilliance of the flash. The flash duration depends on the tube design, the pressure and composition of the gas used in it, and the energy input per flash. For the flash tubes used in this work the effective flash duration is about 2 microseconds, with an input of 1 joule per flash. For critically sharp results, the maximum usable film speed is fixed by the criterion that the allowable motion of the image on the film during one flash should be equal to the diameter of the circle of confusion of the lens.

A simple example will illustrate the severity of the restrictions imposed upon high-speed motion picture photography by the flash duration and the sharpness requirements. Assume a flash duration of 2 microseconds and an allowable circle of confusion of 0.0025 in. diameter. Under these conditions the maximum permissible velocity of the image on the film is the quotient of the circle of confusion divided by the flash duration. This is 1,250 in. per second, or about 104 ft. per second. Assume cavitation pictures are being taken at a tunnel velocity of 100 ft. per second, and that the camera is so located that the image size is one-sixth that of the object. The corresponding image velocity is about 17 ft. per second. Under normal conditions this velocity is at right-angles to the film travel. The solution of the velocity vector triangle gives a maximum permissible film velocity of slightly over 100 ft. per second. If a picture-taking rate of 20,000 frames per second is required, the maximum permissible frame height is $\frac{1}{2000}$ in., which means that the experimenter must be satisfied with a long and very narrow picture. This calculation also shows that in nearly all cases the film speed is the governing factor and that, unless the object being photographed is moving very rapidly, its speed may safely be ignored.

The light intensity of the flash must be very high to produce an image of reasonable density in the very short exposure time available. Imagine a motion-picture camera of the standard type, using a normal shutter but operating at 20,000 exposures per second. Such a shutter has an effective exposure time of about one-half of the time that has elapsed between successive pictures. In this case, the exposure would be $\frac{1}{40000}$ second, compared with $\frac{1}{24}$ second for a normal motion-

picture camera. Thus, a thousandfold increase in the intensity of illumination would be required if an equal exposure were to be secured. However, $\frac{1}{40000}$ second is 12.5 times as long as the duration of the flash. Hence, the intensity of the flash must be 12,500 times as bright as a light source which would be adequate for a motion-picture camera photographing the same object at the normal rate of 16 frames per second. The flash-lamp system requires a continuous input of 20 kW; however, as the lamp is burning only one-twenty-fifth of the total time, the energy input to it during the exposure is at the rate of 500 kW. The flash lamp used is a small straight quartz tube about 8 in. long and $\frac{1}{4}$ in. in diameter. This is mounted in a cylindrical reflector having an elliptical cross-section of proper dimensions to concentrate the light in a fairly narrow band on the body under test. Fig. 11, above, shows the appearance of the working section when taking the photographs.

Supplementary Experiments.—Supplementary experiments were carried out in conjunction with the high-speed photographs of the cavitation process. Measurements were made of the pressure distribution on the surfaces of the test bodies when operating both under non-cavitating and cavitating conditions. For this purpose, special models were constructed in which a series of piezometer openings was provided. These openings were connected by means of tubes of very small diameter to pressure-measuring equipment on the outside of the tunnel. Some tests of these were made in the Hydrodynamics Laboratory. A more complete series was carried out in the water tunnel at the State University of Iowa.* A few measurements were made of the effect of cavitation on the drag or resistance force by mounting the body on the spindle of the balance, and measuring the drag force directly. This procedure was not so simple because of the severe vibrations induced by cavitation; thus measurements were not as satisfactory as could be desired.

(To be continued.)

* "Cavitation and Pressure Distribution: Head Forms at Zero Angle of Yaw." State University of Iowa Studies in Engineering, Bulletin 32. No. 420, by Hunter Rouse and John S. McNown. 1948.

MERCHANT SHIP DESIGN.*

By SIR WILFRID AYRE.

THE history of shipbuilding tells of a continuous struggle waged by progress in design development against the forces of expediency, complacency, and even deliberate obstruction. Progress in the future will fight this battle also. Shipowners themselves are showing much interest in the future. At least one has inaugurated a prize competition for a cargo-ship design which, as far as aesthetics are concerned, is not restricted to naval architects.

It is unlikely that solid developments in merchant ship design will be influenced to any important degree by mere desire for change. Rather will progress be a result of alterations in economic standards and sociological changes, brought about by such factors as bulk buying and currency restrictions instituted by governments, or by national and international systems of planning. These already have affected the kinds of cargoes carried, and are in process of altering the sea routes over which they are now transported. Shipping services turn on these things, and upon newly-developed habits or tastes of populations. For example, the "average" tanker has grown from 10,000 to 30,000 tons deadweight since 1945, but, as a result of the present world hunger for oil, tank ships of up to 60,000 tons capacity are contemplated.

Progress of sea transport can also be seen in the shift of recognised trade routes, arising from the relocation and recent obscurity in fields of supply of virgin ores, oil, and other commodities greatly in world demand. Thus, a decision to construct the projected St. Lawrence Seaway would immediately stimulate the design and construction of dual-purpose ships for transporting iron ore from the Labrador ranges to the Lower Lake ports, returning with cargoes of grain or oil from the prairie provinces to Montreal and, equally important, for their transshipment during the open lake season to Europe.

The virtual disappearance of coal as a British export has reduced by many millions of tons per annum the volume of bulk carrying by sea, a trade in which the 7,000 to 9,500-ton tramp ships of other days were usually employed. This loss of bulk carrying, accounting for thousands of coal-cargo voyages each year, has without doubt stimulated the demand for oil tank ships, and has caused tramp ship operators to look to the general cargo trades and liner services for employment of their ships. The ease with which higher propulsive powers can be obtained with Diesel engines, compared with triple-expansion steam engines, has also had the effect of increasing modern standards of sea speed, and thus shifting some recently-built ships from the tramp to a more marginal class. Bulk cargoes, such as cereals, hitherto reckoned as the counterpart cargo for the coal and grain tramp ship, will in future be taken care of to a greater extent by general-purpose types and cargo liners which, being adaptable by size, type, and speed, are able to cater for the unclassifiable variety of much sea-borne merchandise.

RAW MATERIALS AND SPECIALIST SHIP TYPES.

In a world craving for raw materials, it is suggested that bulk commodities such as iron, bauxite, titanium, and other essential or strategic ores from new-found ranges, bulk sugar, and minerals such as bauxite in the form of alumina, will be transported in quasi-single-purpose ships, rather than, as hitherto, by any kind of ship that happened to be available. There is little doubt that the policy of some far-seeing shipping companies in building specialist ship types, e.g., for ore carrying, will be followed by operators in other trades where shuttle services are the order of the day. The policy of designing and building ships for a specific route or service will inevitably lead to some compromises in design; while retaining the basic features of the quasi-single-purpose ship, this will enable such vessels to operate as dual-purpose carriers as occasion serves, transporting ore, oil, or grain.

The shipment of edible and other oils in otherwise dry cargo spaces is now a recognised feature of any modern merchant ship. The present arrangement of a deep tank available for water ballast, dry cargo or oil may disappear if a better alternative could be found, which would, no doubt, be welcomed by many shipowners. In the type of vessel with engines amidship, side tanks constructed for water ballast only or for cargo oil could be arranged at the sides of the shaft tunnel in the aftermost holds, as is now fairly common practice in a number of vessels of cargo-liner type. For the bulk cargo carrier the loss of cubic capacity and consequent effect on loaded trim occasioned by such side tanks could be adjusted by increasing the depth of the ship over the after holds.

In view of increasing demands for the transport of perishable merchandise, and developments in the

technique of production of deep-frozen foods such as fish, meat, vegetables and fruit, specially constructed holds for this purpose will soon become a necessity in merchant ships. Processed food in the future will be transported in bulk, and in fresh condition, from cold northern fishing grounds to hot countries. Progress in the processing and deep-freezing of fish will stimulate demand for sea-going fish factories, prototypes of the big whaling ships operating on the fishing grounds, and fed by trawlers or drifters in similar fashion to whale catchers. The carriage by sea of fresh fruits—a growing development over the last 30 years—is now only a matter of ventilation, air conditioning, insulation, or refrigeration, according to the nature of the fruit. In recent years, ships of all kinds have been pressed into this service; but the proved performance of the modern fruit carrier has demonstrated the economic wisdom of transporting perishable fruits in the imperishable way. More ships, it is expected, will be fitted out for this ever-increasing trade.

So long as present international regulations limit the number of passengers that can be carried in a merchant ship to a dozen—if she is to avoid the stringent requirements for full passenger carrying—it is certain that this mode of travel will continue to satisfy the person who prefers to move around the sea routes of the world in a leisurely fashion. Contemporary experience with, and opinion about, the modern 12-passenger cargo ship favours the single-berth cabin arrangement, convertible to a double cabin *en suite* when desired, each with built-in bath or shower with toilet facilities. The 12-passenger cargo ship to-day caters for a marginal service. This mode of sea travel may well develop into a competitor of passenger liner services.

SEA SPEED.

What will be the average sea speed of to-morrow's merchant ship? Past experience has shown that opinion on the speed of cargo ships has generally been influenced by economic considerations. In the case of purely deadweight carriers of similar dimensions, it is an academic statement that, as between a slow-speed ship and a ship having a sea speed, say, 50 per cent. faster, each having appropriate hull form and engine power, the slow-speed ship could transport more cargo in a given time than its speedier rival. Capital, operating, and fuel costs would be lower, resulting in an overall reduced cost per ton carried.

It can be argued that, in a period of low freight rates, the slow-speed ship would benefit, but is it right to assume that, when freights are high, the fast ship, while carrying less, would earn more? There is little recent or reliable experience available on which to pass judgment on this question, because, for the past 13 years at least, no really depressed condition of shipping freights has been encountered; but it is doubtful if any shipowner would to-day revert to slower sea speeds, except in special circumstances. In fact, if the past 13 years had experienced similar fluctuations in the fortunes or misfortunes of shipping to those met with in earlier years, the same progressive increase in ships' speed would have been seen. It is reasonable to predict, therefore, that the future trend of sea speed will be upward rather than downward, and that speeds for vessels of the cargo-liner type will move up to beyond 20 knots.

The growing competition of cargo transport by air may push ship sea speeds to figures far in excess of those current to-day, and even in excess of what is loosely termed the economic speed. If, however, cargo-handling continues to be disrupted, as at present, by avoidable delays in port, it is possible to foresee a tendency to revert to slower sea speeds, with resulting increased deadweight carrying capacity, reduction in capital cost and operating expense, with more days at sea but fewer spent in port.

With regard to the future of hull forms, it is possible that, in future, degrees of fullness or fineness of hull forms in relation to sea speed will show greater discrimination between deadweight carriers, that are more often loaded down to their assigned draught, and "space" ships, where cubic capacity is the dominant consideration while assigned draught is generally only secondary. Deadweight or bulk carriers in the future, helped by still further research in model tank work, are likely to have much fuller forms than is current practice to-day. Space or cubic capacity ships, it is reasonable to envisage, may have finer hull forms than at present. Increased efficiency in hull resistance will result from finer hull form, and from the effect of deeper immersion without increase in average working displacement.

To-day it can be accepted that there are large spheres of influence, respectively, for air and for sea transport. It would be wrong to neglect the possibility that, taking full advantage of progressive improvements and developments in aircraft design or of the products of an atomic age where weight of fuel might be a negligible consideration, the deadweight carrying capacity of aircraft might be raised to much higher levels, resulting in much reduced air freights. This would compete to an increasing degree with

sea-borne transport, and might result in some encroachment on certain classes of goods at present handled by fast cargo liners—perishable foods, costly metals and parcels traffic. Looking some distance ahead, one could predict that cargo transport by air will increase, and that passenger air travel will rise in popularity. Competition in this field will obviously be felt by passenger shipping services.

CARGO HANDLING.

Many attempts have been made to change the time-honoured system of employing derricks and winches for loading and discharging of cargo. The practical and economic possibilities of deck cranes, remote-controlled overhead equipment, and other novel systems of athwartship handling through side ports have been investigated, and a number of Swedish and American ships are already fitted with these arrangements. There are at present certain limitations in the use of cranes and overhead equipment that retard progress along these lines—restrictions of out-reach, lifting capacity, weight and capital cost.

For many years to come it may be difficult to envisage the complete elimination of shipboard loading and discharging equipment. Nevertheless, it is reasonable to predict complete reliance on shore-based equipment in the future for handling general or package-type merchandise. It is opposed to all tenets of economical transport that a ship should carry on all her voyages heavy and costly equipment for handling the goods she carries. Specialist vessels having no cargo-handling gear, such as ore carriers, bulk sugar carriers, also tankers designed primarily for trading between more or less fixed terminal ports, are occasionally required to make diversions from their regular routes and to go to other ports. They are restricted, of course, to those which can accommodate a ship having no discharging equipment. The classification of cargo often varies during a world voyage. Cargo, in many instances, has to be loaded from or discharged into barges, or from and to wharves devoid of handling facilities. There can be little hope, therefore, at least for the immediate future, that shipboard loading and discharging gear can be dispensed with.

But look at this matter from another angle. Delays in discharge of bulk cargoes at terminal ports may well stimulate the wider adoption of mechanically-operated self-loading and discharging gear, in conjunction with hopper-shaped cargo holds. This is no innovation; it has been employed for many years on sea transport services on the Great Lakes and elsewhere. An obvious objection is that in bulk or deadweight carriers the weight of mechanical cargo-handling gear represents a loss of carrying capacity. The use of light metals in the construction of this kind of equipment could considerably reduce the weight handicap. The extra capital cost involved—also substantial—is a matter for actuarial accounting in relation to the circumstances of the case.

It would seem that bulk cargo transport in the future must support mechanisation, to the fullest extent, of every single operation concerned with putting cargo into a ship and landing it overside or on to a wharf. The rival claims for cranes or derricks, or any other system, can only be determined according to the character of cargo to be carried, and the facilities at ports where ships are likely to trade. Where the variety of cargo is wide and requires long out-reach between ship and shore, with occasional heavy lifts, it is difficult to envisage an easy change-over from derricks and winches to any other system that has emerged to date. There is surely a wide field here for the imaginative designer who would wish to change the present system; for so long as cargo handling is performed by shipboard equipment it must be concerned with the speed of turn-round in port, and it cannot be easily divorced from speed at sea because the total time involved in a voyage determines, in large measure, the profit or loss.

TYPE AND LOCATION OF MACHINERY.

The future of the many types of propelling machinery available to-day will be influenced by the trend of sea speed no less than by an ultimate ceiling of carrying capacities of merchant ships. Upper limits of horsepower per shaft are being extended. It may be that this has been stimulated by the growing demand for mammoth oil tank ships and ore carriers. Because of these demands, for increased powers, it would seem that Diesel engines may reach power limits per shaft much higher than those in common practice to-day. The present level of power rating, where the choice is between Diesel engine or steam turbine, i.e., about 7,000 brake horse-power, is therefore likely to move up to a much higher ceiling on a single-screw basis. Diesel-engine propulsion will retain its operational attractiveness so long as its fuel consumption, compared with steam turbines, is of the order of 0.40 lb. as against 0.60 lb. per horse-power per hour. While double-acting Diesel engines have fallen into some disfavour in recent years, a revival of this type might

* Paper read at the Spring Meeting of the Institution of Naval Architects, held in London, April 2 to 4, 1952. Abridged.

well be envisaged if only to reach the higher powers per shaft likely to be required.

Not many years ago, the direct-coupled cross-head type of Diesel engine of some 2,000 to 3,000 horse-power was somewhat lightly described as "just a lump of cast iron." The adoption of welded steel construction has substantially reduced its weight and minimised the risks of structural fractures. If, however, the present high type of Diesel engine is to retain its place in large and fast ships, some far-reaching changes for achieving economy of weight, by the use of light metals, would seem to be its surest hope of survival. The geared Diesel engine, which can offer advantages in regard to weight saving, has long since passed the stage of novelty. Further, the increase in propeller efficiency that can result from reduced screw revolutions more than offsets the power absorbed by couplings and gearing.

The gas turbine and—more remotely, perhaps—atomic energy, may well change the whole outlook for Diesel and steam-turbine propulsion. Present research and experience indicate that the gas turbine is lighter per horse-power than Diesels or steam turbines. It is also predicted that, when further metallurgical research is carried out and sea experience has been gained, fuel consumption may equal that of the Diesel engine. It seems sure, therefore, that engines of the future will put more power into less space. If the gas turbine is to be the next stage in ship propulsion, it is quite probable that the controllable-pitch propeller, in association with non-reversing propulsion engines, will be more generally favoured.

More attention might be directed to the use of multiple Diesel engines where lightness of weight is important. Multiple-engine layouts have other merits, including the carrying of complete cylinders as spare gear, as well as of bringing the application of big horse-powers within the orbit of high-speed Diesel power plants. If these ideas are taken farther, the possibility exists of controlling the machinery directly from the bridge. It is yet too early to predict what may be expected from the adoption of gas turbines. It is safe to suggest, however, that it will be the next stage, following the Diesel engine.

The need for unobstructed cargo spaces directs attention to the question whether, in the future, propelling machinery will be located amidships or right aft. Weight of machinery per horse-power is fast diminishing, and, while the installed power and total weight of machinery may tend to increase, it seems inevitable that engines aft will be more favoured. In large cargo vessels with engines aft, the important question of loaded trim would arise. Following the principle that efficient hull form in relation to speed should have first consideration, and that trim can be taken care of by adjustments to the dimensions of cargo and water-ballast spaces, some re-designing would be inevitable. This is easily secured in tankers and ore carriers by arranging an unused space forward of the main cargo holds, but in a general-cargo vessel this would be bad designing. It would seem, therefore, that in either a single-deck or shelter-deck vessel some form of raised quarterdeck would require to be introduced. This idea has been adopted in some tankers, enabling cargo oil tanks to be arranged right forward to the forepeak, and avoiding the dummy cargo hold with resulting reduction in depth of ship. With engines aft, all living accommodation is naturally arranged round the machinery casings.

NEW MATERIALS.

Much has been written about the use of light alloys in ship construction. If progress in this direction has been slow, it is perhaps because of the problems of providing the essential standards of strength, and reluctance to appreciate the benefits that weight reduction can give over the lifetime of a ship. There can be little doubt that aluminium is destined to play an important part in the future design of ships. Apart from its employment for funnels, ventilators, masts, hatch covers, and minor bulkheads, aluminium in a passenger vessel can effect a considerable reduction in the weight—as much as 50 per cent.—of high super-structures, with consequential increase in stability or, alternatively, reduction in breadth of ship, economy in propulsive power and fuel consumption, or increase in speed, or both.

It has been stated that in the new American passenger liner United States some 2,000 tons of aluminium are being incorporated in the hull structure, thus displacing approximately 4,000 tons of steel. Its employment with bulk cargo carriers, because of the additional dead-weight carrying capacity it gives, suggests higher 'tween-deck spaces or, in the case of single-deck ships, increased moulded depth without increasing draught. In the case of the cubic or space ship, reduction in weight might be utilised in fining the hull form without appreciably reducing cubic capacity, thus making possible some reduction in propulsive power required, or, alternatively, permitting an increase in speed.

Two matters of importance deserve early and serious

consideration, namely, the ability to weld stressed structures effectively, and its use in an unpainted state. Electric welding of steel structures is steadily eliminating riveting. If aluminium is to displace steel, it is illogical to revert to riveting. The attractiveness of aluminium as a material should not be effaced by covering it with paint, so that it cannot be easily distinguished from steel.

If the shipbuilding industry is to witness an increasing interest in the use of light metals, is it not possible that the existing fabricating facilities of shipyards will require to undergo changes of importance? In particular may be mentioned the substantial increase in shipyard crane capacity from 5 to 35 tons and over. Light alloys of half the weight of steel can change this. Certainly, any change from steel to aluminium would reflect on the character of ship construction and would change it from a heavy to a light industry, while a new generation of shipbuilding operatives would gradually emerge.

The change in constructional technique in shipbuilding from riveting to electric welding is now firmly established in British shipyards and its future will be seen in a logical development towards the goal of the all-welded hull. Experience to date from some thousands of ships, almost completely or partially welded, is providing valuable material for metallurgical research, the results of which are progressively solving problems associated with electric welding of steel structures, and raising its technique to higher levels of reliability.

SHAPE AND APPEARANCE.

A sensible measure of streamlining of ships' super-structures is a necessity, and, indeed, desirable. Streamlining purely for its own sake is, of course, nonsense. The capital cost involved in relation to the economic advantage, or of the artistic effect on ship profiles, can be disproportionate to the few per cent. reduction in air resistance. Much attention has been given to new shapes of funnels. The near future, however, may see the disappearance of the funnel, for the reason that it does not now serve the purpose for which it was originally intended. In the ship of the future, exhausts will be taken care of in an unobtrusive way via the derrick posts or masts. Shapes of bows and sterns may develop towards securing the greatest water-line length within the limits of overall ship dimensions. Excessively raked stems and elongated stern overhangs do little to improve propulsive efficiency; in fact, they detract from it. Minimum length of stern overhang, sufficient only to protect the rudder and propeller, with maximum effective length of under-water hull form, will give a real and sensible increase in propulsive efficiency. As shelter 'tween-deck height, or depth moulded, may require to be increased in the search for additional cubic capacity, sheer may be either reduced or, preferably, eliminated altogether. For the same reason, the top-gallant forecastle may, and should, also disappear.

CONTRACTS.

DURING March, the British Electricity Authority placed contracts for equipment for power stations, transforming stations and transmission lines, amounting in the aggregate to 2,070,393*l*. The principal orders included one 60,000 kW turbo-generator set, feed-heating and condensing plant for Littlebrook "C" power station, Dartford, with C. A. PARSONS & CO., LTD.; two 30,000-kW turbo-generator sets, feed-heating and condensing plants for Connah's Quay power station, near Flint, also with C. A. PARSONS & CO., LTD.; two generator transformers for Doncaster power station, with the GENERAL ELECTRIC CO., LTD.; 275-kV 7,500-MVA switchgear and 132-kV, 3,500-MVA switchgear, for Elstree substation, with A. REYROLLE & CO., LTD.; and a 132-kV double-circuit overhead line from Little Barford to Fulbourne, with BRITISH INSULATED CABLES LTD. CONSTRUCTION CO., LTD.

THE ENGLISH ELECTRIC CO., LTD., Queen's House, Kingsway, London, W.C.2, have received an order from the South African Railways and Harbours Administration for 60 electric locomotives to operate on the 300-volts direct-current electrified lines of the Union. The order is worth approximately 2,500,000*l*. Each locomotive will weigh 77 tons and will have a maximum axle load of 19.5 tons. The locomotives will be of the class 5E double-bogie type, the wheel arrangement being Bo-Bo, with one-piece cast-steel bogie frames. The four traction motors will develop a total of 2,000 h.p., at the one-hour rating.

STEPHEN EASTON, LTD., Westgate-road, Newcastle-upon-Tyne, are to construct a light machine shop, offices and an apprentices' training school for C. A. Parsons & Co. Ltd., Shields-road, Newcastle.

J. L. THOMPSON & SONS, LTD., Sunderland, are to build a tank ship of 26,450 tons deadweight capacity for the St. Helen's Shipping Co., Ltd., London. She will be engined by WILLIAM DOXFORD & SONS, LTD., Sunderland.

SEMI-AUTOMATIC BUTTON-BLANKING MACHINE.

THE first stage in the production of clothing buttons of animal horn is that of cutting the blanks from irregular pieces of raw material. The material is a natural product, varying in shape, size and thickness and, as it is expensive, the best possible use has to be made of every piece. A single piece of horn may be of such a shape or thickness that part of it is suitable for a particular size of blank, while the remainder will produce blanks of a different size or sizes. It is necessary, therefore, for an operator to present the material to the blanking machine in such a way as to use all of it to the best advantage. This consideration, coupled with the variations in size and shape of the material, precludes the use of a fully-automatic machine with a hopper or other means of feeding the raw material. In the past, blanking has been carried out on a special type of swing lathe, which required of the operator not only skill in selecting the appropriate part of the material, but also considerable physical effort. Moreover, the machine was slow and costly to use.

The machine illustrated on the opposite page has been designed and built by George H. Whitehouse and Son, Limited, Great Bridge, Staffordshire, in co-operation with James Grove and Sons, Limited, button manufacturers, of Halesowen, Worcestershire. It requires a minimum of physical effort on the part of the operator, and works at a speed not possible with the older machine. Basically, it consists of a gripping device to hold the material stationary, two machining heads to work simultaneously on each side of the material, and mechanism for controlling the automatic working cycle.

The general appearance of the machine is shown in Fig. 1, which illustrates it ready for operation, with all guards in position. The operator sits in front of it, a knee-hole being provided in the machine base to enable the working position to be taken up in comfort. A piece of horn is taken by hand, and inserted through the slot in the front cover. The material is seized by the grippers, and the two machining heads (which can be seen in Fig. 2, showing the machine with the guard raised) start work on an automatic cycle, facing and forming the blank, and then trepanning it out of the piece of horn. When this is done, the grippers release the material, and the operator moves it to a new position, or inserts a fresh piece. The slot in the cover is sufficiently wide to enable the operator to see how to place the material relative to the machining heads. To ensure that the operator's hands do not enter the slot, a Perspex screen is provided which itself is also slotted, but only sufficiently to pass the material. By changing the tools and gripper faces, any size of blank between $\frac{3}{8}$ in. to $1\frac{1}{2}$ in. in diameter can be made, and the speed of the machine can be varied to suit any size in the range. An infinitely-variable gear gives machining speeds from 3,200 r.p.m. to 4,400 r.p.m., and 15 to 25 cycles of operation a minute.

The only controls accessible to the operator are a push-button "stop-start" and a clutch lever, both of which can be seen in Figs. 1 and 2. Other controls, such as those for the variable-speed gear and for adjustment, are only used by a machine setter, and so are placed behind the covers, where the operator is not tempted to interfere with them. Normally, the operator need not use the clutch, which is provided to enable the automatic cycle to be stopped or started at any point; but the clutch-control handle is placed at the front of the machine so that it can be used by learners who have not acquired the necessary dexterity in placing the raw material in position quickly. Thus, they can locate the material and then engage the clutch for the machine to carry out its normal cycle, disengaging it again at any time. As it is necessary to hold the material in one hand and to engage the clutch with the other, the control lever has been duplicated, to suit either a right-handed or a left-handed operator.

The machine is mounted on a fabricated mild-steel base, totally enclosed at the front and sides, and fitted with a detachable door occupying the whole of the rear. A Brook 2-h.p. electric motor is mounted in the base, as shown in Fig. 5, and coupled to a Stone-Wallwork positive infinitely-variable gear. From the output pulley, *a*, of this gear a Stephens "Miracle" flat belt transmits the drive to a pulley, *b*, mounted on a countershaft, carried on ball bearings in a cast-iron housing and having at each end, outside the housing, a pulley *c* (Fig. 4).

Two further "Miracle" belts connect the countershaft to splined shafts, *d*, which are carried by Hoffmann angular-contact bearings in reciprocating heads, *e*. The inner ends of these shafts are provided with taper holes and locking rings to take the cutting tools. The machining heads can thus reciprocate freely while the shafts are rotating. The pulleys on these shafts are carried on ball bearings on the splined bushes.

Carried on the countershaft is a grooved pulley, *f*,

SEMI-AUTOMATIC BUTTON-BLANKING MACHINE.

GEORGE H. WHITEHOUSE AND SON, LIMITED, GREAT BRIDGE, STAFFORDSHIRE.

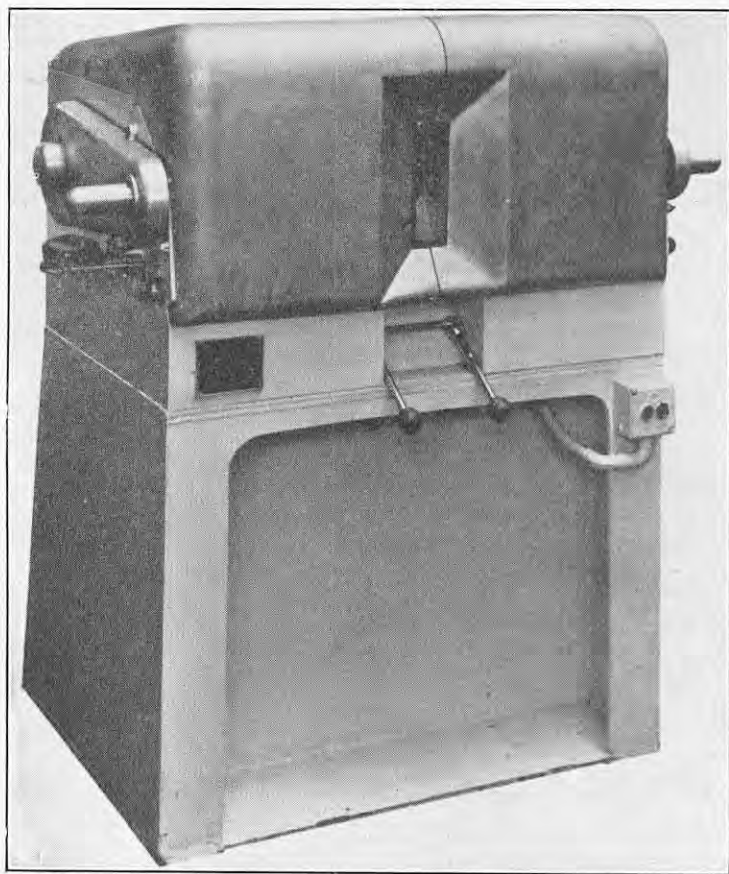


FIG. 1. MACHINE READY FOR OPERATION.

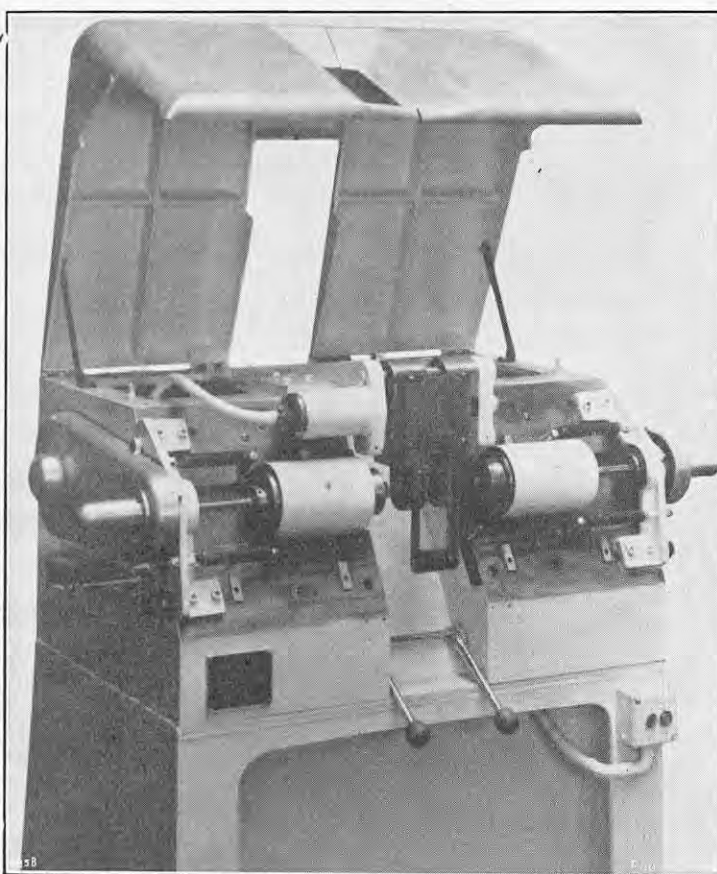


FIG. 2. MACHINE WITH GUARD RAISED.

Fig. 3.

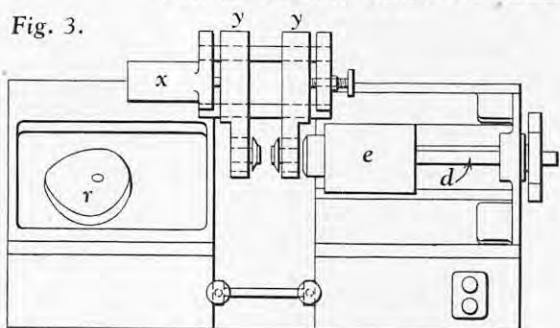
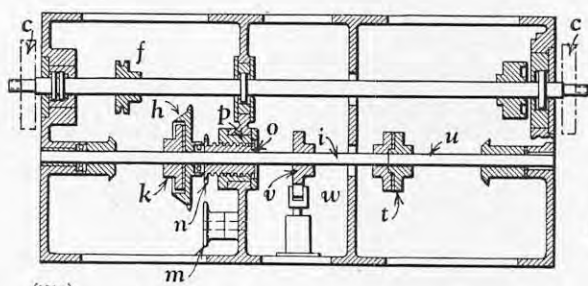
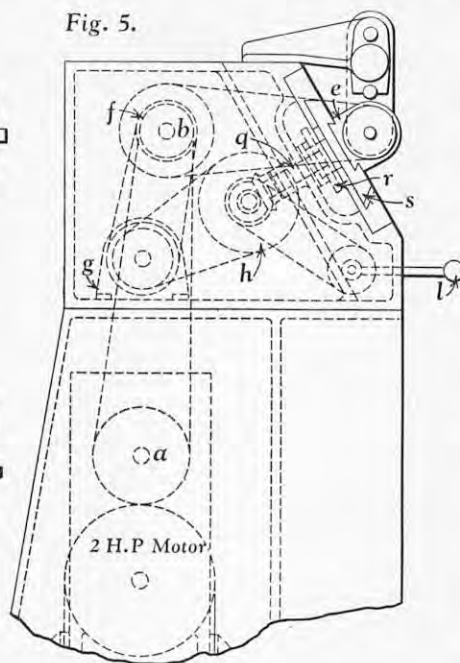


Fig. 4.



(685.C)

Fig. 5.



cam face gives a quick forward motion to bring the tool close to the work, a coarse cutting feed, a fine cutting feed, a quick return, and finally, a dwell at the end of the stroke. The cams are housed in recesses in the housing, in which a small quantity of oil is kept. As the cam rotates, the high part dips in the oil, and carries a little of it upwards, thus oiling itself and the follower roller, which is a standard ball race.

It is necessary for one machining head to work slightly in advance of the other, so that the flat facing tool can finish its work before the shaped trepanning tool breaks through the material. To permit this, the second countershaft is split, and provided with a coupling, *t*, which enables the short portion, *u*, of the shaft to be set at an angle to the main part.

The second countershaft also carries a small cam, *v*, which operates a Ross air valve, *w*. This controls the pneumatic gripping cylinder, *x*. The gripping of the material is effected by two grippers *y, y*, mounted on guide bars in a bracket on the head of the machine. The assembly can be seen in Fig. 2. The grippers carry serrated hardened rings through which the tools pass to work on the material. The rings are interchangeable to suit different sizes of blank. The right-hand gripper is stationary, but it is adjustable, by means of a screw and locking nut, to allow for varying thicknesses of material. A rubber stop prevents the hardened faces of the gripping rings from coming into contact if the operator fails to put a piece of material in position.

To provide for safety if the compressed-air supply to the machine should fail, a pressure switch, supplied by the British Thomson-Houston Company, Limited, is mounted in the main housing, and is wired into the motor circuit. It is set to operate at 80 lb. per square inch; if the pressure falls below this figure, the motor circuit is opened and the machine stops. Similarly, if the operator attempts to start the machine before the air compressor is at work, or before it has built up the correct pressure in the supply line, the motor will not start.

The operation of the machine is as follows. Having been set for the size of blank required, it is started by the push button. A piece of horn is then inserted in the slot in the front of the machine, and aligned correctly relative to the grippers. It is held there until the grippers close automatically. Both machining heads then move forward rapidly, slowing down as they reach the working position. One head (usually that on the right, though it can be either, according to which is selected for the trepanning

from which a Brammer built-up V belt transfers the drive to a heliocentric gear, *g*, of 80 to 1 ratio, supplied by Sanderson Brothers and Newbould, Limited. From the output side of this gear there is a Renold $\frac{1}{2}$ -in. pitch roller-chain drive to a clutch sprocket *h*, freely mounted on a second countershaft, *i*. There is a friction disc between the sprocket and the fixed clutch member, *k*, which is keyed to the shaft. To engage the clutch, the lever, *l*, is moved upwards. This turns a chain sprocket, *m*, which, by means of a chain and a second sprocket, *n*, partly rotates a coarse-thread screw, *o*, in a fixed threaded screw block, *p*. By this means the free clutch member is forced against the fixed member, and the shaft revolves. The end-thrust thus caused is taken by two ball thrust-bearings, one in the free clutch member, and one in the main housing.

At each end of the second countershaft is a bevel gear connecting it with another shaft, *q*. Each of

these shafts carries a cam *r*, which engages a roller, projecting from the underside of a slide, *s*, carrying the machining head, *e*. Rotation of this cam causes the slide, and therefore the head which is mounted on it, to move forward to the working position. Each head is adjustably mounted on its slide so that the depth of penetration of the tool can be set as required. Contact between the cam and the roller is maintained by coil springs, which also return the slide to its "start" position.

The slides themselves are mounted in removable plates recessed into the housing, and also carrying the brackets for the sliding pulleys. The heads, slides, and pulleys can therefore be removed as complete units, to give access to the cams underneath. Long gibs are provided under the lower parts of the slides to allow for wear. The cams, which are of cast iron, are readily interchangeable to give different feed rates if the machine is required to work on other material. The

operation) works a little in advance of the other, and begins to form a flat face in the material. The first head finishes its work and returns rapidly to its start position, where it dwells. The second head finishes the trepanning, and also returns to dwell. The grippers then open, allowing the material to be re-located by hand, or a fresh piece to be inserted. Finally, the grippers close and the cycle repeats.

The machine is provided with grease-gun nipples for lubrication, and, if required, can have an extra fitting, a mechanical counter to record the number of strokes made by the heads. It is designed so that automatic feeding equipment can be incorporated if desired, when working on material of uniform shape and size, such as plastic sheet, in which case it would be made fully automatic.

ANNUALS AND REFERENCE BOOKS.

Post Office London Directory, 1952.

Kelly's Directories Ltd., 186, Strand, London, W.C.2.
[Price 5s. net.]

In the 1952 edition, the 153rd annual issue of this *Directory*, all the familiar sections have been thoroughly revised. As heretofore, the three main sections comprise a street directory, an alphabetical list of commercial, business and professional firms, companies and individuals, and a classified trades directory. In addition, shorter lists give the names and addresses of lawyers, Members of Parliament, municipal officers, clergy, etc. There are also sections dealing with the Royal Households, Government offices, embassies, legations, consulates, etc.; the postal services; various banking houses; rail, sea and air transport services and other matters. The street plan issued with the volume is always a highly useful feature, and, this year, in addition to the usual four sectional plans drawn to a scale of 4 in. to a mile, a large part of Central London has been reproduced to a scale of 6 in. to a mile. Notwithstanding its comprehensiveness and the bulk of its 3,000-odd pages, the adoption of a light strong paper makes the *Directory* reasonably easy to handle. The general arrangement and adequate indexing greatly facilitate reference.

Directory of Shipowners, Shipbuilders and Marine Engineers, 1952.

Tothill Press, Limited, 33, Tothill-street, London, S.W.1. [Price 40s. net.]

This year's edition of this standard work of reference is the 50th, a circumstance on which the publishers are to be congratulated. It is compiled, as has been the case for the past 30 years, under the direction of the editor of *The Shipbuilding and Shipping Record*, whose task of revision, he admits, has been unusually heavy. As there are five indexes to be kept up to date, as well as the main sections of shipowners and their fleets, and shipbuilders and marine engineers, not to mention those listing consultants, shipping societies and federations, and Government departments concerned with shipping, it will be appreciated that a single alteration to a name of a man or ship may affect several entries. Nevertheless, our own experience as regular users of the *Directory* confirms that this annual revision is carried out with exemplary care and a notable freedom from error.

Wire Industry Encyclopaedic Handbook, 1952.

The Wire Industry, Limited, 33, Farnival-street, London, E.C.4. [Free to subscribers to *The Wire Industry*; 21s. to non-subscribers.]

THE first edition of the *Encyclopaedic Handbook* was published in 1951 and, as a consequence of the reception accorded to it, the present second enlarged and amended edition has now been issued. The book is divided into seven sections, the first of which is a directory of the names, addresses and telephone numbers of firms listed in the second section, which consists of a buyers' guide. This constitutes a classified guide to materials for, and products of, the wire industry. The next two sections consist of publicity matter displayed by suppliers of the materials, products and machinery used in wire manufacture and ancillary industries. Similarly, sections five and six are devoted to publicity matter supplied by manufacturers of ferrous and non-ferrous metal wire, and of wire articles, springs and other components. The last section is an encyclopaedia comprising technical, commercial and other data covering a wide field intended for the use of all branches of the wire industry. In an appendix are to be found, among other matters of interest, conversion and gauge tables and lists of British Standard publications and of those of overseas standardising organisations.

ALUMINIUM LAUNCH FOR THE ROYAL NAVY.

GRIMSTON ASTOR, LIMITED, BIDEFORD, DEVON.



ALUMINIUM-ALLOY LAUNCH FOR THE ROYAL NAVY.

THE aluminium-alloy launch illustrated above, which was designed and built by Messrs. Grimston Astor, Limited, Bideford, North Devon, is of more than usual interest in that she is the first vessel constructed on the builders' "Two-Way Tension" method to be accepted by the Royal Navy. This method of construction was described at length in an article published in *ENGINEERING*, vol. 171, page 188 (1951), which dealt with the aluminium survey launch Ain-Al-Bahr, constructed for the Pakistan Government by the same builders. In brief, the system entails the fabrication of the shell of the boat in a flat, unstressed condition, the shape of the flat surface corresponding to the developed form of the complete hull. The gunwales, stringers, bilge keels, etc., are riveted to the cladding while it is still in the flat condition and the hull form is obtained by flexing the prefabricated flat skin upwards about the centre line so that it encompasses the transom, the flexing being continued until the two parts forming the stern are joined. The framework previously secured to the flat sheet is arranged so that, during the flexing, or "moulding" process, it controls the movement of the skin and ensures that it automatically assumes the correct form. The sheet, which, in its flat form, was flexible, then forms a tensioned shell or stressed envelope which may be strengthened by the insertion of athwartships frames and bulkheads to withstand wringing strains.

Owing to the fact that the hull is not built from shaped plates fitted to frames but has a skin stressed by double curvature to a spring-like tension, there is a considerable reduction in weight, which in some cases may be as much as 60 per cent. over a hull constructed in the traditional manner. This gives a corresponding reduction in engine power with a commensurate reduction in the space required for fuel stowage. It is understood that the first cost of a boat built on these lines is considerably less than that of a similar wooden or steel vessel, as fabrication of the parts requires no expensive presses or machine tools, standard hand tools sufficing in most cases. Furthermore, the parts can be handled easily and a number of craft built on this system can be exported in the flat state in a single packing case and erected at their destination.

The new launch for the Navy has a length of 26 ft. and can accommodate 12 persons, the design being based on a similar launch built for Lord Bruntisfield last year, when representatives of the Directorate of Naval Construction witnessed the trials before she was dispatched under her own power to the west coast of Ireland, a journey of approximately 350 miles. She is built from aluminium-alloy sheet supplied by the British Aluminium Company, Limited, to specification NS5. There are twin screws each driven by a separate Parsons C4M Ford "Ten" engine developing 22 brake horse-power at 2,600 r.p.m. on the continuous rating. The propellers are 9½ in. in diameter and are coupled to their respective engines through Parsons direct-drive reversing gearboxes. Manoeuvrability is particularly good and it is claimed that with one engine running forward and the other astern the vessel can be turned in approximately her own length. An unusual feature is the extension of the propeller protection skids forward so that they form two keels, the vessel, as a consequence, remaining upright when aground. Steering is controlled from the cockpit, where the

coxswain, seated behind the after cabin bulkhead, can obtain a good view forward through the cabin windscreen. During her trials, which were carried out in Bideford harbour, the launch achieved a mean speed in excess of 15 knots with three passengers and 15 gallons of fuel on board, a creditable achievement.

BOOKS RECEIVED.

The British Journal Photographic Almanac, 1952. Edited by ARTHUR J. DALLADAY. Henry Greenwood and Company, Limited, 24, Wellington-street, London, W.C.2. [Price 5s. net.]

Proceedings at a Symposium on Welding and Riveting Larger Aluminium Structures. Claridges, London, W.1. November, 1951. The Aluminium Development Association, 33, Grosvenor-street, London, W.1. [Price 4s. in boards, 6s. 6d. cloth bound.]

Welding Practice. Edited by E. FUCHS and H. BRADLEY. Volume III. *Welding of Non-Ferrous Metals*. Published, in association with Imperial Chemical Industries, Limited, by Butterworths Scientific Publications, Bell-yard, Temple Bar, London, W.C.2. [Price 22s. 6d. net; the three volumes, 55s. net.]

Symposium on Structural Sandwich Construction. Presented at the Fifty-Fourth Annual Meeting, American Society for Testing Materials, Atlantic City, New Jersey, June 21, 1951. The American Society for Testing Materials, 1916, Race-street, Philadelphia 3, Pennsylvania, U.S.A.

Reinforced Concrete. By DR. OSCAR FABER. E. and F. N. Spon, Limited, 22, Henrietta-street, London, W.C.2. [Price 30s. net.]

Modern Electrical Contracting. By H. R. TAUNTON. Iliffe and Sons, Limited, Dorset House, Stamford-street, London, S.E.1. [Price 10s. 6d. net.]

Marine Auxiliary Machinery. Edited by E. MOLLOY. George Newnes, Limited, Tower House, Southampton-street, London, W.C.2. [Price 35s. net.]

The Purpose and Practice of Motion Study. By ANNE G. SHAW. Harlequin Press Company, Limited, Old Colony House, South King-street, Manchester, 2. [Price 50s. net.]

Steel Defects and Their Detection. By HENRY THOMPSON. Sir Isaac Pitman and Sons, Limited, Pitman House, Parker-street, Kingsway, London, W.C.2. [Price 15s. net.]

Foundations of Electrical Engineering. Volume I. By PROFESSOR H. COTTON and E. W. GOLDING. Sir Isaac Pitman and Sons, Limited, Pitman House, Parker-street, Kingsway, London, W.C.2. [Price 20s. net.]

United States National Bureau of Standards. Circular No. 530. *Printed Circuit Techniques: An Adhesive Tape-Resistor System*. By B. L. DAVIS. The Superintendent of Documents, U.S. Government Printing Office, Washington 25, D.C., U.S.A. [Price 30 cents.]

Canada. Department of Mines and Technical Surveys. Memorandum Series No. 117. *Preliminary Report on Coated Lightweight Concrete Aggregate from Canadian Clays and Shales*. Part I. *Alberta*. By J. G. MATTHEWS. The Director, Mines Branch, Department of Mines and Technical Surveys, Ottawa, Canada.

A Register of Ex-Apprentices and Ex-Trainees of the Metropolitan-Vickers Electrical Company, Limited. Third edition. Metropolitan-Vickers Electrical Company, Limited, Trafford Park, Manchester, 17.

Leçons sur les Principes de l'Electrodynamique Classique. By PROFESSOR ANDRÉ MERCIER. Editions du Griffon, Neuchâtel, Switzerland. [Price 7.80 francs.]