

PRELIMINARY INVESTIGATION OF HYDRAULIC LOCK.

By D. C. SWEENEY, Ph.D., G.I.Mech.E.

THE form of sticking in valves and pumps known as hydraulic lock is sometimes a source of difficulty to manufacturers and users of high-pressure hydraulic equipment. Its increasing frequency of occurrence is undoubtedly a consequence of the trend towards higher pressures and finer working clear-

ances. The following account describes an investigation carried out in the Mechanical Engineering Department of Birmingham University into the characteristics of the phenomenon, with the object of determining its origin and, if possible, means for its avoidance. The influence of hydraulic pressure on the locking force, the build-up of the force with time and the radial movement of a piston in a cylinder were studied. As an indication of the magnitude which the force required to free a locked piston may attain, it may be mentioned that values up to 17 lb. weight were measured on a 2-in. diameter piston subjected to an oil pressure of only 100 lb. per square inch gauge. The results indicate the importance of macroscopic surface irregularities of the components in the form of slight deviations from parallelism, and an explanation is put forward based on the tapering fluid films in the clearances to which these irregularities give rise.

The phenomenon came to the author's notice

from distortion, in which the spindle was forced against the bore by excess pressure in part of the clearance.* The effect was also encountered by J. F. Alcock† in experiments dealing with the sticking of piston valves employed in gas-turbine fuel systems. He suggested that an out-of-balance pressure distribution in the clearances might occur with a plunger tilted across the cylinder bore, or with a displaced conical plunger. Circumferential grooving of the plunger was found helpful. sticking being found in preliminary trials which would have made accurate measurement of these reactions impossible. Experiment showed that the locking force was a function of the static oil pressure and was independent of the flow through the valve. As in the case mentioned by Alcock, circumferential grooving of the piston lands substantially reduced the force, and the original research was continued after treating the pistons in this manner. At this stage, it appeared reasonably certain that the locking could be attributed to an asymmetric

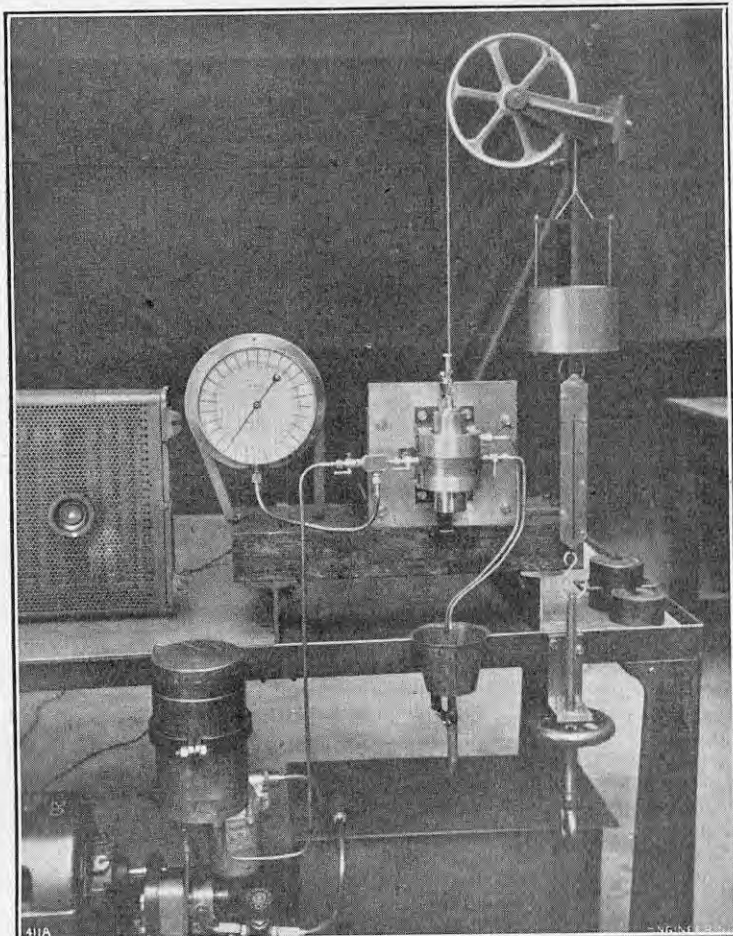


FIG. 1. EXPERIMENTAL APPARATUS.

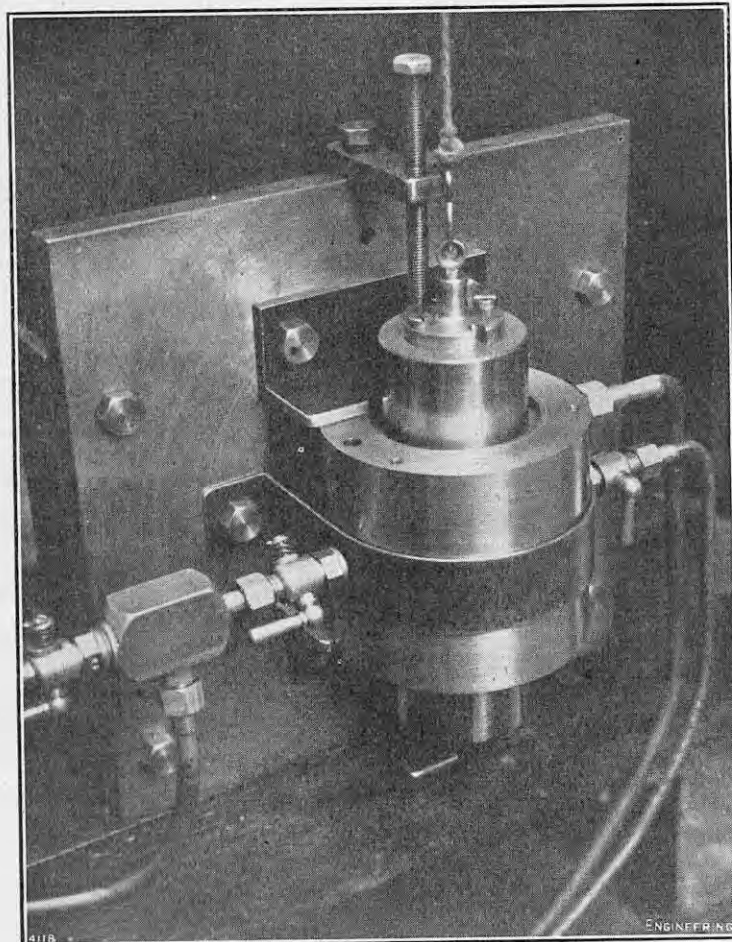
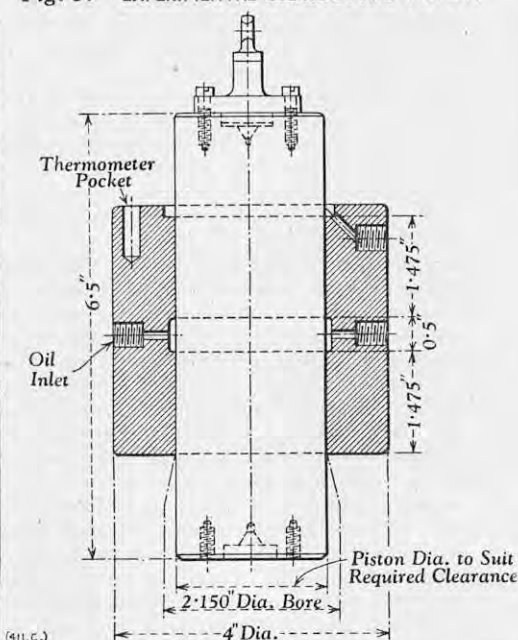


FIG. 2. DETAIL OF CYLINDER.

Fig. 3. EXPERIMENTAL CYLINDER AND PISTON.



during an investigation into unbalanced axial reactions in hydraulic piston valves, an amount of

* Discussion on "The Development of Ultra High-Pressure Hydraulic Systems," by S. M. Parker. *Proc. I. Mech. E.*, vol. 156, No. 3, page 293 (1947).

† Discussion on "Fuel Systems for the Aero Gas Turbine," by E. A. Watson. *Proc. I. Mech. E.*, vol. 158, No. 2, page 203 (1948).

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The phenomenon may occur whenever a piston or shaft slides in a cylinder or bush under conditions producing an axial pressure gradient in the fluid in the working clearances. It is manifested, when the piston is stationary, by a very considerable increase in friction over a period of time. Rapid movement is effective in freeing the locked parts, and a stationary period varying between a few seconds and several hours may be required for the force to build up again. Little information exists concerning this subject, and there appears to be no published work dealing with it specifically. The first reference traced by the writer is to F. H. Towler, who put forward a theory based on lack of concentric stability in a valve, arising possibly

pressure distribution in the clearances between the piston lands and cylinder bore, but the reason for such a distribution was not immediately apparent. It was considered that a more detailed investigation might be profitable, but, before proceeding with this, it was established that neither the wedging in the working clearances of small particles suspended in the fluid, nor distortion of the valve, were responsible for the effect. Measurements of the locking force were made, using pistons and cylinders of various materials, and the influence of oil pressure and the time of its application were observed. Erratic variation of the locking force with the relative positions of the components proved an unexpected difficulty and, as certain time and repetition effects also required more detailed study than was foreseen, it was necessary to curtail the experimental programme. Although full confirmation of the suggested theory was not possible, it is felt that the information obtained helps towards a better understanding of the underlying causes of the phenomenon.

The apparatus used for the experiments is illustrated in Fig. 1, on this page; and, in Fig. 2, the mounting of the cylinder is shown on a larger scale. The internal arrangement and chief dimensions of the experimental cylinders and pistons are shown in Fig. 3. This form for the components was decided on after a number of preliminary tests. Initially, a plain cylinder was used, together with a dumb-bell type piston similar to that in the hydraulic control valve in which the locking effect was first observed, but a change was made to the arrangement shown in Fig. 3 on account of the greater ease with which an accurate bore could be machined

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Fig. 4. VARIATION OF LOCKING FORCE WITH AXIAL POSITION.

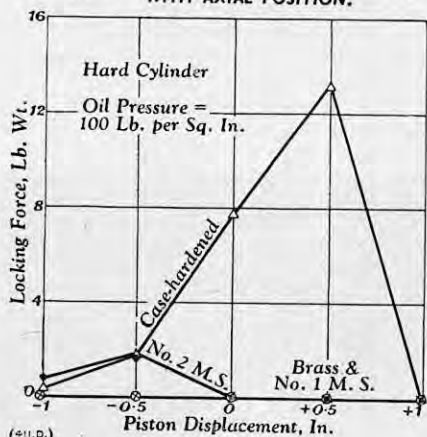


Fig. 5. VARIATION OF LOCKING FORCE WITH AXIAL POSITION.

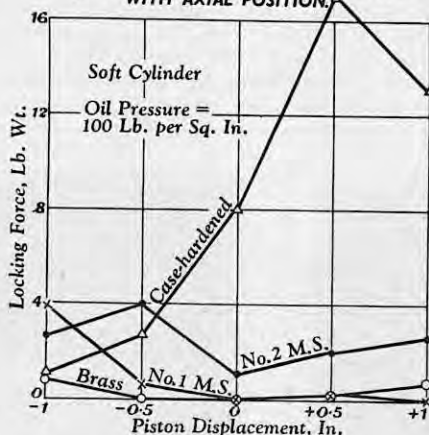
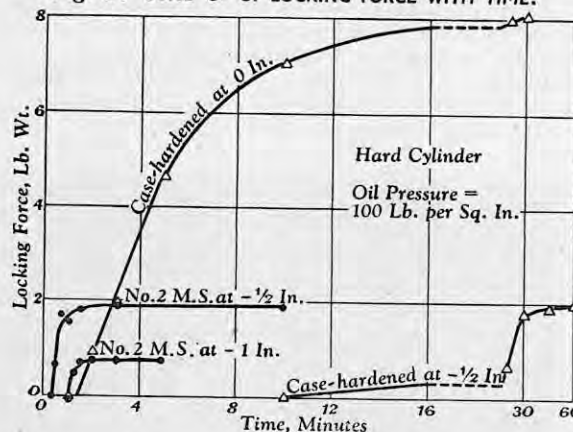


Fig. 6. BUILD UP OF LOCKING FORCE WITH TIME.



in a short cylinder. The cylinder walls were of ample thickness to preclude any possibility of appreciable distortion, arising either from the clamping or from the internally applied oil pressure. Two tapped holes, communicating with the central pressure annulus, were provided for the admission and release of oil. A recess machined in the upper face of the cylinder collected oil leaking through the clearance. A hole drilled in this face formed a pocket into which a mercury thermometer could be dipped for temperature measurement.

The piston was a plain spindle machined from solid bar. To allow it to be suspended from a cord a short link was provided which could be secured to it at either end. The cylinder was clamped to a vertical plate mounted on a channel-section beam, which was bolted to a substantial steel-framed table. Suspended from a cord passed over a pulley carried on ball bearings, the piston was counter-balanced by weights placed in a pan. The force required to free the locked piston was measured on a calibrated spring balance reading to 12 lb. and graduated in 1 oz. divisions, an extension of the range to 30 lb. weight being possible by placing additional weights in the balance pan. A handwheel controlling a threaded rod attached to the balance permitted smooth and gradual application of the load. The method of mounting the cylinder, provided positive location for the latter while leaving it accessible for measurement and observation. A copper pad, having a suitable radius, formed a seating for the cylinder, which was lightly clamped under a steel band. Axial movement of the piston was limited by two stops, the upper of which was adjustable for height and could be swung aside for withdrawal of the piston.

A small gear pump, driven by a variable-speed direct-current motor, provided a supply of oil at pressures up to 200 lb. per square inch, and an air vessel was incorporated to damp out pressure fluctuations on the delivery side. The oil pressure was recorded on a calibrated Bourdon-type gauge connected to a tapping close to the cylinder, the main flow from the pump being by-passed to the reservoir tank through a valve the regulation of which controlled the pressure at the cylinder. A filter of the felt-element type was fitted on the suction side of the pump. The oil employed, manufactured by Price's Lubricants, Limited, Belmont Works, Battersea, London, S.W.11, under the name of "Albaline," was a light mineral oil with a viscosity of 32.3 centipoises at 60 deg. F. Measurements of the locking force were made in the following manner. With the surfaces of the cylinder and piston well lubricated, the piston was accurately counter-balanced. The oil pressure was adjusted to the desired value and the piston, after being released by a rapid reciprocating movement in the cylinder, was set in the desired position. This was conveniently determined by the upper stop, against which the piston was lightly held by an excess weight of about 0.01 lb. placed in the balance pan. After maintaining the oil pressure for a known interval, the stop was withdrawn a short distance, the spring balance hooked on to the threaded tension rod, and the force required to release the piston was

measured. Generally, release was instantaneous and the force therefore clearly defined. A minimum of three readings was obtained at each setting. Measurements were carried out at room temperature with natural fluctuations from 55 deg. F. to 70 deg. F. The pistons, when not in use, were kept immersed in the hydraulic fluid. Beyond this, no precaution was taken to ensure specially clean surfaces, since it was desired to simulate as closely as possible conditions normally found in practice.

Two cylinders, both of mild steel and with a nominal bore diameter of 2.15 in., were used in the investigation, one having a case-hardened bore and the other a soft bore. The former was ground and lapped and the latter fine turned and lapped. Trials were begun with the case-hardened cylinder, in conjunction with two pistons, of mild steel and brass, respectively, each having a nominal diametral clearance of 0.0005 in. When neither piston was found to lock in this cylinder, the soft cylinder, together with a case-hardened piston having the same clearance, was constructed in order to determine whether the surface finish of the bore, or some other cause, was responsible. At a later stage a fourth, mild-steel, piston with a diametral clearance of 0.002 in. was made, primarily to facilitate observation of radial movement within the cylinder bore. All pistons had ground and lightly lapped surfaces. In all, therefore, eight different combinations were available for test. Accurate measurements of the cylinder bores and piston diameters showed the cylinders to be highly uniform and their mean dimensions to be identical within 0.00001 in. The pistons, however, varied considerably, and the mean values of the clearance, nominally 0.0005 in., were found to lie between 0.00029 in. (case-hardened piston) and 0.00085 in. (No. 1 mild-steel piston). These deviations from the nominal size were not entirely disadvantageous, however, since they enabled some of the effects of variation of the working clearance to be observed.

The original intention was to obtain average values of locking force for each combination of piston and cylinder, and so to compare different materials, working clearances, etc. It became apparent at the outset, however, that an erratic variation of the locking force with relative position of the components would have to be accepted as an essential feature of the phenomenon. For this reason, the first measurements were made to obtain representative values of the locking force over a given range of movement with each combination. These were followed by measurements at selected positions, in order to investigate the influence of the time and pressure factors. Figs. 4 and 5, on this page, show values of the locking force obtained with each piston in five axial positions in the hard and soft cylinders, respectively. Piston displacement was measured from the axially central position, and, as in all subsequent tests (unless otherwise stated), readings were taken with an oil pressure of 100 lb. per square inch gauge. In general, an appreciable time was required for the force to build up; this was investigated later. Preliminary measurements enabled a minimum time interval to be determined for each piston.

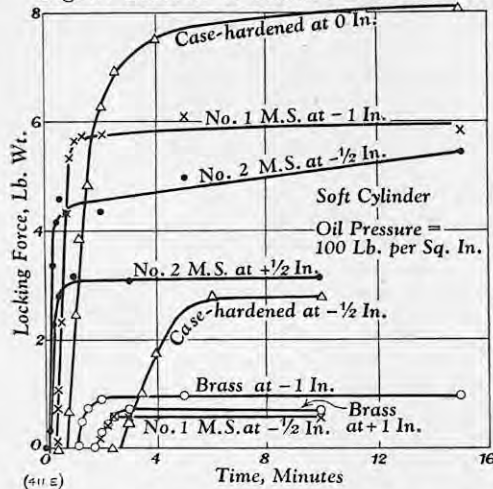
It will be observed that the trends in force variation were somewhat similar with a given piston in each of the cylinders. Such variation could be attributed only to dimensional irregularities of the components. The fact that, with the particular components employed, irregularities in the pistons had the greater influence on the locking force was demonstrated by reversing the pistons in the cylinders. Approximately the same force was measured with the same portion of the piston surface inside the cylinder, so that graphs for the normal and reversed positions were approximately mirror images of each other. The measurements were made at a constant angular setting of the piston relative to the cylinder but, in a number of cases, readings were also taken at four angular positions, spaced 90 deg. apart, at a given axial setting. Although never as extreme as those for axial movement, the observed variations in the locking force were considerable, being of the order of ± 30 per cent. from the mean. Surface irregularities consisting of deviations from true roundness in both cylinder and piston would be necessary to account for this behaviour, since conditions would remain unchanged with relative rotation if either component were perfect.

Tests to determine the influence of time on the build-up of the force were carried out with each piston in two axial positions, chosen, where possible, to give considerably different locking forces. Readings were obtained by measuring the locking force a known time after releasing the piston by reciprocation in the cylinder and resetting it in position. The results are shown in Figs. 6 and 7, on this and the opposite pages. A characteristic feature of the curves is an initial period during which the force is zero, followed by a rise, occupying varying intervals, to a stable value. The total interval tends to increase with decreasing diametral clearance, and, with a given piston, is shorter at the position giving the greater locking force. In certain cases with the soft cylinder, there was a complication, eventually traced to a repetition effect, in the form of a continued, slow increase in the force, of which the curve for the No. 2 mild-steel piston at $-\frac{1}{2}$ in. is an example. It was shown, during a series of 30 readings taken at two-minute intervals with the No. 1 mild-steel piston in the -1 in. position, that a progressive increase in the force from 4 lb. to a fairly consistent value of 6 lb. took place. After an idle period of 40 hours, a locking force of 5 lb. was measured, but a value in the region of 6 lb. was regained after about a dozen measurements.

A likely explanation was that repeated rubbing of the areas of contact between piston and cylinder resulted in local breakdown of the contaminating surface films. The area of intimate metallic contact was then increased, with a consequent increase in the coefficient of friction. The time curves in this case and that of the No. 2 mild-steel piston at a displacement of $+\frac{1}{2}$ in. were recorded after repeatable values of the force were obtained. In the remaining cases, it was apparent that the number of readings had been insufficient for the effect to become appreciable, since trials, in which the hard cylinder was included, showed that, in general, an

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Fig. 7. BUILD UP OF LOCKING FORCE WITH TIME.



increase in the locking force of between 30 and 50 per cent. could be obtained with continued repetition.

Results plotted in Fig. 8, on this page, demonstrate a linear relationship between the locking force and the pressure difference across the working clearances. Although the pressure range covered is comparatively small, having been limited by the type of oil pump employed, there is no indication that the relationship might differ over a wider range. The influence of pressure on the force-time curves is illustrated in Fig. 9 for two pistons in the soft cylinder. The interval before commencement of force build-up at 50 lb. per square inch is seen to be approximately double that at 100 lb. per square inch, and the total time of build-up, also, is increased. The measurements in the soft cylinder, which are plotted in Figs. 8 and 9, were repeatable values. It was observed that, on release of the oil pressure, a locked piston became free if allowed sufficient time. This was not investigated in detail, but some measurements with the case-hardened piston at the axially central position in the soft cylinder showed that the locking force of 9.4 lb. at 100 lb. per square inch had decreased to 1.3 lb. two minutes after pressure release and to 0.25 lb. eight minutes after release, the rate of decrease becoming increasingly slow. A much more rapid fall was obtained with the No. 1 and No. 2 mild-steel pistons in the same cylinder, appreciably less than one minute being sufficient for a decrease to the almost negligible force of 0.06 lb. In general, it appeared that a long release-time was associated with a large locking force or small diametral clearance.

At this stage, it was considered that a knowledge of the attitude of the piston relative to the cylinder bore would be useful. Some information could be obtained by measuring the rate of oil leakage through the clearance between piston and cylinder. It may be shown that the rate of leakage, Q , of a liquid of dynamic viscosity μ through a uniform clearance-volume between two eccentric cylindrical surfaces is

$$Q = \frac{\pi P r}{12 \mu L} c^3 (2 + 3 \epsilon^2), \quad (1)$$

where P is the pressure difference between the ends of the clearance of length L , c is the difference between the radii of the surfaces, which is small compared with their mean radius r , and ϵ is the eccentricity of the surfaces defined as the ratio of the displacement of the cylinder axes to the clearance, c . Since ϵ may assume any value between zero and unity, the rate of leakage may vary over a 2.5 to 1 range. Measurements were made with the No. 1 and No. 2 mild-steel pistons in various axial positions in both cylinders. In all cases, sufficient time was allowed for stable conditions to be attained, and readings were corrected for the variation of viscosity with temperature. Analysis of the results showed that the rate of leakage when sticking occurred agreed substantially with the theoretical value corresponding to the fully-eccentric position. On the other hand, in all non-sticking positions, reduced leakage was observed

Fig. 8. VARIATION OF LOCKING FORCE WITH OIL PRESSURE.

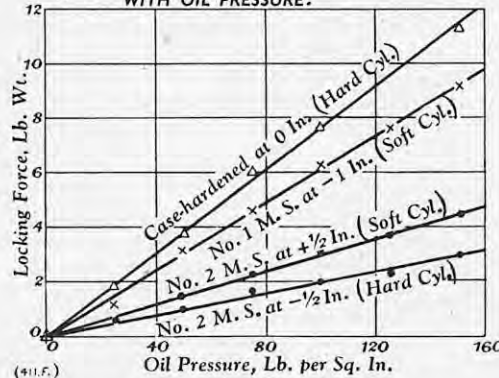


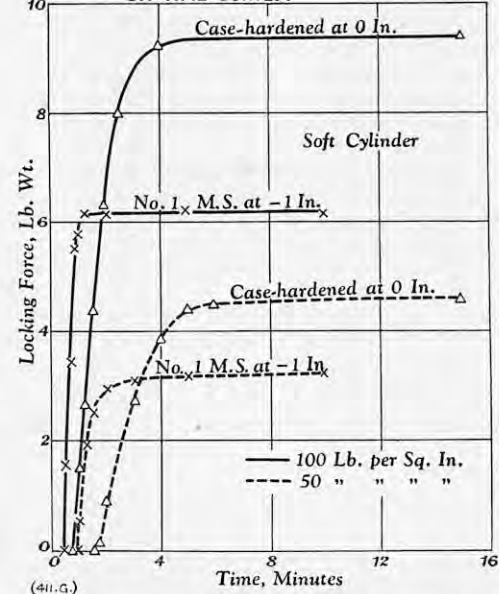
FIG. 10. ARRANGEMENT OF DIAL GAUGES.

and its value lay between the theoretical extremes. All readings were closely reproducible, which indicated that, at a given setting, the piston always assumed the same attitude in the bore, though it was not necessarily in actual contact with the surface of the cylinder.

While this method showed, fairly conclusively, that the piston was fully eccentric in the cylinder whenever sticking occurred, it did not give precise information about the non-sticking condition. This was because a reduction in leakage could occur in either of two ways, namely, by the piston being partly eccentric but parallel to the bore or by its tilting diagonally across the bore. The latter possibility, as will be apparent later, was improbable. However, on this account, and because it was hoped to throw light on the build-up of the locking force, an attempt was made to measure the piston movement directly. Dial gauges graduated in divisions of 0.0001 in. were employed, the arrangement being as illustrated in Fig. 10, on this page. Two brass rings secured to the upper and lower faces of the cylinder carried four gauges, mounted in radial positions separated by 90 deg., with their spindles in contact with the piston. The gauges were set to zero with the piston concentric in the bore, and it was possible from their readings to deduce the movement of the piston in any direction, a tilted position being indicated by lack of agreement between the upper and lower pairs. Pressure of the spindles on the piston was counterbalanced by a spring-loaded plunger located in each of the mounting rings.

Measurements were carried out with the No. 2 mild-steel piston in the hard cylinder at a pressure of 100 lb. per square inch. With the piston set at the $-1/2$ in. axial position and placed in different angular and radial positions, it was found that application of oil pressure resulted in movement of the piston to a stable position in contact with the

Fig. 9. INFLUENCE OF OIL PRESSURE ON TIME CURVES.



bore. Within the limits of accuracy of these measurements (probably ± 0.00005 in.), the piston appeared always to remain parallel to the bore. In the first set of observations, the piston was placed in the bore centrally and was rotated through 90 deg. between successive observations. In the second, the angular position was maintained at 0 deg. and the piston was placed in fully eccentric positions at different points of contact with the cylinder. The zero for angular measurement was the same as that maintained in all previous tests. It was observed that, with the components in different relative angular positions, the nominal line of contact at equilibrium occurred within a limited arc of the piston surface, and that from a given position in contact with the cylinder bore, the piston rolled around the bore to virtually the same position as was reached from the initially concentric position. (It is not unlikely that friction in the dial gauges prevented completion of this movement.) The results indicated the existence of surface irregularities in the form of deviations from true roundness in the components, and pointed again to the greater influence of those on the surface of the piston.

In tests with the piston initially tilted across the bore and making contact on opposite sides at top and bottom, application of pressure resulted in the piston quickly righting itself parallel to, and nearly central in, the bore. This was followed by movement to the normal equilibrium position. As nearly as could be estimated, the movements recorded occupied periods varying between $1\frac{1}{2}$ and 9 min. The piston movement, however, became increasingly slow near the stable position, rendering precise observation difficult. For the same reason, little could be learned about the build-up interval shown by the curves in Figs. 6 and 7, since release of the piston, subsequent to locking, by reciprocation in the cylinder, gave barely perceptible radial movement. Release of the oil pressure after allowing the piston to lock produced no visible movement. Observations were made next with the piston at the $+1/2$ in. position, at which (see Fig. 4) no locking effect was obtained. These established that the piston took up a position parallel to and displaced 0.00045 in. from the centre line of the bore at an angle of 210 deg. for any initial radial placing. That a fully-eccentric position was not attained had been deduced from the measurements of oil leakage. With the knowledge that the piston and cylinder axes remain parallel, the value of the displacement appropriate to the observed leakage was found to agree with the above figure within 0.0001 in.

In order to ascertain whether the differences in locking force exhibited by the various cylinder and piston pairs depended on differences in their coefficients of static friction some measurements of the coefficients were made by placing the cylinder in a horizontal position and measuring the frictional force due to the weight of the piston. Ten readings

were averaged for each pair and measurements were made both with the surfaces flooded with hydraulic fluid and also with dry surfaces. For the latter measurements, the piston and cylinder were cleaned with a mixture of petrol and carbon tetrachloride. Values of the coefficient of friction lying between 0.20 and 0.25 were obtained in all cases.

The experimental work was concluded by making a set of measurements with the case-hardened piston in the soft cylinder, to demonstrate the effect of circumferential grooving as a means of reducing the locking force. Readings were taken at 100 lb. per square inch with the piston in the axially central position. The grooves, $\frac{1}{16}$ -in. wide and $\frac{1}{32}$ -in. deep, were machined in the sections of the piston enclosed by the cylinder, and the first was situated mid-way in the clearance with the remainder added at equally-spaced intervals. The results are given in Table I. It will be seen that a substantial reduction

TABLE I.—Effect of Grooves on Locking Force.

Number of Grooves in Each Clearance.	Locking Force, lb. wt.	Percentage of Initial Force.
0	9.35	100
1	3.73	39.9
3	0.59	6.3
7	0.25	2.7

in the locking force was achieved with as few as three grooves in each of the upper and lower sections of the bore. The reduction may be different in other cases, but the results suggest that the treatment is beneficial. Which of the components is grooved should be immaterial; in the present case, the piston was selected, since it was desired not to modify the cylinder.

(To be continued.)

LITERATURE.

Destins Industriels du Monde.

By ALBERT DUCROCQ. Editions Berger-Levrault, 5, Rue Auguste-Comte, Paris (VI^e). [Price 560 francs.]

THE continued expansion of industry makes progressively increasing demands for energy to drive machines, and materials to feed them, and it is important that those responsible for its direction should have clear ideas concerning the present situation as well as of the future prospects not only in their own country, but throughout the world. This broad basic theme, involving incursions into geography, geology, engineering, economics and politics, is the subject of Mr. Ducrocq's timely survey. Primary consideration is accorded to sources of energy. Practically all derive ultimately from the sun, though some, e.g., coal and oil, represent capital, whereas others, such as water and wind power, constitute revenue. The mechanical equivalent of the energy available per head of population affords a measure of the level of industrial development in a country. This M. Ducrocq expresses in terms of "mechanical slaves," of which each American has at his command 200, each Englishman 32, each Frenchman and each Russian 20, and each Chinese only one.

Coal and oil are still the primary fuels, particularly for transport. During the Nineteenth Century the consumption of coal approximately doubled every 20 years, and at the beginning of the present century, that of oil roughly doubled every ten years. The increasing cost of extraction and the diminishing output from existing deposits has, however, stimulated an active search for alternative sources of energy. Those proposed include hydro-electric schemes, the gasification of poor coal seams *in situ*, the utilisation of solar heat and of the temperature gradients existing in the ocean and within the earth, the harnessing of tides and winds, and the application of nuclear energy to constructive ends. The principles of operation of each are outlined in the book, with accompanying details concerning their stage of advancement and of the heavy capital outlay involved in most of them. In the chapter devoted to electricity, mention is made of the feasibility of transmitting electrical power to this country from Norway with the aid of tubular conductors filled with very low-resistance organic liquids,

and of the present approach to the perplexing problem of an economical accumulator of electricity.

The next section deals with the role of metals in industry, starting with the manufacture of iron and steel, which so largely determines the industrial potential of a nation. A chapter is devoted to the light metals now extensively incorporated in aircraft and for the extraction of which abundant electrical power is essential. A valuable summary follows, covering the sources, isolation and properties of all the metals employed, either singly or as alloy constituents, to satisfy the complex current requirements of industry. From metals, Mr. Ducrocq turns to the contributions of chemistry to civilised living and, in particular, to the part played by plastics, the consumption of which is already beginning to follow the familiar law of geometrical expansion. The special features of the chief synthetic high polymers are described and illustrated by significant instances of their application.

The remainder of the book is devoted to an appraisal of the repercussions of technical progress upon the economic, social and political status of nations. The factors singled out as contributing to increase the true wealth of a nation are expansion of its peacetime industrial potential, improvement in its manufacturing techniques, the employment of more individuals in production and of securing a greater output from each, together with a reduction in the margin between cost of production and cost to the consumer. Sections dealing with the two great and largely self-supporting communities—the United States and Russia—contrast and compare their respective, and largely antagonistic, economic structures, though the absence of reliable statistical data for the latter make definite pronouncements difficult. The causes underlying the plight of England and the misfortunes of Europe are critically examined. Future developments in Africa and South America are reviewed, but prospects in the Far East are deemed too uncertain to merit consideration. Wherever possible, figures are given, and many are very revealing. There is much to provoke thought and stimulate action in this broadly planned, soberly written and clearly presented contribution on a subject of vital concern to all.

The First Hundred Road Motors.

By R. W. KIDNER. Oakwood Press, Tanglewood, South Godstone, Surrey. [Price 9s. net.]

MR. KIDNER's interest and activity in the collection and recording of the history of locomotion are well known to workers in this field, and the various little books on the subject that have emanated from the Oakwood Press—several of which have been noticed in our columns—must have inspired many amateur researches among the confused and often conflicting sources of information that remain. Railways, tramways, motor-buses and steam navigation are, however, almost simple and straightforward in their documentation by comparison with the mass of *ex parte* statements, garbled reports and flat contradictions that confronts the seeker after the truth about early steam locomotion on common roads, and it is no reflection on the author's industry that the present volume raises almost as many queries in the mind of the critical reader as it presents established facts for a foundation on which other inquirers may build. Broadly, Mr. Kidner shows that one hundred British road motors, of which all but two were steam-propelled, had been constructed by 1871; and his text shows how widely his search has ranged for details of their construction and performance. Considering its modest price, too, the book is liberally illustrated; and the bibliography and, still more, the appendix listing the 100 machines in chronological order, should be of some assistance to those who are moved to explore the subject.

Whoever does so, however, is likely to wish that Mr. Kidner had gone much farther towards making this book a source of reference that would avoid the need to repeat much of his own industrious spade-work. In many instances, he does give the dates of newspapers, etc., from which he has quoted, but there are many more cases where this information is lacking. In the appendix mentioned above,

the "first 100" are named in heavy type; but there are intermediate names, not numbered, which are in italic type, and others in ordinary roman characters. The italicised names, it appears from a study of the list, are those of foreign inventors of mechanically-propelled road vehicles, and the introduction to the appendix seems to suggest that the others refer to traction engines, farm vehicles, etc.; but this is not entirely borne out by some of the entries. The Yarrow and Hilditch car of 1861, incidentally, is described as having been built by "W. Cowan" at Greenwich. Possibly the author was not aware that this was the Dr. T. W. Cowan who, after a number of years of active and ingenious mechanical engineering, abandoned it to devote himself to other studies and eventually became an international authority on bees. He received a lengthy obituary notice in *ENGINEERING*, on page 670 of our 121st volume (1926), in which reference was made to his share in the Yarrow and Hilditch car.

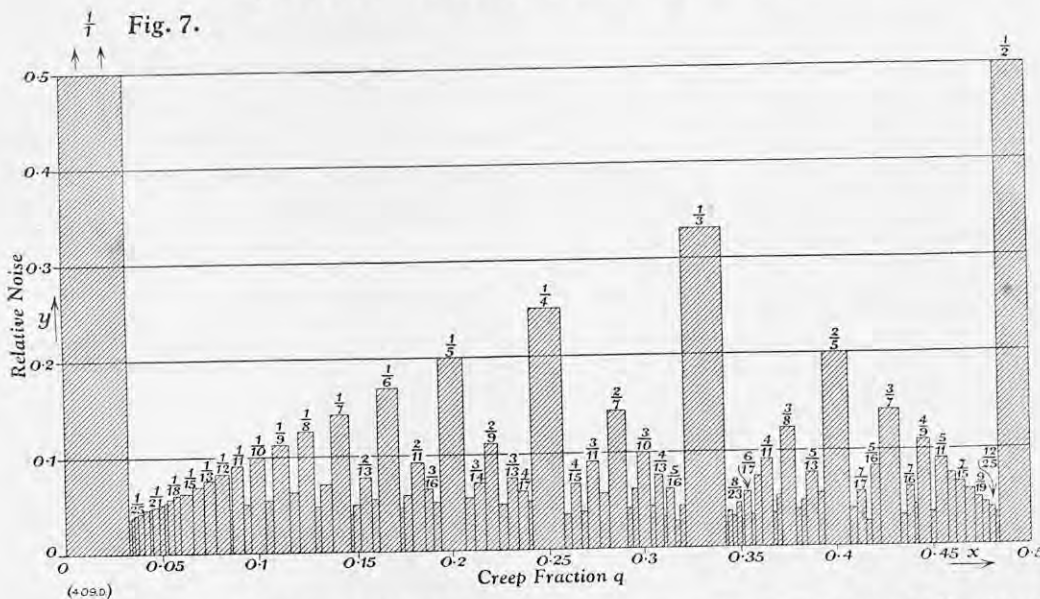
The omission of an initial from the name of Cowan is a small matter, but a careful reading of the book suggests that some other identities have not been quite clear in the author's mind; for example, that he may have confused Joshua Field, F.R.S., who was concerned with Dance's steam car of 1833, with Edward Field, who was associated with Merryweather and Sons, and who gave his name to the Field boiler-tube and to various forms of water-tube boiler in which such tubes were used. Most serious of all, however, are the repeated references (we counted eight) to Sir Frederick Bramwell as "Bramall." So elementary an error, escaping correction on so many occasions, exposes the whole book to a suspicion of inaccuracy which we believe to be generally undeserved, but which the average reader will probably have neither the time nor the means to disprove in detail.

Chemical Engineering Operations.

By DR. F. RUMFORD. Constable and Company, Limited, 10, Orange-street, London, W.C.2. [Price 30s. net.]

MANY of the processes in a chemical factory are of a specialised kind, and the apparatus employed has often to operate under conditions much more arduous than those commonly met with in engineering work. Hence a book like the present one, which reviews the types of plant developed for characteristic duties and explains the principles of their design, should be useful to young engineers and others entering the chemical industry. Its sub-title, "An introduction to the study of chemical plant," is as apt an indication of its nature as could be given. The subject is treated from a practical point of view, with reasons for the methods employed and a good deal of information about the results obtainable. The plan adopted is to deal with each process in a separate chapter, of which there are 14 allotted to operations more or less peculiar to the industry, and three more concerned with heat transfer, metering, and automatic control, respectively. Methods of pumping corrosive and difficult liquids, distillation, gas absorption, leaching, evaporation, drying, mixing, crystallisation, gas-cleaning, crushing, grinding and screening, all have their share of attention, with a discussion of theoretical considerations when this appears necessary. A number of worked-out examples, particularly in the chapter on heat transfer, are very helpful to the student. Within its 370 pages the book contains about 240 illustrations, including graphs and diagrams, though the drawings of actual plant are often rather too small and sketchy to give much more than a general idea of the object depicted. The author makes no claim to comprehensiveness, for, as he says, any one of the processes would require a volume for its full treatment. Within his appointed limits, however, he has produced a most instructive and readable little book, well adapted to the needs of students. It contains much to praise and little to criticise, though, in stating the accuracy of a Venturi meter to be within ± 1 per cent., he might have pointed out that these instruments can give seriously misleading readings if used on a pulsating flow such as the discharge from a reciprocating pump, no matter how large an air-vessel may be provided.

TOOTH SURFACES OF CREEP-CUT HELICAL GEARS.



THE FORM OF TOOTH SURFACES OF CREEP-CUT HELICAL GEARS.

By W. A. TUPLIN, D.Sc., M.I.Mech.E.*

(Continued from page 486.)

It has been pointed out that the effect of a creep fraction with a small denominator is to produce the effect of perceptible ridges parallel to the generator. A small change in creep fraction, although it may mean a very much larger denominator, clearly makes little difference to the physical conditions and it therefore becomes necessary to ask "By how much must a creep fraction differ from one with a low denominator before the effect of the latter on noise is extinguished?" It is suggested, as an answer to this question, that slewing of the ridges of high spots corresponding to the simple fraction until any generator must always cross one of them may be regarded as neutralising the noise effect of the ridges. The change of creep fraction necessary for this purpose is shown in Appendix IV to be of the order of $\frac{0.033}{b}$, where b is the

denominator of the creep fraction and 0.033 is about the usual value of a factor that depends on the depth of tooth and on the feed of the hob per revolution of the work.

The noise effect produced by ridges of high spots distributed according to different creep fractions with denominators 1, 2, 3, 4, etc., may be represented by relative values $\frac{1}{2}, \frac{1}{3}, \frac{1}{4}$, etc., and on each side of each of such points the severity may be regarded as falling abruptly to zero as q changes sufficiently to cause the generator always to cross at least one ridge. This is slightly pessimistic, as there is some reduction in noise effect as the overlap condition is approached. A graph, Fig. 7, may then be constructed to relate "noise effect" to creep fraction $q = \frac{a}{b}$ by erecting ordinates proportional to $\frac{1}{b}$ at each of the points corresponding to values of q with denominator b , and numerators prime to b (see Table I). Each such ordinate is used as the vertical centre line of a rectangle of height $\frac{1}{b}$ and width $\frac{2 \times 0.033}{b}$. This procedure is repeated with

increasing values of b until the whole base line from $q = 0$ to $q = 0.5$ is covered. The noise effect of any creep fraction may be taken as proportional to the height of the rectangle at the appropriate ordinate on Fig. 7. The diagram is drawn only for values of q between 0 and 0.5. For other values of q the noise effect is the same as for $1 - q$, e.g., for 0.6 it is the same as for $1 - 0.6 = 0.4$. (Figs. 6A to 6N (page 485, ante) show, however, that the

same is not necessarily true in respect of local tooth loading.)

It will be seen that a creep fraction of $0.5 - 0.0165 = 0.4835$ is at the limit of the effect of $q = 0.5$ and gives the lowest noise effect. It will also be seen, however, that if the difference from 0.5 is doubled, leading to $q = 0.5 - 0.033 = 0.467$,

TABLE I.

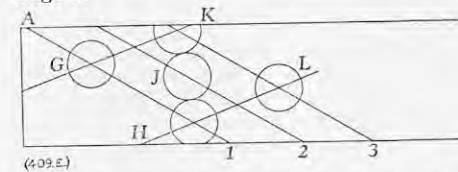
b	q	Noise Effect.
1	1 (or 0)	1
2	$\frac{1}{2}$	$\frac{1}{2}$
3	$\frac{1}{3}, \frac{2}{3}$	$\frac{1}{3}, \frac{2}{3}$
4	$\frac{1}{4}, \frac{3}{4}$	$\frac{1}{4}, \frac{3}{4}$
5	$\frac{1}{5}, \frac{2}{5}, \frac{3}{5}, \frac{4}{5}$	$\frac{1}{5}, \frac{2}{5}, \frac{3}{5}, \frac{4}{5}$
etc.	etc.	etc.

the noise effect is not greatly increased, and the generator always lies on two ridges corresponding to $q = 0.5$. This may be expected to be a distinct improvement in respect of load capacity and suggests that $q = 0.467$ (and the complementary $q = 0.533$) are the most desirable worm creep fractions so far as noise production is concerned. It may be noted that a value of q near to 0.5 may produce ridges parallel to the tip of the tooth, thus causing the Tomlinson undulation instrument to show a very long wave, which in the limit, is no wave at all (see Appendix III), but that does not affect the validity of the foregoing analysis. It must be emphasised that the decimal fractions specified above are based on typical tooth-depths and feed rates; they are not "natural numbers."

It should be noted that a creep fraction of about 0.5 has a special advantage indicated in Fig. 8. If $q = 0.5$ or thereabouts, the low-cut J on line 2 lies about half-way between the nearest low-cuts G and H on line 1, and about half-way between the nearest low-cuts K and L on line 3. In other words, it is about as close as possible to the high-spots that separate G and H on line 1 and K and L on line 3. This creep fraction thus gives the low-cut J the maximum effect in reducing the heights of the adjacent high spots. It would seem, therefore, that a creep fraction that differs from 0.5 only sufficiently to ensure contact of the generator with two of the slightly displaced ridges corresponding to $q = 0.5$ is about the most useful that can be found.

The width of any rectangle in Fig. 7 is proportional to the axial feed of the hob during each revolution of the work. By adopting a finer feed, the widths of all the rectangles are proportionately reduced, and so an ordinate that originally stood within a certain rectangle may be outside its narrowed form when the feed is reduced. In that case, the noise effect corresponding to the ordinate concerned is reduced, but it can never come down to

Fig. 8.



zero, for the narrowing of one rectangle always exposes shorter ones. The minimum possible noise effect for any creep fraction is proportional to the reciprocal of its denominator, but the attainment of that minimum effect demands a feed also proportional to that reciprocal. A very large denominator for the creep fraction has the advantage that if, in special circumstances, a very fine feed is permissible, then teeth with very low noise effect combined with high load capacity may be produced. A large denominator may offer little advantage with a normal feed-rate, but it is never a disadvantage.

It is shown in Appendix I that a non-creep machine places the low-cuts on lines parallel to the generator and therefore inclined at about 11 deg. to the tip of the tooth. A small change of creep fraction from zero turns the low-cut lines through a small angle and if this occurs in the right direction and by the right amount (see Appendix III) the low-cuts and the intervening ridges become parallel to the tip of the tooth. A section of the tooth flank on any line parallel to the tip will therefore show no evidence of the alternations of low-cuts and intervening ridges, although it will have slight corrugations inseparable from hobbing even on a perfect machine. If, alternatively, the creep fraction is such that the low-cut line is not quite parallel to the tip, a section parallel to the tip will intersect low-cut lines at relatively long distances and will show a long wave. A similar effect tends to be produced by a creep fraction that differs by the appropriate small amount from any of the fractions $\frac{1}{2}, \frac{1}{3}, \frac{1}{4}$, etc.

Now the Tomlinson undulation tester, which is commonly used in checking the regularity of helix of helical gears, records the undulations on a line parallel to the tip of the tooth. It will be seen, however, that its record may be misleading because (a) it may show no wave at all on a tooth that is heavily ridged parallel to the tip, and (b) its record may suggest a long wave on a surface that is actually markedly furrowed on a short wavelength. It is, of course, inevitable that a record taken along a line should give an incomplete picture of the roughnesses of a surface, but it is important to note that the picture may be not only inadequate, but positively misleading when the testing line has been chosen for convenience in measurement and not because it is really significant.

In the case of a gear cut with a highly effective combination of creep-fraction and feed, the tooth surface may be expected to be an array of humps and hollows with no marked directional characteristic of its own. The only significant directions are then (a) that of the generator, because irregularity along it may afford some indication of intimacy of contact with a perfect pinion; (b) perpendicular to the generator, because irregularity in that direction may afford some indication of the vibration to which a perfect mating tooth will be subject in running; and (c) that of the generator of a tooth of a shaving cutter in mesh with the gear, because irregularity of the gear-tooth surface along it may afford some indication of the probable effectiveness of the shaving operation.

It has been seen (for example, in Fig. 1, page 484, ante) that as the dividing worm may rotate through more than a revolution while a tooth of the work passes through the zone of engagement with the hob, there may be high and low cuts representing more than a complete cycle of worm error in a single line of cuts down the flank of a tooth of the work. Other cycles of error occur at much lower frequency. For example, the cycle of accumulated pitch error in the teeth of the table gear is repeated only after a revolution of the work. During the passage of a single tooth of the work through the zone of engagement

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with the hob the angle of rotation of the table is that corresponding to about two pitches of the teeth of the work, and, when cutting a wheel with a large number of teeth, is usually so small that the variation in accumulated pitch error of the table gear teeth concerned is negligible. Thus the low "spot" in the accumulated pitch-error curve corresponds to a full line of low-cuts down the flank of a tooth of the work. The low spot on the work is thus a "low line" in one tooth and the cuts made on adjacent teeth before and after it are very nearly low lines.

In a hobbing machine of the conventional creep-cutting type, the gear that meshes with the table gear (here called the "creep gear") is of the same order of size as the table gear and the effects of its accumulated pitch error occur in a cycle that repeats itself while the table makes rather more, or rather less, than one revolution. In Fig. 9 is shown a developed view of the pitch cylinder of the work. The lines slightly inclined to the horizontal represent the "feed helix," i.e., the path of the pitch point of engagement of work and hob. The lines inclined at about 7 deg. to the vertical represent the intersections of a set of tooth flanks with the pitch cylinder. The short thick lines represent "low-lines" produced by an extreme error in a cycle repeated in about two-thirds of a revolution of the work-table. This represents a velocity ratio of about $\frac{3}{2}$ and a creep fraction of about $\frac{1}{2}$. The dots represent the mid points of the intervening "high lines." It will be seen that on any tooth (for example, No. 1) low lines are repeated after slightly more than 11 convolutions of the feed helix and therefore that the distance (measured along the tooth helix) between adjacent low lines is about 11 sec ϕ times the feed of the hob per revolution of the work. This is the "wavelength" of the undulation of the tooth surface in the direction parallel to its tip. With other creep fractions, the distribution of low lines may be markedly different from what is shown in Fig. 9. For example, a creep fraction of 0.95 (see Fig. 10) causes the wavelength on each tooth to be about 20 sec ϕ times the feed.

A velocity ratio less than unity by the small amount $\frac{f}{L}$ (where f is the axial feed of the hob per revolution of the work and L is the lead of the tooth helix) causes all the low lines to occur on the same tooth and all the high lines on another tooth (see Fig. 11). In this case, the wavelength of the undulation on any tooth is infinite, i.e., there is no wave at all, but each tooth is bodily "out of pitch" by an amount proportional to the cyclic machine error associated with it. So the freedom of the helix from "wave" is an advantage that is offset by the disadvantage of pitch errors between the teeth. The low lines due to accumulated pitch error in the table gear of a hobbing machine occur on a single tooth of a spur gear cut on the machine. Similarly, the low cuts due to accumulated pitch error in the creep gear of a hobbing machine occur on a single tooth of a helical gear cut on the machine if the velocity ratio of the creep gear is $(1 - \frac{f}{L})$. A velocity ratio of $1.5(1 - \frac{f}{L})$ causes all the low lines and high lines to occur in alternating sequence on three teeth of the work (see Fig. 12). With a feed of the usual small amount, the low lines overlap and obliterate the high lines and the resulting finish is the same as would be produced by twice the feed-rate on a machine with no creep-gear error.

Every other tooth flank is similarly defined by the lower of two alternating lines of hob cuts corresponding to antiphased points in the cyclic machine error concerned. At points half way in the error cycle between high-spots and low-spots, the error is usually about the mean of the maximum and minimum errors and the corresponding teeth in the work are "high" teeth because the lower of the cuts on them are the highest low-cuts on the entire work. Consequently the difference in pitch error between the three "low" teeth in Fig. 12 and the intervening high teeth (marked in the diagram by crosses) corresponds to the difference between the lowest pitch error and the mean pitch error in the machine cycle concerned and that is about half that between the high and low teeth in Fig. 11.

A creep gear velocity ratio of about $1.5(1 - \frac{f}{L})$ therefore makes use of the overlapping effect of the hob cuts to reduce pitch error in the teeth of the work and that is advantageous. On the other hand, the "high" teeth are so widely separated that each one has passed out of the zone of engagement with the mating gear before the next one has entered it. Comparison between Fig. 9 and Fig. 12 illustrates this point. In the former a contact zone (two to three pitches wide) parallel to the axis must always contain at least one high line, whereas that is not the case in Fig. 12.

If, however, the face width of the gear is so great that the upper end of a high tooth of the "waveless" type overlaps the lower end of the adjacent high tooth, the contact zone of wheel and pinion will always contain a "high line" and this is desirable in the interest of quiet running. The condition

Fig. 9. $R_c = 1.45$

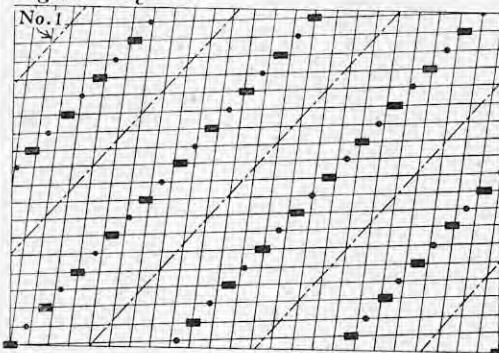
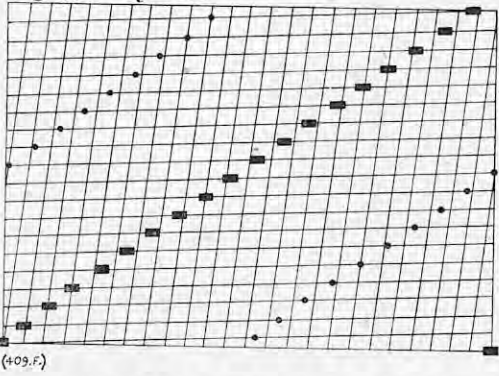


Fig. 10. $R_c = 0.95$



for waveless helices produced by alternation of equal high and low lines on each tooth is that

$$\text{Creep gear velocity ratio} = (S + \frac{1}{2}) \left(1 - \frac{f}{L}\right)$$

where S is a whole number (or zero) and if this is secured, the additional condition for the desirable overlap of high teeth is that the angular advance of each helix in an axial distance equal to the face-width is the angular spacing of the "high" helices

$$\frac{F}{L} = \frac{1}{2S + 1}, \text{ or face width} = \frac{\text{Lead}}{2S + 1}$$

This latter condition is not usually satisfied in large wheels cut on conventional creep machines for which S is less than 2. In that case, the feed may be adjusted to give either waveless helices or overlap of high teeth, but not both. It will be seen therefore that the adoption of a creep gear velocity ratio of $1.5(1 - \frac{f}{L})$ may sacrifice an important advantage of "creep," as the advantage of waveless helices may be offset by the disadvantage of pitch errors between helices that are not long enough to overlap the corresponding helices with the same pitch errors. This velocity ratio certainly produces teeth that reveal no appreciable undulation to the Tomlinson instrument, but the impression of excellence produced by that result gives a misleading idea of the running characteristics of the gear. It may be noted that f is usually of the order of 0.05 in. and for a gear wheel, L is usually not less than about 50 in. Hence $\frac{f}{L}$ is usually less than 0.001.

It is desirable in the interest of noise reduction to choose the creep fraction of the creep gear so

that lines of low lines as shown in Figs. 9 to 12 are inclined at such an angle to the axis that the upper end of one overlaps the lower end of the next. The problem here is analogous to that concerned with the creep fraction of the worm and the solution is $q = \frac{A}{B} - \frac{f}{F} \frac{1}{B}$, where A and B are integers.

If, for example $A = 1$ and $B = 2$, the undesirable range of q is $\frac{1}{2} \pm \frac{f}{F}$. For $\frac{f}{F} = 300$, some of the undesirable ranges for the creep gear creep fraction are as indicated in Table II. It will be seen that it is permissible for the creep gear creep fraction to lie near to 0.5 and thus to give the advantage of obliteration of high lines by low lines in addition to that of causing one end of a line of low lines to overlap the opposite end of the adjacent line.

The motion of the hob saddle in the direction parallel to the axis of the gear blank may differ

Fig. 11. $R_c = 1 - \frac{f}{L}$

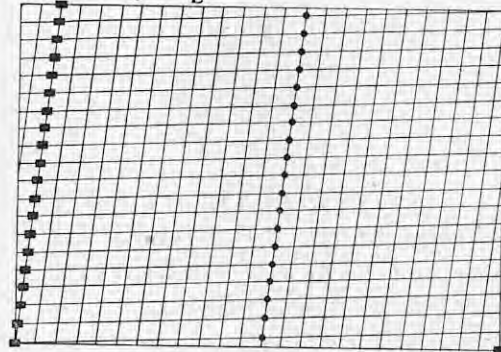
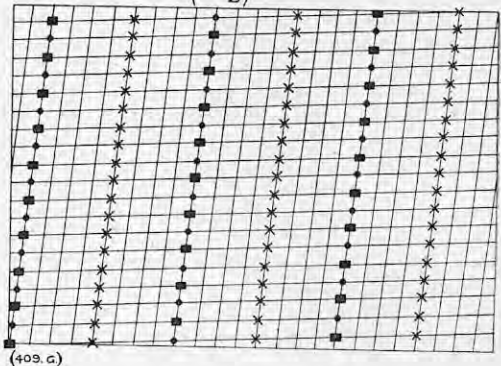


Fig. 12. $R_c = 1.5(1 - \frac{f}{L})$



from uniformity by an amount that varies over a cycle completed in every revolution of the feed screw. (This error may arise from "wave" in the thread of the screw or from errors in the thrust bearings.) The result is that on each tooth of the work there are "high ridges" in the A B direction (Fig. 1) at intervals equal to the pitch of the feed screw multiplied by the secant of the helix angle.

TABLE II.

a	b	Ranges to be Avoided.
1	2	0.498 to 0.502
1	3	0.332 to 0.334
2	3	0.666 to 0.668
1	4	0.249 to 0.251
3	4	0.749 to 0.751
1	5	0.199 to 0.201
2	5	0.399 to 0.401
3	5	0.599 to 0.601
4	5	0.799 to 0.801

This distance is, in all ordinary cases, small compared with the length of a generator between tip and root of the tooth and so these ridges are unlikely to be a cause of noise although they tend to cause high local surface stresses.

If the axial pitch of the gear teeth is a multiple of the axial pitch of the feed screw, the ends of a ridge produced by feed-screw error on any tooth lie on the same axial lines as the corresponding ends of ridges on adjacent teeth and so the leading ends of the generators on different teeth encounter feed-screw ridges simultaneously. A very slight reduction in noise effect may be expected if this condition

is avoided. The best possible result in this respect is achieved if no whole number of axial pitches of the gear teeth within the face width corresponds to a whole number of pitches of the feed screw. This is the case if $\frac{\text{Face width}}{\text{Axial pitch}}$ is less than the denominator of the fraction $\frac{\text{Axial pitch}}{\text{Lead of feed screw}}$ reduced to its lowest terms. Compliance with this condition is merely a refinement that will, at best, have a small effect on noise. It has no influence on the tendency of local load concentration, which is the more serious effect of periodic error in the feed screw.

The following conclusions may be drawn from the foregoing:

(1) A hobbing-machine error that varies in a cycle completed a whole number of times during a revolution of the work-table leads to work errors that tend to produce noisy running.

(2) If the number of error cycles completed during a revolution of the work-table is not a whole number, the resulting work errors have an appreciably smaller tendency to produce noise than if the creep fraction were zero.

(3) Every rotating part in a hobbing machine has its own creep fraction.

(4) The denominator of a creep fraction should preferably be not less than 30.

(5) In order to secure the most effective overlapping action of hob cuts, the creep fraction should be approximately $\frac{1}{30}$.

(6) The most useful creep fractions are about $(\frac{1}{30} + \frac{1}{30})$ and $(\frac{1}{30} - \frac{1}{30})$ for average feed-rates.

(7) Variation of feed in a non-creep machine makes no difference to the pattern of ridges on the teeth of the work and little difference to their height.

(8) Variation of feed in a creep machine can make great differences to the pattern of high-spot distribution on the teeth of the work. If the denominator of the creep fraction is large, an exceedingly fine feed can lead to an exceptionally smooth finish.

(9) Before finish-cutting any large helical gear on a "creep" machine the effect of a number of practicable feeds on finish should be calculated, so that use may be made of the one that gives the smoothest finish in an acceptable cutting-time.

(To be continued.)

METAL ECONOMICS.

A GENERAL discussion on "Metal Economics" was held under the auspices of the Institute of Metals at the Park Lane Hotel, Piccadilly, London, W.1, on Wednesday, October 17. The chair was occupied by the President of the Institute, Professor A. J. Murphy, whose address was reprinted on page 500, *ante*. The meeting was divided into two half-day sessions, and at each session several short papers were presented, after which there was a general discussion restricted to the subject of the session. The first session dealt with "Primary Resources of Ferrous and Non-Ferrous Metals," and at the commencement of this, three papers were presented, by Mr. R. Lewis Stubbs, of the British Non-Ferrous Smelters' Association; Professor S. Zuckerman, C.B., F.R.S., of the University of Birmingham; and Dr. T. P. Colclough, C.B.E., of the British Iron and Steel Federation. The afternoon session covered "Scrap Reclamation, Secondary Metals and Substitute Metals," and, at this, five short papers were presented.

WORLD SUPPLY OF NON-FERROUS METALS.

The first paper at the morning session, that by Mr. R. Lewis Stubbs, was entitled "The World Supply of Non-Ferrous Metals, including the Light Metals." The author began by examining the current supply situation in the "free world" and showed the extent to which the present shortages were due to stockpiling. He stated that if there had been no stockpiling in the post-war years, the supply and demand for copper and zinc, in which the shortages were most acute, would have been in reasonable balance. The shortages were being further aggravated by unforeseen defence demands which most countries hoped to superimpose on the growing

civilian consumption. Stockpiling and defence demands, however, would not continue indefinitely. The greatly increased consumption in the last decade had been due to the needs of war and rehabilitation, but the increasing importance of the light metals and their relative cheapness seemed likely to bring about an entirely new pattern of consumption.

The quantity of metals used between 1900 and 1949 had far exceeded the total consumption in the preceding centuries and this had led to speculation that the world resources might soon be exhausted if consumption continued to increase. This theory, however, overlooked the fact that known reserves had increased faster than consumption. Furthermore, the stimulus to prospecting, brought about by the present high prices, had already led to important new discoveries of ore during the last year or two, and declared reserves were now growing more rapidly than ever before. If the increasingly important role of the plentiful light metals were acknowledged, there would seem to be no cause for undue pessimism concerning the general future.

The immediate future, however, was less clear. In planning the increases in production, which were undoubtedly necessary if the growing civilian consumption were to be met, industry had, at the same time, to take into account the fact that defence and stockpiling requirements might come to an end soon and that the disposal of stockpiles or of some of the defence material now being produced could supplement the supply of new metal. If, however, the non-ferrous metals industry were to continue to expand to meet rising demands, new ore bodies would have to continue to be brought into production and means of overcoming the factors tending to restrict this expansion would have to be found.

METALS AS NATURAL RESOURCES.

In the course of his paper on "Metals as Natural Resources," Professor S. Zuckerman stated that, although the demand for raw materials had always undergone short-term fluctuations, its general trend over the years had continued in an upward direction. The views of economists were divided about possible future recessions in industrial activity and demand, and about the continuation of the present inflation, which simply reflected the fact that the demand was in excess of the supply. There were certain features in the existing situation, such as rearmament and stockpiling, which we might hope were temporary. But, as an article "Agenda for the Age of Inflation" in the issue of August 18 of the *Economist* showed, there were other good reasons for supposing that the demand for commodities would continue to outstrip supply for "as far as human wisdom can see ahead."

The particular feature of the present situation, which was of interest to this discussion on "Metal Economics," was the remarkably steep increase there had been over the past ten years in the demand for both steel and non-ferrous metals. It was said that the United States were now embarking on plans to increase the capacity of their steel industry by some 20 million tons. This implied a collateral demand for non-ferrous metals, etc., approximately equal to the amounts we required to "balance" our own steel production.

Although the distinction between the two categories should not be drawn too finely, metals came into the category of non-creatable as opposed to creatable resources. It was widely held by geologists and others that our own resources of the conventional base metals, as well as of iron-ore itself, were being depleted faster than new workable deposits were being discovered. At the same time the limiting factor on the output of such "newer" metals as aluminium and magnesium—cheap electric power—confined their production to Northern America and to distant parts of the world, and precluded any major participation by ourselves in these developments. Although the optimistic view was that one did not know what new and rich minefields of ferrous and non-ferrous metals were about to be discovered (cf. the recent discovery of the new sulphur-dome in the Mississippi Delta), or what new technological discoveries were about to be made, it was a safe assumption that the pattern of relative values of such metals as copper, zinc, tin,

aluminium and magnesium would continue to alter as it had in the past, and that commodities such as the first three would go on diverging in relative cost from those like the latter two.

While the price mechanism would help to correct shortages of the non-ferrous metals, it was essential that we took realistic steps to discover and develop new sources of non-ferrous metals, and to improve the efficiency of our production. Exploration needed to be increased, at the same time as improved methods of extraction of metals and of economy in use were elaborated. We should not turn our backs on possible domestic sources. In view of the fact that there was no obvious end to the rising trend of world demand, it was clear that unless these things were done, we should become increasingly aware of the fact that the rate of investment in manufacturing industry had outstripped the rate of investment in the raw materials industries of the world.

IRON ORE: WORLD DEMAND AND RESOURCES.

In presenting the last paper of the morning session, entitled "Iron Ore: World Demand and Resources," Dr. T. P. Colclough stated that the world production of steel in 1949 had been about 160 million tons. This steel had been made from scrap and pig iron. Scrap returns averaged about 50 per cent. of the ingot, and the total metallic materials charged were about 110 per cent. of the ingot. Therefore, about 60 per cent. of the ingot weight must be supplied as pig iron. Other iron was used for castings, etc., and the total pig iron made in 1949 had been 110 million tons. For this iron production the iron ore mined had been practically 220 million tons.

This production could be divided into four groups, namely, the United States and Canada: iron and steel 46 per cent., ore 40 per cent.; Western Europe: iron and steel 30 per cent., ore 37 per cent.; the U.S.S.R. and associates: iron and steel 18 per cent., ore 17 per cent.; finally, "other" countries: iron and steel and ore 5.6 per cent. The data for the U.S.S.R. were estimated, and could not be discussed in detail. "Other" countries were well supplied with ore.

The United States and Canada had a combined capacity for over 100 million tons of steel per annum and required approximately 100 million tons of ore. The ore reserves were extremely large and, while enormous tonnages had already been extracted, further resources were being revealed. Experimental work on the beneficiation of the low-grade taconite had reached the stage of pilot-plant development and large-scale production was anticipated within a very few years. Meanwhile, developments on a large scale were in hand for the exploitation of the vast reserves of high-grade ore in Venezuela and the Quebec-Labrador border. The high cost of mining equipment and the long distances necessitated the planning of these enterprises on a large scale with mechanical appliances and large ships to reduce costs to a minimum.

There was also a growing tendency to import ore from Sweden and West Africa. These increased imports of ore must be used mainly at seaboard locations, and a second large steel-producing plant was planned for the Atlantic coast. The known resources of iron ore were estimated to assure the life of the industry in the United States for over 100 years. Canada, with her limited steel production of about 3 million tons per annum, had ample reserves of iron ore and would undoubtedly act as an exporter of ore to the United States and Europe, the strongest limiting factor being the severe winter conditions and the confining of exports to about six months of the year.

The Western Europe group of steelmakers had been responsible for the production of about 30 per cent. of the world tonnage as regards iron and steel. Owing to its relatively lower grade, the ore production had been about 37 per cent. of the world production. The total ore production of Western Europe, including North Africa, had been, in 1949, over 80 million tons and of this about 95 per cent. had been consumed within the area. Large developments in iron and steel production were planned for the next three years, the increases being of the order of 15 million tons each of iron and steel. This would necessitate an increase in iron ore supply

from about 80 million to 120 million tons per annum. It was proposed to meet this demand by expansion of the existing ore producers, the increased use of ore fines as sinter, and the development of new ore properties in Sierra Leone, at Conakry (French Guinea) and in Mauritania (French West Africa).

Each of these new developments, as in the United States, must be on a large scale and involved greater distance of transport, both inland and ocean, than had formerly been the case. The additional tonnage of ore to be transported involved the creation of new shipping capacity. The ships to be provided should be of special design, and of a size to give the most favourable conditions for economy in operation and for rapid loading and unloading. Provided that the plans already formulated were implemented, there should be adequate supplies of iron ore to meet the demand of the expanding steel market.

DISCUSSION.

Professor W. R. Jones, C.B.E., who opened the discussion, said that there was a great deal of difference between the connotation of the term "mineral reserves" to the geologist and the mining engineer, on the one hand, and to almost anyone else who was not closely associated with the mining industry, on the other. Thus, five years ago, Mr. G. F. Laycock, in his presidential address to the Institution of Mining and Metallurgy, had made this statement: "There would appear to be only sufficient known reserves of the ores of lead in the world at the present time to last about 14 years at the pre-war rate of production, and in the case of zinc probably about 21 years." That statement had been quoted in the daily papers in this country and several others, and in several technical journals also. It had been quoted very widely, and as widely misinterpreted. It was assumed that at the end of two decades the world would be faced with a very acute shortage of lead and zinc. The statement meant nothing of the kind. Mr. Laycock knew—no one knew better—that, in any mineral field, the known reserves were often only a small fraction of the mineral resources of that field. He knew perfectly well that there were many mines which, fifty years ago, had known reserves of four or five years and had been in constant production for the past fifty years. At the present time these mines had known reserves of from four to five years, and many of them, in twenty years' time, would again have known reserves of from four or five years.

It was true that in the decades preceding the war of 1914-18 there had been a spate of discoveries of enormous ore bodies which had supplied, and continued to supply, the world's main production of the base and other metals. It was true that between the two World Wars there were some notable discoveries, but that they could not compare in magnitude or in diversity with the discoveries that preceded the First World War. It was also true that the demand and the diversity of minerals had been increasing greatly. What was not true, however, was the conception that it had been established, for any particular mineral, that in twenty years or in forty years or even in a hundred years there would be a very acute shortage because of the exhaustion, not of the proved reserves of to-day but of the mineral resources of the world. Turning to the mineral reserves of zinc, Professor Jones stated that he had chosen zinc for the reason that it was a mineral which was in very short supply, and it was a mineral which caused a tremendous "flurry" on the part of statisticians, economists and certain Government departments.

There had been a number of genuine attempts to assess the mineral resources of zinc. Thirty years ago, W. R. Ingalls, a man of international reputation, had taken a great deal of trouble to estimate the reserves of zinc—actually he did not confine himself to the known reserves, but took all categories at that time; the proved reserves, the probable reserves and the possible reserves—and he had come to the conclusion that, on the consumption of that day, there were enough proved reserves to supply the world with 27 million tons of zinc metal. Twenty years later, in 1940, W. L. Shea estimated that the reserves would provide 43 million tons of the metal, and seven years later, as a result of further informa-

tion, he had changed the figure, and, instead of 43 million tons for the whole world he had said 20 million tons for the United States and 43 millions for "other" countries, bringing the total to 63 million. That was 2½ times Ingalls's figure, but in the thirty years that intervened between Ingalls's estimates and Shea's estimates over 30 million tons of the metal had been produced, i.e., 3 million tons more than the total estimate of Ingalls for the world. These spectacular increases in these estimates might strike one as being very extraordinary, but they were not at all extraordinary to the mining engineer or to the geologist, who knew that a few bores put down in a few months might add hundreds of thousands of tons of ore reserves on a mining property. Thus, in this country, less than two years ago, a borehole or two increased our coal reserves by 350 million tons. At the present time our known reserves of coal were far greater than they were fifty years ago.

An increase in price of a metal at once increased the mineral reserves, because all the marginal reserves, those that did not come into the picture because they were too low grade, at once assumed importance with an increase in price. Moreover, high prices created an added incentive for the discovery of these deposits. It was true, as had been said that morning, that in the United States certain mineral reserves were being depleted more quickly than they were being added to, but that was not true in other parts of the world. Quebec, a province which, in 1935, had not produced a pound of zinc, was producing thousands of tons at the present time, and mines were being opened in numerous places. Whatever the factors were which had caused the present shortage of zinc, they did not lie with Nature, and the blame did not lie with geologists and mining engineers. For the five years ended 1939, zinc production had been 1,750,000 tons; for the four years ended 1949 it had been 1,736,000 tons, a difference of 14,000 tons. That was just three months' production of the Baldwin mines in Burma, which had not been producing zinc in late years, not because of the depletion of the reserves but because of the dominant political situation.

Mr. L. Tarring said that, until recently, the centuries-old metal industry had progressed, under the economic influences of supply and demand and the price factor. When demand was large, in relation to supply, prices rose and new risk capital was attracted to the exploration and exploitation of metal deposits and more efficient collection of scrap. When demand was small, in relation to supply, prices fell and marginal production declined. On occasion, it was true, new properties were developed on the crest of a boom only to come into production in a subsequent period of depression. Nevertheless, since the general trend of world consumption of metals had been upwards, the booms conveniently served to develop production resources to meet the long-term increase in world demand, and price levels adjusted themselves to variations in the value of money, to metallurgical developments and to standards of living as reflected in production costs.

With the more obvious, richer and most easily exploitable deposits developed, attention had been directed to the lower grade, less accessible and more complex deposits. Their development frequently involved lengthy exploration and development work and a large capital investment. The new and technologically improved methods of prospecting were also generally much more expensive than the older methods. In view of the huge sums of money required, considerable inducements were needed to attract them from the private investor. The present policy of attempting to stabilise prices at what might be levels adequately remunerative to existing mines, nevertheless might have a deterrent effect on the search for, and development of, new mines to meet the requirements of the next generation. Coupled with the movement towards price stabilisation had been the more or less world-wide establishment of high rates of mining taxation—few more penal than in this country, where there was also now the additional threat of dividend limitation—with the result that the glittering rewards sometimes achieved by the mining industry in the past were practically impossible to-day.

Nevertheless, it was the hope of such rewards that made a continuing flow of capital into mining possible, despite the many unprofitable "holes in the ground" into which many millions of pounds of investors' money have been poured. Price stabilisation schemes, whilst limiting the reward, offered little or nothing in the way of protection to the mining companies, should adverse economic conditions again develop.

Another aspect of metal-price stabilisation which deserved attention was that, by regimentation of prices, the normal competitive influences as between one metal and another, or between a metal and a non-metal, were emasculated or temporarily suspended, and, in their place, were put arbitrary restrictions banning certain uses by governmental decree. If the excess of demand over supply was to be very prolonged, as Professor Zuckerman envisaged, and not confined to a temporary rearmament phase, it meant that the pattern of metal consumption would be decided by a small group, irrespective of personal predilection or normal economic pressure. We would be told whether we might have brass ash-trays or plastic ones; the farmer might have to do without galvanised steel for roofing his barn, however suitable he might consider it. There would be regulations as to whether lead, zinc or titanium paints could be used, and so on, with the probability that, in the long run, the regulations would become complex and unworkable and the price factor would eventually be called into play to solve the matter on ordinary economic grounds. The manufacturer was likely to be told what he might and might not export.

Admittedly unrestricted commodity markets at times resulted in extremes of prices. But the more rapidly the extremes were reached the more rapidly the cures were brought into being. If the world would pay 450*l.* a ton for copper (as it was doing in places) such a price would more quickly bring new production into being than a price of 250*l.*, and would more quickly sort out the uses of copper which had become uneconomic and ascertain the places in which other materials could satisfactorily be substituted.

As far as this country was concerned, one inclined to the view that many of the arguments advanced in favour of bulk buying, controlled distribution and semi-stabilised prices, merely covered up weaknesses in other directions, notably the foreign exchange position, which had been the main stumbling block to the re-opening of the London Metal Exchange. It was not without significance that, despite considerable American pressure, there seemed to have been little official attempt in this country to regulate the price of tin, which had been, and would be again, a substantial dollar earner, and was one of the mainstays of the economy of Malaya. Unilateral or bilateral price policies were no long-term substitute for the free evolution on an open commodity market (through the multifarious influences of the metal industry of the world) of a price that was a balanced judgment of all concerned and enabled everyone to buy or to sell at the same price. On an open market future developments were discounted in advance and their impact modified accordingly, whereas the present system tended to result in delayed price movements of a major character and the establishment of varying price levels in different parts of the world. At present, copper was quoted officially at 196*l.* and 220*l.* in the United States, 227*l.* in the United Kingdom, 238*l.* (excluding taxes) in France, 235*l.* in Western Germany, and 464*l.* in Italy, which was something like the price ruling in the uncontrolled world market.

War conditions and near-war conditions were economically unnatural and admittedly must call for economically unnatural practices. It was desirable to guard against measures necessitated by a nation's emergency becoming the plaything of theorists. No consumer liked to pay extravagantly high prices for the material he fabricated or manufactured, but he liked much less a condition of semi-permanent organised scarcity, which stultification of the normal economic influences seemed to engender.

Mr. C. F. Carter said that one feature of the growth of production over many years past had been

its increasing complication. An aeroplane, for instance, embodied an immense amount of human labour on a comparatively light weight of metals. Thus, we could have a very large growth in what was called production without necessarily calling on a greater volume of raw materials. The kind of thing which was in the minds of some people when they became a little frightened about the future possibilities for raw-material production was this: First, the growth in world population was fairly considerable, and although it had been thought, some years ago, that it might be coming to an end in Western countries, this was by no means as certain as had been supposed. Secondly, the total amount of goods and services produced per head was rising fairly fast. In the last 45 years it had risen by 40 per cent. in this country, and by nearly 60 per cent. in the United States. That was in terms of real income produced per head. Thirdly, industrial production grew faster than real income as a whole. In the United Kingdom, it had risen in the past 45 years by 85 per cent., and in the United States by 185 per cent. Fourthly, engineering production, in this period, had been rising very much faster than industrial production as a whole. In the United Kingdom, it had risen in the past 45 years by 260 per cent. The United States figures were not easy to interpret, but in the last half of the period it had risen there by 140 per cent.

It did not, of course, follow that the demand for metals would increase as fast as engineering production and it certainly did not justify any assumption by the economist that these rates, which tended to proceed on a geometrical progression rather than on a declining curve would exhaust reserves, as far as one could see. What the economist was justified in saying was that this enormous rate of growth would soak up reserves at so great a rate as to lead to much more rapid moves, in producing areas, than had taken place in the past, and that these moves might very well be extremely adverse for the established producing countries. What would happen was that iron ore would be fetched over greater and greater distances, or that more and more remote areas might have to be opened up for the mining of non-ferrous metals, and they might be remote not only because they were so geographically but also because they were so politically. A very large part of the unexplored area of the world was no longer in a condition in which British or United States capital could enter it. Consequently, the costs—the real costs, not merely money costs—of providing the raw materials of British industry would tend to rise. But what would be interesting to know, and what was quite impossible to decide from the figures or from the other evidence put before the meeting that morning, was whether this meant that prices had to go even higher than they were now, or whether it could be hoped that the growth of production would for a short period proceed a little faster, so that raw-material prices would go back into some kind of relationship with prices in general. This applied particularly to those raw materials the prices of which were running at four or five times the pre-war level.

Mr. E. H. Bucknall, in closing the discussion, referred to the meetings of the International Materials Conference, and in particular to the part of it with which he was connected, namely, the Joint Sub-Committee on the Utilisation of Manganese, Nickel, Cobalt, Tungsten and Molybdenum. The agenda covered by that Sub-Committee, said Mr. Bucknall, included a review of existing specifications, the important problems of substitution and limitation, with special reference to "end" uses, and salvage and the use of scrap, in certain of the main fields of utilisation of the five metals involved. In its deliberations, the sub-committee had tried to adopt a practical outlook and to concern itself with measures which could be applied on the basis of existing technological knowledge. The discussion of the substitution of these five elements had been limited to cases in which it seemed likely to ameliorate the present shortages. It had been found that great efforts were being made to increase the production of the metals. For example, the production of nickel was expected to be increased by over 30 per cent. in 1954. These steps, however,

were thought to be not sufficient to remedy the present supply deficiencies of the metals.

It seemed that one of the most effective means of increasing the availability of these metals was improved scrap salvage. In that connection, it seemed also of interest to wonder whether there ought not to be special consideration of limiting the employment of these metals in circumstances in which they became completely unsalvageable, as presumably was the case with the use of cobalt in vitreous enamelling. It was also the case with the use of lead in tetraethyl lead in petroleum, but, since there was no substitute known, there seemed to be no possibility of applying any restrictive decision. It seemed to the sub-committee that there were few fields of present application which could be regarded as non-essential, and none of the civilian fields of application which could be called frivolous. On the contrary, it was felt that even in the most favourable cases any substitution of one metal for another involved some sacrifice, and that there were many instances in which a reduction in the content of one of these elements in a steel alloy or other product would lower its efficiency in service to an extent which would be intolerable.

(To be continued.)

621-3 INDEXED SINGLE-PHASE ELECTRIC TRACTION AT 50 CYCLES.

THE technical problems of single-phase electric traction when current at the industrial frequency of 50 cycles is used were fully discussed in some 30 papers which were presented at a conference organised by the Société Nationale des Chemins de Fer Français and held at Annecy in Haute-Savoie from Friday, October 12, to Monday, October 15. As Mr. H. Parodi remarked in an introductory lecture at this gathering, it might seem strange to re-open the controversy on systems of electric traction, since a decision on this matter, which appeared to be definitive, had been reached after the 1914-18 war. At that time, Germany, Austria, Switzerland, Sweden and Norway had chosen low-frequency single-phase alternating current for this purpose, while France, England, Belgium, Italy, Russia, Holland, Denmark and Spain (to mention European countries only) had selected direct current. This strangeness was not mitigated by the fact that in France direct current had given every satisfaction, and to quote Mr. Parodi again, had enabled heavy traffic to be hauled at speeds which have no equivalent in other countries. It had also been highly profitable, a statement which, he felt, was not equally true of all the low-frequency single-phase systems.

The reasons for this re-examination were, however, clearly stated by Mr. Louis Armand, Directeur Général de la Société Nationale des Chemins de Fer Français, who has been responsible for the experiments which were dealt with at the conference and which are described more fully below. In France, he said, the increasing use of electric traction was important, since the railways consumed about 9 million tons of good-quality coal a year, a great deal of which could be saved by conversion, especially as such conversion would enable water power to be more fully employed. Electric traction would also lead to economies in personnel of all classes and to the elimination of unpleasant duties, such as firing. At present, only about 10 per cent. of the French railway mileage was operated electrically on the 1,500-volt direct-current system, although the electrified lines carried about 24 per cent. of the traffic, and every effort was being made to use them more fully so as to obtain the maximum return on the investment. The conversion of further lines could, however, only be justified where the traffic was sufficiently dense to enable the necessary capital charges to be met. These charges were, unfortunately, particularly high as the use of the 1,500-volt direct-current system necessitated the installation of substations at intervals of 2 to 3 miles compared with the 60 miles which was possible when single-phase current at 50 cycles was used, while the cross-section of the collecting wires had to be large, owing to the heavy current. Under the present conditions, electrification on the 1,500-volt direct-current system could therefore only be

extended to some hundred further miles of track, although to comply with the Government's fuel economy programme, it was necessary that from 30 to 40 per cent. of the branch lines should be converted.

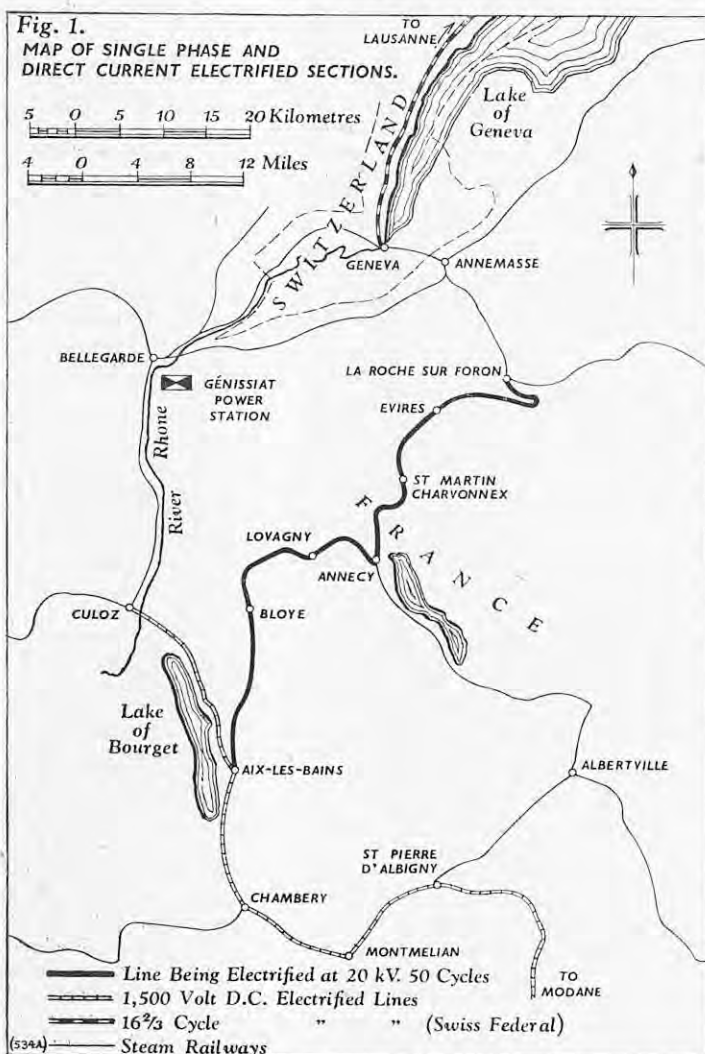
The most attractive solution of this difficulty, which has been reached by the French engineers after investigations have been made on the Höllental line in Germany, is to use single-phase current at a frequency of 50 cycles, mainly on the grounds of its lower cost. The system is not new. It was, in fact, employed on the Seebach-Wettingen line in Switzerland as long ago as 1904. It has, however, been argued against its employment that while the cost of the fixed installations compared with that for direct-current, is low, that of the locomotives and multiple-unit stock is higher; also the cost of maintenance is greater. It is also argued that to take a large single-phase load from a three-phase industrial system may result in serious unbalance and harmfully affect the convenience of other consumers, while the liability to interference with communication circuits must also be taken into account. The main difficulties of using single-phase current at 50 cycles are, however, those associated with the motors, although the conference showed that they are in process of being overcome. A possible alternative solution is to employ direct-current motors in conjunction with rectifiers or some other type of convertor. This solution would seem to be particularly worth consideration in France, as it would enable the same rolling stock to be used on both the alternating and direct-current sections of the railway system.

French engineers have therefore reached the conclusion that, given co-operation between the railway, electricity-supply and telephone authorities, there need be no insuperable difficulty with regard either to out-of-balance on the general power system or to interference with communication circuits. As regards the economic aspects, two hypothetical installations, one operating on 1,500 volts direct current and the other on 25-kV 50-cycle single-phase alternating current, were chosen for comparison. Three cases were assumed: that 75 evenly-spaced trains would carry 32,000 tons-km. gross per day; that the same number of trains would carry the same load with marked peaks; and that 50 trains would carry 22,000 tons-km. gross. It was found that the cost of the high-tension feeders and substations with the single-phase system was only 77 per cent., 68 per cent., and 76 per cent. of that for the direct-current system in the three cases. The corresponding figures for the overhead system were 69 per cent., 67 per cent., and 69 per cent., and for safety measures, 84 per cent., 70 per cent. and 84 per cent. The overall economy obtained in installing single-phase traction was therefore nearly 40 per cent.

It is admitted that the basic drawback is the alternating-current motor, and the difficulties under this head increase with the frequency. It is not felt, however, that this difficulty is insuperable. The results obtained during a year's trial indicate, in fact, not only that the main role of 50-cycle traction would be on lines with a low or medium traffic density, where the employment of 1,500-volt direct current would not be justified, but that it could be satisfactorily employed on sections where the traffic is heavy. This conclusion has recently been emphasised by the decision to convert one of the most heavily-loaded freight lines in France to this system.

In addition to listening to the papers presented, those attending the conference were given the opportunity of inspecting the equipment of the section of railway between Aix-les-Bains and La Roche-sur-Foron, which has recently been converted from steam to single-phase electric traction at 50 cycles. As will be seen from the map, Fig. 1, on page 522, this section runs from Aix-les-Bains, on the main line between Culoz and Modane, to La Roche-sur-Foron, a distance of 48½ miles. At Aix-les-Bains, a connection is made with the 1,500-volt direct-current system. As will be seen from the profile reproduced in Fig. 2, the gradients on the section are long and severe, reaching a maximum of 1 in 50 (i.e., 20 in 1,000). There are also numerous curves and tunnels. The conversion was completed between Aix-les-Bains and

SINGLE-PHASE ELECTRIC TRACTION AT 50 CYCLES.



Annecy on September 16, 1950, and between Annecy and La Roche-sur-Foron in May last. Since that time, extensive trials have been carried out both with locomotives and with rail coaches. It is now intended to extend the electrification from La Roche-sur-Foron to Annemasse, about four miles from Geneva, as well as to Le Fayet-St. Gervais, whence a mountain railway leads to Chamonix, for Mont Blanc, and to Vallorcine.

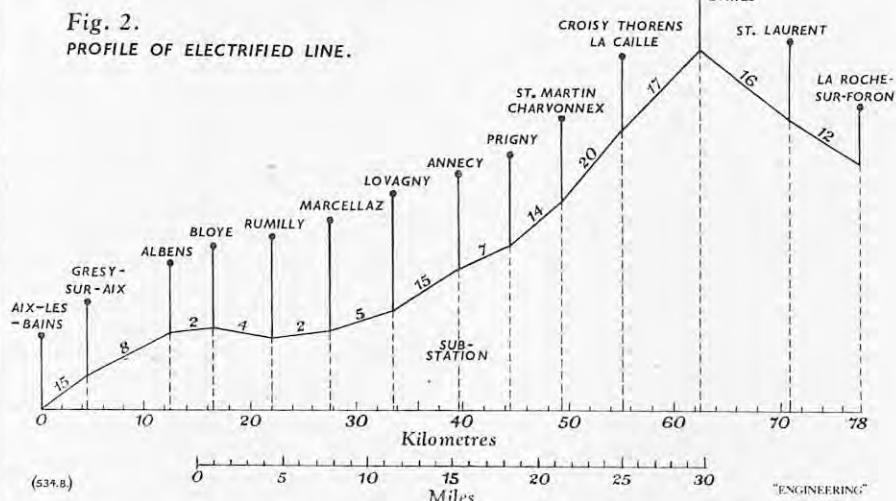
A supply of power for operating this section is being obtained temporarily at 42 kV from the three-phase substation of Electricité de France at Cran, a distance of about 30 miles. This supply is transmitted through conductors carried on wooden poles to a traction substation at Annecy, about midway between the terminals of the 50-cycle section. In this substation, which is of the outdoor type, the incoming three-phase feeder is connected through a mechanically-operated triple-pole isolator and current and voltage transformers to a low oil-content circuit breaker. The isolating switch was made by the Société d'Installations et de Constructions Electriques et Mécaniques, and the circuit-breaker by Les Ateliers de Constructions Electriques de Deele, Villeurbanne. From the primary of a Scott-connected transformer group which is indicated at *a* in Fig. 3. This group consists of two identical transformers manufactured by the Société Alsthom, Paris, the continuous rating of each being 6 kVA. The primaries of these transformers are provided with on-load tapping changing switches enabling the nominal voltage to be varied from -2.5 to +5 per cent. The Scott connection thus provides two 20-kV secondary circuits, one side of which is connected to a separate section of the contact line through a circuit-breaker and isolators, and the other to earth. Both circuits are provided with voltage and current transformers for protection and measurement purposes and with lightning arresters. The 42-kV and 20-kV circuit-breakers are controlled from a switchboard in the Annecy signal box, a distance of about 100 yards

of the arc, excluding the resistance between the foot of the support and earth, the relay operates at constant impedance, irrespective of the load.

In constructing the substation, economy in first cost was obtained by placing the various items of apparatus as close together as possible. For the same reason, the connections, which generally consist of aluminium tubing, are mounted on wooden poles, although the supports for the feeder anchors and the 42-kV isolating switch are carried on steel joists secured to posts similar to those used on the contact line. The 42-kV circuit breakers are mounted on concrete plinths, and the lengths of the connections have been reduced to a minimum.

As will also be seen from Fig. 3, the two "live" sections of the contact are separated by a neutral section, the length of which is sufficient to accommodate a locomotive with both pantographs raised. The risk of connection between the two live sections is therefore reduced, while it is unnecessary to lower the pantographs when a neutral section is entered, although the current must be switched off. Special signals at the entry to the section indicate to the driver that this must be done. Switches are also provided so that the neutral section can be fed from either live section or so that both live sections can be fed from one transformer secondary. These switches are interlocked so that they can only be closed when one of the 20-kV isolators is open. They are operated from the Annecy signal box. The substation is normally unattended, but the 20-kV isolators can be operated from outside the enclosure.

Although Electricité de France have guaranteed a supply from Cran substation until 1953, it is expected that subsequently other arrangements will have to be made owing to the increase in the general demand for electricity in the area. It is therefore proposed to erect a 60-kV line from Angèlefort to Annecy, as shown in Fig. 4, which will pass near Rumilly. This line will supply a traction substation at Rumilly containing a Scott-connected transformer from which the railway will be supplied.



from the substation. The usual protective devices are fitted on the circuit-breakers. There is also a maximum impedance relay on each outgoing feeder, which operates when, as the result of a fault, the impedance of the circuit being protected falls below a value which is less than that of the system (when the latter is carrying a 50 per cent. overload of 9 MVA) and higher than the impedance corresponding to that of a fault at the maximum possible distance. As the supports of the contact system are connected to the running rails in such a way that the fault resistance is only equal to that

The Scott-connected transformer at present at Annecy will be moved to this substation after its primaries have been re-wound for 66 kV. Electricité de France also propose to build a substation about 1½ miles from the railway at La Roche-sur-Foron, where power transmitted at 150 kV from the Genissiat power station to Pacy will be stepped down to 42 kV and transmitted through two single-phase transformers, each of which will feed a section of the railway. When the electrification is extended to Annemasse and Geneva (Eaux-Vives) in one direction, and to St. Gervais-le-Fayet in the other, the single-phase transformers in the La Roche-sur-Foron substation will be replaced by two 8-MVA three-phase units. The delta-wound primaries of these units will be supplied at 42 kV, while the star-connected secondaries will feed the Geneva, Rumilly and St. Gervais-le-Fayet sections, respectively. Owing to the length of the La Roche-St. Gervais section, it will be divided into two, one section of which will be supplied from two 3-MVA transformers in the Pacy substation.

(To be continued.)

SEVENTY-FIVE YEARS OF THE OTTO FOUR-STROKE ENGINE.

As a vital step in the development of the internal-combustion engine, the successful realisation, in 1876, by Nikolaus August Otto of the four-stroke cycle deserves to rank with that made, with the steam engine, by James Watt, when he arranged for the condensation of the steam to take place outside of the cylinder in a separate condenser. It was thus clearly desirable to mark 75 years of the existence of the Otto four-stroke engine, and celebrations to this end took place at Cologne on Friday, October 19, 1951. The arrangements were made by the Verein deutscher Ingenieure, in collaboration with Messrs. Klöckner-Humboldt-Deutz, A.G., the present name of the company, which was founded as N. A. Otto and Company in 1864, and became, in 1872, the Gasmotorenfabrik Deutz, A.G., and in the works of which Otto carried on his main development activities. The actual celebrations were preceded by three technical sessions, at which papers representing the present state of development of reciprocating internal-combustion engines were presented, followed by a visit to the works.

Otto was born at Holzhausen, Nassau, in 1832, and died in 1891 at Cologne. He was the son of a small farmer who, however, arranged for him to obtain secondary education until he was 16 years old, when he became an apprentice to the grocery trade. He worked in several towns in West Germany, eventually obtaining a post in Cologne. He had had, so far, no contact with mechanical engineering. About 1860, when he was 28, he became interested in the Lenoir engine, which, based in its design on the steam engine, was already achieving some success. This engine, it will be

SINGLE-PHASE ELECTRIC TRACTION AT 50 CYCLES.

(For Description, see Opposite Page.)

Fig. 3. LA ROCHE-SUR-FORON. DIAGRAM OF ANNECY SUBSTATION.

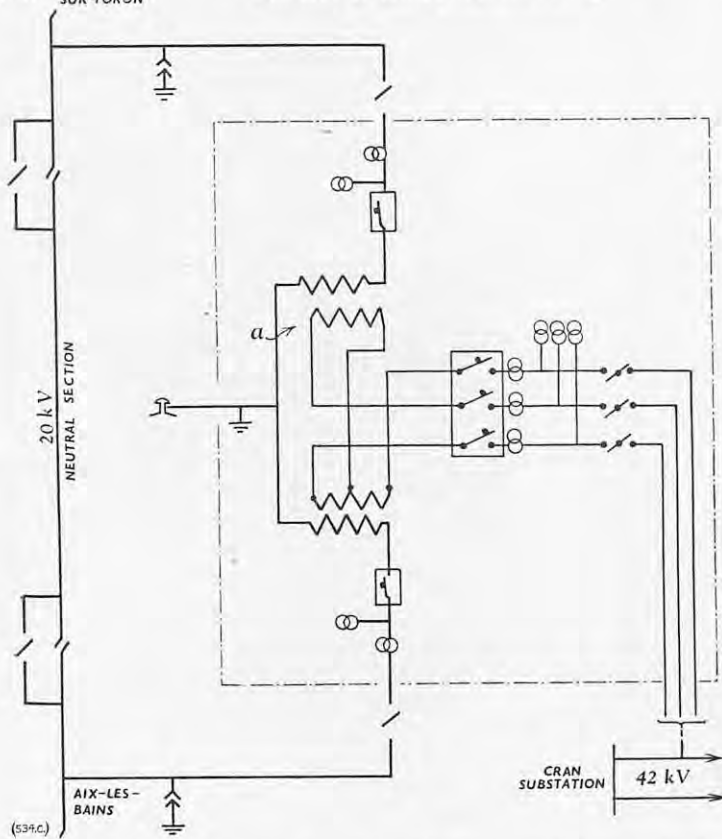
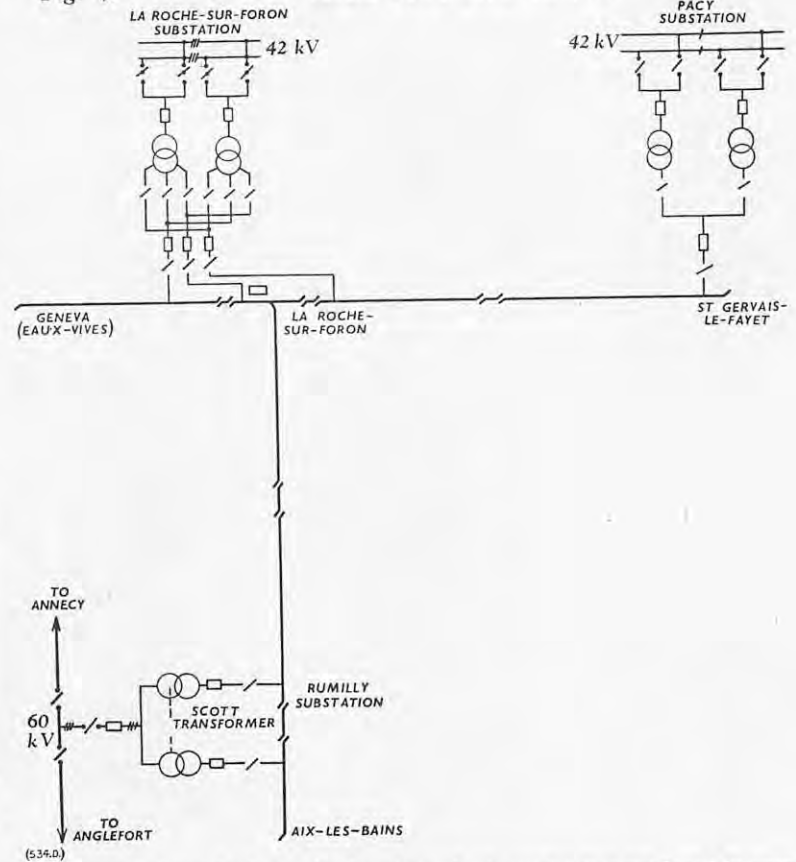


Fig. 4. FUTURE SUPPLY ARRANGEMENTS.



recalled, worked on a two-stroke cycle. During about the first half of the out-stroke a charge of gas and air was drawn into the cylinder behind the piston. Admission was then cut-off and the mixture was ignited, with a sudden rise of pressure. The charge expanded during the remainder of the out-stroke and was expelled, during the return stroke, from the cylinder. The chief drawback of the engine was its low thermal efficiency.

In 1861, Otto, after he had already applied for patents covering the use of vaporised spirit instead of coal gas in the Lenoir engine and the application of the engine to driving a vehicle, had a small experimental Lenoir engine built. He observed that this engine gave improved results as the point of the cut-off was advanced, and, in his own words: "I came thereby to the right idea that the ignition and burning must take place at the beginning of the piston stroke. I drew in the explosive mixture during one half, and eventually three-quarters, of the stroke, and then, by turning the flywheel in the reverse direction, tried to force the piston as far back as possible, ignited at once and noticed that the flywheel, with great force, made several revolutions. That was the starting point for a four-stroke engine." This pre-compression of the gases, is, of course, no longer a unique feature of four-stroke engines, since it is also used in two-stroke engines. With great optimism Otto had a four-cylinder two-stroke engine built. This proved a false step, since, owing to the heavy explosions, the engine smashed itself to pieces. Otto had learned a great deal, however, and to utilise the energy of these explosions he built his "atmospheric gas engine," which, in some respects, resembled the Newcomen steam engine. He arranged the centre line of his engine vertical, with the cylinder below. The piston was free on its up-stroke but, through a ratchet mechanism, exerted force on its down-stroke. During the first small part of the up-stroke the explosive mixture was drawn in; it was next ignited and brought about a rapid rise of pressure; as the piston moved up, the gases expanded, producing a depression under the piston. In the return stroke, the piston, under the influence of its weight and of the depression formed beneath it, moved downwards, and drove the power shaft; the burnt gases beneath the piston were compressed and, as soon as the pressure

exceeded atmospheric, were discharged through the exhaust port. An engine of this type was produced by the end of 1863.

At this stage Otto was very short of money, but, fortunately for his further work, met Eugen Langen, a young well-qualified engineer. N. A. Otto and Company was established, Otto giving his engines, his patents and his experience, and Langen providing the capital, and it was now possible for Otto to perfect his atmospheric engine. Langen was an experienced designer, and his contribution to the design of the mechanical parts was important, while Otto had made possible control of the point of ignition by inventing a gas-flame igniter. The engine was one of 15 types shown at the Paris Exhibition of 1867. A profusion of ideas was revealed by these types but, when Reuleaux, a German professor of engineering, was called on to measure the fuel consumption, that of Otto's engine was found to be little more than one-third of that of the next most efficient engine, and was awarded the gold medal as the best engine. Orders for the engine followed, but the practical difficulties of manufacture were such that Otto and Langen actually thought of giving up. Reuleaux's letter to Langen was decisive; he wrote: "The matter is so far forward that the engine has proved itself; great success is achieved; if you throw away your success you will miss the gain as well as the fame. . . . Think of the time 50 years hence with the gas engine in full flower as the steam engine now is: can you hesitate?" Reuleaux's prophetic judgment was remarkable, and, under his influence, Langen took in a young merchant who found the necessary money; in 1872, the Gasmotorenfabrik Deutz, A.G., was formed. The association of Langen with Otto, which ended only at Otto's death in 1891, was a happy one and recalls that of Boulton with Watt. In both cases, the inventor needed the help of a man with a severely practical outlook; and both collaborations led to great success. There is a further parallel in the lives of Watt and Otto in that both men had difficulty in connection with their patents, and both suffered severely in health from defending their inventions. In Otto's case, the British Patent Office was more understanding than the then German Patent Office.

As the atmospheric engine was produced in ever-increasing numbers, the two drawbacks of noise and a small output limited its application. Otto looked for ways of improvement and went back to his earlier idea of pre-compression of the charge: a "high-pressure" engine in contrast with the "atmospheric" one. He still feared the explosive shocks, and, to reduce them, thought of a stratified charge. He continued with his experiments, however, and in October, 1876, the new four-stroke engine was on the test-bed. It was called the "silent" engine on account of the great reduction in noise. Otto's new engine was the talk of engineers at the Paris Exhibition of 1878. Other firms began to make his engines and contested the validity of his patent; in particular, the claim dealing with the four-stroke cycle. The description of the cycle in 1862 by Beau de Rochas, and a small engine produced by Reithmann, in Munich, were cited against him in the subsequent action. Even in France, the writings of Beau de Rochas had been forgotten and the real state of affairs may well be that expressed by the French engineer, Aimé Witz: "In truth, it is only Otto who is copied, but those doing so excuse themselves by talking of Beau de Rochas." Whatever opinions may be held on this matter, there is no doubt that Otto produced the first successful four-stroke engine, and, by his contribution, deserves to rank with Watt and Parsons in the field of power production.

At the commemoration meeting, there were present, in addition to the President of the Verein deutscher Ingenieure, the directors of the Klöckner-Humboldt-Deutz Company, and the Lord Mayor of Cologne, the President of the German Federal Republic, and the Rectors of the Technische Hochschule, Aachen, and of the Universities of Cologne and Würzburg. There were also present engineers from Austria, France, Great Britain, Holland, Switzerland and the United States. The German President, Professor Heuss, who formerly held a Chair of the History of Science, pointed out in his speech that in the three cases of coal-gas, petroleum and electricity, all were first applied to improve lighting and only later for the production of mechanical power. The Oberbürgermeister announced that the station square at Deutz, on which the monument to Otto is erected, would henceforth be named Otto

Platz. The monument gives a representation in cast iron of Otto's atmospheric engine.

The progress made in internal-combustion engines in the 75 years since Otto's first successful four-stroke engine was well brought out by the papers in the technical sessions. The chairman, Professor Ernst Schmidt, in his introduction, referred to certain changes in our space-time perceptions which result from progress in the internal-combustion engine: while the steam engine reduced the time of circumnavigating the world to one-tenth of its former magnitude, namely, about a month, the internal-combustion engine had again divided the time by ten. The broad subject of "Transport" was thus chosen for the technical sessions; the first session was devoted to combustion and fuels, including one paper on a new engine combination, the second to problems of charging engine cylinders, and the third mainly to the supercharging of Diesel engines.

The first paper was by Professor W. Jost, on the "Mechanics of Combustion, with Special Reference to Engine Conditions." He pointed out that the zone of burning is actually only about 0.1 mm. thick, a matter of little importance in connection with the propagation of combustion in an explosive mixture contained in a pipe of reasonable diameter, but vital in a capillary tube, in which the heat losses may lead to extinction of the flame. He took the view that flame propagation in turbulent gas, even when detonation occurs, takes place by a similar mechanical process. The speed of propagation is a maximum for the stoichiometric, or chemically correct, air-fuel ratio. Even if the heat conductivity were independent of the composition of the mixture, the minimum energy of ignition coincides with the maximum speed of flame propagation.

Professor F. A. F. Schmidt took as his subject "The Criterion of the Self-Ignition Characteristics of Fuels." He underlined the importance of the ignition properties in the engine, and the limits of power in the range of satisfactory fuel consumption as set by fuel properties. He discussed the influence of mixture ratios, the differences between fuels of differing structure as regards their ignition behaviour, and the limited possibilities of the octane number. He urged the advantages of fuel tests in a special compression apparatus over tests in special engines. The differing ignition lags of fuels of different structure is associated with their different behaviour during the lag and, in particular, with their rates of heat development. He proposed an intermediate solution related to the present methods of test in engines, and a long-term attack on improving methods of fuel testing.

Professor O. Holfelder, in a paper entitled "Experiences with the Exhaust-Gas-Oxygen System in an Otto Engine," described an engine system, developed for torpedoes, which might also be applied to submarines. The system, proposed during the First World War by Becker and Kaufmann, was called the exhaust-gas-oxygen cycle system; it was revived during the recent war. The engine used had eight cylinders, arranged in V form, and itself was of normal design, but dimensioned to withstand very high pressures. While such a system is suitable only for special cases, the thermal and technical problems, and especially those of control, are not without general interest. Oxygen, instead of air, is supplied to the engine, and, as a carrier of this oxygen, the exhaust gases, which are normal in composition except for the absence of nitrogen, are used. The fuel, petrol, and the oxygen, together with a suitable proportion of exhaust gases, are supplied to the engine. The exhaust gases are cooled by sea-water to about 100 deg. C., and then passed to a governor in which the desired proportion for duty as carrier is separated, while the remainder is allowed to escape. The gases can also be cooled by water-injection, the condensate being removed afterwards by a centrifugal separator. The volume escaping is, of course, considerably less than would be the case if the oxygen for combustion were supplied in air; although nitrogen may be present at starting, the proportion rapidly decreases, and the exhaust gases consist almost entirely of CO_2 , H_2O and CO . The track of the torpedo is thus much less easily seen than it is when normal methods of power production are used. To avoid back-firing of the new charge on coming

DOUBLE-ACTING PISTON PUMP.

J. L. C. ENGINEERING COMPANY, LIMITED, LONDON.

(For Description see Opposite Page.)

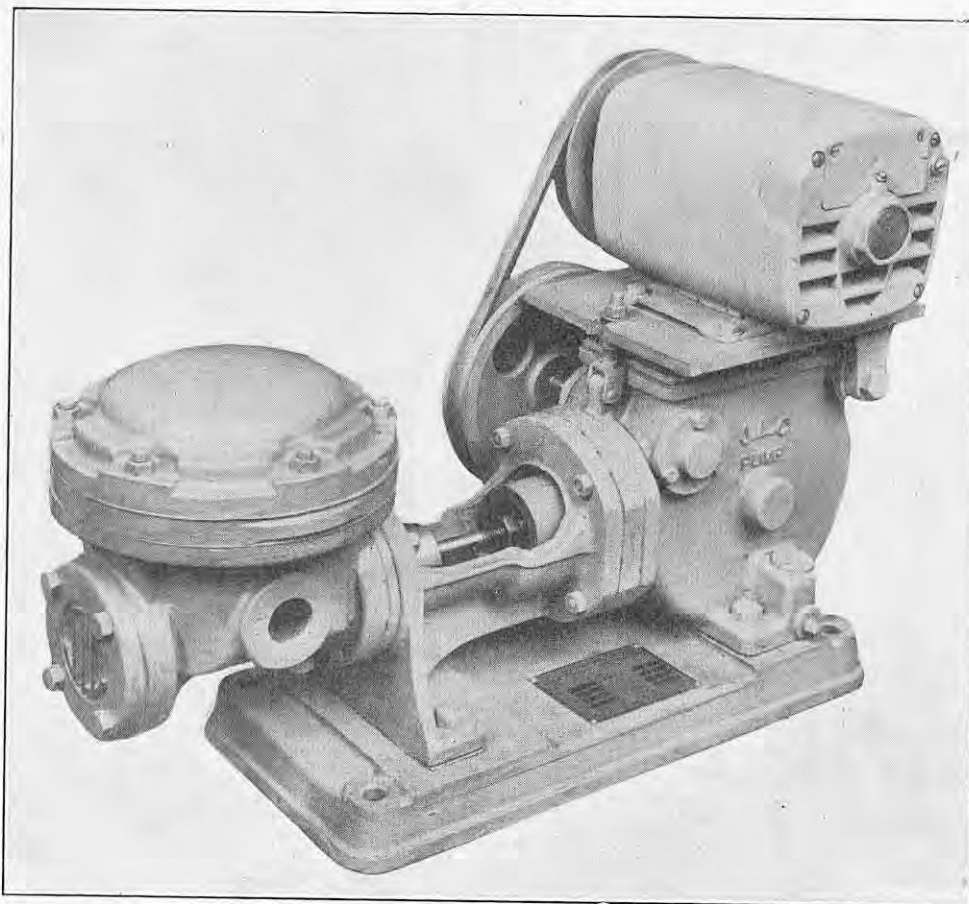


FIG. 1.

into contact with the hot exhaust gas remaining in the cylinder, the oxygen was limited to 28 per cent. by volume.

The engine was highly supercharged by building up pressure in the exhaust system to about 3 atmospheres. The ratio of compression was 6.6:1, while the H_2O from the exhaust gases, by its re-evaporation during the compression stroke, made it possible to reduce the index of compression to 1.25. The CO_2 reduced the ignition rate to about one-half. The combustion temperature was higher than in conventional engines and marked dissociation took place, which accounted for the presence of considerable hydrogen in the exhaust gases; the rich mixture supplied for ease of control also increased the CO content. An increase of oxygen led to a rate of increase in the maximum pressure relatively greater than that of the mean effective pressure. Increase of supercharge with constant m.e.p., on the other hand, led to lower maximum pressures. The output of the engine was conveniently effected by control of the back pressure.

The second session opened with Professor H. List's paper, "Investigations into the Charging of Two-Stroke and Four-Stroke Engines." This covered the analysis of the flow of the gases through the elements of the complete charging and exhausting systems of the engines in question, a subject on which he is the author of two comprehensive books in the series: "Die Verbrennungskraftmaschine" (Springer, Vienna). He was followed by Dr. M. Leiker who, in his paper "The Exhaust System of the Two-Stroke Engine," described his experiments. The next paper, by Professor O. Klüsener and Dr. W. Schröder, was entitled "Tests on Engines with Crankcase Compression." The engines in question had a swept volume of about 500 cub. cm., and the tests substantiated the importance of the influence upon engine performance of the dimensions of the suction and exhaust-pipe systems. The volume of the air taken in is especially influenced by vibrations in the pipes. The vibrations in the

whole system—crankcase, transfer passage, cylinder and exhaust pipe—are important. An equation was derived which was found to be in good agreement with their test results. It is possible by observing the vibrations during the admission and exhaust processes, to control, within given limits, the air consumption with the speed. Since the heights of the diagrams taken from the crankcase are proportional to the air consumption, the work done in the crankcase is also roughly proportional to the air consumption. The ratio of charging work to air consumption depends on the magnitude of the clearance volume, and on the mean temperature of the air in the crankcase. It was shown that, owing to this relationship, the total work lost is reduced when less air is taken, so that the mechanical efficiency increases with decrease of load.

The last of the three technical sessions was opened by Professor W. Pflaum, with his paper "Increase of Output by Supercharging: New Test-Results on a Highly-Supercharged Diesel Engine." In this, he gave the results of independent tests, conducted by Professor G. Eichelberg and himself, on a new M.A.N. six-cylinder engine of 300 mm. bore and 450 mm. stroke, running at 400 r.p.m. High supercharging is only economically possible with an exhaust-gas turbine directly-coupled to the blower. The increased air quantity in the cylinder involves higher pressure, but not higher temperature, so long as the new air temperature and the air quantity for combustion are controlled. A higher back pressure increases the exhaust temperature, which is desirable for an exhaust-gas turbine; this temperature can, however, be kept within proper limits. The engine gave 1,360 h.p. at minimum specific consumptions of 140 gr. (0.31 lb.) per brake horse-power per hour, corresponding to an overall thermal efficiency of 45 per cent. The supercharge pressure ranged from 2 to 2.5 atmospheres, the maximum pressure from 1,700 lb. to 2,000 lb. per square inch; the brake mean effective pressure at normal output

DOUBLE-ACTING PISTON PUMP.

J. L. C. ENGINEERING COMPANY, LIMITED, LONDON.

Fig. 2. SECTION B-B

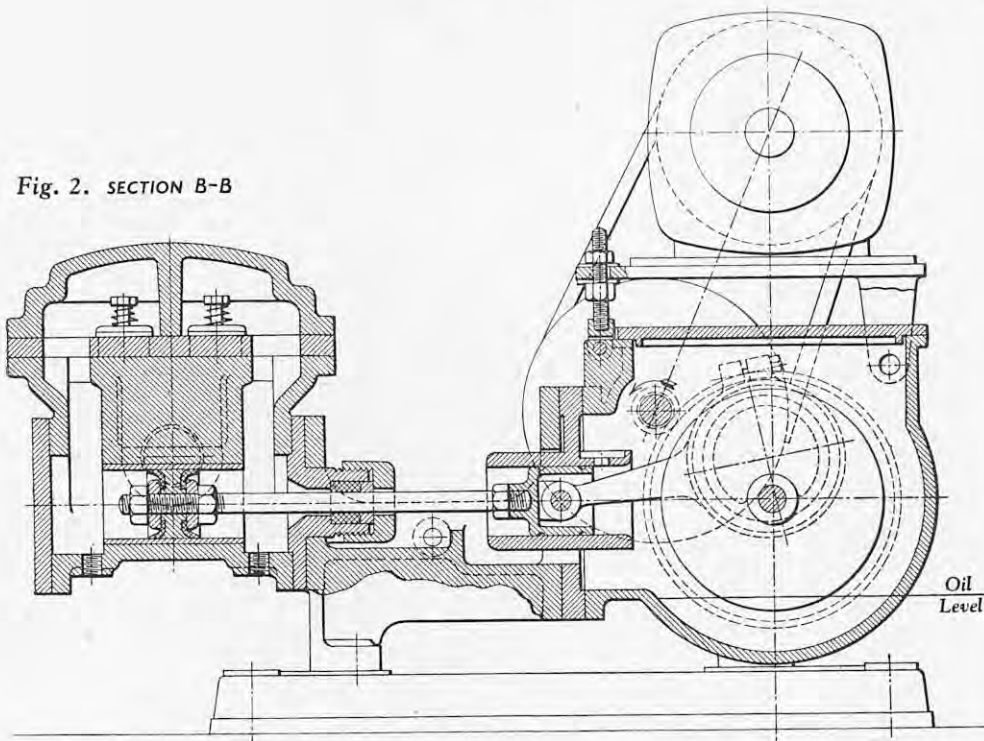
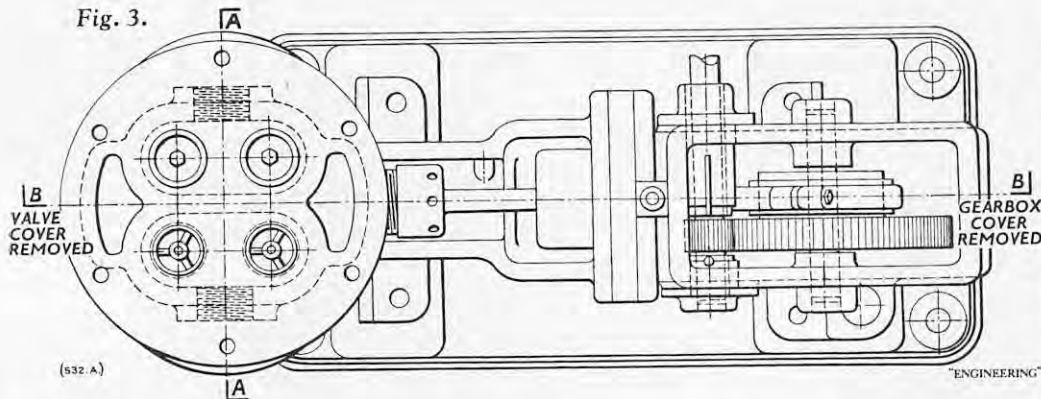


Fig. 3.

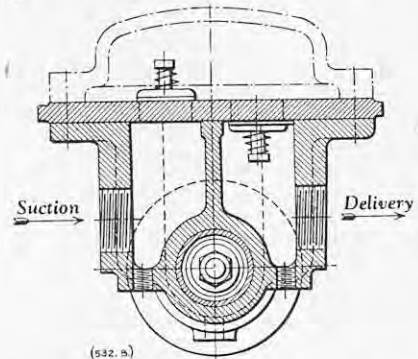


was 228 lb. per square inch, and reached 280 lb. per square inch at maximum loads. The engine has already run 1,000 hours.

Dr. K. Zinner gave the next paper, "The Behaviour as Regards Acceleration of the Diesel Engine with Exhaust-Gas Turbo-Supercharger." He pointed out first that the supercharger cannot follow immediately changes of load of the engine, but follows with a certain delay, which may, in certain applications, be a disadvantage. There were three basic cases: increasing turning moment at constant revolutions per minute, so that only the supercharge requires to be accelerated; increasing revolutions per minute with constant turning moment, when both engine and supercharger must be accelerated; and increasing turning moment and speed, when again both must be accelerated. In all cases, a distinction must be drawn between the time for the engine to make the desired change of turning moment or speed and the time for the supercharger to reach a new state of equilibrium. Tests were made on engines of different sizes, the changes of speed being measured by oscillographs. It is seen that the engine attains the new conditions much faster than the supercharger; this follows from the fact that the engine, especially when supercharged, usually has enough excess air in the cylinder to follow the changes in fuel supply, even when going from part-load to full-load. To illustrate the first case, the engine was loaded from no-load to full-load with electrical resistances. The speed of the engine, owing to the governor fluctuation, fell, and then, as a result of the difference

between the engine turning moment and that imposed by the resistances, increased. This change of speed is covered by the kinetic energy of the rotating masses. The fall of speed below that corresponding to equilibrium at full load was 4 per cent. Even after one second the engine speed began to increase, and reached equilibrium about 2.5 seconds after applying the resistances. The blower reached 92 per cent. after about 3 seconds, and, after 6 seconds, 99 per cent. of the equilibrium speed. A simple method of calculation was developed to enable the test results to be applied to the acceleration processes of the blower under other conditions. Two results of a deficient air quantity in the engine when increasing the load may be: firstly, the exhaust temperature, and thus the supply temperature to the engine, is higher than under equilibrium (this is unimportant since, the high temperature is only of short duration and the metal parts cannot follow it); and secondly, the colour of the exhaust may be worse during acceleration. Tests show, however, that this state is also of short duration. By means of a simple fitting, which retards the charging link of the fuel pump at the beginning of acceleration, it is possible to avoid this bad exhaust without greatly affecting the acceleration of the engine.

Professor H. Triebnigg, in his paper "Flow Processes in the Combustion Chambers of Diesel Engines," described a sectioned reproduction of the engine in which, with the use of water, these processes could be followed by analogy. The combustion chambers were all of the direct-injection

Fig. 4. SECTION A-A
VALVE CHAMBER ONLY.

type, and embodied cavities of various forms in the pistons. The method enables a good picture to be obtained of the processes, and gives visible proof of the soundness or otherwise of the calculations normally made, comparison being made on the basis of the Reynolds number.

DOUBLE-ACTING PISTON PUMP.

For boiler-feed and general purposes, the J.L.C. Engineering Company, Limited, Oxgate Farm Works, Coles Green-road, Cricklewood, London, N.W.2, have introduced the self-lubricating double-acting pump illustrated in Fig. 1, opposite, and shown in section, plan and part end section in Figs. 2, 3 and 4. The unit consists of an electric motor, gearbox and pump, mounted on a common bedplate, though it can, if desired, be supplied without the motor and arranged for independent pulley drive. The two suction valves and two delivery valves are mounted on a cast valve plate which is fixed between a cover and the main cylinder casting. Thus, the valve plate, with valves, is readily removed for inspection, maintenance or renewal, without disturbing any other part. Further, the suction and delivery connections can be reversed simply by turning the valve plate through 180 deg. Three sizes of pump, A, B and C are made; all have a stroke of 2 in., and are driven by a $\frac{3}{4}$ -h.p. motor running at 1,425 r.p.m., giving a main-shaft speed of 200 r.p.m. The piston diameters are as follows: A, $1\frac{1}{4}$ in.; B, $1\frac{1}{2}$ in.; and C, $1\frac{3}{4}$ in.; the corresponding outputs in gallons per hour are 300, 230 and 130; the maximum pressures are 90, 110 and 200 lb. per square inch; and the maximum heads are 200, 250 and 460 ft., respectively. The total weight, including motor, is in all cases 168 lb.

Considering the arrangement of the valves in plan (Fig. 3), they are separated below the valve plate into the suction pair and the delivery pair by a longitudinal web that is integral with the cylinder casting, as shown in Fig. 4. Above the valve plate, as shown in Fig. 2, they are divided into two pairs (each pair being the one associated with one end of the cylinder) by a transverse web integral with the valve cover. Below the valve plate, the valves are in communication only with the suction and delivery connections, respectively; above the plate they are in communication with the ends of the cylinder bore. The action of the piston and valves will now be clear from Figs. 2, 3 and 4.

The piston is driven by a cast-iron eccentric through a crosshead and piston rod, and the eccentric shaft is driven through a V-belt and pulleys, a mild-steel pinion and cast-iron spur wheel. The driving gear is housed in a cast-iron gearbox which forms an oil bath. Splash lubrication is employed; oil is also flung off the pinion into a recess formed in the top of the crosshead trunk guide, whence it passes through a hole on to the crosshead. By swinging the motor and its mounting plate on the hinge at the top outer corner of the gearbox, and removing the cover, a large opening provides access to the gearbox. The belt tension is regulated by adjusting the pair of nuts which hold the motor-mounting plate. The countershaft runs in gun-metal bushes, and the connecting rod and crosshead are also of gun-metal. The main pump casting is fitted with a removable gun-metal liner, and "Seatrist" piston cup packings and gland packings are employed. Gun-metal is also used for valves and seats, and phosphor-bronze for the spindle. The valves are spring-loaded. The pumps are of simple and robust construction and are designed to handle water up to 180 deg. F. in temperature.

NOTES FROM THE INDUSTRIAL CENTRES.

SCOTLAND.

IRON AND STEEL PRODUCTION.—The production of steel ingots and castings in Scotland was at an annual rate of 2,114,200 tons in September, which compared with 2,122,600 tons in August, and 2,495,800 tons in September, 1950. The production rate in the first half of this year was 2,231,800 tons, so that last year's final total of 2,426,000 tons is out of the question for 1951. The scrap shortage, which is responsible for the decline, has stimulated blast furnace activity, but while last month's output of pig iron was equivalent to 852,900 tons per annum, in contrast with 796,100 tons in August, it failed to reach the level of 864,100 tons in September of last year. It is becoming more apparent that the reduction in steel production is being felt by consumers of all kinds. Reserves, which have eked out deliveries since the cut began, are now approaching exhaustion in many cases, and hand-to-mouth working is more common. Re-rollers have lost occasional shifts for want of semies.

EXTENSIONS AT COLVILLES' STEELWORKS.—Plans for extensions costing 80,000l. at Colvilles' Steelworks, Motherwell, were approved yesterday at the Motherwell and Wishaw Dean of Guild Court. They include a scheme for the alteration of buildings at the Dalzell works for the installation of a new bar mill, which, it is estimated, will cost 33,000l.

STEEL SHORTAGE AND SHIPBUILDING.—The disturbing position in the shipbuilding industry, on account of the shortage of steel, was referred to by Sir Murray Stephen, chairman of Alexander Stephen & Sons, Ltd., Linthouse, Glasgow, on October 17, at a launching ceremony. Sir Murray said that the supply position was getting slower and slower, and the amount of steel was far short of their requirements. If that continued, the ships they were building would be delayed, and those to come afterwards would be delayed still further.

MECHANICAL BOILER-FIRING PROBLEMS.—Addressing the Glasgow branch of Incorporated Plant Engineers on boiler efficiency, Dr. E. G. Ritchie, President-elect of the Association, said, on October 16, that, in his experience, mechanical-firing appliances were less selective in relation to fuel sizes than might be expected, and that $\frac{1}{2}$ in. coal containing 30 to 40 per cent. fines below $\frac{1}{2}$ in. gave, on the whole, better results than graded fuel. He emphasised the importance of surface moisture, and said that the difference in boiler-operating efficiency, as between substantially dry fine coal and the same coal properly conditioned as to surface moisture, was equivalent to about 16 per cent. gain in efficiency with wetted coal. This corresponded to a saving in fuel consumption of the order of 20 per cent.

COURSES IN BOILER-HOUSE PRACTICE.—The Scottish Fuel Efficiency Committee, in association with the Department of Education, several local authorities, and the Smoke Abatement Society, have arranged for 23 classes in boiler-house practice to be held, this winter, at various leading Scottish centres. Additional classes may be arranged if a sufficient number of pupils come forward. Applications are invited by the secretary of the Committee, Mr. W. M. Cunningham, 145, St. Vincent-street, Glasgow.

ELECTRICITY-SUPPLY SCHEMES, ORKNEY.—The North of Scotland Hydro-Electric Board have informed Orkney County Council that they have now surveyed the main islands of the County and have prepared schemes for submarine cables and, where necessary, for Diesel generating plant. Arrangements for the future, to some extent, would be made on the experience gained in the use of submarine cables.

CLEVELAND AND THE NORTHERN COUNTIES.

SHIPBUILDING ACTIVITIES.—North-East Coast shipyards are as actively engaged as conditions justify and are turning out heavy tonnages. At the yard of John Crown & Sons, Ltd., Sunderland, the fore end of the 23,000-ton tanker, Rondefjell, was launched on October 15. The after-end of the vessel is having her engines fitted on the Tyne. The two halves of the Rondefjell will be united in the not far distant future. As yet, Tees builders have experienced no difficulty in completing orders in the ordinary way. When the 19,000-ton M.S. Kosmos V, the biggest ship so far to be built on that river, was sent down the ways there was not much room to spare for her launching but the fact that her builders, Messrs. Furness Shipbuilding Co., Ltd., have accepted an order for a still larger vessel indicates that the capacity of the yard has not yet been tested to the full.

PIG-IRON SUPPLIES.—Tees-side pig-iron consumers are securing welcome improved supplies but distributable parcels still fall considerably below the current needs of customers. The extra tonnage now available is largely absorbed by the steel plants and deliveries to the foundries are still inadequate and very irregular.

LANCASHIRE AND SOUTH YORKSHIRE.

WORKS EXTENSIONS.—After protracted negotiations, a building licence has been granted to Newton, Chambers & Co., Ltd., for new buildings at the Warren Lane Factory and extensions to the welding bay, estimated to cost 85,000l. The work will include two additional storage bays measuring 100 ft. by 50 ft., the extension of the old welding shop by a bay having a floor area of 195 ft. by 50 ft., and the provision of a new bay 200 ft. long at Warren Lane. Additional machine tools are estimated to cost 33,000l.

CENTRIFUGAL CASTING OF STEEL.—There will shortly be ready for operation at the works of Steel, Peech and Tozer, Sheffield, a pilot plant for the centrifugal casting of steel. It is intended to determine by experiment whether a full-sized plant would be a useful addition to the present finishing facilities. Similar equipment is being operated successfully in Australia for the production of railway wheels and gears. The process is suitable for the manufacture of many circular steel articles.

LOWER STEEL PRODUCTION.—The Sheffield-area steel production, in September, was more than 4,000 tons a week below that of September, 1950, because sufficient melting materials were unprocureable. The weekly average was 40,900 tons, compared with 45,100 tons in September, 1950. For the quarter ended September 30, the weekly average production was 36,900 tons, compared with 41,300 tons in the corresponding quarter last year.

AUTOMATIC STOKERS' AT COLLIERIES.—Automatic-stoking equipment, installed at Brodsworth Main Colliery last year, is stated to be saving 80 tons of coal a week and 130 man-shifts. It is hoped to install similar apparatus at Markham Main Colliery, near Doncaster, where two new boilers are to be put in shortly. Shortage of equipment is delaying the installation of similar boilers at all pits in the Doncaster area.

A NEW COAL SEAM.—A seam of coal 5 ft. 6 in. thick has been reached at Manton Colliery, Worksop, Nottinghamshire, after many years' work on a new shaft. Work was begun by the original owners, the Wigan Coal Corporation, Ltd., and has been continued by the National Coal Board. The coal is said to be of good quality, and was reached at a depth of 750 yards. It is expected that a more valuable seam will be attained shortly at a lower level.

THE MIDLANDS.

NAVIGATION STREET BRIDGE, BIRMINGHAM.—The main girder for the first half of the new bridge carrying Navigation-street, Birmingham, over the tracks of the London Midland Region of British Railways, has been placed in position. The rebuilding of the bridge is a task of some difficulty, owing to the heavy traffic on both road and rail, and is being done in two parts. Half the old bridge is being retained until road traffic can be transferred to the new portion, when work will be started on the second half.

APPROVAL OF THE APPLEBY-FRODINGHAM SCHEME.—Approval has been given by the Iron and Steel Corporation of Great Britain to the expenditure of 10,000,000l. at the Appleby-Frodingham works, Scunthorpe, of the United Steel Companies, Ltd., on extensions to include two large blast-furnaces and ancillary plant. When full production is reached in about three years' time the yield will be approximately 500,000 tons of pig iron yearly. Production of metallurgical coke is to be expanded considerably.

THE 2,000,000TH NUFFIELD CAR.—The Nuffield Organisation have produced their two-millionth vehicle, a Morris Minor four-door saloon motor car, which is now on exhibition at the International Motor Show, Earl's Court. The Nuffield Organisation, which have most of their factories in the Midlands, are stated to be the first firm outside the United States of America to reach this figure.

INSPECTION OF PUBLIC WEIGHING MACHINES AT WOLVERHAMPTON.—Under a by-law passed by Wolverhampton Corporation, and taking effect from November 1, all public person-weighting machines in the Borough will become subject to inspection and test by the Weights and Measures inspectors. Wolverhampton is one of the few local authorities so far to have taken advantage of the Weights and Measures Acts which permit the making of such by-laws. It is not known how many machines

there are in Wolverhampton, and the inspectors are to carry out a survey to ascertain this. The estimated number is 150, and as there has been no control previously, many of them may require attention before they comply with the standards now laid down.

LABOUR SHORTAGE AT GASWORKS.—The gasworks of the West Midlands Gas Board are due to start increased production for the winter season at the end of this month, but as a result of the labour shortage it is probable that some of the shifts will be undermanned. In the principal industrial centres, from Coventry in the south to Stoke-on-Trent in the north, there are 400 vacancies for gas-employees, particularly stokers and labourers. The Gas Board attributes its difficulties in this direction to the competition of lighter and cleaner industries where there is no shift work. At the Smethwick Gasworks, in particular, there are already 25 vacancies, and the position is expected to become more difficult in the near future, as new plant comes into operation.

INDUSTRY IN BRIDGNORTH.—The youth employment committee of Bridgnorth, Shropshire, has expressed the hope that light engineering firms seeking new premises will be attracted to the town, which has factory sites available, with all the necessary services. The only industries at present in Bridgnorth are carpet making and radio manufacture, and some workpeople in the town have had to find employment in the Wolverhampton area, 14 miles away.

PLATING ON PORCELAIN.—A Midland firm, the Ionic Plating Co., Ltd., Grove-street, Smethwick, have introduced a method of plating on porcelain. Silver and speculum metal are being deposited, and metals can also be deposited on plastics. Plating on non-metallic surfaces is not new, but the Ionic Plating Co. claim to have developed it as a commercial proposition.

BLAST-FURNACE DEVELOPMENTS AT SCUNTHORPE.—Referring in these notes, on page 462, *ante*, to recent developments at the Redbourn Works, Scunthorpe, Lincolnshire, of Richard Thomas and Baldwins, Ltd., we stated that a new blast furnace had been blown in which was expected to produce 500 tons a week. We are now informed that this figure was in error and that the new unit is expected to produce about 2,500 tons weekly. The figure of 500 tons represents the excess, over previous outputs, brought about by the new developments.

SOUTH-WEST ENGLAND AND SOUTH WALES.

DELIVERY OF COAL BY SEA.—Efforts are being made to ease the pressure on the railway system, during the winter months, by delivering more of the South Wales coal for consumers in this country by sea. Talks have been going on with the consumers and the Ministry of Fuel and Power, and already, some supplies have been diverted for shipment. The electricity stations and gasworks have always received most of their coal by ship and it is now hoped to send more of the industrial users' supplies in this manner. Clients who must receive their coal in good condition fear that the extra breakage, liable during shipment, may necessitate re-screening at the distribution centres.

TRAFFIC AT S. WALES PORTS.—An eleven-year trade record for the South Wales group of ports was broken in the four weeks ended October 7 when a total of 1,824,262 tons of traffic was handled; the previous best four-weekly period occurred in May, 1940. During 1951, from January 1 to October 7, a total tonnage of 15,447,704 tons was dealt with, a rise of 1,138,936 tons over the corresponding period of a year ago. The growing oil trade of Swansea, where the total traffic was 7,271,467 tons, almost as much as all the other ports put together, was chiefly responsible for the gain which amounted to 4,857,559 tons. Imports of foreign iron and steel at the South Wales ports, during the period from January 1 to October 7, totalled 388,208 tons compared with 416,143 tons in the comparative period of 1950. In the same periods shipments of partly-manufactured iron and steel goods were 209,025 tons against 229,844 tons and tin-plate exports were 159,406 tons against 171,421 tons. Imports of iron ore totalled 1,494,714 tons, compared with 1,372,690 tons, and those of other ores, 205,758 tons compared with 137,731 tons. South Wales coal exports to foreign markets in the period from January 1 to October 7, 1951, were 2,227,619 tons, constituting a drop of over 1½ million tons on the corresponding period of last year.

UNEMPLOYMENT IN WALES.—On September 17 last, 22,320 persons were registered as unemployed in Wales, an increase of 686 since August 13, but 9,736 fewer than the figure for September last year. Of the 22,320 persons registered 14,123 were men, 614 boys, 6,508 women and 1,075 girls.

NOTICES OF MEETINGS.

It is requested that particulars for insertion in this column shall reach the Editor not later than Tuesday morning in the week preceding the date of the meeting.

INSTITUTION OF ELECTRICAL ENGINEERS.—*Radio Group*: Monday, October 29, 5.30 p.m., The Institution, Savoy-place, London, W.C.2. Discussion on "The Social Implications of Television," opened by Mr. F. H. Townsend. *North Midland Centre*: Tuesday, October 30, 7 p.m., Royal Station Hotel, York. "The Control of Hydro-Electric Plant," by Messrs. A. C. H. Frost and W. Brittlebank. *Supply Group*: Wednesday, October 31, 5.30 p.m., the Institution, Savoy-place, London, W.C.2. Chairman's Address, by Mr. R. Davis. *East Midland Centre*: Thursday, November 1, 8 p.m., George Hotel, Kettering. Dinner-dance.

WOMEN'S ENGINEERING SOCIETY.—*Manchester Branch*: Monday, October 29, 6.30 p.m., Engineers' Club, Albert-square, Manchester, 2. "Some New Materials and their Application," by Mr. R. F. Archer.

INSTITUTION OF WORKS MANAGERS.—*Manchester Branch*: Monday, October 29, 6.30 p.m., Grand Hotel, Manchester. Open forum. *Tees-Side Branch*: Thursday, November 1, 7.30 p.m., Vane Arms Hotel, Stockton. Discussion on "Is Management Entirely Commonsense?" opened by Mr. P. G. McCarthy.

INCORPORATED PLANT ENGINEERS.—*West and East Yorkshire Branch*: Monday, October 29, 7.30 p.m., The University, Leeds. "Civil Engineering," by Professor Evans.

ASSOCIATION OF SUPERVISING ELECTRICAL ENGINEERS.—*Bournemouth Branch*: Monday, October 29, 8.15 p.m., Grand Hotel, Fivale-road, Bournemouth. Film show. *Kent Branch*: Wednesday, October 31, 8 p.m., Sun Hotel, Chatham. Film Show. *South London Branch*: Thursday, November 1, 8 p.m., Café Royal, North End, Croydon. "Fluorescent Lighting," by Mr. H. Windebank.

INSTITUTION OF CIVIL ENGINEERS.—*Maritime Engineering Division*: Tuesday, October 30, 5.30 p.m., Great George-street, London, S.W.1. "The Design and Construction of New Deep-Water Quays at Leith," by Mr. M. C. White.

INSTITUTION OF HEATING AND VENTILATING ENGINEERS.—*Scottish Branch*: Tuesday, October 30, 6.30 p.m., Engineering Centre, 351, Sauchiehall-street, Glasgow, C.2. "A Brief Survey of Metallic Arc Welding," by Mr. E. Flinham, with film.

INSTITUTION OF STRUCTURAL ENGINEERS.—*Wales and Monmouthshire Branch*: Tuesday, October 30, 6.30 p.m., South Wales Institute of Engineers, Park-place, Cardiff. Chairman's Address, by Mr. G. H. Hodgson, "Problems in the Conveyance and Storage of Crushed Rock." Wednesday, October 31, 6.30 p.m., Mackworth Hotel, Swansea. Chairman's Address, by Mr. G. H. Hodgson, with discussion.

ROYAL AERONAUTICAL SOCIETY.—Tuesday, October 30, 7 p.m., 4, Hamilton-place, London, W.1. "Supersonic Propellers," by Dr. W. F. Hilton. Thursday, November 1, 6 p.m., Institution of Civil Engineers, Great George-street, London, S.W.1. Sound films associated with Mr. E. G. Stout's lecture on "A Review of High-Speed Hydrodynamic Development" to the Third Anglo-American Aeronautical Conference.

ROYAL UNITED SERVICE INSTITUTION.—Wednesday, October 31, 3 p.m., Whitehall, London, S.W.1. "Europe To-day," by Mr. Sebastian Haffner.

INSTITUTE OF BRITISH FOUNDRYMEN.—*Lincolnshire Branch*: Wednesday, October 31, 7.30 p.m., Staff Canteen, Ruston and Hornsby Limited, Boultham Works, Lincoln. Joint meeting with the INSTITUTION OF PRODUCTION ENGINEERS. "The Craftsmanship of Output Applied to American Brass Foundry," by Messrs. F. E. Rattlidge and E. Mantle. *Wales and Monmouth Branch*: Saturday, November 3, 6 p.m., Engineers' Institute, Cardiff. "Intricate Castings from Durable Loam Moulds," by Mr. J. Currie.

INSTITUTION OF PRODUCTION ENGINEERS.—*Lincoln Section*: Wednesday, October 31, 7.30 p.m., Staff Canteen, Ruston and Hornsby, Limited, Boultham Works, Lincoln. Joint meeting with the INSTITUTION OF BRITISH FOUNDRYMEN. "The Craftsmanship of Output Applied to American Brass Foundry," by Messrs. F. E. Rattlidge and E. Mantle. *Shrewsbury Section*: Wednesday, October 31, 7.30 p.m., Walker Technical College, Oakengates, Salop. "Ball and Roller Bearings Manufacture and Application," by Mr. R. K. Allan. *Glasgow Section*: Thursday, November 1, 7.30 p.m., Institution of Engineers and Shipbuilders in Scotland, 39, Elmbank-crescent, Glasgow, C.2. Film night and discussion. "Hydroptic Boring and Milling Machines" and "The Hone Abrading Process and the Generation of Metallic Bearing Surfaces." *West Wales Section*: Friday, November 2, 7.30 p.m., Central Library, Alexander-road, Swansea. "Jig and Tool Design," by Mr. R. O. Jeakings.

ILLUMINATING ENGINEERING SOCIETY.—*Nottingham Centre*: Thursday, November 1, 5.30 p.m., Demonstration Theatre, East Midlands Electricity Board, Smithy-row, Nottingham. "Modern Airport Lighting," by Mr. J. W. Morse.

INSTITUTE OF MARINE ENGINEERS.—Thursday, November 1, 7 p.m., Medway Technical College, Gardiner-street, Gillingham. "The Construction of Marine Boilers," by Lt.-Commander (E) A. P. Monk, R.N. (ret.).

LEEDS METALLURGICAL SOCIETY.—Thursday, November 1, 7 p.m., Chemistry Department, The University, Leeds. "Some Structural Aspects of Recrystallisation," by Mr. R. Eborall.

INSTITUTION OF MECHANICAL ENGINEERS.—Friday, November 2, 5.30 p.m., Storey's Gate, St. James's Park, London, S.W.1. "Some Factors Affecting Wear on Cemented Carbide Tools," by Dr. E. M. Trent.

JUNIOR INSTITUTION OF ENGINEERS.—Friday, November 2, 6.30 p.m., 39, Victoria-street, London, S.W.1. Film evening. "Concrete," and "Moving Earth," introduced by Mr. H. E. Hodgson.

MANCHESTER ASSOCIATION OF ENGINEERS.—Friday, November 2, 6.45 p.m., Engineers' Club, Albert-square, Manchester, 2. "Modern Methods of Sound Reproduction," by Mr. J. R. G. Vernon.

BIRMINGHAM ASSOCIATION OF MECHANICAL ENGINEERS.—Friday, November 2, 7 p.m., James Watt Memorial Institute, Great Charles-street, Birmingham. "Modern Woodworking Machinery: Developments in Design and Production Technique," by Mr. John Franey.

INSTITUTION OF ENGINEERS AND SHIPBUILDERS IN SCOTLAND.—Friday, November 2, 7.45 p.m., Robert Gordon's Technical College, Aberdeen. Joint meeting with ABERDEEN MECHANICAL SOCIETY. "Some Aspects of Research on Friction and Wear," by Dr. F. T. Barwell.

BRITISH STANDARD SPECIFICATIONS.

THE following publications of engineering interest have been issued by the British Standards Institution. Copies are available from the Sales Department of the Institution, 24, Victoria-street, London, S.W.1, at the price quoted at the end of each paragraph.

Pipe Flanges for Use on Internal Combustion Engines.—A new specification, B.S. No. 1770, covers pipe flanges primarily intended for use on systems connected with internal-combustion engines, excluding aeroplane engines. It specifies requirements for the general and detailed construction of oval, square, and triangular pipe flanges for securing, by screwing, brazing and welding, to pipes contained in cooling-media systems, exhaust and induction systems and oil-pipe systems. The flanges are not intended to be used on steam pressure work or other similar services. Tables of the dimensions of flanges for use on a range of pipes of $\frac{1}{2}$ in. to 4 in. nominal bore are given and data on the workmanship of the flanges and on the materials to be utilised in their manufacture are also included. [Price 2s., postage included.]

Electrical Fire Alarms.—The Council for Codes of Practice for Buildings, Construction, and Engineering Services, Lambeth Bridge House, London, S.E.1, have issued, in final form, Code of Practice CP 327. 404/402.501, covering electrical fire alarms. This has been drawn up by a committee convened jointly, on behalf of the Council, by the Institution of Mechanical Engineers and the Institution of Electrical Engineers. The Code deals with the installation, in buildings, of electrical fire-alarm systems including manual call points and automatic fire detectors. It excludes public fire-alarm systems and alarms forming part of automatic sprinkler installations. Advice is given on the necessary consultation at the planning stage and on the choice of materials, appliances and components. Recommendations follow regarding the design of various types of systems, methods of wiring and power supply, and the provision of the necessary structural accommodation for the equipment and wiring. Sections on inspection and testing and on maintenance are included. An appendix deals with the performance and testing of heat-sensitive automatic detectors. [Price 5s., postage included.]

Portable Fire Extinguishers.—A further specification in the series covering fire extinguishers has now been issued. It deals with portable fire extinguishers of the tetrachloride type and constitutes a complete revision of that portion of B.S. No. 740 which related to carbon tetrachloride fire extinguishers. All types of carbon tetrachloride extinguishers are now provided for, and the specification contains definitions of the various types, namely, the hand-pump type, gas-container type, constant-pressure type and air-pump type. In addition, the specification formulates details of the materials to be used, the types and dimensions of the various parts, and methods of testing at different stages of manufacture. Data on methods of welding are contained in appendices. [Price 4s., postage included.]

PERSONAL.

As announced in our columns a year ago, the Kelvin Medal for 1950 has been awarded to DR. THEODORE VON KARMAN, F.R.S., Professor of Aeronautics and director of the Guggenheim aeronautical laboratory, California Institute of Technology, Pasadena, U.S.A., and chairman of the advisory board to the General Commanding the American Air Forces. The presentation of the Medal will take place at the Institution of Civil Engineers at 4 p.m., on Tuesday, November 6.

PROFESSOR W. S. HEMP, M.A., A.F.R.Ae.S., has been appointed to succeed PROFESSOR R. L. LICKLEY, B.Sc., D.I.C., M.I.Mech.E., F.R.Ae.S., as head of the department of aircraft design at the College of Aeronautics, Cranfield, Bletchley, Buckinghamshire. Professor Hemp will retain his present title of Professor of Aircraft Structures and Aero-Elasticity. The new appointment will take effect from November 1.

MR. A. TIMS, B.Sc.(Eng.) (Lond.), A.M.I.C.E., hitherto district engineer, Barrow-in-Furness, British Railways, has been appointed district engineer, Blackburn, London Midland Region, as from November 1. MR. A. H. EMERSON, A.M.I.E.E., A.M.I.Loco.E., A.F.P.W.I., has been appointed electric-traction engineer, Manchester electrified lines, London Midland Region, comprising the Manchester to Bury, the Manchester South Junction and Altrincham, and the Manchester, Sheffield and Wath electrifications. Mr. Emerson's assistant is to be MR. T. E. WILSON, A.M.I.E.E., hitherto assistant resident engineer, Manchester, Sheffield and Wath electrification.

MR. L. E. HAWKINS, M.B.E., B.Sc., A.C.G.I., M.I.C.E., has been appointed assistant civil engineer (structures), London Transport Executive, with responsibility for the maintenance of all buildings, bridges, structures and earthworks and for the design and erection of bridge and structural work.

MR. N. C. ROBERTSON, M.B.E., F.R.S.A., Assoc.I.E.E., deputy managing director of E. K. Cole, Ltd., has accepted the position of director-general of electronics production, Ministry of Supply. He will take over his new duties, which are on a voluntary basis, early in November.

MR. E. J. BATCHELOR, until recently managing director of Brush Coachwork, Ltd., Loughborough, has been appointed managing director of Henry Meadows, Ltd., of Wolverhampton, of which company he has been a director and general manager.

For the third year in succession, MR. C. G. WHITE, director and general sales manager of Kelvin & Hughes (Marine), Ltd., was unanimously re-elected President of the British Nautical Instrument Trade Association, at their annual general meeting on October 17. MR. J. M. MCINTYRE, of Heath & Co., was also re-elected vice-president.

MR. D. G. BEVAN, M.I.C.E., M.I.Mun.E., who came to Birmingham in 1913 and was appointed deputy city engineer and surveyor in 1935, retired on October 22.

MR. T. P. SEARIGHT has relinquished the position of chairman of H. M. Hobson, Ltd., Hobson Works, Fordhouses, Wolverhampton, but remains a director. MR. S. W. HUGHES has been elected chairman and continues as managing director. MR. T. SIMPSON has been appointed assistant managing director and MR. P. H. STOKES, technical director.

MR. CRAWFORD GORDON, jun., O.B.E., has been appointed President and general manager of A. V. Roe (Canada), Ltd., Toronto. The previous general manager was MR. W. H. DEISHER, also vice-president, who has retired owing to ill health but remains a director of the company. SIR ROY DOBSON, C.B.E., F.R.Ae.S., J.P., until now the company's President, becomes chairman of the board, a post left vacant by the recent death of MR. J. P. BICKELL. Sir Roy is managing director of A. V. Roe, Ltd., Manchester.

E. BOYDELL & CO., LTD., manufacturers of Muir-Hill dumpers, loaders and shunters, Old Trafford, Manchester, 16, announce that MR. J. LACHLAN STURROCK, lately area sales manager for the Midlands, S.W. England and S. Wales, has been appointed sales manager of the company and will operate from the head office in Manchester.

MR. H. W. A. WARING, C.M.G., is relinquishing the appointment which he has held for the last four years as secretary of the Guest Keen Baldwins Iron & Steel Co. Ltd., Cardiff, and its subsidiaries in order to take up the appointment of director of the Power and Steel Division of the secretariat of the United Nations Economic Commission for Europe in Geneva. His successor at Cardiff is to be MR. L. R. P. PUGH.

ACCLES AND POLLOCK LTD., and METAL SECTIONS LTD., Oldbury, Birmingham, subsidiary companies of Tube Investments Ltd., opened a new joint Scottish office on October 21, at the Engineering Centre, 351, Sauchiehall-street, Glasgow, C.2 (Telephone: Douglas 6306). The office is being managed by MR. R. H. R. COURT, with MR. H. FOSTER as assistant manager.

THE INTERNATIONAL MOTOR SHOW, EARL'S COURT.

(For Description, see page 532.)



FIG. 1.

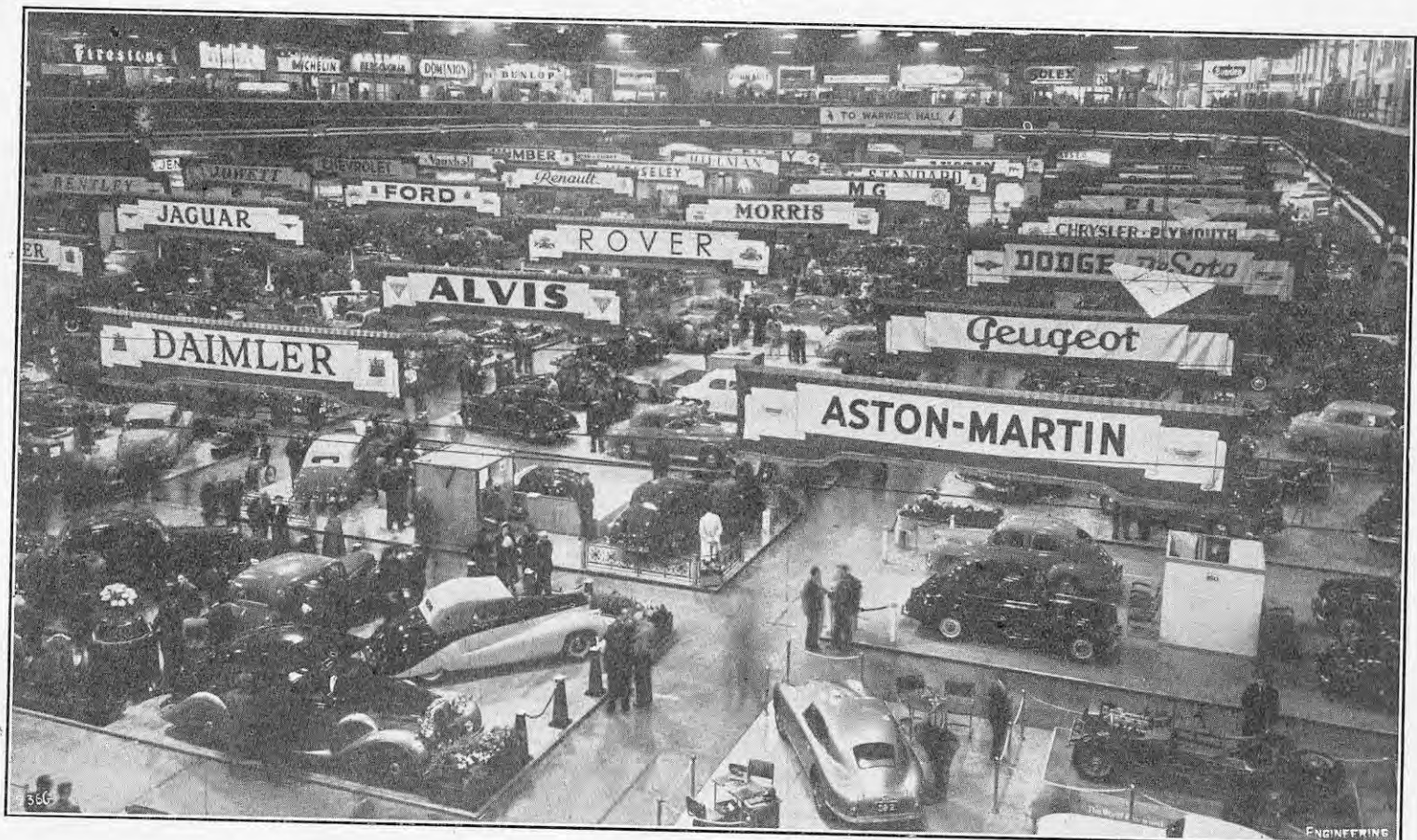


FIG. 2.

FIGS. 1 AND 2 VIEWS OF THE SHOW IN EARL'S COURT.

ENGINEERING,

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

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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For Canada	£5 5 0

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

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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ENGINEERING

FRIDAY, OCTOBER 26, 1951.

VOL. 172.

No. 4474.

STATISTICS OF IRON AND STEEL.

IRON, which, it has been estimated, constitutes about 5 per cent. of the solid crust of the earth, is the basic material of modern industrial civilisation. Apart from negligible quantities of meteoric iron, it is found only in the form of compounds, largely with oxygen and sulphur. The great world-wide iron and steel industry is based on the reduction of such compounds, and the names of British inventors figure prominently in the history of the development of methods of treatment. A certain amount of iron ore is mined in most countries, but large industries have been built up only in those having extensive natural deposits. Intensive exploitation will naturally reduce these, as is illustrated by the fact that the United Kingdom in 1950 imported 8,402,000 tons of ore to sustain an industry originally based on the utilisation of native materials. Actually, this figure is a measure of the development of the industry, and not an indication of the exhaustion of native ore, as, while the production of ore in 1929 was 13·22 million tons, in 1949 it was 13·40 million tons. Compared with some other countries, these are relatively small figures; in 1949, production in the United States was 84·98 million tons and in the U.S.S.R., 35 millions.

The decline of this country from the first position to the third in the iron and steel industry was, no doubt, inevitable on the scores of territorial size and population. It is strikingly illustrated by the fact that, in 1870, the United Kingdom produced 5·96 million tons of pig iron, the United States in the same year producing 1·67 million tons and the U.S.S.R. 0·36 million. The comparative figures for 1949 were, the United Kingdom 9·5 millions, the United States 49·03 millions, and the U.S.S.R. 16·43 millions. These totals are quoted from the latest statistical returns* of the British Iron and

* Statistics of the Iron and Steel Industry of the United Kingdom for 1950 and Statistics of the Iron and Steel Industries of Overseas Countries for 1949. The British Iron and Steel Federation, Steel House, Tothill-street, London, S.W.1. [Prices, respectively, 7s. 6d. and 15s.]

Steel Federation. It is difficult to indicate even the contents of these extensive returns in a small space, but they may be commended to the attention of every serious student of modern industrial development, and especially to those who attended the recent discussion on "Metal Economics," which we report on page 519 of this issue. It may be remarked that the volume dealing with the United Kingdom alone contains 102 tables, covering all aspects of the industry from production, the number of steel furnaces and the labour employed, to details of exports to other countries.

The volume dealing with overseas countries incidentally illustrates the world-wide distribution of iron ore, but the actual production in any country may be a measure of its industrial advance rather than of its mineral wealth. The nature of the ore and the consequent cost of its reduction also carries much weight. The table giving the iron-ore production in various countries shows greatest output, in 1949, by the United States, followed by the U.S.S.R., France, Sweden and the United Kingdom, in that order. The industrial advance of Russia is shown by the figures for 1929, in which the order, in terms of production, was the United States, France, the United Kingdom, Sweden, and the U.S.S.R. The output in 1949, for each of the countries mentioned, was over 10 million tons, but in 1929 the output in the U.S.S.R. was only 7·72 million tons; in that year it was almost equalled by Luxembourg with 7·45 million tons. This latter country had declined to 4·07 million in 1949. International comparisons, of the type made in this table, are necessarily based on statistics issued by various countries and the method of compilation may not always be the same. The report gives, in all cases, the authority from which the figures are quoted, and it is significant that in the cases of the U.S.S.R., Czechoslovakia and Roumania they are indicated as "estimated."

The table giving world production of iron ore contains figures for 42 countries, but those listing pig-iron and crude-steel outputs cover only 30 countries. The reason for this is obvious; a country may well have deposits of iron ore, but no iron and steel industry. Thus Algeria is shown as producing 2·16 million tons of iron ore in 1929 and 2·50 million tons in 1949, but its name does not appear in the lists of pig-iron or crude-steel producers. These latter lists furnish part of the data on which estimates of the social and industrial effects of war may be based. It was about the year 1900 that the production of pig iron in Germany caught up with and surpassed that of the United Kingdom; the respective figures for 1910 were 12·89 million tons and 10·01 million tons. The German lead was maintained during the first world war; in 1916 the United Kingdom produced 9·05 million tons as against 11·15 million tons in Germany. In 1920, however, the output of this latter country fell to 6·30 million tons, compared with 8·03 million tons in the United Kingdom. The decline in the German total was partly due to the loss of the Saar output. By 1939, Germany had drawn very far ahead at 15·35 million tons, compared with 7·98 million tons for this country. The effect of Germany's military adventures on industrial prosperity was that, in 1945, that country's output was only 1·10 million tons, while that of the United Kingdom was 7·11 million tons. Up till 1949, the British output showed a steady increase, reaching 9·50 million tons in that year. Germany, however, showed the same type of progress, and a quicker rate of advance, reaching 7·28 million tons in 1949. A similar drastic fall in output as a result of the second world war is shown in the figures for Japan, which also record some improvement by 1949.

The tables recording the production and importation of iron ore, which are given in the United Kingdom volume, indicate an increasing dependence on foreign sources. In 1913, 15,997,300 tons were

home-mined. Of this total, 12,572,300 tons were the Jurassic ores, of which the deposits of Lincolnshire and Northamptonshire are characteristic examples. In that year, however, useful contributions were furnished by 1,767,100 tons of West Coast hematite and 1,542,000 tons of coal-measure ironstone. By 1950, the outputs of the two latter classes had fallen to 342,700 tons and 200 tons. Including other minor supplies, the output in 1913 was 15,997,300 tons, and in 1950, 12,935,800. The main supply of Jurassic ore, at 12,489,600 tons, was much the same as in 1913. The table giving imports of iron ore does not cite figures earlier than the year 1937, when 5,880,800 tons were received, mainly from France and French North Africa, Spain and Spanish North Africa, Sweden, and Sierra Leone. The total for 1950 was 8,128,200 tons. In that year the main suppliers remained the same, but there was some redistribution in proportionate quantities from various sources; the supply from Sierra Leone doubled and that from Northern Spain was less than one-third of the figure for 1937. France and French North Africa maintained their position and the quantity supplied by Sweden rose from 1,232,000 tons to 2,893,700 tons.

As is well known, the iron and steel industry has had an excellent production record during the difficult years since the end of the war. This is shown by the output figures for both pig-iron and crude steel. In 1945, 7,107,400 tons of pig-iron were produced and each year up till 1950 showed a steady rise to a total of 9,632,900 tons in that year. The same continuous progress was shown in the production of crude steel; the figure for 1945 was 11,824,400 tons and that for 1950, 16,292,700 tons. The growing technical efficiency of the iron and steel industry over recent years is shown by the fact that in 1937 the output per blast-furnace was 68,500 tons per annum, while in 1948 it was 90,900 tons, and in 1950, 96,600 tons. The total number of persons employed in the iron and steel industry, including those in mines and quarries, was 281,083 in 1947 and 298,646 in 1950; the average weekly earnings were 6.52*l.* in 1947 and 7.91*l.* in 1950. These totals do not include workers in iron foundries, the figures for which were 136,869 employees in 1947 and 145,968 in 1950.

NOTES.

BROADCAST WARNINGS OF ELECTRICITY CUTS.

It was announced on Tuesday that the British Electricity Authority have now completed arrangements with the British Broadcasting Corporation for giving warnings of impending cuts in electricity supply. Starting on Monday next, October 29, these warnings will be given in the Light Programme on the 1,500 m. wavelength at any time between 7.30 a.m. and 12 noon and between 3 p.m. and 6 p.m. on the five weekdays, Monday to Friday. As they can only be given after a decision to shed load has been taken by the engineer at the Authority's National Control Centre, the only practical method of doing this is by radio broadcast, and the Authority are therefore grateful to the Corporation for their assistance. After the warning has been given, actual load shedding must follow within a few minutes if a widespread breakdown in supply is to be avoided. The warnings will be sent by teletypewriter from the National Control Centre to Broadcasting House and will then be broadcast immediately. In order to do this the normal programmes will have to be interrupted, the only exceptions being the "Five to Ten" religious service and the gale warning to shipping. To carry out these arrangements the country has been divided into a number of load-shedding areas, which have been designated by numbers, and the extent of the shedding will be indicated by numbered 5-per cent. stages. Important industrial consumers, for whom the warnings are primarily intended, will be notified by the Area Electricity Boards of their area numbers and of the details of their shedding rotas, so that

they will be able to recognise any warnings which apply to them. Other consumers who require warnings should ask their local Area Boards for the full details applicable to them. In view of the short time available for the issue of the warnings, the messages must be as short as possible, a typical form being the word "Caution" followed by three seconds of the tuning note and then by the announcement "Load shedding is about to take place in Area 2, Stage 4, and in Area 4, Stage 3." Since the first two stages of load shedding do not normally involve a disconnection of supply, this will mean cuts of 10 per cent. in Area 2 and of 5 per cent. in Area 4. The Authority wish it to be understood that, owing to the complexity of the grid system and the present difficult operating conditions, there may be occasions when urgent cuts will have to be made without warning. On some occasions, too, it may be impossible for technical reasons to carry out load shedding in small sections of areas for which warnings have been issued, and in any event the warnings will not apply to the Midland region.

EFFECT OF WELDING ON HEALTH.

An investigation into the possibility of ill health arising from the conduct of welding processes has been carried out by the Factory Department of the Ministry of Labour and National Service and the results published in a book entitled *The Health of Welders* by Dr. A. T. Doig, H.M. Medical Inspector of Factories, and Mr. L. N. Duguid, B.Sc.Tech. (Mech.), A.M.I.Mech.E., M.I.W., H.M. Senior Engineering Inspector of Factories. The book is obtainable, price 3*s.* post free, from H.M. Stationery Office. The investigation has consisted of a survey of the various types of welding operations, followed by a clinical examination of 250 welders in various industries. In many cases, this has been supplemented by special examinations, such as radiological inspection of the chest and blood tests. The main conclusions arrived at are that welders do not suffer from any specific illness that could be described as "welders' disease," neither does occupational dermatitis appear to be a frequent or serious cause of disability. It is pointed out that electric welders may suffer from "arc eyes" but it is added that this has no permanent effect on the vision. It is recognised, however, that electric welders also suffer to a greater extent than other workpeople from a slight superficial inflammation of the eyelids. Among welders exposed to high concentrations of fumes, slight irritation of the throat is not uncommon, but it is stated that no serious effects on the throat and nose have been observed. It is added that exposure to welding fumes does not predispose a man to pulmonary tuberculosis, that stomach troubles are no higher among welders than among the general population, that rheumatism is not excessive, that there is no evidence of ill effects on blood pressure or the nervous system, and that, where there is good or even moderately-good ventilation, there is little danger of "gassing" taking place. The need for good ventilation is emphasised in the general recommendations made by the authors. They state that where oxy-acetylene welders are working there should be the same good general ventilation as for workrooms where fairly-hot processes are conducted. Closed localised exhaust ventilation should be applied where articles are electrically welded on benches or stands. In the welding of large articles of mild steel, such as vehicles or the prefabricated parts of bridges, general ventilation should be relied upon if good practical methods of localised exhaust cannot be evolved. Exhaust ventilation, however, should be provided where the fumes produced contain substances in sufficient quantity to be poisonous or irritating. Moreover, when welding is conducted in confined spaces, the exhaust draught should be provided as close as possible to the welding point.

THE INSTITUTION OF MECHANICAL ENGINEERS.

Lord Brabazon and Air Chief Marshal Sir Roderic Hill were the principal guests at the annual dinner of the Institution of Mechanical Engineers, held at the Dorchester Hotel, London, on Friday, October 19. In proposing the toast of the Institution, Sir Roderic Hill said that in 1851 physics owed most

of its progress to the advance in steam engineering, whereas in 1951 "most of us would be prepared to admit that the debt has been heavily repaid by the advances in thermodynamics, metallurgy, applied physical chemistry in relation to the surface structure of metals, extraction metallurgy," etc. Mechanical engineering, he said, had been carried to an altogether new level during this period. Mr. A. C. Hartley, who, as President, was in the chair, responded to this toast. The fact that pleased him most about the large membership of the Institution, he said, was that half of it was composed of students and graduates and half of corporate members; the health of the Institution should be good if that continuity could be maintained. Mr. Hartley, part of whose presidential address, delivered the evening before, is reprinted on page 534, reviewed the main activities of the Institution during the past year, mentioning particularly the presentation of the James Watt Medal to Dr. Blache, the Joint Engineering Conference, the discussion on heat transfer, and the visits of the presidents and secretaries of the three institutions to the Hague, as guests of the Royal Dutch Institute of Engineers. The activities of the Abadan branch of the institutions, with nearly 300 members, were unfortunately in suspense, but the Institution were giving them facilities in London to continue their existence. Dr. D. R. Pye, proposing the toast of "Our Guests," recalled an occasion in 1917 when Sir Roderic Hill, then a pilot in the Royal Flying Corps, undertook the first test of a device which had been designed for severing the cables of tethered balloons, which the Germans were using to protect ammunition dumps. A bowsprit projected from the front of the machine, and a wire was stretched from it to each wing tip. Sir Roderic Hill flew the aircraft into the cable and, as he predicted, it was swung round, went into a spin, was then recovered and landed. Lord Brabazon, responding to the toast, spoke of advances in aeronautics—"that restless science which never remains quiet for three weeks." Whenever a commercial machine was really safe and doing its job it was invariably out of date. He and his colleagues of the Air Registration Board were trying to decide whether machines with doubled speed and flying at twice the height were safe; it was very difficult. Visiting the Motor Show, he was glad to see that the old dog-cart form of suspension was nearly dead; the change had taken nearly 50 years, and for that reason he wished that pneumatic tyres had not come in so early. "If we could have had solid tyres for 30 years, we should have had good suspension to-day."

DISCUSSION ON TOOL AND DIE MATERIALS.

Arrangements have now been concluded for the holding of a general meeting of the Institute of Metals at the University of Birmingham, Edgbaston, Birmingham, 15, at 2.30 p.m. on Thursday, January 3, 1952. The meeting will take the form of an informal discussion on "Tools and Die Materials for the Extrusion of Non-Ferrous Metals and Alloys" and the chair will be taken by Mr. Christopher Smith, who is chairman of the Metallurgical Engineering Committee of the Institute. After short introductory talks by a user and by a manufacturer of tool and die materials, there will be a general discussion in which those engaged in extrusion operations will be encouraged to state their problems. The organisers of the meeting hope that representatives of extrusion-press makers and steel manufacturers will be present to take part in the discussion and to give advice where possible. Non-members who are interested in extrusion will be welcomed. On the morning of the day of the meeting the President of the Institute, Professor A. J. Murphy, has arranged for the new Aitchison Laboratories of the Metallurgy Department of the University of Birmingham to be open for inspection by members at 10.30. Tickets of admission to the laboratories are obtainable from the secretary of the Institute, 4, Grosvenor-gardens, London, S.W.1. In some respects, the above meeting is a new venture on the part of the Institute. It is intended to interest persons actively concerned in production, both as engineers and as metallurgists. If the function is successful it may lead to an extension of the Institute's activities.

INTERNATIONAL EXCHANGE OF TECHNICAL STUDENTS.

The present-day university student enjoys many advantages not accorded to his predecessors and not least among these are greatly improved facilities, as well as a certain measure of financial assistance by way of travelling bursaries, for work and study abroad during vacations. Technical students are well catered for by the International Association for the Exchange of Students for Technical Experience, the fourth annual report of which has just been received. It records continued progress in the Association's work during the past twelve months, both as regards the number of students catered for and the number of countries participating in the exchanges. During the summer, 2,433 students in all were sent abroad for experience in industry and commerce, an increase of 761 on the figure for 1950. Iceland, Israel and Spain joined the Association in January, 1951, bringing the number of member countries up to 16 and enlarging the sphere of influence of the Association to almost the whole of Western Europe as well as the United States of America. Nevertheless, the report says, there are still insufficient places in some countries to meet the needs of all the students wishing to obtain experience abroad, and the Association appeals to all its industrial and commercial members to bear this in mind when offering to receive students in 1952. Applications for membership are considered in January only, at the annual conference of the organisers. Reciprocity is the basis of the scheme, and applicants for places for students abroad should be able to produce offers of places available in their own country for foreign students. The normal period of exchange is eight weeks. The number of British students sent abroad for practical experience during the summer of 1951 was 422, an increase of 69 on last year, and they came from 22 universities and colleges throughout the country. By comparison, the number of students received from abroad was 457, an increase of 89. The general secretary of the Association is Mr. J. Newby, Imperial College, South Kensington, London, S.W.7.

HIGHER NATIONAL CERTIFICATES IN CHEMICAL ENGINEERING.

A scheme for the award of Higher National Certificates in Chemical Engineering has been arranged by the Ministry of Education in conjunction with the Institution of Chemical Engineers, and will become operative in the educational year 1951-52. The arrangements and conditions for the award of the certificates are given in detail in a leaflet designated "Rules 122," which has just been made available and is obtainable, price 4d., from H.M. Stationery Office. The Rules state that courses of instruction must be adapted to the needs of students who already possess an Ordinary National Certificate in chemistry, applied chemistry or mechanical engineering. A part-time grouped course for the award of certificates should normally extend over three years and provide for at least 180 hours of instruction in each year, including examinations. In order to obtain a certificate or supplementary endorsement, a candidate must make not less than 60 per cent. of the possible attendances in each year of a course, must obtain not less than 40 per cent. of the possible marks in each subject in the examinations in each year of the course, and not less than 40 per cent. of the possible marks obtainable in each year for home work, class work and laboratory work, and must secure not less than 50 per cent. of the grand total of marks obtainable in the final year. A distinction may be awarded to any candidate who obtains not less than 85 per cent. of the possible marks in the final examination in any subject, and his certificate may be specially endorsed to show the subject or subjects in which he has thus distinguished himself. Notes on the arrangement of a course for these Higher Certificates are given in a brochure published by the Institution of Chemical Engineers and entitled "Scheme for a Part-Time Course in Chemical Engineering." Copies of the brochure may be obtained from the secretary of the Institution, 56, Victoria-street, London, S.W.1.

LETTERS TO THE EDITOR.

MAXIMUM TORSIONAL STRESS IN A GROOVED SHAFT.

TO THE EDITOR OF ENGINEERING.

SIR,—I was interested in the letter from Professor H. Ōkubo, on page 436, *ante*. The formula $1 + \sqrt{\frac{b}{\rho}}$ is, of course, that proposed many years ago by A. A. Griffith on the basis of an argument similar to that of Professor Ōkubo, and I would like to know whether there is separate justification for the additional factor, which is, in effect, $\frac{r^2}{(r-b)^2}$. This amendment, by representing the effect of depth of notch, extends the utility of the formula considerably. I would add that the validity of the formula $1 + \sqrt{\frac{b}{\rho}}$ for a shallow notch can be demonstrated on a fairly general basis by straightforward stress analysis and that for a wide keyway of depth b with radius ρ at its corners the formula $1 + \frac{1}{2}\sqrt{\frac{b}{\rho}}$ is often moderately accurate.

Yours faithfully,

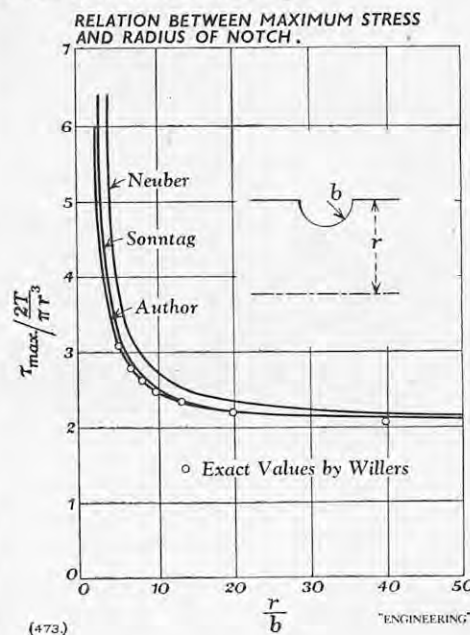
H. L. Cox.

National Physical Laboratory,

Teddington.

October 18, 1951.

[We reproduce below the graph, illustrating Professor Ōkubo's letter, which was unfortunately omitted from our issue of October 5.—Ed., E.]



TESTS ON CONCRETE WITH ELECTRICAL-RESISTANCE STRAIN GAUGES.

TO THE EDITOR OF ENGINEERING.

SIR,—We were glad to learn from Mr. K. R. Peattie's letter, on page 468, *ante*, that compression tests on concrete, using electrical-resistance strain gauges, have been carried out at the University of Nottingham which confirm the technique of our earlier work. In particular, we note that Mr. Peattie also found it necessary to carry out some proof loadings of the specimen before taking readings. We do not, however, agree that this is merely "to minimise the effects of hysteresis in the electrical-resistance strain gauges"; the initial strain readings are far from regular and we believe that the proof loadings are necessary to put the concrete in a "state of ease" as well as to "condition" the gauges.

On the subject of the gauge sensitivity factor we are of the opinion that this will be lower on concrete than on a machined metal surface, due mainly to the increased thickness of adhesive required with the poorer surface texture of the concrete. The sensitivity factor, as normally determined from a gauge

placed in a uni-directional stress field, depends on the shear modulus of elasticity and thickness of the adhesive, and also on the amount of the cross strain which is dependent on the material of the specimen under load. The factor is not therefore "virtually a function of the gauge," as Mr. Peattie suggests, and the gauges should be calibrated on concrete specimens wherever possible.

As stated in the original article, the object of putting pads above and below the specimen was to assist in obtaining a uniform loading pressure. This was thought necessary as the testing machine applied the load through platens which were not ball-seated. The following forms of packing were tried:—cartridge paper (five thicknesses), corrugated cardboard, mill-board ($\frac{1}{8}$ in. thick), rubber sheeting, and foamed rubber ($2\frac{1}{2}$ in. free, $\frac{1}{4}$ in. under load), and also no packing. The criterion was taken to be the magnitude of the eccentricity as determined from the readings of three electrical gauges placed parallel with the axis and around the mid-section of the cylinder. It was found that the eccentricity changed rapidly at low loads, but above a stress of 500 lb. per square inch it remained sensibly constant to one third of the ultimate load, which was the load range used. From these tests it was concluded that rubber sheeting was the most satisfactory since it gave a considerable reduction in the eccentricity, whereas the other forms made little effect.

We did not investigate the effect of rubber sheeting on the magnitude of the end-constraint, but we did carry out such a test with mill-board packing. Six electrical gauges were used to form three pairs, and each pair consisted of a gauge placed at either end of a diameter of a concrete cylinder 10 in. high and 5 in. in diameter. The gauges were affixed transversely to the axis of the specimen so as to measure the hoop strain directly, and were arranged at three positions along the length of the cylinder, which had been previously loaded many times. Taking the mean reading of each pair so as to eliminate the effect of eccentricity, the following results were obtained:—

Gauge position from an end of cylinder, in.	2	$4\frac{1}{2}$	9
Mean electrical strain reading $\times 10^6$, ohms per ohm per lb. per sq. in.	7.8	14.2	5.7

(Note.—The strain is expressed "electrically" and as a rate in terms of unit applied stress.)

Rough extrapolation shows that the hoop strain at the mid-height was of the order of five times that at the extreme ends. The observations confirmed the existence of the barrelling effect expected. It is considered that the effect would be reduced, but not completely lost, if rubber packing were used rather than mill-board.

An axial strain test was carried out under the same conditions as above, in which the mean "electrical" axial strain at an end of the 8-in. gauge length on the 10-in. high cylinder was compared with that at mid-height. The readings agreed between themselves within the limits of accuracy of the gauges and it was inferred that a sensibly uniform strain existed along the length of the cylinder. Theoretical considerations are interesting since, in an extreme case, if the material is considered isotropic and the ends of the specimen are completely constrained from lateral movement, then the effective modulus of direct elasticity at the ends would be raised in the ratio $1 : \frac{(1-\sigma)}{(1+\sigma)(1-2\sigma)}$.

Assuming Poisson's ratio (σ) for concrete to be 0.1, this shows an increase of 2 per cent. in the effective modulus when compared with the value at the mid-height of the specimen where unrestricted expansion can be assumed to occur.

This contradicts Mr. Peattie's experiments. We should be glad if he has an explanation for the lack of symmetry of his results, and if he could indicate what is happening to the ends of his specimen.

Yours faithfully,

N. S. J. GRASSAM,

Lecturer in Mechanical Engineering,
University College, Southampton.

DAVID FISHER,

Civil Engineer,

32, Sandringham-road, London, N.W.11.

October 18, 1951.

THE INTERNATIONAL MOTOR SHOW AT EARL'S COURT.

THE International Motor Exhibition opened at Earl's Court on October 17, and will remain open until tomorrow evening. This is the thirty-sixth exhibition and, in general, follows the pattern of preceding shows of this type. It comes at a time when the emphasis more than ever is on export, there having been a further cut in the allocation of cars for the home market, and to the majority of visitors, therefore, is only of academic interest. The display of cars is truly international in character for, in addition to 32 British manufacturers, 17 American, 10 French and four Italian firms are represented. Germany also is there, but only one firm's products are on view. Figs. 1 and 2, on page 528, are general views of the show.

There are no startling innovations and few new cars. At the present time, there is much to commend this lack of novelty as there was a tendency before the war to introduce new models for novelty's sake, the result being that too many firms manufactured a prodigious number of different types. New designs were introduced before the then existing models had been fully developed and, inevitably, this added to complications, particularly in the supply of replacement parts. The abolition of the crippling horse-power tax has led to the introduction of larger engines with increased-diameter cylinder bores and shorter strokes, a design adopted in all probability to reduce piston speeds. Overhead valves continue to gain in popularity. For the lighter cars, four-cylinder engines are almost universal, probably because they are cheaper to produce and, with modern balancing techniques, very little "rougher" than six-cylinder units.

Transmission assemblies remain much the same as in previous years with, perhaps, a leaning towards the four-speed type of gearbox. Synchronised engagement of the gears is employed in practically every case, the few exceptions including Daimler and Lanchester, who still fit a preselector gearbox used in conjunction with a fluid flywheel, and Armstrong Siddeley, who employ a preselector gearbox on its own. The centrally-located gear-shift lever is only fitted to the smaller cars, most medium-size and larger cars being provided with a gear-shift lever on the steering column. Little attention seems to have been paid to overdrives, the use of which can lead to substantial economies; so far as it could be ascertained, only Standard and Triumph cars are fitted with these. Apart from Lanchester and Daimler cars, automatic transmissions of the hydraulic type seem to have been ignored by British manufacturers; the development of this form of transmission has been left to the Americans. Hydraulic transmissions, as used on existing American cars, are, of course, more expensive to manufacture and their use tends to increase fuel consumption. Nevertheless, the time may come when there will be a wider demand for this form of transmission. Fortunately, there are at least two well-tried systems available in this country and it can safely be assumed that their development will be continued.

A rigid back axle used in conjunction with an open propeller shaft is almost the universal form of final drive, but there is a growing tendency towards the use of the hypoid bevel wheel and pinion, as this permits the use of a lower floor line. Independent suspension for the front wheels is now the rule, instead of the exception, coil springs working in conjunction with swinging levers being the favourite method of achieving this. Some cars, however, employ torsion bars and others transverse-leaf springs, examples being furnished by Riley and Humber, respectively. The universal adoption of independent front suspension has led to a wider use of hydraulic brakes, particularly on the front wheels, as their employment permits free articulation of the wheels without recourse to complicated linkages. Many cars are fitted with a hydro-mechanical braking system, so called because the front brakes are applied hydraulically and the rear brakes mechanically. This has the advantage of providing two separate systems so that either hydraulic or

EXHIBITS AT THE MOTOR SHOW.



FIG. 3. CONVERTIBLE COUPÉ; HILLMAN MOTOR CAR COMPANY, LIMITED.



FIG. 4. EIGHT HORSE-POWER SALOON CAR; AUSTIN MOTOR COMPANY, LIMITED.

mechanical failures do not necessarily mean the loss of all braking power.

Coachwork has altered in detail only, most designs being the same as for last year. There is, however, a perceptible move away from the worst American influences and British designers appear once more to be developing individual styles. In many cases, the body has been designed without accessibility in mind, with the result that the engine is virtually encased and cannot easily be reached to carry out normal servicing. In most cases the front wings have been swept back and their contours carried through the door panelling. This achieves very little beyond making the doors unnecessarily thick. Designs incorporating unit construction of body and chassis are increasing, such well-known firms as the Ford Motor Company, Limited, and Vauxhall Motors, Limited, using this method. It is a logical form of construction as it enables a rigid structure to be obtained with minimum weight. Greater attention is also being paid to the production of convertible coachwork, which has much to commend it, particularly in the export markets. A good example of such coachwork is furnished by the light car illustrated in Fig. 3, on this page, namely, the Minx, which is being shown by the Hillman Motor Car Company, Limited.

The new Austin Seven is illustrated in Fig. 4, from which it will be seen that, although the latest of a famous series, it bears little resemblance to its predecessors. Basically, it is a small version of the firm's Hereford car. Considering its engine size and

performance, it is a roomy four-door saloon for four adults but, unlike other Austin cars, it is of unit, or "chassisless" construction. It is fitted with a four-cylinder engine having a bore and stroke of 2.28 in. and 3 in., respectively, and developing a maximum output of 30 brake horse-power at 4,800 r.p.m. and a maximum torque of 40 lb.-ft. at 2,400 r.p.m. In general, the engine design follows the firm's standard practice, the cylinder block and crankcase forming a single casting which is fitted with a detachable cylinder head carrying the overhead valves. These are operated by push rods and rocking levers from a camshaft set well down in the engine and supported by three bearings. The crankshaft is machined from a steel forging and, like the camshaft, is supported by three bearings of the steel-backed whitmetal-lined type. Aluminium pistons are employed, each being fitted with three compression rings and joined to the crankshaft by forged-steel connecting rods equipped with steel-backed whitmetal-lined big-end bearings. Forced lubrication is employed throughout, the oil being delivered by a self-priming pump to oil galleries incorporated in the crankcase and then to the various bearings.

The transmission assembly consists of a Borg and Beck single dry-plate clutch arranged to drive a four-speed gearbox. The clutch plate has a diameter of 6½ in. and the clutch design is such that the pressure required for withdrawal is exceptionally light. The gearbox forms a single unit with the engine and employs synchronising elements for the

EXHIBITS AT THE MOTOR SHOW.



FIG. 5. THREE-LITRE SALOON CAR; DAIMLER COMPANY, LIMITED.



FIG. 6. "VELOX" SALOON CAR; VAUXHALL MOTORS LIMITED.



FIG. 7. SPORTS COUPÉ; JAGUAR CARS, LIMITED.

engagement of second, third and top gears, the elements being large in comparison with the size of gearbox. A central gear-shaft lever is provided and, to give maximum space inside the car, it is mounted in the rear cover to the side of the third-motion shaft. An open propeller shaft provided with Hardy Spicer needle-roller joints transmits the drive to the rear axle, which is of the three-quarter floating type, fitted with a hypoid crown-wheel and pinion final drive. Independent suspension is employed at the front, each assembly consisting of a coil spring working in conjunction with swinging links of the "wish-bone" type, controlled by a double-acting hydraulic shock absorber. Long semi-elliptical reverse-camber springs of conventional design are used for the rear suspension, which

is also controlled by double-acting hydraulic shock absorbers. The brakes are actuated by a Lockheed system, the design being such that the front brakes are applied hydraulically and the rear brakes mechanically, the mechanical linkage for the rear brakes, however, being connected to a separate hydraulic cylinder. A pull-up type of hand-brake lever is situated between the driver's seat and door, and is arranged to apply the rear brakes mechanically, the hydraulic cylinder being by-passed.

The Daimler Company, Limited, Coventry, were also showing a new car, namely, the three-litre Regency, illustrated in Fig. 5, herewith. It is a full six-seater, powered by a new 3-litre six-cylinder engine developing 90 brake horse-power at 4,100 r.p.m. Careful attention has been paid in the design

to ensuring a good performance with varying grades of fuel. The compression ratio, for example, is 6.7 to 1, a ratio not too high for poor grade fuels, but, on the other hand, not excessively low. Furthermore, the distributor, in addition to being fitted with an automatic advance-and-retard mechanism and vacuum control, is also provided with an over-riding hand adjustment, a feature that will be welcomed by those forced to use low-grade petrol. In general, the engine is of straightforward design, being fitted with in-line overhead valves operated in the usual manner by push rods and rocking levers. As on all Daimler cars, the transmission assembly of the Regency incorporates a fluid clutch and the Wilson pre-selective gearbox. The drive from the gearbox is transmitted to the rear axle by the usual form of open propeller-shaft, and the final-drive assembly comprises a hypoid crown-wheel and pinion.

Independent suspension is employed for the front wheels, the design being based largely on that developed by the company during the war for armoured cars. It comprises coil springs which work in conjunction with a torsional anti-roll bar and hydraulic telescopic shock absorbers. Conventional leaf springs are used for the rear suspension, which, like the front springs, work in conjunction with hydraulic shock absorbers. A Girling hydro-mechanical braking system is installed, the front brakes being applied hydraulically and the rear brakes mechanically. A notable feature of the design is the provision of automatic chassis lubrication system, the parts automatically lubricated including the spring shackle pins and the steering linkage. The system operates by means of a small expansion chamber mounted near the exhaust pipe, the chamber being fitted with valves which permit lubricant to be drawn from a reservoir and forced through the distributing pipes each time the engine warms up.

Two new cars are being shown by Vauxhall Motors, Limited, Luton, namely, the Velox and the Wyvern. The Velox is illustrated in Fig. 6, herewith, from which will be seen that the external appearance has been altered radically. The firm have continued their policy of providing a single body style with alternative engine sizes and the Velox and Wyvern, therefore, are of similar appearance. Basically, the new models are the same as their predecessors, but four major changes, namely, an increased wheelbase, wider tracks at front and rear, a flush-sided body and a more forward mounted engine have given greater roominess inside the body. Both models are of "chassisless" construction, the single-unit steel body giving unusually good torsional stiffness. Independent suspension is employed at the front, the design being entirely new, incorporating coil springs with long and short arms of the "wish-bone" pattern. These arms, and the cross-member which supports them, are rigid steel pressings, the cross-member being bolted to the forward extension of the body. Apart from detail changes, the engines fitted to the two models are the same as their predecessors, the engine for the Wyvern having four cylinders and that for the Velox six cylinders. A new aluminium gearbox-housing saves weight, and the gear-shift linkage has been modified to give better control. A hypoid final-drive assembly is used on both models, while the brakes, which are of Vauxhall design with Lockheed hydraulic operation, now have stiffer drums.

Although not a new car, reference should be made to the Jaguar XK 120 two-seater sports car, as this has done much during the past year to uphold Britain's prestige in motor-racing and sports-car events, the list of successes being far too long to detail here. One of its major successes was winning the Le Mans 24-hours race, during which it covered a record distance and accomplished the fastest lap, and was the first British car for 16 years to win outright this classic event. Two versions of the XK 120 were being shown, namely, an open two-seater and the two-seater coupé illustrated in Fig. 7, herewith, which has been produced for the North American market. The engine is, perhaps, the most interesting feature of these cars, as although the capacity is only $3\frac{1}{2}$ litres, and is not supercharged, it is capable of developing 160 brake horse-power at 5,000 r.p.m.

INSTITUTION OF MECHANICAL ENGINEERS: PRESIDENTIAL ADDRESS.*

By A.C. HARTLEY, C.B.E., B.Sc. (Eng.), M.I.Mech.E.

THE *Proceedings* of our Centenary Celebrations, held in 1947, include a lecture which I gave at that time, entitled "Mechanical Engineering and the Oil Industry." There is little which has not been described fully elsewhere which I could usefully add to that particular subject, and I have therefore decided to develop another theme.

Hard work and continuous application are necessary throughout a young engineer's education, training, and subsequent practical experience. There are no short cuts to professional status, and I had plenty of hard work; but I also had the inestimable advantage of coming under the influence of outstanding men. They were outstanding because of their great capacity for

should like to follow in the footsteps of the late Thomas Monk Newell, the Chief Docks Engineer of the North Eastern Railway, at Hull.

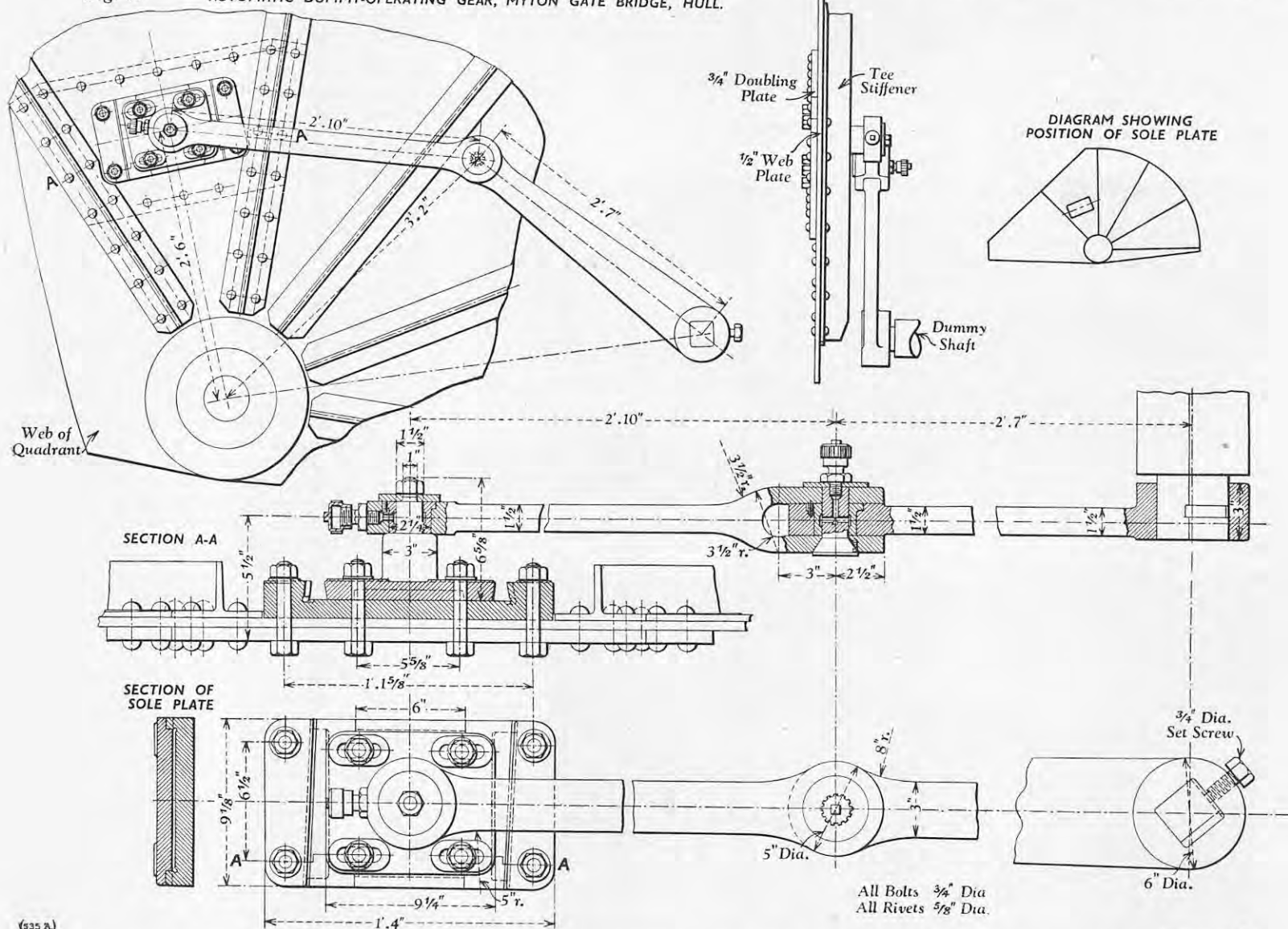
This decision was largely influenced by a day that I spent with him about this time, partly in his office and partly around the docks, during which the two halves of the new Whitefriargate Bridge were lowered together for the first time. The excitement of seeing whether all the work put in by the engineers in the design, fabrication, setting out, and erection of the bridge would result in the two leaves meeting correctly, and, when they did, the further excitement of being told by Mr. Newell to run across and so be able always to say that I was the first person ever to cross that bridge, were, no doubt, the deciding factors.

I transferred to the science side for the rest of my time at school, and spent the next two years at the Hull Municipal Technical Institute preparing for the entrance examination for the Central Technical College, South Kensington. I passed into the second-year

to the most direct and simplest solution of every problem.

After a period of routine drawing office work, I was given a job to carry out by myself. It was to design hydraulic machinery to operate the "dummies" of the Mytongate bridge. The main leaves of this old cast-iron bridge had been fitted with hydraulic power some time before, but the "dummies" or small leaves, which had to be pulled up to make way for the main leaves, were still hand-operated. This was expensive, as extra men had to be on shift duty on both sides of the lock and, as the work was heavy, strains and injuries were frequent. I prepared several schemes with the necessary interlocking to prevent the opening of the main leaves before the "dummies" were clear, and to ensure that the main leaves were fully shut before the "dummies" were closed. These schemes were prepared in the orthodox straightforward way, and became more and more complicated. I was not satisfied, and, influenced no doubt by my City and

Fig. 1. AUTOMATIC DUMMY-OPERATING GEAR, MYTON GATE BRIDGE, HULL.



leadership, and for the imagination, initiative, and self-reliance they possessed. I hope in this address to show how my training and early experience helped me, and so to encourage our younger members to seek every possible opportunity of coming under the influence of good leadership and to realise the importance of being trained to develop to the full these invaluable qualities. I hope also to encourage our senior members in their efforts to lead and inspire those who work under them or who come to them for guidance.

My education was unorthodox by to-day's requirements. This was due to my early intention of following my father and most of my close relations into the medical profession. I was therefore on the classical side of my school, Hymers College, Hull, and matriculated in 1906 in Latin, Greek, French, English and Mathematics. Immediately afterwards, and shortly before I was to go to a London hospital, my father asked me if I really wanted to be a doctor. I then realised I had given it scarcely any thought and that my choice had been rather automatic. After a few weeks of anxious and rather belated thought and talks with many of my father's friends, I decided I

course of the Civil and Mechanical Engineering Department in October, 1908, just after the College became part of the Imperial College of Science and Technology and was renamed the City and Guilds (Engineering) College. I came under the personal influence, although only for a short time, of the four famous founder Professors, Unwin, Ayrton, Armstrong and Henrici, and I count myself most fortunate in this. They concentrated on fundamental first principles and the cultivation of imagination, initiative, and self-reliance, and I feel I owe a very great deal to their methods of teaching because they made me appreciate the inestimable value of these qualities, and thus encouraged me to learn from those men I was to meet later who possessed them in high degree. I took the intermediate B.Sc. engineering degree as an internal student, but the final, after my A.C.G.I. examination, as an external student in 1910, to avoid waiting an extra year. My degree was therefore somewhat mixed.

It was natural that I should return to Hull for training under Mr. Newell, where I also came under the strong influence of his deputy, the late Mr. George Shaw, jun., whose motto was "Believe no man, prove all things," and who was a born engineer, instinctively working from first principles

Guilds training and also daily by Mr. Shaw's approach to problems, I sat back, tried to forget what I had done and to imagine the most direct solution of the problem, which I was then much better able to define than when I first started on the work. The problem was to make the operation of the bridge automatic, and the solution appeared to be to connect the "dummies" to the operating gear of the main leaves in such a way that, without independent driving gear, they would be moved, as required, in the correct sequence. Simple experiments with cardboard links on a drawing board showed that the four-bar mechanism which I had studied at College could be designed, if the linkages and angles were correctly chosen, to ensure foolproof automatic operation. Mr. Newell and Mr. Shaw agreed to adopt my design. This was my first experience of the practical result of applying imagination to solve a problem, and I was fortunate in being encouraged to do this so early and in having my solution adopted. It was a great encouragement for the future.

During the rest of my two years with Mr. Newell, I was given a varied training in the office and out on dock and river work, which has proved extremely useful in later life. For the next two years I was with Messrs. Rose, Downs and Thompson, also of Hull.

* Delivered in London, October 19, 1951. Abridged.

MYTONGATE BRIDGE, HULL.



FIG. 2. LINK MECHANISM.

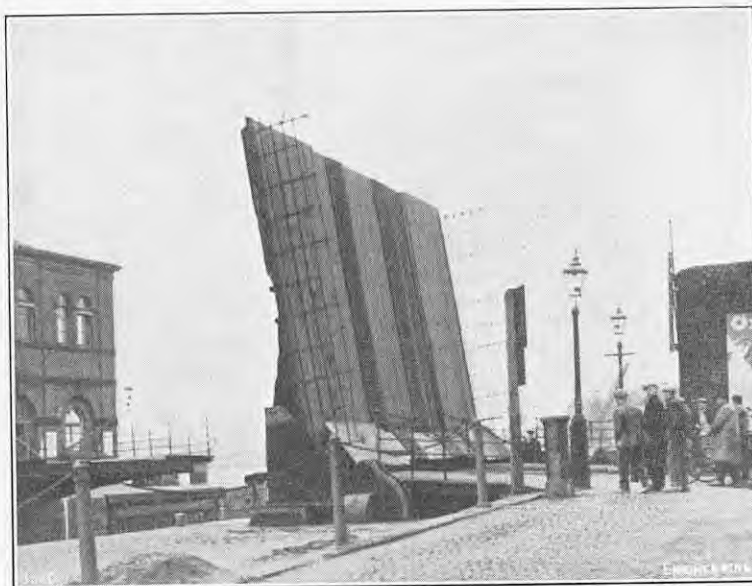


FIG. 3. BRIDGE WITH ONE LEAF OPEN.

This company was established in 1777 and had specialised in the manufacture of seed-crushing machinery and vegetable-oil solvent-extraction plants. I gained experience in the development of a new chemical extraction process, and also valuable training in outside erection under the influence of the late Mr. Charles Downs, a very practical and far-seeing engineer. Throughout these four years in Hull I lectured to evening classes at the Hull Municipal Technical Institute, and I would strongly recommend this to all who would find out how little they really know of what they are supposed to have learnt.

My next move was to become works superintendent for the Limmer Asphalte Company at their Blackwall factory. There I gained experience in management of a process works and in the handling of men, as well as engineering experience in converting intermittent processes to continuous ones, and in the adoption of mechanical-handling devices. The outbreak of the 1914-18 war resulted in increased demands for the Limmer Asphalte Company's products and the improvisation of plant of all kinds. This, with organising munition production in adjoining works, kept me fully occupied, until, in 1916, I was fortunate to be chosen by the late Professor Bertram Hopkinson, F.R.S., Professor of Mechanism and Applied Mechanics at Cambridge University, to work with him in the Experimental Armaments Section of the Air Ministry, and to be commissioned in the Royal Flying Corps.

Sir Harry Ricardo, in his presidential address in 1944, paid tribute to Professor Hopkinson's great influence over him at Cambridge, 40 years before: "Hopkinson was, I think, quite the most stimulating research leader I have ever met, with an almost uncanny perception combined with good judgment and a thoroughly practical outlook. Hopkinson's methods were by no means always orthodox; he believed in following, step by step, a logical and reasoned sequence, but only up to a point: if that looked like becoming too prolonged, then he would fall back on the principle of trying every bottle on the shelf and if that did not achieve his end, his next step was to try something really silly and see what happened. He taught me never to accept anything secondhand, unless it accorded with one's own common sense and experience, to be sceptical of one's own observations when they failed in this respect; and never to cling too long to a theory, however cherished."

That is what Sir Harry said, and Professor Hopkinson's methods at once appealed very strongly to me because they confirmed so emphatically the methods taught at the City and Guilds College, and "drummed into me" since by the engineers who had so greatly influenced my training.

(To be continued.)

FREQUENCY-MODULATED BROADCASTING IN THE UNITED STATES.—A new high-power non-commercial frequency-modulated station for educational broadcasting has been opened at Great Blue Hill, Milton, Massachusetts, and will operate on a frequency of 89.7 megacycles with a radiated power of 20 kW. The programmes transmitted will consist of performances by the Boston Symphony Orchestra and of lectures on scientific, literary and sociological subjects, given in collaboration with Boston's educational institutions.

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.

INTERNATIONAL CYCLE AND MOTOR-CYCLE SHOW.—Sunday, October 28, to Sunday, November 4, at Frankfurt. Organised by the Internationale Fahrrad- u. Motorrad Ausstellung, Frankfurt-on-Main.

SHEET AND STRIP METAL USERS' TECHNICAL ASSOCIATION, ANNUAL WINTER CONFERENCE.—Wednesday and Thursday, October 31 and November 1 and 2, at the Charing Cross Hotel, Strand, London, W.C.2. Apply to the honorary secretary of the Association, 49, Wellington-street, Strand, London, W.C.2.

EXHIBITION OF PERMANENT-WAY EQUIPMENT.—Wednesday and Thursday, October 31 and November 1, at Marylebone goods depot, Rossmore-road, London, N.W.1. Organised by British Railways. Apply to the address given above (Telephone: PADDINGTON 3400).

PETROLEUM INDUSTRY EXHIBITION.—Thursday, November 8, to Saturday, November 17, at the Firth Hall, University of Sheffield; and Monday, December 17, to Sunday, January 27, 1952, at the Royal Scottish Museum, Edinburgh. Organised by the Shell Petroleum Co., Ltd., St. Helen's-court, London, E.C.3 (Telephone: AVENUE 4312); and the Anglo-Iranian Oil Co., Ltd., Britannic House, Finsbury-circus, London, E.C.2 (Telephone: CENTRAL 7422). See also page 480, *ante*.

26TH INTERNATIONAL CYCLE AND MOTOR-CYCLE SHOW.—Saturday, November 10, to Saturday, November 17, at Earl's Court, London, S.W.5. Organisers: British Cycle and Motor-Cycle Manufacturers' and Traders' Union, Ltd., The Towers, Warwick-road, Coventry. (Telephone: COVENTRY 62511.)

SYMPOSIUM ON ORGANISATION OF SCIENTIFIC AND INDUSTRIAL RESEARCH.—Monday, November 12 to Thursday, November 15, at Lancaster House, London, S.W.1 (but Session III at National Physical Laboratory, Teddington). Apply to Dept. of Scientific and Industrial Research, 5-11, Regent-street, London, S.W.1 (Telephone: WHITEHALL 9788).

ROYAL AGRICULTURAL WINTER FAIR, TORONTO.—Tuesday, November 13, to Wednesday, November 21, at the Royal Coliseum Exhibition Park, Toronto 2B.

BUILDING EXHIBITION.—Wednesday, November 14, to Wednesday, November 28, at Olympia, London, W.14. Organised by the Building Trades Exhibition, Ltd., 4 Vernon-place, London, W.C.1. (Tel.: HOLBORN 8146.)

INTERNATIONAL SYMPOSIUM ON ABRASION.—Wednesday and Thursday, November 14 and 15, at Rubberschichting, Oostsingel, Delft, Holland. Apply to the secretary of the symposium, Rubberschichting, Postbox 66, Delft. See also page 243, *ante*.

7TH EXHIBITION OF LABORATORY APPARATUS AND OPTICAL AND SCIENTIFIC INSTRUMENTS.—Thursday, November 22, to Sunday, December 2, at Palais des Congrès, Porte de Versailles, Paris. Apply to the commissaire générale, 28 Rue Saint-Dominique, Paris (7e).

CONFERENCE OF ENGINEERING LIBRARIANS.—Friday, November 23, commencing at 11 a.m., at Chancer House,

Malet-place, London, W.C.1. Organised by the Library Association. Apply to the secretary of the Association at the above address. (Telephone: EUSTON 5856.)

23RD EXPOSITION OF CHEMICAL INDUSTRIES.—Monday, November 26, to Saturday, December 1, at Grand Central Palace, New York 17, U.S.A. Apply to the secretary of the exposition at the Grand Central Palace.

INTERNATIONAL CYCLE AND MOTOR-CYCLE EXHIBITION.—Saturday, December 1, to Monday, December 10, at Milan. Organised by the National Association of Cycle, Motor Cycle and Accessories Manufacturers, Via Macchi 32, Milan, Italy.

SMITHFIELD SHOW AND AGRICULTURAL MACHINERY EXHIBITION.—Monday, December 3, to Friday, December 7, at Earl's Court, London, S.W.5. Organised by the Smithfield Show Joint Committee, 148, Piccadilly, London, W.1. (Telephone: GROSVENOR 4040.)

SYMPOSIUM ON CORROSION OF BURIED METALS.—Wednesday, December 12, at 4, Grosvenor-gardens, Westminster, London, S.W.1. Organised by the Iron and Steel Institute. Apply to the secretary of the Institute at the address given above. (Telephone: SLOANE 0061.) See also page 190, *ante*.

NEW BUILDING MATERIALS AND TECHNIQUES EXHIBITION.—Friday and Saturday, January 18 and 19, 1952, at the Royal York Hotel, Toronto. Agents: Tides, Ltd., 1, Hanover-square, London, W.1. (Telephone: MAYFAIR 1101.)

INTERNATIONAL RADIO AND ELECTRONICS EXHIBITION OF INDIA.—Saturday, February 9, to Friday, February 29, 1952, at Bombay. For further information, apply to the secretary, Radio and Electronics Society of India, Fateh Manzil, Opera House, Bombay, India.

INTERNATIONAL AGRICULTURAL MACHINERY EXHIBITION.—Sunday, February 17, to Sunday, February 24, 1952, at Brussels. Apply to the secretary, Société de Mécanique et d'Industries Agricoles, S.A., 29 Rue de Spa, Brussels, Belgium.

SCOTTISH BUSINESS EQUIPMENT AND MANAGEMENT EXHIBITION.—Tuesday, February 26, to Friday, February 29, 1952, at the Waverley Market, Edinburgh. Organised by the Office Appliance and Business Equipment Trades Association, 11-13, Dowgate-hill, Cannon-street, London, E.C.4. (Telephone: CENTRAL 7771.)

GERMAN INDUSTRIES FAIRS, HANOVER.—*Light Industries*: Wednesday, February 27, to Sunday, March 2, 1952, at Hanover. *Heavy Industries*: Sunday, April 27, to Tuesday, May 6, 1952, at Hanover. Agents: Schenkers, Ltd., 27, Chancery-lane, London, W.C.2 (Telephone: HOLBORN 5595.)

INTERNATIONAL AGRICULTURAL MACHINERY EXHIBITION.—Tuesday, March 4, to Sunday, March 9, 1952, at the Parc des Expositions. Organised by the Union des Exposants des Machines et d'Outils Agricoles, 38 Rue de Chateaudun, Paris 9e.

VIENNA SPRING FAIR.—Sunday, March 9, to Sunday, March 16, 1952. Agents: British Austrian Chamber of Commerce, 29, Dorset-square, London, N.W.1. (Telephone: PADDINGTON 7646.)

GENEVA INTERNATIONAL MOTOR EXHIBITION.—Thursday, March 20, to Sunday, March 30, 1952, at Geneva. For further information, apply to the secretary of the exhibition, 1, Place du Lac, Geneva, Switzerland.

SECOND UNITED STATES INTERNATIONAL TRADE FAIR.—Saturday, March 22, to Sunday, April 6, 1952, at the Nay Pier, Chicago. Representative for the United Kingdom and Ireland: Mr. A. P. Wales, 16-22, Shelton-street, London, W.C.2. (Telephone: TEMple Bar 2972.)

MANCHESTER BUILDING TRADES EXHIBITION.—Tuesday, March 25, to Saturday, April 5, 1952, at the City Hall, Deansgate, Manchester. Apply to Provincial Exhibitions, Ltd., City Hall, Deansgate, Manchester. (Telephone: Deansgate 6363), or to the London agent at 167, Oakhill-road, Putney, London, S.W.15. (Telephone: VANDyke 5635.)

FIRST SUPERVISING ELECTRICAL ENGINEERS NATIONAL EXHIBITION.—Friday and Saturday, March 28 and 29, 1952, at the Royal Horticultural Society's new hall, Greycoat-street, Westminster, London, S.W.1. For further information, apply to the conference secretary, Mr. P. A. Thorogood, 35, Gibbs-green, Edgware, Middlesex. See also page 266.

EXHIBITION OF BRITISH COMPONENTS, VALVES AND TEST GEAR FOR THE RADIO, TELEVISION, ELECTRONIC AND TELECOMMUNICATION INDUSTRIES.—Monday to Wednesday, April 7 to 9, 1952, at Grosvenor House, Park-lane, London, W.1. Organised by the Radio and Electronic Component Manufacturers' Federation, 22, Surrey-street, Strand, London, W.C.2. (Telephone: TEMple Bar 6740.)

SWEDISH INDUSTRIES FAIR.—Thursday, April 17, to Sunday, May 25, 1952, at Gothenburg. Agents: John E. Buck and Co., 47, Brewer-street, London, W.1. (Telephone: GERard 7576.)

SWISS INDUSTRIES FAIR.—Saturday, April 19, to Tuesday, April 29, 1952, at Basle. Apply to the Division Economique, Swiss Legation, 18, Montague-place, London, W.1. (Telephone: PADdington 0701.)

ROYAL SANITARY INSTITUTE HEALTH CONGRESS.—Tuesday, April 22, to Friday, April 25, 1952, at Margate. Apply to the secretary, the Royal Sanitary Institute, 90, Buckingham Palace-road, Westminster, London, S.W.1. (Telephone: SLOane 5134.)

TELEVISION CONVENTION.—Monday, April 28, to Saturday, May 3, 1952, 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 pages 265 and 371, ante.

BRITISH INDUSTRIES FAIR.—Monday, May 5, to Friday, May 16, 1952, 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.

INTERNATIONAL EXHIBITION OF ELECTRICAL APPLIANCES.—Tuesday, May 13, to Tuesday, May 27, 1952, at Bologna. Apply to the Ente Autonomo Fiera di Bologna, via Farina 6, Bologna.

GERMAN EXHIBITION OF CHEMICAL APPARATUS.—Sunday, May 18, to Sunday, May 25, 1952, at Frankfurt-on-Main, Germany. Organisers: Dechema Deutsche Gesellschaft für Chemisches Apparatewesen E.V., Frankfurt.

ELECTRICAL ASSOCIATION FOR WOMEN, 27TH ANNUAL CONFERENCE.—Monday, May 19, to Saturday, May 24, 1952, at Scarborough. Apply to the secretary, the Electrical Association for Women, 35, Grosvenor-place, London, S.W.1. (Telephone: SLOane 0401.)

CANADIAN INTERNATIONAL TRADE FAIR.—Monday, June 2, to Friday, June 13, 1952, 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, 1952, 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.)

ROYAL AGRICULTURAL SHOW.—Tuesday, July 1, to Friday, July 4, 1952, at Newton Abbot. Organised by the Royal Agricultural Society of England, 16, Bedford-square, London, W.C.1. (Telephone: MUSEum 5905.)

INTERNATIONAL ASSOCIATION FOR BRIDGE AND STRUCTURAL ENGINEERING, FOURTH INTERNATIONAL CONGRESS.—Monday, August 25, to Friday, August 29, 1952, at Cambridge. For further information, apply to the secretary of the Association, Swiss Federal Institute of Technology, Zürich, Switzerland.

ASLIB (ASSOCIATION OF SPECIAL LIBRARIES AND INFORMATION BUREAUX).—Friday, September 19, to Monday, September 22, 1952, Annual Conference at The Hayes, Swanwick, Derbyshire. Apply to the secretary of the Association, 4, Palace-gate, Kensington, London, W.8. (WESTern 6321.)

LABOUR NOTES.

SOME interesting comments on the recent Trades Union Congress at Blackpool are contained in an editorial article in the *Monthly Report* of the United Patternmakers' Association for October. Mr. W. B. Beard, O.B.E., the Association's general secretary, writes that the Congress has been described in the Press as a quiet one, which left many problems unsolved and the critics no doubt had in mind the problems of wage stabilisation and prices. There were many people, Mr. Beard states, who thought that the Congress would embark upon some sort of inquiry into a wage plan which would be related to the national income and which would, in fact, determine the different strata of wages throughout the various trades and industries. This idea had its origin in the Civil Service. Its sponsors desired, no doubt, to relate planned wages to a planned economy, "in spite of the fact that such an economy is but a remote possibility." He remarks that some non-industrial trade unions are prone to over-rate the power of the T.U.C.

Resolutions will not determine the wages of engineers in relation to those of non-producers, any more than Congress resolutions can produce an amalgamation of trade unions, Mr. Beard informs his readers. This has to be achieved by agreement—not by compulsion. It will be argued, he states, that an inquiry into a wage plan would not compel the acceptance of such a plan, "but the fear of implied acceptance is apparent, if not real." This is not to say that such an inquiry might not reveal much that was useful. On the contrary, it might well produce useful results.

It has to be remembered, however, Mr. Beard stresses, that the foundation of the T.U.C. is the autonomy of the constituent unions. Although Congress has great influence and exerts great moral force, both on its members and on the nation generally, it is largely an advisory body and therein lies its strength, for, should it depart from that path, dissension would arise immediately. He expresses his belief that for a considerable time to come unions will continue to perform their old-fashioned function of dealing with the wages and working conditions of their members. For as long as this is the case, the unions will resent interference on this subject from any outside organisation, whether it be the T.U.C. or the Government, and no matter what its political complexion may be.

As to the address given at the Congress by Mr. Hugh Gaitskell, the Chancellor of the Exchequer, Mr. Beard writes that it was, "within his considerable experience," one of the best speeches ever made to Congress. It was obvious that some of the points made by Mr. Gaitskell compelled many delegates to revise their own comments when they rose to take part in the debate on "wages, prices and profits," which followed at the close of the Chancellor's address. He recalls that Mr. Gaitskell said: "If we took away all excess net incomes above 2,000l. a year, leaving those in that position with 2,000l. a year and no more, it would bring only 53 million pounds to the revenue." Other quotations by Mr. Beard from the Chancellor's address include "To have held the cost of living index steady during the past year, to the end of 1951, would have meant paying 600 million pounds in subsidies, on the top of the 400 million pounds we were already spending: clearly it could not be done," and "A further 50 million pounds spent in subsidies would make only just over one point difference in the cost-of-living index."

On the subject of profits and dividends, Mr. Beard quotes the Chancellor as saying: "From 1938 to 1950, the incomes of companies and public corporations rose just over 2½ times, or about the same as wages. During the so-called 'period of restraint,' there was a more rapid increase in wage earnings than in profit incomes. If dividends paid to shareholders had been reduced by one-quarter—a fairly savage cut—and these sums used to increase wages and salaries, the average additions would have been 3d. in the pound, or, say, 1s. 6d. a week, for a man earning 6l. a week." Mr. Beard concludes by stating that Mr. Gaitskell dealt with the questions of the overwhelming importance of increasing production and securing a much fairer distribution of wealth and income. At the end of his address, Mr. Gaitskell agreed that many of the points he had made were not very palatable and added that he did not expect the delegates to agree with him on all points.

Unemployment among operatives in the clothing industry increased by 25 per cent. during the four-weekly period ended September 17, according to statistics published in the *Ministry of Labour Gazette* for October. Some increase was general throughout the various branches of the industry. The number of insured workpeople in Great Britain registering as unemployed on September 17 was 10,196 against 7,450

on August 13. The comparative figure for the four weeks ended September 11, 1950, was 7,845. There were 2,739 men and 3,594 women in the industry wholly unemployed on September 17, 1951, against 2,635 men and 2,852 women on August 13. In addition, there were 1,511 men and 2,352 women temporarily out of work on September 17 last, against 850 men and 1,113 women on August 13.

The *Gazette* records the undermentioned variations in unemployment in the several branches of the clothing industry, namely, an increase of from 4,505 in mid-August to 6,319 in mid-September, in the tailoring trade; an increase of from 1,309 in mid-August to 1,462 in mid-September, in the dressmaking trade; an increase of from 454 in mid-August to 834 in mid-September, in the shirts and underwear trade; an increase of from 175 in mid-August to 501 in mid-September, in the hats, caps and millinery trade. Other dress trades were responsible for an increase of from 219 in mid-August to 231 in mid-September. In the boot and shoe trade, included by the *Gazette* in the clothing industry group of trades, unemployment increased from 788 in mid-August to 849 in mid-September.

The hearing of the railwaymen's wage claims before the Railway Staff National Tribunal was begun on Friday last and continued during Monday, Tuesday, and Wednesday of the present week. The proceedings took place in public at the Railway Clearing House, London. Sir John Forster, K.B.E., K.C., who is also President of the Industrial Court, presided; the other members of the Tribunal being Sir Graham Cunningham, K.B.E., a member of the Economic Planning Board, and Sir Luke Fawcett, O.B.E., who was for many years general secretary of the Amalgamated Union of Building Trade Workers. Sir Graham was nominated to the Tribunal by the Railway Executive and Sir Luke by the trade unions concerned in the claims. The National Union of Railwaymen, the Associated Society of Locomotive Engineers and Firemen, and the Transport Salaried Staffs' Association are making a joint claim for an all-round wage increase of 10 per cent. and, in addition, the A.S.L.E.F. are pressing a separate demand for higher pay for week-end work.

Mr. J. B. Figgins, the general secretary of the N.U.R., who opened the evidence given on behalf of the three unions, stated that the claim for a 10 per cent. increase was based on three main facts: the increased cost of living, the relationship between wages and salaries in the railway service and those obtaining in other industries, and the shortage of staff. He contended that the decline in railway recruiting would continue until wages and salaries in the industry were substantially improved. The cost of living had risen, according to the index of retail prices, by 13 points, or about 11½ per cent., since the submission of the railwaymen's previous claim in December, 1950. Between June, 1947, and January, 1951, Mr. Figgins stated, railway wages increased by only 7½ per cent., compared with an increase of 10 per cent. in other industries. Mr. J. G. Baty, general secretary of the A.S.L.E.F., presenting the case for his union, referred to the serious repercussions which were arising in the railway service owing to the lack of trained staff. There was a danger, he said, that the Railway Executive might have to refuse traffic owing to this cause and a heavy loss of revenue might result.

Evidence on behalf of the Transport Salaried Staffs' Association was submitted by the union's general secretary, Mr. G. B. Thorneycroft. He emphasised that the remuneration of the salaried grades of the railway service had not kept pace with the advances in the cost of living and that the percentage increases in such salaries were less than those received by workpeople generally and less even than those granted to other classes of railway employees. He concluded by stating that the existing differentials between the various railway grades was inadequate and did not give sufficient incentive to the salaried staff to take on the responsibilities which go with promotion.

Concern at the large number of wage claims submitted to the Railway Executive was expressed by Mr. W. P. Allen, the member of the Executive responsible for staff and establishment matters, who presented evidence on behalf of the Executive at the Tribunal's sessions on Monday and Tuesday last. He said that there had hardly been one month during which the Executive had been free from the necessity of having to consider major wage claims of one sort or another. Referring to the efforts of the Executive to improve the efficiency of the railway service and to reduce general operating costs, Mr. Allen stated that the Executive was not satisfied with the assistance which it had received in that connection from certain sections of the staff represented before the Tribunal that day.

ADVANCES IN AIRCRAFT STRUCTURAL DESIGN.

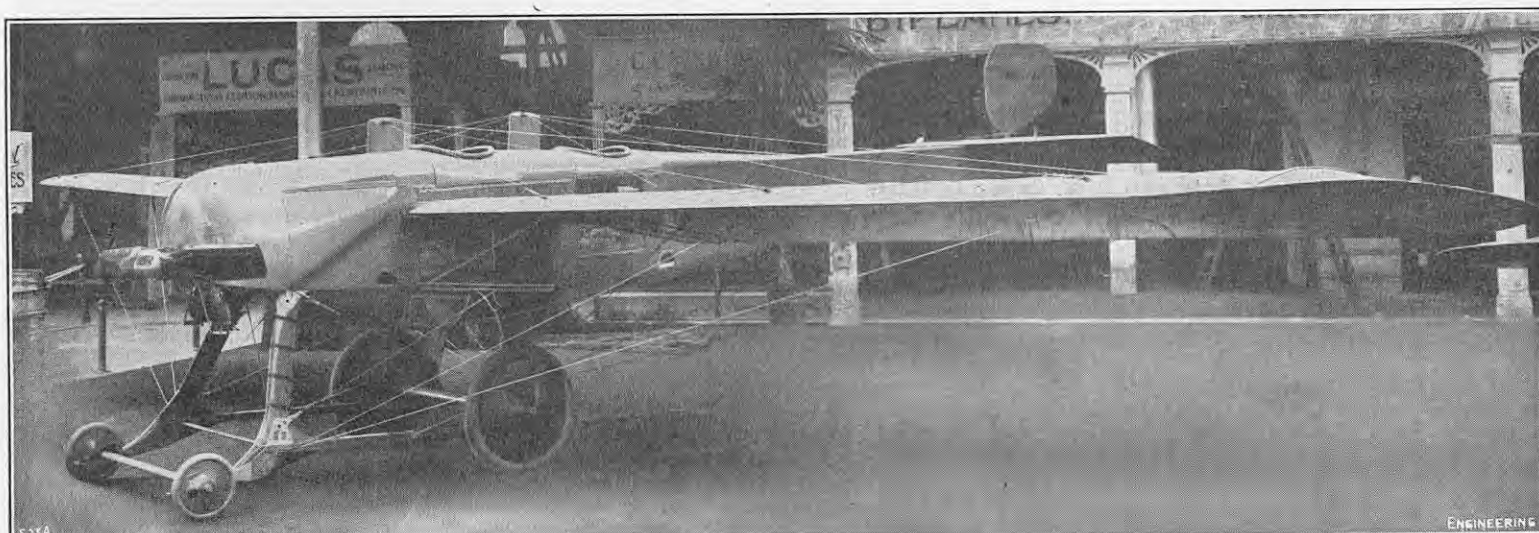


FIG. 1. BRISTOL MONOPLANE, 1913.

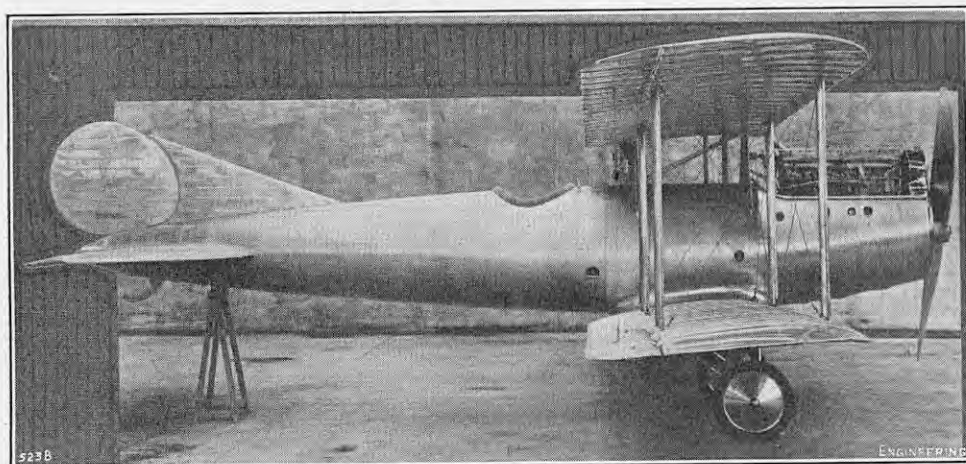


FIG. 2. SHORT "SILVER STREAK," 1921.

ADVANCES IN AIRCRAFT STRUCTURAL DESIGN.*

By G. T. R. HILL, M.C., M.Sc., F.R.Ae.S.

To keep this paper within reasonable limits, there are many aspects of structural development which have been omitted; for example, the technique of full-scale and model testing, dynamic loading, fatigue and temperature effects on the strength of materials, shear lag, the effect of cutouts, and diffusion problems.

The Wright Brothers achieved success in powered flight firstly by their experiments from which they found that they could get enough lift; secondly, they grappled successfully with the problem of providing quick-acting and powerful controls; thirdly, they built a reasonably satisfactory structure; fourthly, they produced a propulsive system light and efficient enough to get themselves off the ground. Their success in achieving fully controlled flight with a human pilot inspired most of the aeronautical world to develop along the lines into which their own design had settled down. Wood was the material chiefly used, and high-tensile steel wire was available for the tension members. These early structures were relatively large with very light loads upon them, and the low density and high specific strength of wood were just what was wanted. Bamboo was often favoured for struts owing to its natural tubular shape with stiffening diaphragms at suitable intervals. Fittings were commonly made of mild-steel sheet, and string and glue were often used to prevent the wooden members from splitting. Fabric of various kinds covered the wing surfaces; waterproof paper was not unknown as a wing covering, its virtue being eloquently expressed in one of the early Avro catalogues in these words, "True it is cheap, but then it is easily repaired."

In the early years of the century, France was the centre of the most active development with biplane design led by the Farman Brothers and Voisin, and

monoplane design led by Blériot. These monoplanes were all fitted with external bracing wires, as fitted half a century before by Henson, and it became clear that it was more difficult to design a light monoplane structure. Some of the Blériot designs were loaded to over 4 lb. per square foot, whereas the corresponding figure for biplanes was below 3 lb. per square foot. The reason was that the wing structure must be capable of carrying down loads as well as up loads. With a wire-braced structure, such as that used on the early monoplane wings, this results in a depth of girder to carry the lift loads equal to the spacing between the lift-wire attachments and the main spars, on top of which must be placed the girder of a depth sufficient to carry the anti-lift wires; there was a tendency to economise in the depth of the monoplane structure, which resulted in higher tension and compression in the members, and consequently a heavier structure.

By about 1913 there was a growing number of fatalities due to the structural collapse of many monoplanes; in many cases there was evidence that the wings collapsed downwards. The War Office, the chief buyer in this country, lost confidence in the monoplane as a type. This had a profound influence on the trend of design in Great Britain, which was one of the last of the great designing countries in the world to abandon the biplane type. If a saving in height between the points of attachment of the lift wires and the anti-lift wires had to be made, it seemed common sense to effect most of the saving on the "cabane" carrying anti-lift wires, because it was felt that these wires did not really do much except hold the wings up when the aircraft was on the ground. In many designs, therefore, the angle of the anti-lift wires was very flat, as may be seen in Fig. 1, which shows the Bristol monoplane of 1913. With the highly cambered wings in use in those days, the moment due to camber was relatively large, so that, under a down gust, the wing structure would twist sufficiently to produce a further downward load, and so on until disaster supervened; nowadays, this is described as "divergence."

Increasing engine reliability and the introduction of multi-engined aircraft reduced the frequency of forced

landings, with the result that wing loadings experienced a steady increase, and it became economical to use metal to replace heavily-loaded wooden members; steel-tube fuselages, the forward ends containing the engine and crew, came into wide use before the First World War. Aluminium was still confined to structurally unimportant parts, such as fairings and cowling panels over the engine. At that time, fabric seemed an excellent material for producing a wing shape of the right contour, both from the point of view of air flow and for transferring air loads on to the primary wing structure. However, with increasing air speeds and higher wing loadings, fabric failures began to occur in the air. One of the earliest attempts to provide a metal skin was made by Junkers, in Germany, who experimented with a highly corrugated steel skin which was only a few thousandths of an inch thick. With the coming of suitable alloys of aluminium, the smooth skin covering of to-day came into almost universal use.

The Short Silver Streak of 1921 (Fig. 2) was the earliest example in Great Britain, and, it is believed, in the world, of the completely all-metal structure; the spars were of tubular steel and the wing skin was non-structural. Junkers built a number of aircraft in which the aluminium skin was corrugated in the line of flight, and was thus an effective equivalent of all the rib flanges. Running the corrugations lengthwise was not directly admissible, for obvious aerodynamic reasons, but with frequent internal longitudinal stringers a comparable result was obtained. The Junkers corrugated skin was applied to the fuselage covering as well as to the wings, which were of the multi-spar, type, fully cantilevered; the spar booms were tubular, with lattice bracing between top and bottom booms.

Fabric stitched on ribs had many advantages; although the ribs underneath caused noticeable ridges, they were along wind, and with care in design and construction the sections down-wind of a fabric-covered wing were quite good. In the ingenious "geodetic" construction due to Wallis, the members supporting the fabric all ran diagonally; the aerodynamic loss was tolerable at the cruising speeds, below 200 knots, of the Wellington, which was largely used during the Second World War. As soon as fabric was abandoned, the difficulty of producing a surface free from waviness along the wind direction had to be faced.

The earliest use of sandwich construction, in which an inner and outer strong skin are stabilised by a very light core which spaces the skins well apart and increases the stiffness of the panel, is believed to be in 1925 on the author's Pterodactyl Mark I, illustrated in Fig. 3, on page 538. In this a special $\frac{1}{8}$ -in. plywood was constructed of outside birch veneers $\frac{1}{16}$ in. thick, with a balsa core $\frac{1}{16}$ in. thick; this was used on the sides of the fuselage. Much later the technique was widely adopted, notably in the de Havilland Mosquito. Whether it is possible to adapt this technique to metal construction is a question as yet unanswered.

With increasing demands for torsional stiffness, thicker sheeting can be used at the top and bottom surfaces of wings, where there is a large concentration of load; the stringer spacing may become very close, and serious attention is being given to extruding skin panels with integral stringers. When skins are thick enough to be extruded, as in many designs to-day, the idea of machining them so as to be smooth enough

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FIG. 3. HILL "PTERODACTYL" MARK I, 1925.

to ensure laminar flow is attractive. Smoothness requirements with limitations on waviness measured in thousandths of an inch, are apparently almost impossible to achieve. On a small scale a suitable surface has been produced, but only as a result of many weeks of hard work on a few square feet. The dividends in speed and range for getting a really smooth surface, however, are greater than any other gains which the structural engineer has in sight; reinforced plastic construction offers attractive possibilities.

It is by no means always true that the design of an aircraft with a lower structure weight percentage is better than that of a rival aircraft with a higher value, particularly on long-range aircraft, where the percentage fuel weight is high. Compare two aircraft designed for the same duty with different spans: normally, the large-span aircraft wing would be heavier than that with the small span, but owing to the reduction of induced drag with span, the fuel load for a given range would be less, and it might well be that the all-up weight of the large-span aircraft would be less.

The square-cube law states that for geometrically-similar aircraft with constant wing-loading and factors of load and safety, the wing area, and therefore the all-up weight, increases with the square of the linear dimension while the structure weight increases with the cube; therefore the structure weight percentage must increase with size. If true, this puts a definite limit on size if any useful load at all is to be carried. In the early days, an aircraft weighing 5 tons was estimated by one well-known authority to be the biggest that could just leave the ground, carrying no useful load at all. Nowadays it has become clear that other factors of comparable importance were neglected by the weight estimators of old. Only an unexpectedly small fraction of the structure weight is really doing the work of an ideally-stressed structure. On large aircraft it is easier to refine the design of non-structural parts.

In 1949, Keith-Lucas showed that, whereas at some fairly large all-up weight the landplane and seaplane came neck-and-neck, at higher weights the seaplane showed a saving in weight compared with its rival. The land undercarriage is a structure in which the loads and stresses can be fairly accurately assessed; it would thus tend to follow the square-cube law, and hence its percentage structure weight would increase with size; on the other hand, the seaplane hull is a structure which can be progressively refined with increasing size, and the square-cube law therefore applies to a small fraction of its weight, thus giving it an advantage in large sizes over the landplane undercarriage.

With the advent of jet-propelled aircraft there has been a sudden increase in speeds and cruising heights. When flying in disturbed air, speed is a major factor in producing gust loads, the additional load being

roughly proportional to the speed of the aircraft entering the gust, assuming a constant wing loading. It is now possible to fly high enough to encounter the turbulence which is associated with jet streams, where wind speeds relative to the earth of upwards of 200 m.p.h. produce a high rate of wind shear, and corresponding turbulence. There is, however, no indication to the pilot by visible cloud. By fitting velocity-acceleration recorders and recording accelerometers to large numbers of aircraft, it has been possible to build up a considerable volume of statistical evidence which defines the kind of gust in the lower height range, say up to 20,000 ft., and also the frequency of gusts of any given severity. In order to be sure that the structural strength of an aircraft is adequate for the kind of gusts which may be met at 30,000 ft. or 40,000 ft., however, it is necessary to go to these heights and measure the gusts which are to be found there; work on this task has been undertaken since the Second World War. The earlier results in Great Britain confirmed the belief that, on the whole, the air is much calmer at these high altitudes, particularly if flying in relatively thin layers of disturbed air is avoided; but at least one case is on record of alarmingly high accelerations at high altitude measured on a day when a jet stream was present. The present design requirements for gusts are admittedly based on guesswork.

While accelerations produced by gusts act in any direction, it is only the accelerations produced by changes of lift on the wing that are serious from the point of view of both structural safety and passenger comfort. To reduce these accelerations, the slope of the lift curve must be reduced, involving a loss of stability and a loss of manoeuvrability of the aircraft. The various arrangements proposed for reducing the slope of the lift curve consist essentially of a detector to measure the gust, a device, usually a flap, to alter the lift on the wing, and a servo-motor to amplify the signal received by the detector to an extent sufficient to operate the flap. The whole apparatus must produce the answer in a small fraction of a second. Since some aircraft now have power-operated ailerons, it is attractive to explore the possibility of coupling these up to the detector so that both ailerons move in synchronism when a gust is met. From the point of view of structural safety alone, it would be sufficient to "cut off the top of the lift curve," and the mechanism would then act only when the danger point was approached. It would be preferable, however, either to flatten the slope of the lift curve all along its length or to reduce the slope considerably over a limited range, leaving it unaltered outside this range. There are many problems to be solved: the degree to which the lift-curve slope can be safely reduced, the amount of lift reduction at which it is useful to aim, the acceptable time lag, and whether it is possible to reduce the lag sufficiently with such large surfaces as ailerons, or whether much smaller surfaces, which could easily be moved much faster, would be effective. If the gust-alleviator could be developed to such a pitch that its reliability was comparable with that of the aircraft-control system (a by no means impossible task) then for a given load factor and factor of safety, a lower structure weight might be justified with the gust-alleviator in action.

The common manifestations of aeroelasticity in flight may be conveniently divided into the non-oscillatory and oscillatory types. Perhaps the simplest and most familiar of the first group is the progressive loss of aileron control with increasing speed of flight. If the speed increases sufficiently a point is reached at which the movement of the control surface has no effect at all on the aircraft; above this speed the effect of the

controls is actually reversed, this critical change-over being known as the "reversal speed." A given angle of aileron produces a given change in pitching-moment coefficient on that part of the wing affected by the aileron itself. Under this pitching moment the wing twists elastically, and always in the opposite sense to the motion of the aileron; a down-going aileron produces a loss of wing incidence, and thus the lift due to the aileron is diminished by reason of the wing twist. This loss in aileron effectiveness increases with the square of the speed, and at the reversal speed it overcomes the additional lift which the pilot intends to get by moving his aileron. The pilot has a continuous warning of the approach of aileron reversal as he increases his speed; sufficient torsional stiffening of the wing structure will postpone the reversal speed.

If a straight wing of conventional construction has a symmetrical section, its centre of pressure at the quarter-chord point will be somewhat in front of the flexural axis. The lift force in flight will then twist the wing in the direction of increased incidence with a resulting increase of lift. If now the angle of incidence is suddenly altered, say by a vertical gust, then the twisting moment on the wing will be proportional to the square of the forward speed; since twisting is resisted by the constant elastic stiffness of the wing in torsion, it is easily seen that if the forward speed of the aircraft is increased sufficiently these two effects will become equal. At that speed, the divergence speed, the wing twist can become theoretically infinite. Fortunately the divergence speed is usually well beyond the range of flying speeds of present-day aircraft.

The simplest examples of flutter involve motion in two modes at the same frequency, with a phase difference between the modes; this phase difference enables energy to be extracted from the air stream, and if the extraction of energy exceeds that dissipated by the damping, both structural and aerodynamic, then the motion builds up in amplitude until the structure collapses. Sometimes the motion involves more than two degrees of freedom, but never less, except in cases where, for example, there is a movement of a shock wave, and the motion is no longer of the simple-harmonic type. One of the first well-authenticated examples of flutter occurred on the tailplanes of the twin-engined Handley Page 0/400 aircraft built at the beginning of the First World War. The rear end of the fuselage and the attached tail surfaces formed an oscillating system with two degrees of freedom; in one mode, the port and starboard elevators could oscillate about their hinges 180 deg. out of phase, the relatively weak spring restoring force being provided by long flexible control cables through which each individual elevator was connected to the pilot's control column. In the other mode, the tailplanes and rear end of the fuselage could oscillate in torsion, and the possibility of a phase difference between the two modes of oscillation was diagnosed as the cause of flutter. The cure proposed was simply to cross-connect the port and starboard elevators, so as to synchronise their movements.

The effectiveness of mass balance in preventing oscillation involving the control surfaces is now well established. The oscillation is a binary one with rotation of the control surface about its hinge and either translatory motion of the surface to which it is attached in the direction perpendicular to the line of flight, or torsion of this surface, giving rise to incidence changes. The weight penalty attached to mass balance is of the order of $\frac{1}{2}$ per cent. of the all-up weight, both for small and large aircraft. It can, therefore, appreciably affect the payload of a long-range aeroplane;



FIG. 4. DUNNE BIPLANE.

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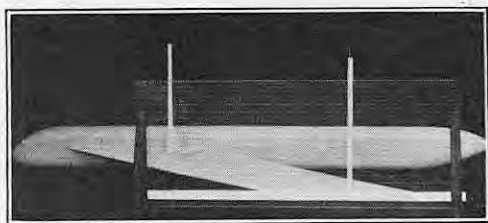


FIG. 5.

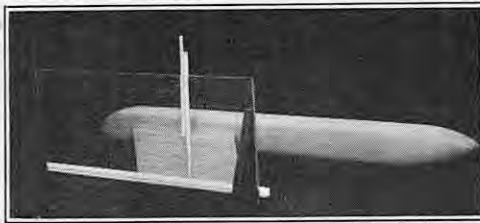


FIG. 6.

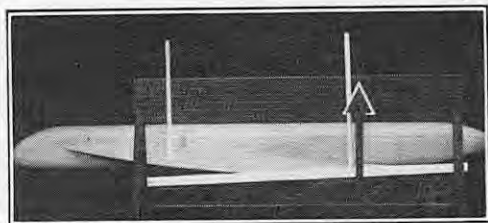


FIG. 7.

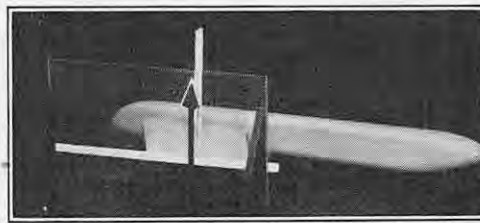


FIG. 8.

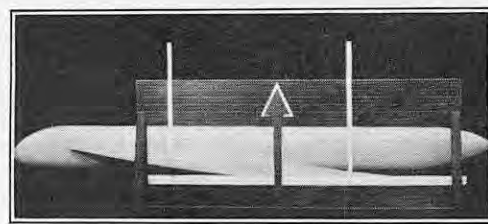


FIG. 9.

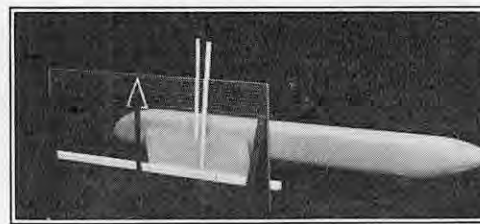


FIG. 10.

FIGS. 5 TO 10. AERODYNAMIC AND STRUCTURAL DISTORTION OF SWEEP-BACK WING.

mass-balancing is, however, one of the most reliable devices ever fitted to an aircraft.

With the advent of speeds of flight near, and even surpassing, the sonic speed, the provision of adequate wing stiffness often involves appreciable increases in structural weight. The appearance, or the reappearance, of aircraft with highly swept-back wings has accentuated the aeroelastic difficulties which the designer has to meet. Fig. 4 shows the Dunne biplane of 1911, which had swept-back wings. On the straight wing, bending and twisting can be controlled separately. The twist produces change in incidence and therefore in air load; bending produces no change of incidence and thus the air load on the wings is independent of their bending flexibility. With a swept-back wing, both bending and twisting produce changes of incidence. Much study at the present time is being given to the exact modes of distortion of the swept-back wing under lift loads. When the wing tips bend up there is a loss of incidence and when the wing twists there is a change of incidence in the same sense, although different in amount from the change of twist, depending on the angle of sweepback.

Consider an increase of incidence along the wing such as that encountered when meeting an up-gust. Upward deflection of the wing tips as compared with the wing root will produce a loss of incidence at the tips, with a resulting nose-up moment on the whole aircraft. This nose-up moment rotates the aircraft to yet higher incidence; in other words, a condition tending towards instability is experienced. It is also clear that the whole effect is proportional to the wing flexibility in bending. High speed appears to demand small wing thickness and high sweepback; the maintenance of longitudinal stability calls for high thickness and small sweepback. The users of the aircraft call for low structure weight; it will be interesting therefore to see what kind of solution to these various conflicting requirements the future will provide.

Some fifteen years ago, the general layout of aircraft seemed to be reaching a degree of stability appropriate to the dignity of a well-established art, whereas now the design of high-speed aircraft has changed and is changing rapidly. By the time the Second World War was over, Lippisch in Germany had brought on to the drawing board the delta design, where the very heavy sweep of the leading edge is associated with little or no sweep of the trailing edge. In some ways, such a design eases the task of the structural engineer, who would perhaps regard as ideal square or circular plan forms, with reasonable depth in the centre. The delta wing has a smaller span and aspect ratio than is usual and thus, in general, less bending moment. In

addition, with the same thickness/chord ratio, the absolute depth in which the main spars are housed is greater, since the root chord is large; questions of torsional stiffness are eased by the area towards the wing root of what may be called the torsion box.

Large span, which favours the reduction of induced drag, is costly in structure weight as the sweepback becomes more pronounced. One of the many enemies of low wing-structure weight is the stiffness required to ensure freedom from control reversal, flutter and adverse movement of the aerodynamic centre due to wing distortion. Control reversal arises basically from the added load due to control-surface movement acting near the half-chord point, while added load due to incidence changes acts near the quarter chord. The wing structure must be both strong and stiff enough to deal with loads applied at either point; if these two points of application of load could be brought closer together, less structural stiffness would be adequate for safety at a given speed of flight. One way of tackling this problem is to consider types of control which, when they are moved, do not bring in their train such backward points of application of added load, such as increasing the control-surface chord, and the use of the spoiler control. If the drawbacks of either method could be diminished sufficiently, the span for greatest economy might be increased if flutter and shift of aerodynamic centre due to distortion could be looked after.

The loss of incidence hitherto inseparable from the upward bending of a swept-back wing is the primary cause of the latter trouble. In the past there has been some confusion between structural twist and incidence change, which for straight wings are identical. The photographs reproduced in Figs. 5 to 10 show the distortion of a swept-back wing loaded in two different ways from two points of view, that of the aerodynamicist who is interested in the tip incidence, as measured by the transparent grid, and that of the structural engineer who looks along the length of the wing from tip to root and studies the twist by observing the alignment of the two pillars, inboard and outboard, mounted at right angles to the local wing chord. Figs. 5 and 6 show the wing under no load, with zero incidence change from root to tip, and zero twist. Figs. 7 and 8 show that when the wing is loaded at the arrow, which is on the flexural axis, there is no twist, but there is a loss of incidence due to bending. The aerodynamicist would like to see the wing distorting under load into the shape shown in Figs. 9 and 10, where the arrow showing the loading point is in front of the flexural axis. Here, there is no change in tip incidence, although there is some structural twist. If such a wing could be

designed, and the flutter problem solved, it might be possible to avoid the increase in torsional stiffness and structure weight usually demanded by sweepback.

Turning to the formidable problem of landing aircraft of heavy sweepback, it has long been known that the slope of the lift curve falls off as the aspect ratio is reduced, and that the maximum lift with low aspect ratio is developed at angles of incidence higher than those in common use; even when the maximum lift is reached it attains only a modest value, which it is difficult to raise by flaps or other means, especially when account is taken of the need to trim longitudinally. There may be serious difficulty with the lateral stability at the lower end of the speed range, at any rate with the less extreme angles of sweepback; furthermore, the rapid increase of drag as speed is lost in the approach to land means that any attempt at putting the aircraft on the ground after an engine failure would be hazardous.

One possible solution would be to hinge each wing about a vertical axis, so that in the landing configuration the wings are projected more or less at right angles to the plane of symmetry, and in the high-speed configuration they are swept-back to give the delta shape. This would appear to lead to formidable structural problems. Preliminary examination, however, suggests that, on the whole, there would be a net gain. Apart from complication, the penalty in structure weight is likely to be quite small. Many years ago, the author had some experience of sweepback variable in flight with the Pterodactyl Mark VI. The range of sweepback was much less than would be needed in the application now under consideration; the variable sweep was delightfully easy to operate in flight, and the structure weight penalty was only 2 per cent. of the all-up weight. On the modern version where large angles of sweep will be needed, great ingenuity will be called for in making good the cracks and gaps near the hinge, but the whole philosophy of a change in geometry to deal with the immense speed range foreseen for this kind of aircraft is in line with what has been done with success in the past, namely, the high-lift flap, retractable undercarriage and the variable-pitch propeller.

These speculations on the shapes into which aircraft may change in the course of the next few years have as their main object the stimulation of discussion and experimentation. Looking back over a period of nearly fifty years since the Wrights first demonstrated the possibility of human flight, one of the many lessons which emerges is that progress comes in two ways—by steady methodical development, and in gigantic bursts when a new idea is born, is at first laughed at, is then taken seriously, and, finally, sweeps the board. The present is a time of ferment, of galloping progress in the world. As a distinguished former President of the Royal Aeronautical Society, Dr. Roxbee Cox, has said, some ten years ago, "We must have ideas, develop them and use them. Too often we seem to have had ideas and forgotten them until others have developed them." How truly he spoke, and how dimly is any change in attitude to be seen in Great Britain. Let us, therefore, see that every encouragement is given to those who are ready to break with tradition and carry us to new heights of achievement.

ALLOCATION OF BUILDING STEEL.—The allocation of steel, which was freed from control in May, 1950, is to be re-introduced by the Ministry of Supply. In general, the scheme will be the same as that which was then in force, except that alloy-steel will be controlled under a separate scheme and cast iron will not be included in the allocation arrangements. This will apply to ingots, billets, blooms, slabs, sheet bars, plates, certain sheets, tin-plates, sections, bars, rails and sleepers, hoop and strip, tubes and pipes, tyres and axles, blocks for forging and pressing, colliery arches and pit props, large springs, wire rods, wire, wire ropes and other materials. We learn that a notice has been sent to all registered building and civil-engineering contractors informing them how to apply for steel authorisations for licensed building work in progress; this includes steel for which a preferential treatment certificate, or D.O. symbol, has been awarded. For this purpose, Form M.O.W. 2065 is to be employed, and, henceforth, all applications for new building licences should state the requirements of steel for delivery after December 2. A special arrangement is being made for conduit and other steel required for electrical installation work. Electrical contractors who are members of the Electrical Contractors Association (or the E.C.A. of Scotland) are being asked by their association to submit their requirements of steel for use directly on electrical installation work in building. The purchase of manufactured fittings, such as steel windows, cookers and meters, will not require an authorisation. For sheet steel the present arrangements will continue. Small quantities of steel may be purchased in any one month without an authorisation, on submission of a certificate made out in a form to be specified in the Order to be issued by the Ministry of Supply.

THE INSTITUTION OF ENGINEERS AND SHIPBUILDERS IN SCOTLAND: PRESIDENTIAL ADDRESS.*

By SIR ANDREW McCANCE, D.L., D.Sc., LL.D., F.R.S.

(Concluded from page 504.)

THE cracking that, in the early days, so frequently accompanied welding was held up as an illustration of the dangers of residual stresses. On the other hand, it was known that mild-steel joists always retained high residual stresses after rolling, yet cracking due to their presence was unknown. The practice of scragging or pre-setting the components of laminated springs has been known for generations to give a better life, and, more recently, the shot-peening of springs has been found a decided advantage. When, therefore, are residual stresses helpful and when are they dangerous?

This question has been strongly debated in recent years. The answer that can be given is that such stresses are only dangerous when they act as a constraint to plastic deformation. When their line of action lies in the same direction as the external stress, they can do little harm, or, as in leaf springs, can actually be of benefit. If their direction lies across that of the external stress, then residual tension stresses can be a source of danger. From what has been previously stated, if their intensity is greater than approximately 40 per cent. of the breaking strength, side contraction will be prevented and it will be possible to attain the breaking stress with a total extension corresponding to that of pure elastic extension only. For all practical purposes, such extensions are negligible and the crack which forms has the appearance of a brittle fracture.

With fluctuating or impulsive stresses, the time factor has a very obvious bearing on what actually happens. The stress may increase so rapidly that there is no time for plastic movement owing to sluggishness and inertia, and the breaking stress can be reached before the relieving shear glides are effective. This peculiarity in the behaviour of metals, and particularly of steel, has received much prominence and notice. It is one to which there are two avenues of approach. It is, in the first instance, a problem in the deformation of visco-elastic solids under stress with time. In the second place, it is a metallurgical problem pertaining to the influence of the commonly occurring elements and of temperature on these same visco-elastic properties—a matter of immediate practical usefulness.

The differences that exist between different samples of steel are shown up most strikingly by their response to an impact test. I am not concerned with what impact test is used, so long as it contains a notch with a known and accurately machined radius and a depth which has a proper relation to that radius. To my mind, all other details are unimportant, although they should be kept to some agreed standard to make comparison between different laboratories possible. The essential action of an impact test is to apply a stress which increases uniformly at a fixed velocity and to measure the response of the material to such conditions of stressing. Impact machines in use do not carry out this provision very accurately. In fact, in the pendulum type of machine the rate of stressing is determined by a rate of extension in which substantial variations take place during the course of each test. But all tests suffer approximately from the same state of affairs, and so they are reasonably comparable.

In a notched test-piece, the increase in stress due to the notch is proportional to $2\sqrt{\frac{d}{R}}$ where d is the depth of the notch from the surface and R is the radius at the root. As this radius becomes smaller, the maximum stress increases fairly rapidly. In the standard Izod test-piece, it is about 6.6 times the stress in a plain specimen. The higher the rate at which it is broken, the more discriminating does the test become. Why this should be so can best be shown with the aid of a diagram. I have worked out the case where a stress is suddenly applied to a uniform bar and I find that the extension of the bar, which varies with time, is directly proportional to the applied stress and inversely proportional to the viscosity of the material. Since this viscosity may vary with temperature by a ratio of a million to one or more, very large differences in the rate of extension due to a given stress are possible when the temperature is varied. I have taken three examples which are represented on Fig. 4 by the letters A, B and C, and they correspond to roughly equal differences in temperature of the material at the time of the test. Any uniformly increasing stress applied to the bar can be represented by a uniform rate of extension, that is, by a straight line in the diagram. The line (1) is the representation of one such line.

At temperature A, the straight line lies wholly below

the curve so that all the atoms can follow the stress extension without difficulty, no matter how great the extension becomes. At temperature B, the material can move with the extension at the beginning, but later the lines cross. If the atoms cannot move sufficiently quickly, they must be pulled apart and fracture will ensue. At temperature C, the rate of extension is faster than the atoms can follow and fracture will take place almost immediately after the application of the stress. These diagrams show that there is a critical rate of stressing for each temperature which brings about immediate fracture, and this critical rate falls off very rapidly with the temperature. When fracture does take place under any rate of stressing above the critical value, it will take place without noticeable extension of the test and will be regarded as a brittle fracture. Alternatively, as the temperature is lowered at a constant rate of application of the stress, the transition from a state of toughness with appreciable extension to one of brittleness with no extension will be very sharply defined owing to the fact that the viscosity varies exponentially with the inverse of the absolute temperature.

Interpreted in the light of these deductions, the variations of the transition temperature of ship plates, which has become so important in the behaviour of

Fig. 4. EFFECT OF UNIFORMLY INCREASING STRESS ON STEEL AT DIFFERENT TEMPERATURES.

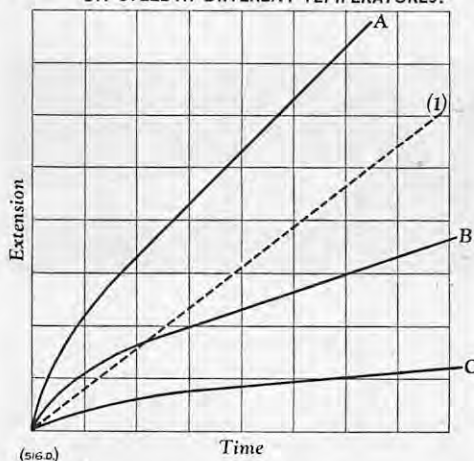
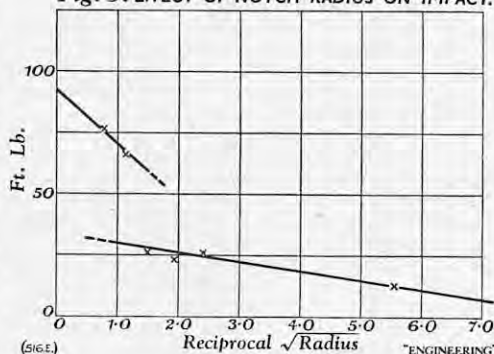


Fig. 5. EFFECT OF NOTCH RADIUS ON IMPACT.



welded construction, become clearer. All materials will behave in a similar manner, and if cooled to sufficiently low temperatures they will show the characteristics of brittleness. Alternatively, a substance like rock salt, which is quite brittle at ordinary temperatures, becomes tough and plastic when heated—a temperature of only 200 deg. C is required. Sealing wax stretches almost indefinitely at the temperature of boiling water, but, even with the most slowly applied stress, breaks like glass at the freezing point. Glass itself is another very striking example, and for brittleness it has indeed become the standard of reference for all other materials. Its viscosity has been measured and at 500 deg. C. the value is one million million times greater than it is at 1,300 deg. C. With this enormous range, no wonder it has been so universally accepted as a pattern of behaviour for the change from the brittle to the plastic state.

When material with notches or other stress-raising changes in section has to withstand fluctuating or impulsive stresses, the rate of variation of the stress becomes a matter of definite importance. Sharp sudden blows may well cause a rise in the stress rate at one particular part which is greater than the critical rate and so initiate a brittle type of crack. How far such a crack will spread will depend on the general stress conditions over the area where it originated. If the material in the immediate vicinity is already highly stressed, a crack once started may go far. I recall the case of the German-built *Majestic*, where a crack started at the sharp corner of a lift-opening, cut out of the main

deck. The fracture took place during a severe Atlantic storm and the crack was 60 ft. in length before it fortunately stopped. Bearing in mind temperature effects on steel, had it taken place in a vessel in the Arctic regions, where the hull might have been below freezing point, such an event would have caused a major disaster, as the crack would not have stopped at all.

To try to show by means of an impact test the effect of different rates of stressing, standard 10-mm. square test-pieces had notches cut in them of constant depth but different root radii. The stress rates will then vary

in proportion to $\sqrt{\frac{1}{R}}$, the radius of the notch, and in Fig. 5 the impact value does show a definite discontinuity when plotted against this variable.

It is our misfortune that the critical stress rates at ordinary temperatures for the one material in universal use by engineers—steel—should fall within the range of stress conditions which occur in their everyday work. In the case of copper and nickel—and, indeed, in the case also of austenitic stainless steels—the temperature range for a corresponding sensitivity lies much nearer the absolute zero of temperature and is completely outside the range of ordinary practical work. When the effect of low temperature in promoting brittle behaviour first came to notice during the second World War, it was recognised at once as a matter of serious importance and extensive investigations into the subject were commenced. The transition from a tough fracture with a fibrous surface to a brittle one with a crystalline surface was fairly sharp and the temperature range within which this change took place was examined in many specimens. It was soon found by Barr and Honeyman that the determining practical factor affecting the transition range was the ratio of manganese to carbon in the composition, and the importance of this discovery has now been universally acknowledged. Other factors, such as the crystal grain size, have since been shown also to exert their influence, but these other factors are secondary to that of composition. Why manganese should have this favourable effect is not yet known with certainty. It has been explained earlier how carbon and nitrogen by their presence in the iron lattice cause distortion and a predisposition to easy separation of the cleavage planes. Manganese has a greater affinity than iron for both of these elements, so that, when it is in solution in iron, it will tend to cluster round the atoms of these impurities. In other words, every dissolved carbon atom will, on the average, have more manganese atoms as neighbours than will the iron atoms. The effect of the carbon on the iron lattice is cut off by this manganese shield and the more manganese atoms there are to each carbon atom the greater the shielding effect. In some such way does manganese act.

TRADE PUBLICATIONS.

Meter Switch.—Details of the ten-way double-pole meter switch which is being manufactured by them for use by the Post Office Engineering Department, are given in a pamphlet received from Precision Components (Barnet), Ltd., 13, Byng-road, Barnet, Hertfordshire.

Electric Welding Plant.—Metropolitan-Vickers Electrical Co., Ltd., Trafford Park, Manchester, 17, have sent us copies of pamphlets dealing with their atomic-hydrogen arc-welding plant, spot welding machines and welding electrodes.

Diesel Engines.—Particulars of the Diesel engines manufactured by them for industrial, traction and marine purposes (together with data sheets) are contained in a number of pamphlets issued by the Diesel Engine Division of the English Electric Co., Ltd., Brownover Hall, Rugby.

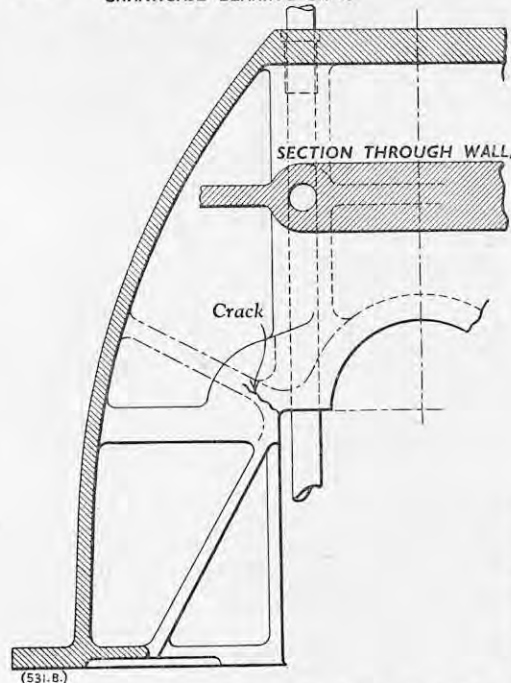
Draughting Machine.—W. G. Pinner & Co., 1, York-road, Birmingham, 16, have recently brought out a "Precima Major" draughting machine, which is suitable for Double Elephant (42 in. by 29 in.) and Antiquarian (54 in. by 32 in.) drawing boards. It can be used on boards that are horizontal or inclined up to 20 deg. The arms, of light alloy, are supported on precision ball bearings; the protractor head is located automatically in steps of 15 deg. and can be adjusted to any intermediate angle over a range of 180 deg.

Screw Threads and Threading Dies.—W. H. A. Robertson & Co., Ltd., Small Part Division, Lynton Works, Bedford, have produced an unusually comprehensive guide to screw threads and threading dies and chasers. It gives, *inter alia*, details of over 300 types of dies for die-heads, screwing machines and hand-stocks, of British, American and Continental makes; a comparison of the principal screw-thread systems of the world, including the Unified System; tables of helix angles, depth of threads, cutting speeds, etc.; the international practice for "rounding off" decimals; and details of the firm's service for recutting and regrinding dies, which avoids delays in supplies and saves steel.

* Delivered in Glasgow on October 9, 1951. Abridged.

AUTOMOBILE OIL-ENGINE DEVELOPMENT.

Fig. 5. CRACKING FROM CORNER OF REGISTER OF CRANKCASE BEARING CAPS.



TWENTY YEARS OF OIL-ENGINE DEVELOPMENT.*

By C. B. DICKSEE, M.I.Mech.E.

(Concluded from page 491.)

As originally built [i.e. the early road-vehicle oil engines with which Mr. Dicksee was associated] the main bearings were provided with aluminium caps with the usual steel strap behind them. The strap, though generously proportioned, proved inadequate, and the aluminium caps failed by cracking across the crown. The life of any bearing, no matter what service it is called upon to perform, is dependent upon the adequacy of its support, and to provide the maximum possible support steel caps were adopted with babbit run directly into them. This arrangement was moderately successful, but it caused service difficulties owing to the weight of material which had to be carried when servicing a bearing failure, as at that date the engines, almost without exception, were being serviced from the factory. The design was therefore changed to incorporate replaceable shells fitted into drop-forged steel caps. The shells themselves had heavy steel backs and were babbit-lined. Later, after the adoption of copper-lead had cured the connecting-rod bearing trouble, this material was applied to the main bearings also, as the life of babbit main bearings, though good, fell a good way behind that of copper-lead rod bearings. In the case of the main bearings, however, babbit was, and still is, retained for the upper halves, an arrangement which was adopted partly on the score of cost and partly because of limited production facilities; it appears, however, to have some practical advantages also. With this arrangement, bearings ultimately ceased to be a problem, but before this satisfactory state of affairs was reached certain other problems, which reflected upon both bearing and crankshaft life, had first to be solved.

About 1933, a new and somewhat smaller six-cylinder engine was produced. The crankcase of the earlier engine had originally been cast in aluminium of the usual L5 Air Ministry specification, and some trouble had been experienced both from a lack of soundness and from cracks which developed at the crown of the bearing housings. For the new design a change was made to a light alloy of a different type, which provided both a saving in weight and a freedom from unsound castings. At the same time, the crankcase of the old design also was changed to the new material.

Following this change in material, main-bearing troubles increased considerably and numerous crankshaft breakages occurred with the new engine and, to a lesser extent, with the old engine as well. The application of copper-lead to the main bearings served at the time only to aggravate matters rather than to improve them, because, instead of breaking up as the babbit had done, the lead-bronze fired up and damaged the crankshaft. At the same time there were numerous cases of the bearings tightening up after a short period

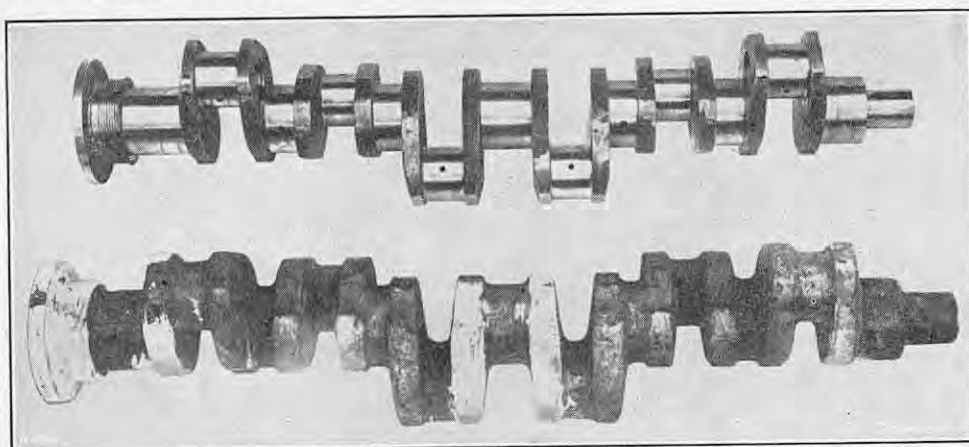


FIG. 6. SIX-THROW CRANKSHAFT IN ROUGH-FORGED AND FINISHED STATES.

of service, and ultimately the crankcases themselves gave trouble by cracking from the corners of the register of the intermediate bearing caps, as shown in Fig. 5, herewith. The chain-dotted line shows the original construction.

The crankcases of both engines included the normal arrangement of through-bolts extending from the cylinder feet to the main bearing caps, designed to relieve the crankcase itself of all gas loading. To obtain the desired bearing area without an undesirable increase in cylinder centre distance, the crankshaft was given a generous diameter, and in this way the intermediate bearings had been reduced to a minimum length; but, as it turned out, the abutment area for the bearing caps had been reduced below that necessary to enable the new alloy to carry the bolt load safely. Several changes to the pattern intended to provide a heavier section, and to stiffen up the case where the cracking occurred, failed to make any improvement, and, instances having been observed where the bearing caps had bedded themselves into the crankcase material, the conditions surrounding the intermediate bearings were studied in detail.

Experiments were made to determine the load produced by tightening the nuts on the main-bearing bolts, and this proved to average 20,000 lb. per bolt. The whole of this load did not, of course, come on to the cap-to-crankcase abutment area, as some of it was carried by the bearing shells. To gain some idea of the load absorbed in pressing home the shells, strips of shim steel were fitted at the joint between the two shells, and strips of equal thickness were fitted between the cap and the crankcase. By measuring the stretch of the bolt, when the nut had been tightened so as just to nip the strips under the bearing caps, a fair idea was obtained of the load needed to take up the draw of the shells and of how much remained to be carried by the abutment faces.

The results showed that, in the case of the intermediate bearings, the compression stress in the material, both on the abutment face and in the cross-wall of the case itself, was dangerously on the high side. As the bearings were line-bored in position and the nuts were all marked, and always pulled back to their original position, this might not have caused any serious trouble had not the load been increased still further by operating conditions. This additional load was the result of the difference in expansion between the steel through-bolts and the crankcase material. The caps, being in steel, did not affect the result, but the dimensions of the crankcase were such that there was a difference in expansion of nearly 0.012 in. for a rise in temperature of 100 deg. C. above that at which the bolts had been tightened.

Actual measurements showed that a temperature rise of this order could, and did, arise in the bearing housing, the bearings themselves and the housing being normally some 30 deg. C. hotter than the oil in the sump. Assuming that the limit of proportionality was not exceeded either for the steel of the bolt or for the light alloy of the crankcase, a rise in temperature of 100 deg. C. would result in a total stress in the bolt of 82,500 lb. per square inch and that in the crankcase wall, as originally designed, of nearly 18,000 lb. per square inch. The modifications already made to the crankcase had reduced the stress in the crankcase wall to 9,000 lb. per square inch but raised the stress in the bolts to 87,500 lb. per square inch and produced a load on the abutment area of the cap amounting to the alarming figure of 37,000 lb. per square inch. The yield point of the crankcase alloy was only 15,000 lb. per square inch, so that a serious deformation of the material was to be expected.

That deformation actually occurred was shown experimentally by cutting from a crankcase the intermediate bearing walls, fitting the shells and bolting down the bearing caps in the normal manner and then heating up the assembly, after first having recorded the amount of elongation of the bolts caused by tightening the nuts. The assembly was heated to 130 deg. C., representing some 110 to 115 deg. C. above the temperature at which the nuts were tightened and therefore a somewhat extreme condition. (The figure was dictated by the temperature of an oil bath which was available at the time.) On cooling again to atmospheric temperature, the average loss of elongation of the bolts was found to be just under 50 per cent., and at the same time a small crack was found to have developed at the corner of one of the cap registers, exactly as occurred under service conditions. The initial elongation of the bolts averaged 0.023 in., so that a loss of nearly 50 per cent. meant that the cap and the bearing would be raised by some 0.010 in.

The front, centre, and rear bearings being of greater length, and having therefore a larger abutment area, were in much better position to withstand the load due to expansion; especially as, in common with the intermediate bearings, the front and centre bearings had only a single bolt on each side. These three bearings were consequently little effected, with the result that the intermediate bearings could be anything up to 0.010 in. out of line with the others. Such a condition provided ample explanation of tightening-up which occurred and, even without the assistance of yet another factor, would probably have increased the bending moment on the crankshaft sufficiently to produce fatigue failures. Further, by increasing the loading on the intermediate bearings the break-up of babbit linings was accelerated and, when copper-lead linings were substituted, overheating took place on numerous occasions. In some of these latter cases the load resulting from the high temperature caused a collapse of the crankcase material sufficient to release all tension from the bolts.

Using one of the crankcase sections as a pattern, samples were cast in several different alloys. These were machined and submitted to the same treatment, and showed that alloys such as those used for aircraft engines were free from this trouble, and that, even when heated to 200 deg. C. above atmospheric temperature, the loss of bolt elongation did not exceed 0.005 in.

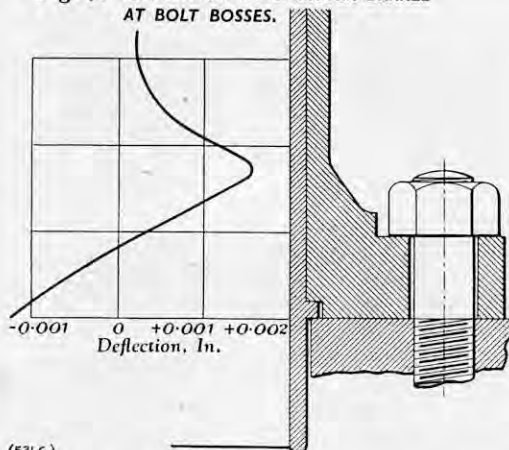
A change was therefore made to this class of alloy and this gave complete freedom from further trouble. Later, in order to reduce cost, a new design was prepared and cast in iron, the scantlings being reduced to the minimum so as to reduce weight. Although somewhat heavier, the increase was not prohibitive and this design proved materially less costly and entirely free from trouble, and to-day cast iron is used exclusively for crankcases.

The crankshaft failures were not, as it turned out, entirely due to the crankcase trouble, although they were at first assumed to be incidental damage consequent upon bearing failure. A number of breakages occurred which were unaccompanied by bearing failure, and a very careful and complete record was made of all failures and the circumstances attending them. In a large proportion of the shafts, the failure occurred towards the centre of the shaft. This ruled out the possibility that torsional vibration was the cause, because, though the sixth-order critical came in only just above the normal operating range, and might therefore have caused a certain amount of trouble, breakages in the region of No. 6 crank were almost unknown. The two-node mode of vibration was ruled out as having a natural frequency far too high to bring

* Chairman's address to the Automobile Division, Institution of Mechanical Engineers, delivered in London on October 9, 1951. Abridged.

AUTOMOBILE OIL-ENGINE DEVELOPMENT.

Fig. 7. DISTORTION IN CYLINDER BARREL AT BOLT BOSSES.



(531.C.)

a dangerous critical anywhere within the operating range.

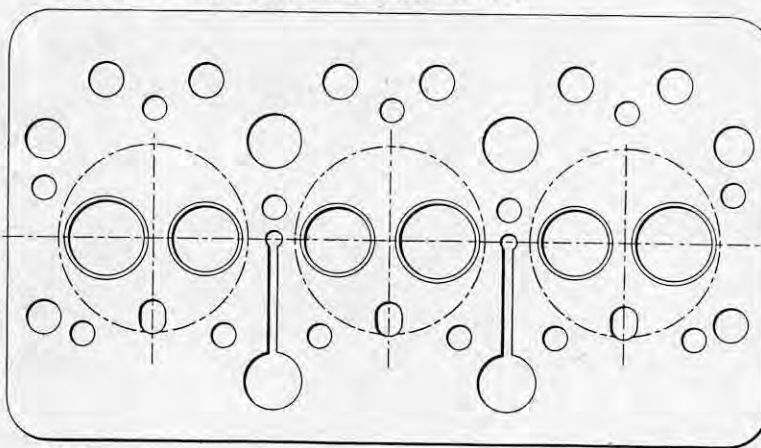
The outstanding point which emerged from the record was that by far the largest proportion of the failures occurred with cranks made from forgings procured from one particular supplier. It was found that these shafts suffered from so much distortion during rough machining, that often the shaft would not clean up during subsequent operations. In extreme cases, with the shaft supported on the front and rear bearings, the distortion amounted to as much as $\frac{1}{8}$ in. eccentricity at the centre main bearing, the average value being nearly $\frac{1}{16}$ in. It was, therefore, the practice to straighten these shafts in a hydraulic press. In the case of forgings from the alternative suppliers, the distortion which occurred was, as a rule, small enough to enable it to be corrected during the subsequent machining operations, and in only a small proportion of cases was it necessary to resort to straightening. Inquiries revealed that the troublesome forgings were stamped with all the cranks in one plane and were then twisted when hot in order to obtain the required 120 deg. between throws. Fig. 6, on page 541, which shows a rough forging and a finished shaft, will give some idea of the brutality of such treatment. From the records it became clear that the majority of failures took place at the points where the largest amount of bending was required in order to straighten the shafts.

Experiments with rotating-beam fatigue specimens made in the crankshaft material showed that whereas, when tested in the form of the standard fatigue specimen, the material had an endurance limit of ± 34 tons per square inch, and ± 18 tons per square inch in the form of a specimen grooved to provide some measure of stress concentration, the grooved specimen, after being bent to a small angle and restrengthened cold before finish-machining, had an endurance limit of only ± 9.5 tons per square inch. In actual crankshaft form, the endurance limit of the material was ± 10 tons per square inch, so that the danger of straightening the shafts cold became abundantly clear. Cold straightening was therefore ruled out and all stampings are now called for to be made with the throws stamped at the correct angle; and any shaft which distorts to an extent such that it cannot be straightened in subsequent machining operations is now straightened hot and again heat-treated—a procedure which has effectively removed this cause of failure.

A feature examined during the investigation just recorded was the effect of temperature upon a cast-iron cylinder block bolted firmly to a light-alloy crankcase, the two parts forming what is virtually a bi-metallic strip. This, however, will become important only when the cylinder block is in a single casting and reaches an appreciable length. At operating temperatures a measurable amount of bowing was found, though not such as would be likely to affect the crankshaft or the bearings. Careful measurements revealed a bowing to the extent of 0.012 in., in one case running from 0.003 in. "hogged" at atmospheric temperature to 0.009 in. "sagged" when at operating temperature; these figures represent the movement of the centre main bearing relative to the two end bearings. The crankshaft itself deflected an equal amount under a very small load at the centre, so that deflection of this order did not represent very heavy bending stress on the shaft.

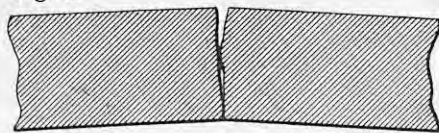
A point where a considerable stress is produced, however, is at the feet of the two ends of the block, and breakage of the cylinder feet and of the bolts has occurred at this point. Evidence of the heavy loading at this point was found on the top surface of the crankcase, where the corners of the cylinder feet had

Fig. 9. EXPANSION SLOTS IN CYLINDER HEADS.



(531.E.)

Fig. 8.



(531.D.)

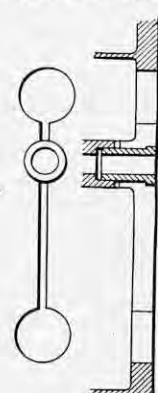
actually dug into the light alloy. This loading is accentuated by the fact that the top deck of the block is normally hotter than the lower, and the block itself tends to bow in the opposite direction. With the use of the same material for both block and crankcase this trouble disappears.

It is not unusual for the bolt bosses at the ends of the block to be made to the same dimensions as those which lie between two cylinders, but, the end bosses not deriving any assistance from a neighbouring cylinder, a design which is adequate between two cylinders may prove inadequate at the ends of the block. Even when no failures have been recorded it is surprising how much distortion can be measured in the cylinder barrel just above the bolt bosses, if the bolt bosses are not tied well back into the casting. Fig. 7, herewith, shows some distortion actually measured. The presence of a gasket under the block helps to increase the distortion.

In the early days, a good deal of trouble was caused by cracked cylinder heads. The heads themselves were made to cover three cylinder bores, and the trouble occurred most commonly over the centre bore of the three. Temperature measurements, made on the valve face of the head, showed that on these particular heads there was a wide variation in temperature, one side of the head being materially hotter than the other. Various changes in design were tried without removing the trouble. The lack of symmetry of the temperature was owing to the arrangement of the combustion chamber and was therefore unavoidable unless some means could be devised for equalising the temperature by local cooling or some such device. Attempts to effect this by directing the cooling water proved ineffective, and it was decided to try aluminium heads, with the idea that the greater conductivity of the material might result in a more even distribution of heat. This, as temperature measurements showed, it undoubtedly did, but the much greater expansion of the aluminium offset the gain in uniformity and cracking still occurred. In actual fact, the aluminium heads cracked in a number of places where the iron heads were free from trouble, but they served a very useful purpose in that they provided a clue to the real nature of the failure and indicated the direction in which to find the answer.

The examination of the cracked aluminium heads made it clear that the failures were caused by a compression stress in the lower face of the head, resulting from its inability to expand freely on account of being bolted securely to the cylinder block. With three highly heated zones in line with each other on one side of the head and with freedom of expansion restricted, the material over the centre of the three bores was subjected to a very heavy compressive stress under which it probably took a permanent set, and, on cooling off, was then subjected to a tensile stress. After a number of such reversals the material failed. In the case of the aluminium heads the fractures showed a marked lifting of the material at the edges of the crack, as shown in Fig. 8, herewith, indicative of the severe cramping to which the material had been subjected. The solution was to provide room for the metal to expand. This was done by cutting a slot right through the lower face of the head midway

Fig. 10. SLOT PASSING THROUGH STUD HOLE.



"ENGINEERING"

between adjacent bores. This slot was $\frac{1}{8}$ in. wide and extended from an existing core hole to a small hole drilled specially on the centre line, as shown in Fig. 9, herewith. At that time it was not considered desirable to extend the slot right across the head as it would have had to pass across a stud hole, and, fortunately, it did not appear necessary for it to do so. Later, on another head, the slot was carried right across, the gap at the stud hole being made good by the insertion of a steel ferrule (Fig. 10).

The immediate result was a big improvement. The cracks in the area which had troubled the iron heads were eliminated, and, though cracking of the light alloy heads was never entirely cured, the number of failures was reduced to a fraction of its former proportions. A return was therefore made to iron heads on the assumption that the remedy would be equally effective. A further incentive was that the iron heads were much less expensive and, moreover, had been free from the cracks which still appeared in the light-alloy heads. The assumption proved justified, and with a modification to the combustion chamber, which improved the temperature distribution, cracking was ultimately reduced to the occasional sample, which will probably happen as long as internal-combustion engines are built. With the greatly reduced rate of cooling loss of the present-day open combustion chamber, the use of this expansion slot has proved unnecessary.

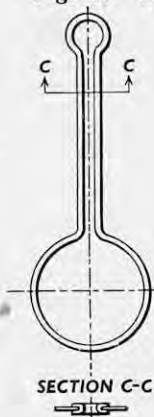
The elimination of head cracking by the use of "breathing" slots in the lower face of the head introduced a trouble with the head gaskets, which, in turn, had to be solved. The original gaskets were provided with holes to correspond with the core holes in the head from which the slots were cut. These holes had the usual eyelets, and, as was perhaps natural, it was felt necessary to make the hole in the gasket to conform with the slot in the head. This produced a keyhole-shaped opening in the gasket (Fig. 11, opposite), eyeletted in the approved fashion, although, to avoid conflict with the cylinder openings, the slot in the gasket did not extend to quite the full length of the slot in the head. In time, trouble occurred with the gasket in the form of the eyeletting, along the edge of the slot in the gasket, being pushed off by the expansion of the head and allowing water to penetrate the asbestos, with the inevitable result. Various modifications were tried before a solution was found. The first modification, shown in Fig. 12, was to make the opening pear-shaped instead of following the shape of the hole and slot in the head. This, however, made no improvement.

Then, instead of the usual form of eyeletting, two pan-shaped pressings were tried coupled together with a central eyelet, as shown in Fig. 13. This modification also failed to give satisfaction and, finally, the attempt to embrace the slot in the head by any form of opening the gasket was abandoned, and the original circular opening, embracing the cored hole only, was restored, and provided the solution. With these gaskets the effect of the expansion of the head could clearly be seen in the way the copper was forced up into the slot after a period of service. In a few instances a crack in the copper developed, but not before the gaskets had already reached the end of their normal period of life and this was never, so far as the author is aware, responsible for terminating their life.

In the very early days, trouble was caused by the thickening of the lubricating oil. The oil used at first was the same as was at that time used for petrol engines. This oil had been chosen to allow for the dilution which normally takes place in service with the petrol engine. When used for the oil engine, however, not only was there an absence of dilution, but, with the early combustion chambers, a considerable amount of

AUTOMOBILE OIL-ENGINE DEVELOPMENT.

Fig. 11. OPENINGS IN GASKET TO CONFORM WITH SLOTS IN CYLINDER HEAD.



(531.F)

Fig. 12.



Fig. 13.

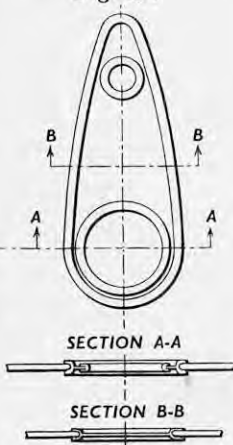


Fig. 14. FUEL CONSUMPTION AND BRAKE MEAN EFFECTIVE PRESSURE.

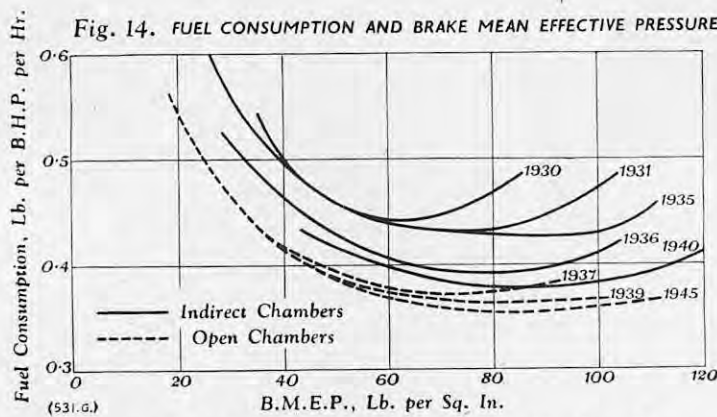


Fig. 15. FUEL CONSUMPTION AND AIR USED FOR MODERN OPEN-CHAMBER ENGINE.

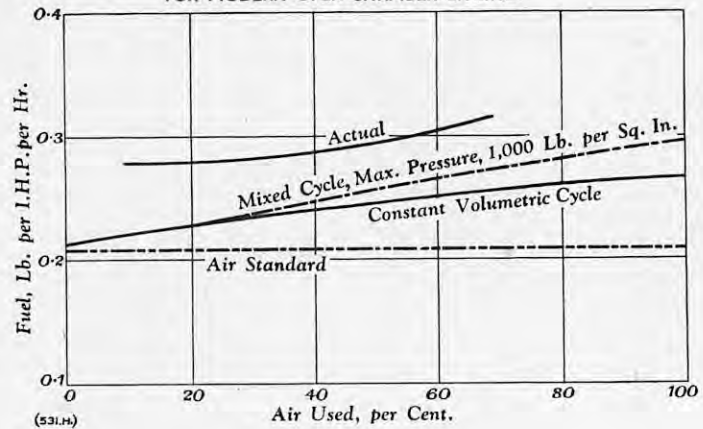
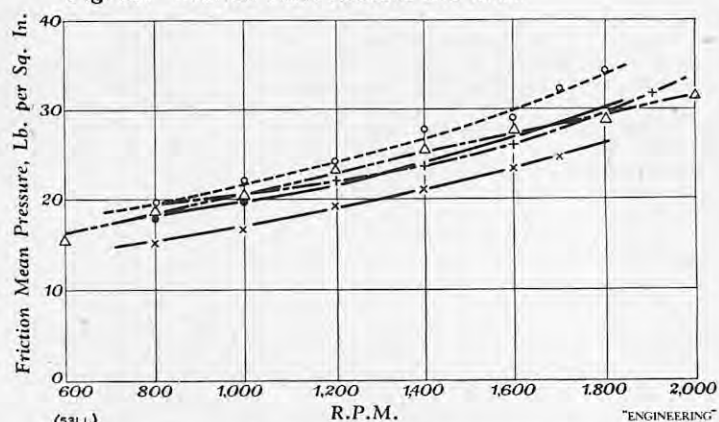


Fig. 16. FRICTION MEAN PRESSURE AND R.P.M.



carbon was absorbed by the oil on the cylinder walls and this worked its way down into the sump. At the same time, owing to oxidation, the oil itself increased in viscosity and the result was that the oil thickened to such an extent that, in extreme cases, such as when oil changing had been neglected, it assumed the consistency of thick cream. The effect of such oil on the bearings can easily be imagined. Fortunately, solvent-extracted oils made their appearance about the same time as the oil engine, and provided a solution to this particular problem. While it lasted, however, the trouble proved distinctly expensive and the complete wrecking of the engine resulted in a number of cases.

More recently, by the use of suitable additives, the ability of lubricants to withstand severe operating conditions has been greatly increased, and, although these oils first came into everyday use in the United States of America, it should be placed on record that their development is the direct outcome of the pioneer work done in Great Britain by Mr. E. A. Evans.

Although the scantling of pistons was increased materially as compared with those of the petrol engine, many piston failures occurred from a fracture starting in the lower ring groove at a point immediately above the gudgeon-pin boss. The presence of oil drain holes behind the scraper ring was a serious aggravation, as they produced a stress concentration and made fracture more likely. A generous increase in metal thickness, and the banishment of drain holes from a zone about 45 deg. each side of the pin boss, effected a cure. The splitting of the gudgeon-pin bosses along the crown and starting at the inner end of the boss was another source of trouble. This was accentuated by the persistence of some makers in drilling an oil hole right through the boss. The removal of the oil hole and the provision of ample material to transmit the load from the top of the piston to the gudgeon-pin bosses helped to remove this trouble, which was largely due to the deflection of the pin or the bosses, or both, which threw the load towards the inner edges of the bosses. Rounding off the inner end of the pin bore, to prevent the load being concentrated on the extreme end of the boss, finally cleared up this trouble.

Examples can occasionally still be seen of oil holes drilled through the upper side of the gudgeon-pin boss. This not only courts fracture, but does not assist lubrication, because a hole drilled in a heavily loaded zone of a bearing acts as a drain and not as a feeder, a fact which was demonstrated as long ago as 1885 by Beauchamp Tower's classic experiments, but which still seems not to be fully appreciated.

The best way to lubricate the pin boss, if any special

provision is really necessary, is to drill two holes, one each side of the pin, with their centre-line tangential to the pin bore and parallel with the axis of the piston, the depth of the drilling being such that the end of the drill passes a little beyond the centre of the pin hole. Oil is thereby delivered to a point on each side of the pin where no load is carried by the bearing surface and has, therefore, the best possible chance of working into the bearing. The holes themselves are in the least-stressed part of the structure.

In addition to making progress in mechanical reliability, there has been a considerable improvement in fuel economy during the past 20 years. So long as competition was with the petrol engine, the difference in fuel consumption between different types of oil engine was not very important. This remained true even for some time after fuel oil was called upon to pay the same tax as petrol, but, as the petrol engine was gradually ousted from the heavy-vehicle field, the difference in consumption between different types of combustion chamber assumed a steadily increasing importance, and every effort was made to improve the fuel consumption to the utmost. It is not possible here to give even a brief survey of combustion-chamber development and it must suffice to say that, as each type seemed to have reached its limit of development, it has been abandoned for one showing more promise, until to-day only a single type of chamber, the open combustion chamber, is in use for any of the heaviest classes of vehicle manufactured in Great Britain.

The reason for the high efficiency of the open chamber lies partly in the relatively low jacket loss consequent upon a very favourable surface-volume ratio, and partly in the avoidance of any great expenditure of energy in the production of the air movement needed to promote rapid and complete combustion, and in the fact that the combustion is completed very early in the expansion stroke so that the maximum benefit is derived from the expansion ratio.

Not all open combustion-chamber engines give equally good consumptions, and in the smaller sizes a relatively higher friction loss and a less favourable surface-volume ratio make it somewhat difficult to achieve consumption figures as low as those of the larger sizes. Fig. 14, herewith, shows some consumption figures recorded at different periods during the past two decades. These are in the form of the consumption loops at 1,200 r.p.m., this being about the speed at which most engines give their optimum results. All readings are those actually recorded, no correction having been applied.

Fig. 15, herewith, shows the consumption loop at

1,200 r.p.m. of a present-day open-chamber engine, and gives the fuel in lb. per indicated horse-power per hour, plotted against the proportion of air used. Included for comparative purposes are the indicated consumption which theoretically is possible when allowance has been made for the change both in the specific heats, and the composition of the gases with the change in air utilisation, when the maximum pressure is limited, as in the actual engine from which the figures were obtained, to 1,000 lb. per square inch, and when all combustion takes place at constant volume. For further reference the consumption corresponding to the "air standard" efficiency is shown also. The compression ratio for the engine is 16:1, the theoretical values being those for this ratio also.

The outstanding point is the very high proportion of the theoretical figure which the modern engine actually develops. These figures suggest that to obtain any further improvement in fuel per brake horse-power per hour there will have to be an appreciable reduction in the friction losses. These are not particularly high at the lower speeds, but they increase somewhat rapidly as the speed increases, as shown in Fig. 16, herewith, and affect the consumptions at the higher speeds. Any reduction in the friction figures would result in a definite improvement in the net specific consumption, especially at reduced loads, and this, being the condition under which a vehicle engine spends a large part of its time, would result in a much bigger saving in fuel than appears possible from any improvement in cycle efficiency likely to be achieved in the immediate future.

The foregoing describes some of the difficulties and troubles which were experienced in the early days of the development of the automobile oil engine, and the remedies which were applied in order to bring it to its present position as an extremely reliable and highly economical power unit. Some of the difficulties were, no doubt, peculiar to this particular design, while others were experienced in common with other manufacturers. All are now ancient history, but since they have not previously been discussed in public, they, and their remedies, may perhaps be of interest, especially if the remedies differ somewhat from those that others have used.

"AIRSTOPS" FOR HELICOPTERS.—Lord Ogmore, the Minister of Civil Aviation, has announced that helicopter passenger stations in the centres of cities and towns will, in the future, be known officially as "airstops."

LAUNCHES AND TRIAL TRIPS.

M.S. "OSWESTRY GRANGE."—Single-screw cargo vessel, with accommodation for four passengers, built and engined by R. and W. Hawthorn, Leslie & Co., Ltd., Hebburn-on-Tyne, County Durham, for the Houlder Line, Ltd. (Managers: Houlder Brothers & Co., Ltd.), London, E.C.3. Main dimensions: 450 ft. between perpendiculars by 61 ft. 6 in. by 40 ft. to upper deck. Hawthorn-Doxford four-cylinder opposed-piston oil engine, developing 3,780 b.h.p. at 100 r.p.m. in service. Speed, about 12½ knots. Launch, October 3.

S.S. "CAPE ARGOS."—Single-screw trawler, built by Cochrane & Sons, Ltd., Selby, Yorkshire, for National Sea Products, Ltd., Halifax, Nova Scotia. Main dimensions: 137 ft. between perpendiculars by 26 ft. 6 in. by 13 ft. 9 in.; gross tonnage, 395. Triple-expansion steam engines, developing 700 i.h.p. and one oil-burning boiler, constructed and installed by Amos and Smith, Ltd., Hull. Launch, October 3.

M.S. "LONDON GLORY."—Single-screw oil tanker, built by Sir James Laing and Sons, Ltd., Sunderland, for London and Overseas Freighters, Ltd., London, W.1. First vessel of an order for three. Main dimensions: 475 ft. between perpendiculars by 67 ft. 4½ in. by 37 ft. 4 in.; deadweight capacity, about 15,300 tons on a summer draught of 29 ft. Four-cylinder opposed-piston oil engine, constructed by William Doxford & Sons, Ltd., Sunderland. Service speed, 12½ knots. Launch, October 4.

M.S. "BOLLSTA."—Single-screw oil tanker, built and engined by Harland and Wolff, Ltd., Govan, Glasgow, for Fred Olsen & Co., Oslo, Norway. Main dimensions: 580 ft. between perpendiculars by 78 ft. by 42 ft. 6 in. to upper deck; deadweight capacity, 24,000 tons on a draught of about 32 ft. Harland-B. and W. seven-cylinder single-acting two-stroke opposed-piston eccentric type oil engine. Trial trip, October 6.

M.S. "ILIAD."—Single-screw oil tanker, built and engined by Harland and Wolff, Ltd., Govan, Glasgow, for the joint ownership of the Société Navale Delmas-Vieljeux and the Société Anonyme Courtage et Transports, Paris. Main dimensions: 540 ft. between perpendiculars by 73 ft. by 39 ft. 3 in. to upper deck; deadweight capacity, about 18,700 tons. Harland-B. and W. six-cylinder single-acting two-stroke opposed-piston eccentric-type oil engine. Launch, October 11.

M.S. "PROMETHEUS."—Single-screw oil tanker, built and engined by Burmeister & Wain, Copenhagen, Denmark, for Jacob Odland S.S., Haugesund, Norway. Main dimensions: 465 ft. between perpendiculars by 62 ft. 10½ in. by 34 ft. 8 in. to main deck; deadweight capacity, about 13,250 tons on a draught of 27 ft. 4 in.; capacity of cargo tanks, about 632,000 cub. ft. Six-cylinder two-stroke single-acting direct-reversible oil engine, developing 4,600 b.h.p. at 110 r.p.m. Speed, 14 knots, fully loaded. Launch, October 11.

M.S. "CHAKDARA."—Single-screw cargo liner, carrying twelve passengers, built and engined by Barclay, Curle & Co., Ltd., Whiteinch, Glasgow, for the British India Steam Navigation Co., Ltd., London, E.C.3. Main dimensions: 485 ft. by 62 ft. 6 in. by 40 ft. 9 in. to shelter deck; deadweight capacity, about 10,000 tons on a draught of 27 ft. 3 in.; gross tonnage, 7,150; cargo-carrying capacity, 562,800 cub. ft., including 12,800 cub. ft. insulated. Barclay Curle-Doxford six-cylinder opposed-piston solid-injection oil engines, developing 6,800 b.h.p. at 116 r.p.m. on service. Loaded speed, 14½ knots. Trial trip, October 12.

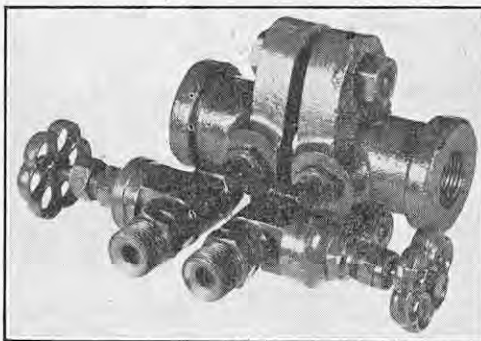
M.S. "CHAKRATA."—Single-screw cargo vessel, accommodating twelve passengers, built and engined by Swan, Hunter, and Wigham Richardson, Ltd., Newcastle-upon-Tyne, for the British India Steam Navigation Co., Ltd., London, E.C.3. Main dimensions: 455 ft. between perpendiculars by 62 ft. 6 in. by 40 ft. 9 in. to shelter deck; deadweight capacity, about 9,600 tons on a draught of 27 ft. 3 in.; gross tonnage, 7,150; cargo-carrying capacity, 94,000 cub. ft. insulated and 423,000 cub. ft. uninsulated. Swan Hunter-Doxford opposed-piston oil engine, developing 6,800 b.h.p. at 116 r.p.m. Service speed, about 15 knots. Launch, October 15.

M.S. "STANHOPE."—Single-screw cargo vessel, built by Short Brothers, Ltd., Sunderland, for the Stanhope Steamship Co., Ltd., London, E.C.2. Main dimensions: 435 ft. between perpendiculars by 58 ft. 9 in. by 38 ft. to shelter deck; deadweight capacity, 10,150 tons on a summer draught of 25 ft. 11 in. N.E.M.-Doxford four-cylinder opposed-piston airless-injection oil engine, to develop 3,300 b.h.p. at 109 r.p.m., constructed by the North Eastern Marine Engineering Co. (1938), Ltd., Wallsend-on-Tyne. Service speed, 12 knots. Trial trip, October 16.

M.S. "JUAN PERON."—Twin-screw whale factory ship, built and engined by Harland and Wolff, Ltd., Belfast, for the Compañía Argentina de Pesca, Soc. Anon., Buenos Aires. Main dimensions: 635 ft. between perpendiculars by 80 ft. by 36 ft. to tank deck; gross tonnage, 24,570. Two Harland-B. and W. six-cylinder Diesel engines. Trial trip, October 16.

APPARATUS FOR MEASURING VISCOUS-FLUID FLOW.

UNTIL recently, it has not been considered practicable to measure the rate of flow of viscous fluids by the orifice method since, below a certain Reynolds number, the coefficient of discharge ceases to be uniform with Reynolds number. A new type of orifice, known as the PL, has, however, been introduced this year by Messrs. George Kent, Limited, Luton, Bedfordshire, in which the discharge coefficient remains constant to a much lower value of Reynolds number than that of the standard square-edged orifice, and consequently, it can be used for measuring the flow of relatively viscous oils and fluids. Below the limiting value of Reynolds number for uniform discharge, in a square-edged circular orifice the discharge coefficient tends, initially, to increase as Reynolds number is reduced; whereas, in a Venturi tube, the discharge coefficient falls with decreasing Reynolds number. In the PL orifice, a successful attempt has been made to balance these two viscosity effects. It consists of a fairly thick stainless-steel plate, from ⅛ in. thick upwards, depending on



the diameter of the oil pipe, with a circular orifice, having a short conical entrance followed by a short parallel section, and is used with "corner tap" pressure connections—i.e., the tappings are flush with the boundary of the orifice plate.

The PL orifice can be fitted in horizontal or vertical pipelines. It can be supplied as a plate to be clamped between the existing flanges of the oil pipeline, for pipes of 1 in. diameter and upwards; in this case, the space required for the installation is only the thickness of the plate plus the jointing washers. Two shut-off cocks are also supplied for screwing into the pressure tappings. Alternatively, the PL orifice can be supplied for 1-in. and 2-in. diameter pipelines in a self-contained carrier unit, as shown in the accompanying illustration, comprising a gun-metal carrier in two sections, an orifice plate and shut-off cocks.

The orifice is normally used in conjunction with a Kent 120-in. water-gauge standard mercurial meter type KM. With a meter designed for a maximum flow of 125 gallons an hour, the maximum limiting viscosity for accurate flow measurement is 200 Redwood No. 1 seconds; for a maximum flow of 128,000 gallons an hour, the maximum limiting viscosity is 6,300 Redwood No. 1 seconds. If only a small flow range is to be measured, however, the upper limiting viscosity may be increased two or three times. It can be increased by using a 240-in. water-gauge meter in place of the 120-in. meter.

NEW DIESEL-ELECTRIC LOCOMOTIVE.—The English Electric Company, Limited, Kingsway, London, W.C.2., have recently completed the third, No. 10202, of the main-line Diesel-electric locomotives for British Railways. The engine develops 1,750 brake horse-power.

THE DUNAPENTELE IRON WORKS, HUNGARY.—A new Hungarian iron and steel works at Dunapentele, 40 miles from Budapest, is due to commence production on November 7, when the first tapping of iron will be made from a blast furnace. Suitable coke will be produced from soft coal obtained from the Komló and Pécs mines in a coke-oven battery consisting of 51 ovens. A total of 810,000 tons of coal a year will be utilised in the coke-oven plant, the gas being used in open-hearth steel furnaces and also for generating electricity. The by-products from the coke ovens will pass on to an adjacent chemical works. The iron ore is to be imported, ready graded and concentrated, from the Soviet Union. Like the coal it will be conveyed by barge down the Danube to a port specially constructed to serve the new works. Four 125-ton open-hearth steel furnaces are being built and a further four furnaces are contemplated. A new residential town to house the employees has been constructed and 12,000 workpeople are already installed there. The town is separated from the Danube Valley Iron Works, as they are called, by a belt of trees 2½ km. (1·6 miles) in length, and 400 m. (437 yards) wide.

BOOKS RECEIVED.

Department of Scientific and Industrial Research. *Report of the Water Pollution Research Board, with the Report of the Director of Water Pollution Research for the Year 1950.* H.M. Stationery Office, Kingsway, London, W.C.2. [Price 1s. 6d. net.] See page 498, ante.

Mechanical Engineers' Handbook. Edited by PROFESSOR LIONEL S. MARKS. Fifth edition. McGraw-Hill Publishing Company, Limited, Aldwych House, Aldwych, London, W.C.2. [Price 107s. 6d.]

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Mitteilungen aus dem Institut für Aerodynamik an der eidgenössischen technischen Hochschule in Zürich. No. 18. *Experiments on Aerodynamic Cooling.* By DR. LLOYD F. RYAN. *Untersuchungen an einem Gegenlaufpropeller im Windkanal.* By M. DEGEN. Verlag Leemann, Stockerstrasse 64, Zürich, Switzerland. [Price 12 Swiss francs.]

Werkstatthbücher. No. 101. *Hydraulische und mechanische Triebe für Geradwege an Werkzeugmaschinen.* By DR.-ING. HANS RÖGNITZ. [Price 3·60 D.M.] No. 104. *Längenmessungen.* By DR.-ING. HANS SCHMIDT. [Price 3·60 D.M.] Springer-Verlag, Reichpietschufer 20, Berlin W.35, Germany.

Rugby Engineering Society. Proceedings. Session 1950-51. Volume XLII. The Secretary, Rugby Engineering Society, c/o The British Thomson-Houston Company, Limited, Rugby. [Price 10s. 6d.]

Det Kongelige Danske Videnskabernes Selskab. Matematisk-fysiske Meddelelser, vol. 26. No. 10. *Synchronisation of Air-Jet Generators with an Appendix on the Stem Generator.* By JUL. HARTMANN and ERIK TRUDSØ. [Price 5 kronen, or 1 dol.] No. 11. *The Air-Jet Generator as a Means for Setting up Waves in a Liquid Medium.* By JUL. HARTMANN and F. LARRIS. [Price 3 kronen, or 75 cents.] Ejnar Munksgaard, 6, Nørregade, Copenhagen, Denmark.

Investigations into the Structural Use of Aluminium in Ships. A Summary, 1943-1950. By W. MUCKLE. Research Report No. 10. The Aluminium Development Association, 33, Grosvenor-street, London, W.1. [Price 7s. 6d.]

National Physical Laboratory. Units and Standards of Measurement Employed at the National Physical Laboratory. I. Length, Mass, Time, Volume, Density and Specific Gravity, Gravity, Force and Pressure. H.M. Stationery Office, Kingsway, London, W.C.2. [Price 9d. net.]

Memorandum on Safety Precautions Recommended for Workers in Wells. The Institution of Civil Engineers, Great George-street, London, S.W.1. [Price 1s. 6d. post free.]

Simplified Mechanics and Strength of Materials. By PROFESSOR HARRY PARKER. John Wiley and Sons, Incorporated, 440, Fourth-avenue, New York 16, U.S.A. [Price 4·75 dol.] and Chapman and Hall, Limited, 37, Essex-street, Strand, London, W.C.2. [Price 35s. net.]

Steel Serves the Nation, 1901-1951. The Fifty Year Story of United States Steel. By DOUGLAS A. FISHER. United States Steel Corporation, 71, Broadway, New York 6, U.S.A. [For private circulation.]

Electrolytic Polishing and Bright Plating of Metals. By DR. S. WERNICK. Second edition. Alvin Redman Limited, 4, Fitzroy-street, London, W.1. [Price 30s. net.]

Refrigeration Principles and Practice. Edited by DR. EZER GRIFFITHS. George Newnes Limited, Tower House, Southampton-street, Strand, London, W.C.2. [Price 42s. net.]

Industrial High Vacuum. By J. R. DAVY. Sir Isaac Pitman and Sons, Limited, Pitman House, Parker-street, Kingsway, London, W.C.2. [Price 25s. net.]

Industrial Administration and Management. By F. L. MEYENBERG. Sir Isaac Pitman and Sons, Limited, Pitman House, Parker-street, Kingsway, London, W.C.2. [Price 35s. net.]

Ohio State University Engineering Experiment Station. Bulletin No. 143. Further Studies of Ohio Coals and Oil Shales. Part I. Some Studies of Ohio Coals and Oil Shales. By PROFESSOR PETER O. KRUMIN. Part II. *Ohio Coals.* By WILLIAM H. SMITH. Part III. *Ohio Shales and Cannel Coals.* By CHARLES H. BOWEN. [Price 1 dol.] No. 144. *Studies of Compressive Stress Distribution in Simply Reinforced Concrete near the Point of Failure.* By LESTER A. HERR and PROFESSOR LOUIS E. VANDEGRIFT. [Price 50 cents.] The Director, Engineering Experiment Station, Ohio State University, Columbus, Ohio.

"Hütte." *Taschenbuch für Betriebsingenieure.* Fourth revised and enlarged edition. Part I. Wilhelm Ernst und Sohn, Hohenzollerndamm 169, Berlin-Wilmersdorf, Germany. [Price 36 D.M.]; and Lange, Maxwell and Springer, Limited, 41-45, Neal-street, London, W.C.2. [Price 63s.]