SINGLE-PHASE ELECTRIC TRACTION AT 50 CYCLES.

(*Continued from page* 522.)

The Aix-les-Bains to La Roche-sur-Foron section is supplied from the Annecy substation through two feeders, each of which consists of copper wire with a cross-section of 0·23 sq. in. In order to ensure continuity of supply these are connected to the contact line at the entry to and exit from each station and, as shown in Fig. 5, each section can be isolated by rotary switches, which are installed in the stations or near an operating post. There is also a neutral section at Aix-les-Bains where the single-phase and direct-current systems join. Two arrangements of contact wire systems are used: the vertical or polygonal and the inclined or hyperbolic. The former is employed between Aix-les-Bains and Albens and between Annecy and St. Laurent, a total length of about 28 miles, and the latter between Albens and Annecy and between St. Laurent and La Roche-sur-Foron, a distance of 22 miles. In the former, the contact wire and its catenary lie in the same vertical plane, the contact wire being maintained in position by adjustable arms. On curves, therefore, the contact wire forms a polygon, the angles of which are at the supports. The length of the sides of this polygon are some multiple of 4·5 m. and are such that the sag, which coincides with the circle circumscribing the polygon, does not exceed 0·4 m. In alignment the contact wire zig-zags from one side to the other of the centre line of the track, the maximum deviation being 0·2 m. On the other hand, with the hyperbolic system the contact wire generally follows the axis of the track on curves, while on straight stretches it is forced by the catenary to trace a succession of curves on either side of that axis.

In both cases, the contact wire consists of hard-drawn grooved copper wire 107 sq. mm. in section and the catenary of 60 per cent. conductivity bronze with a cross section of 65 sq. mm. The catenary is suspended from two cap insulators of the conventional type, which are fixed to a bracket. On curves of a radius less than 600 m., two insulators, consisting of rods arranged to form a V, are employed. The polygonal overhead line is provided with tensioning devices at intervals of 1,000 to 1,500 m. These consist of a soft-steel cable with a hemp core, one end of which supports a counterweight, while the other runs over a pulley and thence on to a drum. The cable next passes over a second pulley to the supporting arm. A safety device is fitted, so that should the tensioning wire break the pull due to the counterweight is taken up. On the hyperbolic overhead line, on the other hand, the radial tension of the contact wire is transmitted to the catenary by droppers and thence to steadying arms. The contact wire is attached to the droppers by hooks, which allow the droppers to swing through 10 deg. on either side. The line is only anchored at the entrance and exit of each section but, in order to limit the effects of any breakage, it is secured to the catenary every 1,500 m. by an auxiliary cable which, in turn, is anchored to the supports.

The steel supports, which are usually erected about 2·4 m. from the centre of the track, are earthed to the running rails by a copper wire 7 mm. in diameter. Generally speaking, two types of assembly have been used, one consisting of long masts to which horizontal brackets are fixed and the other of shorter masts, the brackets on which are inclined. In both cases the brackets are fixed to the mast through a joint so that the point of suspension of the catenary can be adjusted in planes both at right-angles and parallel to the track. The supports have been arranged so that at the majority of over-crossings the catenary lies at the lowest point of its span. In other cases it is anchored to the side walls of the structure. Where polygonal suspension has been used, it has been possible to run the contact wire under the structure without making use of any special arrangements. Where, however, the inclined overhead line has been employed, it has been necessary to fix a spring on both sides of the structure, so as to limit the distance the contact wire can rise either at low temperatures, or when it is forced up by the pantograph. Where current-carrying parts pass under the structure, the side walls are protected by expanded metal sheets. At level-crossings the contact wire usually lies at least 20 ft. above the track, but where this is impossible a steel framework has been erected on each approach to prevent any loads on road vehicles coming into contact with the line.

There are eight tunnels on the electrified line, four of which are of circular and four of elliptical section. In general, the overhead line is suspended over the centre of the track, but in one case, where there is a curve, the inclined system is used and in another, on a straight stretch, the "undulated" system is employed. An extra insulator is added to the suspension system in the tunnels to counteract the effect of vapour from the steam locomotives which are still being used. In certain places, the track has had to be lowered to provide additional clearance. In the open country, where the trains will run at high speeds, the overhead system has been sectionalised by air gaps, but at the stations and sidings insulators of two types are used for this purpose. One of these is designed so that it takes up both the tension and the torque of the anchored contact wire. The second comprises two insulators, one of which takes up the tension and the other the compression.

The steel supports are set in concrete bases which vary in diameter from 1 ft. 9 in. to 1 ft. 11 in. and are 6 ft. 7 in. deep. The holes for about half of these bases were excavated by a special machine, consisting of a boring tool carrying two blades, which were rotated and moved up and down by a 20-h.p. motor operating through gearing and a rack and pinion. Where rock was encountered, or where it was necessary to place the support more than 6 ft. from the track, the holes were excavated by hand. The supports were lowered into the bases by crane and packed temporarily until the concrete, which was poured from plant carried on a specially equipped train, had set. A special train was also used for stringing the catenaries and contact wires. Although in most cases the positions of the existing signals did not have to be altered, it was necessary to replace the direct-current track circuits by others operating on the two running rails with alternating current at a frequency of 83 cycles; by rail circuits isolated on a single running rail and operated by

Fig. 5. ELECTRICAL DIAGRAM OF LINE.

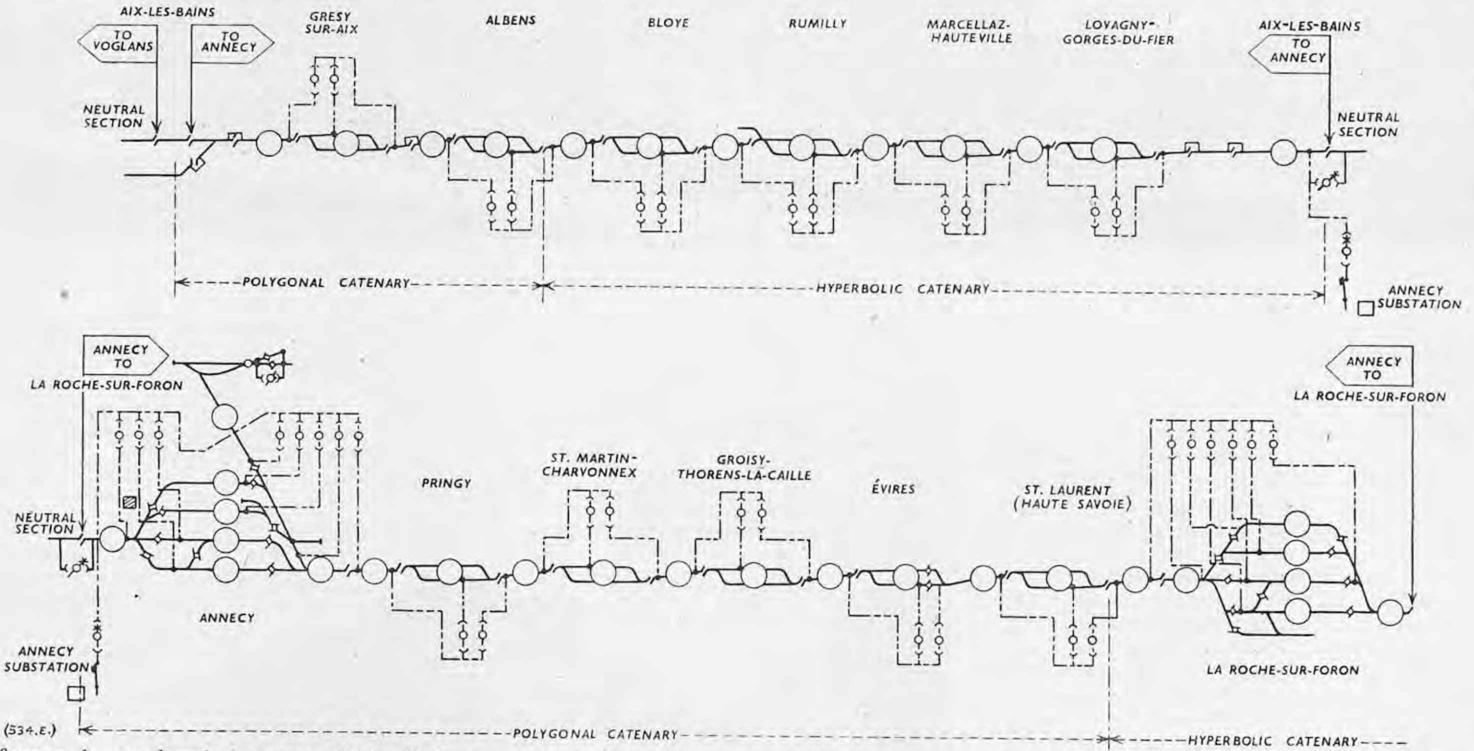
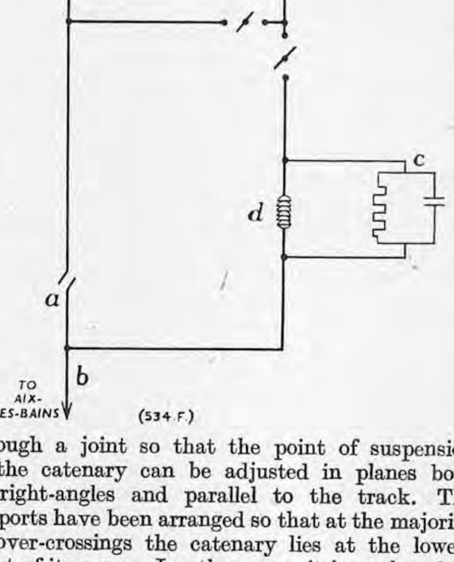


Fig. 6. ARRANGEMENT OF CAPACITOR STATION.



SINGLE-PHASE ELECTRIC TRACTION AT 50 CYCLES.

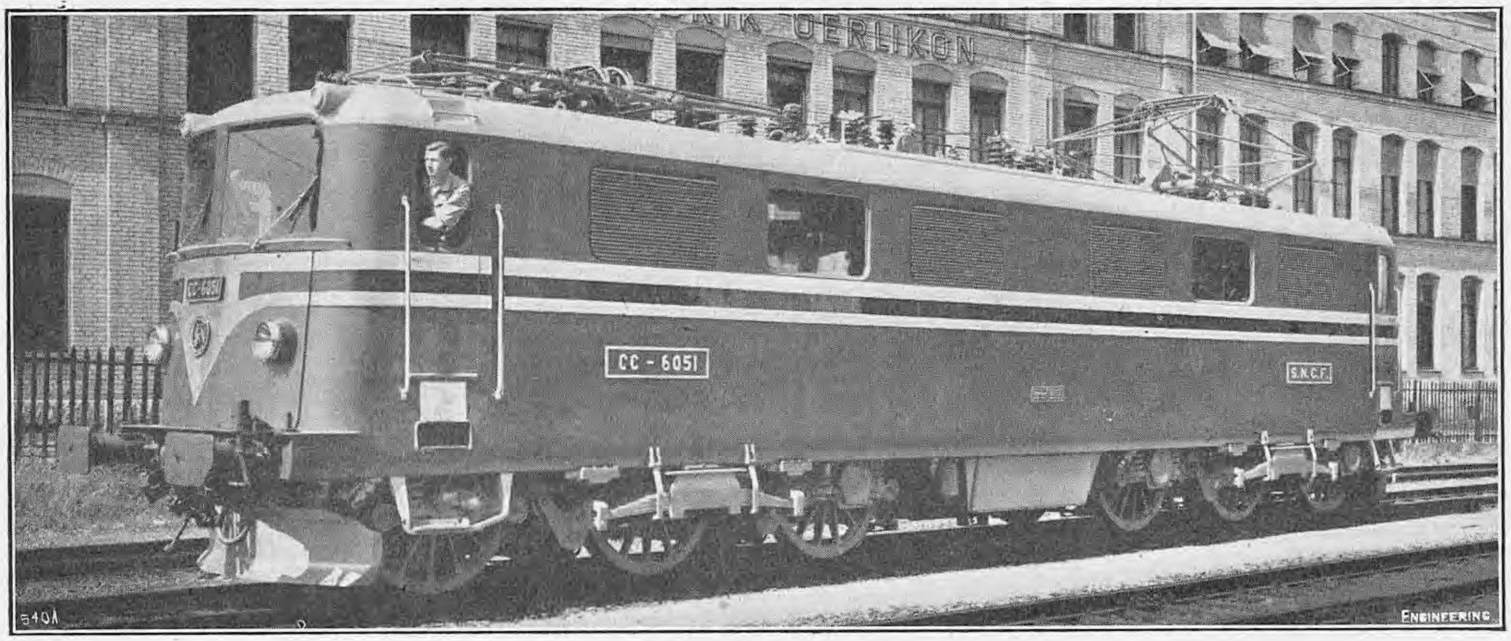


Fig. 7. C_0–C_0 Oerlikon-Winterthur Locomotive.

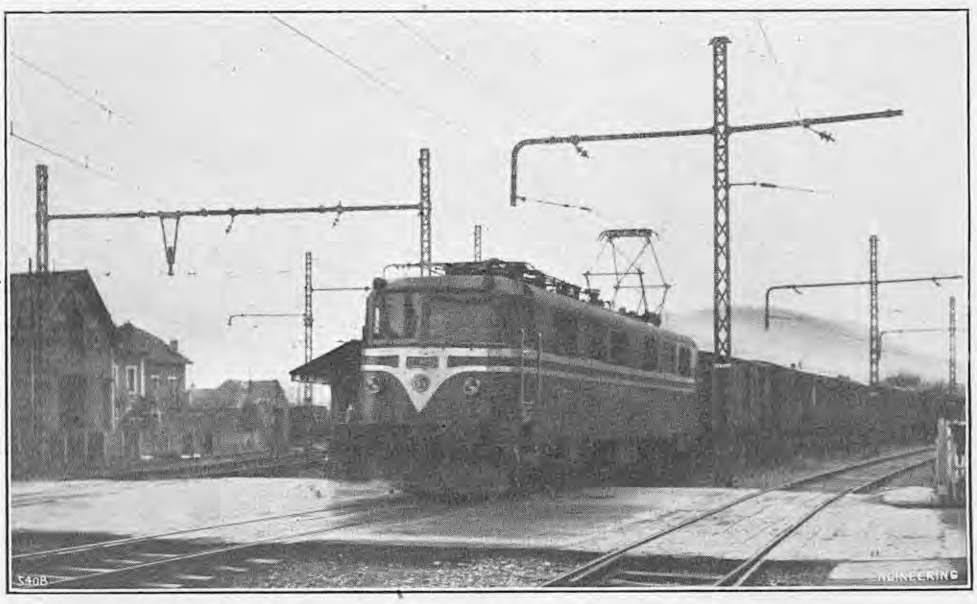


Fig. 8. Locomotive in Service.

pulsating current; and by circuits also isolated on one rail but fed by direct current. The overhead telephone lines had also to be replaced by underground cables.

An incidental problem which arose in connection with the electrification of the Aix-les-Bains—La Roche-sur-Foron section was how best to maintain the desired voltage on the contact wire in view of the fact that initially there is only one point of supply, and this is at the end of a low-capacity feeder. Possible solutions of this problem were the installation of on-load tap changers on the main transformers, of auto-transformers distributed along the line and of either shunt or series capacitors. After consideration of these alternatives it was decided that the employment of series capacitors would be most economical both in time and money. Their use had the further advantage of being simple, since the only ancillary apparatus required is some form of protection against short-circuits. Eight batteries of series capacitors were therefore installed along the line, two with capacities of 320 kVA, at Albens and Marcellaz, and two with capacities of 160 kVA, at Bloye and Rumilly. As will be seen from Fig. 6, on page 545, which is a diagram of the arrangement, air-break switches *a* are installed, in the overhead line *b* on each side of the station, and the capacitor batteries *c* are inserted in feeders linking the two sections. Either battery can be short-circuited by the isolator *d*.

The capacitors, which are housed in concrete buildings, are of the standard indoor type and consist of paper immersed in Pyralene, which has a higher specific inductive capacity than oil, besides being non-inflammable. Those at Marcellaz and Rumilly, which were manufactured by the Société Savoisienne de Constructions Electriques, consist of 36 cylindrical elements, each with a capacity of 24 microfarads, which are mounted on frames. The capacitors at Albens and Bloye are of rectangular type and each has a capacity of 10 microfarads. Series, parallel and semi-parallel connections are all used; and the batteries can be shunted with resistances for discharging the individual capacitors when the latter are disconnected from the line. These resistances also allow the impedance of the combination to be adjusted and, by ensuring the metallic continuity of the line, prevent the building up of dangerous voltage. Each capacitor element is provided with a fuse as a protection against internal short-circuit, and each battery with lightning arresters, which operate when an excessive rise in the voltage across the terminals occurs. Each battery is also shunted by a contactor which opens where the line current exceed a specified value. Finally, a maximum-current relay trips the feeder circuit-breaker in the Annecy sub-station when the line current exceeds a value which might damage the capacitors. These capacitor batteries have now been in service for at least four months and allow the voltage to be increased from 1,600 to 1,700 volts when the current in the outgoing feeder at Aix-les-Bains reaches 150 amperes.

Before describing the 50-cycle single-phase electric rolling stock, which is being used on the Aix-les-Bains–La Roche-sur-Foron section of the French railways, it is advisable to deal with certain technical problems relating to the motors employed. It is this part of the equipment, which, as Mr. A. Garreau said in the paper which he presented at the Annecy Conference, that gives rise to basic difficulties. As is well known, series-wound commutator motors are generally used on both direct-current and single-phase systems, as their power/speed characteristics are admirably suited for traction purposes. Moreover, they are of robust construction. Compared with the direct-current motor, however, the high self-induction which occurs in single-phase motors necessitates a reduction in the specific output, although this is not a grave defect and is no worse at 50 than at $16\frac{2}{3}$ cycles. A more important drawback is that at the higher frequency, power factor difficulties increase, owing to the reactance both of the motor and of the overhead line.

The main difficulty with the single-phase series motor, however, is that associated with commutation; for, where an armature coil is short-circuited by the brushes, it is subjected to an electromotive force which can be resolved into two components in quadrature. One of these is set up, as in the direct-current motor, by the reversal of the current and, as it is proportional to the speed, is often known as the "dynamic" electromotive force. The other component is induced by the pulsations of the alternating-current flux, as is the case in a transformer, and is known as the "static" flux; it is independent of the speed, but is proportional to the field flux and to the frequency. As was discovered by Behn-Eschenburg in 1904, the dynamic electromotive force can be compensated by the use of interpoles, with the windings of which a resistance is connected in parallel to ensure the correct phasing of the flux. To provide perfect commutation, a different resistance is, however, necessary for each speed, but as the provision of these is obviously impossible in practice, one resistance suitable for compensating at the average speed of the motor is chosen. At higher or lower speeds than this, compensation becomes progressively worse and at starting is non-existent. Indeed, it is inadvisable, if not impossible, to run for long periods at speeds less than about one-third of the maximum.

On the other hand, the static flux cannot be compensated and, as its value is proportional to the frequency, it is desirable that the latter should be

SINGLE-PHASE ELECTRIC TRACTION AT 50 CYCLES.

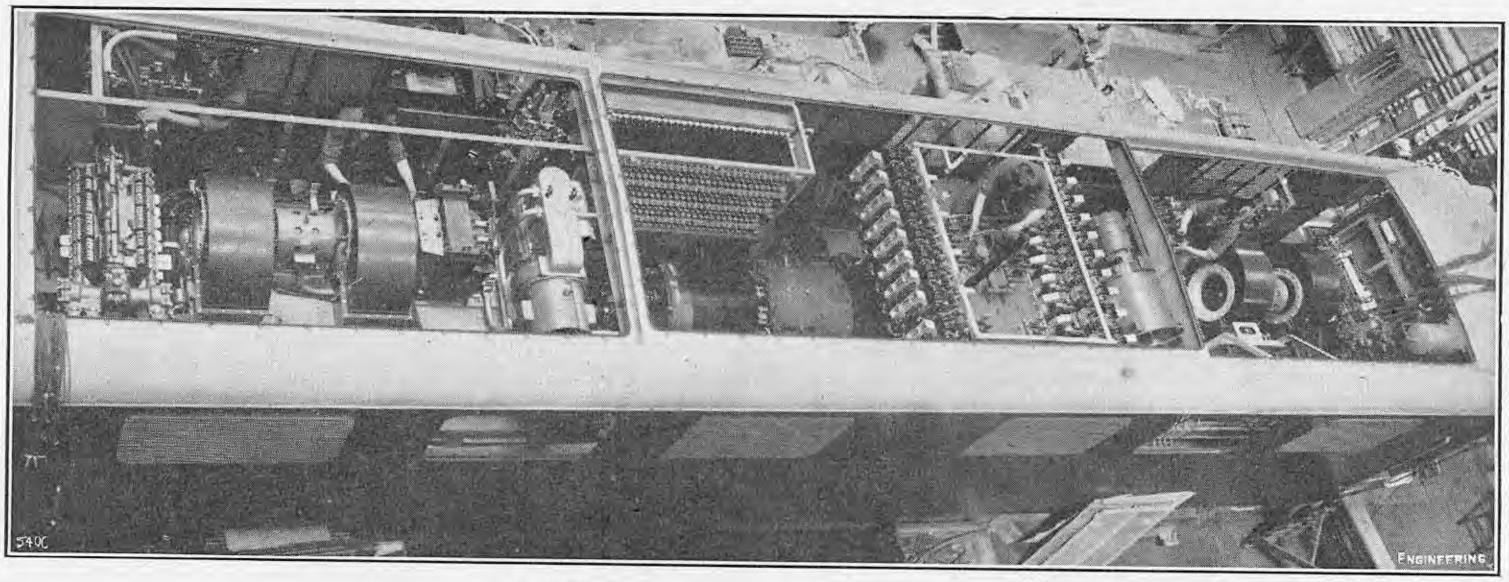


Fig. 9. Locomotive under Construction.

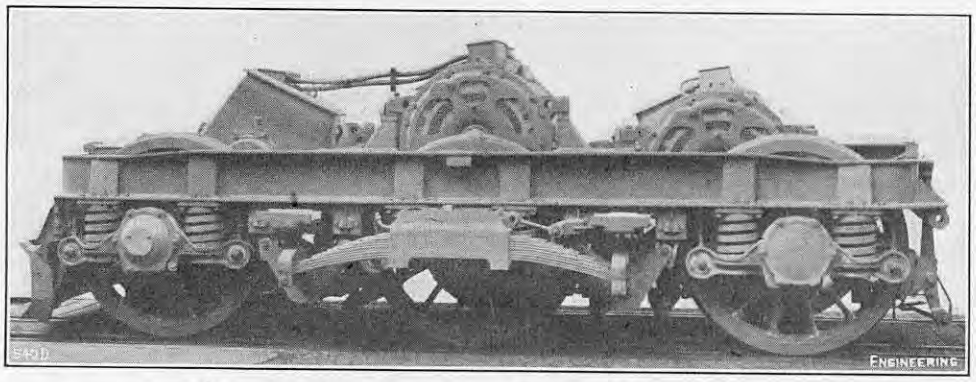


Fig. 10. Bogie, with Traction Motors.

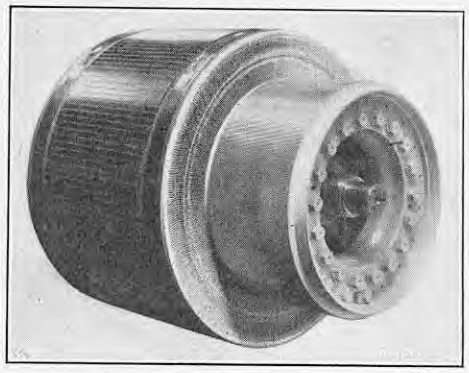


Fig. 11. Traction-Motor Rotor.

kept as low as possible. It is, in fact, for this reason that a low frequency has been so widely adopted for single-phase traction. Since an increase in the static flux, which would occur when 50-cycle traction is employed, is inadmissible, the only method of effecting compensation is to decrease the flux per pole and consequently to increase the number of poles for a given output. As the distance between the brush holders cannot be reduced for technical reasons, it follows that the diameter of the 50-cycle motor must be larger than that of a $16\frac{2}{3}$-cycle motor of similar power. At the same time, the lower value of the flux per pole at 50 cycles leads to a reduction in the voltage and, consequently, to larger current, which in turn means larger commutators. These increases can, however, be compensated to some extent by raising the speed of the armature and therefore of the commutator, by improving the ventilation, by subdividing the commutator, and by reducing the losses by a better arrangement of the coils. As a result, it has been found possible, with 50 cycles, to use a value of flux per pole which is sensibly greater than one third of that obtained at $16\frac{2}{3}$ cycles. It is also possible to employ a greater number of poles at 50 than at $16\frac{2}{3}$ cycles with a given diameter of motor. Further, adjustable auxiliary poles can be fitted and the zone of good commutation thus extended. While, naturally, this is an added complication, it may be worthwhile where the locomotive is required to operate on services of varying types.

Owing to the effect produced by the static electromotive force on the main flux, there may be some reduction in the starting torque, but information on this subject is not at present very precise. The combined reactance of the transformer and of the motor, which may be considerable at 50 cycles, results in the inclination of the tractive effort/speed curves to the speed ordinate being small. This has the advantage that it is possible to obtain equally

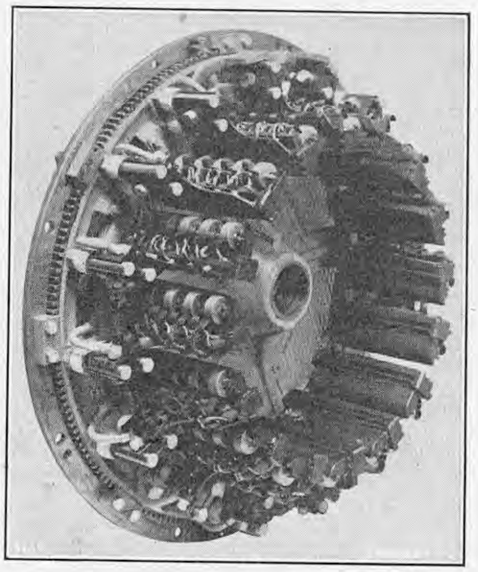


Fig. 12. Traction-Motor Brush Gear.

smooth starting at 50 cycles with a reduced number of controller switches and hence to simplify the electrical equipment. On the other hand, the effect on the adhesion is unfavourable and recovery from slipping may therefore be difficult.

Although the power factor depends to some extent on the current, it is generally proportional to the speed, being about 0·89 at 70 per cent. of the maximum speed. Compared with the $16\frac{2}{3}$-cycle motor, the efficiency of the 50-cycle motor is less—84 as against 90 per cent. Although the 50-cycle motor is more bulky than that for the lower frequency, it is only of moderate weight.

The brush wear with the 50-cycle motor is about two to three times as great as with the direct-current motor, and is even higher at starting and at maximum speeds. As the number of brushes is about five times as much, the total wear is 15 times higher. Actually, however, the cost of maintenance due to this item is small.

Turning to the rolling stock, an illustration of the 4,300-h.p. C_0-C_0 Oerlikon-Winterthur locomotive which is being used in the French trials is given in Fig. 7, and a train in service is shown in Fig. 8. The locomotive has a maximum load of 18 metric tons per axle and is designed for dealing with mixed traffic on lines with gradients up to 2·5 per cent. It is supplied with single-phase 50-cycle current at a normal voltage of 20 kV, with a permissible range of variation from 16 kV to 23 kV. It will also be possible to operate it from the 1,500-volt direct-current supply. At a voltage of 20 kV, the locomotive is rated to haul a load of 630 metric tons at a speed of 60 km. per hour on a gradient of 1·5 per cent., and a load of 430 tons on a gradient of 2·5 per cent. at the same speed. It is also capable of hauling a load of 1,350 metric tons continuously on the level at a speed of 80 km. per hour and of 780 tons on a gradient of 1 per cent. at 65 km. per hour. Its maximum speed is 100 km. per hour. Characteristic curves of its performance are reproduced in Fig. 14, in which *a* shows the continuous, *b* the one-hour, and *c* the maximum tractive effort, while *d* indicates the effort on the last controller notch. The continuous, one-hour and maximum tractive effort when direct-current at 1,500 volts is employed is shown by curves *e*, *f* and *g*, respectively, and the braking efforts which are obtained from electric regenerative brakes at this one-hour and maximum ratings are indicated at *h* and *i*. The total weight of the mechanical parts is 60·9 tons and of the electrical equipment 42·2 tons; the total weight in running order is 104 tons.

The mechanical portion, which was constructed

SINGLE-PHASE ELECTRIC TRACTION AT 50 CYCLES.

Fig. 13.

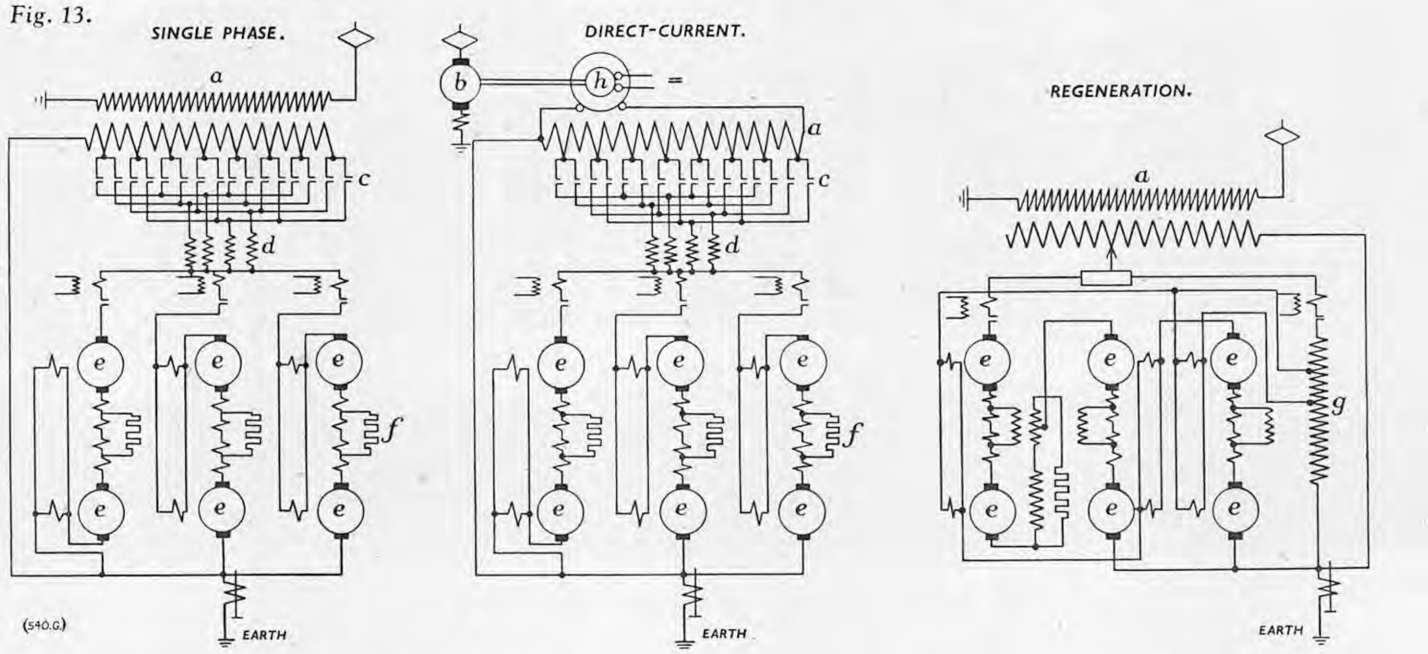


Fig. 14.

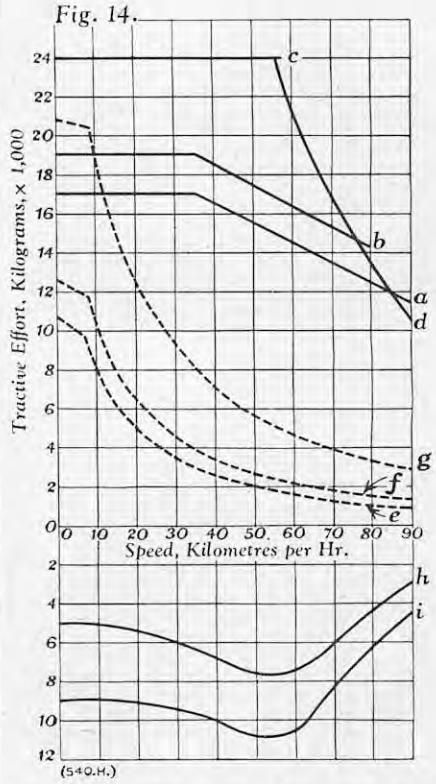
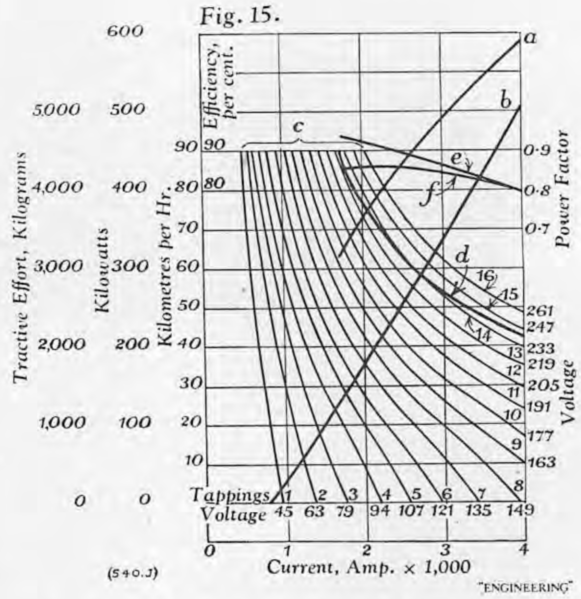


Fig. 15.



by the Société Suisse pour la Construction de Locomotives et de Machines, Winterthur, consists of a single body which is borne through two longitudinal laminated springs and swinging bolsters on each of two three-axle bogies. These bogies, one of which is shown in Fig. 10, on page 547, rotate about two pivots which are arranged symmetrically. on either side of the central axle. The primary suspension is by damped coil springs. The axle-boxes are retained by vertical cylindrical guides, which are secured to them by "Silentblocs." Transmission to the 1,400-mm. diameter wheels is effected on the firm's "floating ring" system.

Power is obtained from the overhead line through two pantographs, only one of which is normally employed at a time. When single phase current is being used it is led through a small-volume oil circuit-breaker with a rupturing capacity of 200 MVA to the 2,450-kVA transformer shown at *a* in Fig. 13. On the other hand, when direct-current is being employed it is led through a high-speed circuit-breaker to the motor *b* of a motor-generator set. The high-speed circuit-breaker is isolated from the single-phase circuit-breaker by an electro-pneumatically-operated switch. Both single-phase and direct-current-breakers are also interlocked to prevent incorrect operation and are controlled automatically. As will be seen from Fig. 13, the secondary winding of the transformer *a* is provided with taps *c* for adjusting the voltage of the current supplied to the traction motors, the train heating system and the auxiliary services. The necessary adjustments are carried out by 16 electro-pneumatic contactors. The transformer tanks also contain a quadruple bridging inductor *d*.

The six motors, which are shown at *e* in Fig. 13, are of the single-phase slip-ring traction type, each having an output of 720 h.p. at a speed of 65 km. per hour on the one-hour rating. They are provided with 16 poles, compensation being obtained by displacing the phase of the field by the shunts *f*. The stators are of welded construction, and are such that any motor can be placed in one of three different positions on the driving axle. Owing to the large currents, the stator windings are divided into a number of parallel circuits. Although the motors are coupled in pairs and are connected in series, the stators are designed to carry half the armature current and those of each pair are permanently connected in parallel. The rotor, which is shown in Fig. 11, on page 547, is provided with a multi-parallel winding with equipotential connections. The cast-steel armatures are mounted on steel shafts which, in turn, are carried on grease-lubricated roller bearings. The brush gear is illustrated in Fig. 12. It can be easily rotated, and is provided with 16 brush carriers on each of which are five brushes.

The weight of the complete motor is 2,940 kg. and its characteristics are shown in Fig. 15, in which curves *a* and *b* are the output at the wheel rims in kilowatts and the tractive effort in kilograms, respectively. Curve *c* is the speed in kilometres per hour on the various transformer tappings, with a contact wire voltage of 20 kV, and curve *d* the speed with a voltage of 230 volts across the motor terminals. Curve *e* indicates the power factor and *f* the efficiency.

Reversal is effected by three electro-pneumatically-operated switches, and the same switches are used for bringing the regenerative braking system, the connections of which are shown on the right of Fig. 13, into operation. This regeneration is effected by an exciter transformer *g*, which is supplied with current from one of the motor groups and, in turn, supplies it to the other two groups. This arrangement enables the power factor to be maintained at a high value within the 50 to 90 km. per hour speed range, and permits the brakes to be applied until the motor comes to rest. Regenerative braking can be begun at any desired speed, the force being 7,500 kg. at the one-hour rating and 11,000 kg. at the maximum rating.

To enable the locomotive to be operated on the 1,500-volt direct-current system, and thus to assist in inter-running, the equipment includes a motor-generator set, the generator of which is shown at *h* in Fig. 13. This machine, which has an output of 984 kVA on the one-hour rating, supplies single-phase current at a frequency of from 30 to 50 to the secondary of the regulating transformer *a* and thence to the traction motors. Operation and control are therefore the same whether single-phase or direct-current is being used, and to change from one to the other it is only necessary for the driver to close the appropriate main circuit-breaker. Faulty manipulation is prevented by interlocks, so that it is impossible for direct-current to flow through the transformer or for single-phase current to pass through the motor of the convertor set.

The auxiliary equipment consists of an Arno converter, which supplies the three-phase motors driving the fans for cooling the motors, the interpole shunts and the transformer oil, as well as an air compressor and a transformer oil pump. Train heating is provided at 1,500 volts. In addition to the usual safety devices and interlocks, the locomotive is fitted with a relay which cuts out the traction motors should violent skidding occur.

The general arrangement of the equipment of the locomotive will be clear from Fig. 9, which shows the reverser on the left, followed, in turn, by a fan, motor-driven compressor, main convertor, main transformer and, finally, a second fan.

(To be continued.)

LITERATURE.

Lubrication : Its Principles and Practice.

By A. G. M. Michell, M.C.E. (Melb.), F.R.S. Blackie and Son, Limited, 66 Chandos-place, London, W.C.2, and 17, Stanhope-street, Glasgow, C.4. [Price 35s. net.]

The name of A. G. M. Michell requires no introduction to engineers. It is now nearly fifty years since he made his spectacularly successful application of Reynolds' hydrodynamic theory of lubrication in the invention of the tilting pad which revolutionised the design of heavy thrust bearings. Osborne Reynolds published his celebrated explanation of the automatic formation of continuous films of lubricant between the surfaces of bearings in 1886, and Michell's original patent dates from 1905, while the mathematical theory which he adduced in support of it was published by him in the *Zeitschrift für Mathematik und Physik* in the same year. Many British engineers owe their first acquaintance with the subject to the detailed exposition of its mathematical fundamentals by the late H. M. Martin in the pages of Engineering and, in later years, Mr. Michell himself included a condensed version of the theory in a collective work on the mechanical properties of fluids which, like the present work, was published by Messrs. Blackie and Son.

Of his new book, the author says that its primary aim is to assist practice ; and practice, in this case, being virtually synonymous with fluid-film lubrication, it is natural that the bulk of the subject matter should deal with this topic. We might even go farther and say that, for the author, hydrodynamic or "fluent-film" lubrication, as he prefers to call it, is the only true form of lubrication, since he makes it clear in his introductory chapter that he has little time for either "survivals" or "neologisms" such as "boundary-lubrication," the phenomena attributed to which he regards as largely, if not wholly, explained by the simultaneous occurrence of solid friction and viscous fluid flow when the amount of lubricant is insufficient to form a continuous film between the bearing surfaces. There are, doubtless, others who share the author's opinions on this point, and his view that, in all circumstances, viscosity alone is the property on which the lubricative action of a fluid depends ; but to do so is to disregard a considerable body of evidence which has been patiently accumulated in the past decade or more, largely in England and in the author's own country of Australia, on such matters as the influence of the molecular structure of a lubricant and the effect of its chemical reactivity with the bearing surfaces on its lubricating properties when it is present only as a thin film of molecular dimensions.

Every author of a text-book must apply some criterion in the selection of his material, and Mr. Michell states in his preface that the one which has decided the inclusion or omission of any particular matter in his book, either as text or reference, has been "practical utility." Furthermore, he makes it clear that he includes under the heading of the practically useful "not only matter immediately applicable to the current needs of the practician, but also whatever leads directly to improvement and advance in the art of lubrication." The trouble about such a criterion is that it cannot be impersonal and is unlikely to be impartial; thus, although no one will question the author's special qualifications for his task, he would be bold indeed who would deny the possibility that much of the recent research on lubrication which appears to have little practical value, and which is not referred to in the book, may have important applications in the future.

It is not, however, only in the field of boundary lubrication—*pace* the author—that omissions are to be found in the book ; there are lacunae in the hydrodynamic field also. For example, it is beyond denial that the existence of a continuous wedge of lubricant between bearing surfaces, tapering and flowing in the direction of motion of the moving surface, is, as Reynolds showed, a sufficient condition for hydrodynamic lubrication, that is, for maintaining the surfaces apart in opposition to a force between them ; but to assert that a geometrical taper is also essential is to disregard the work of Fogg and others who have shown, within recent years, that temperature changes within the lubricant itself can achieve the same result between geometrically parallel bearing surfaces by forming what has been termed a "thermal wedge" having a load-carrying capacity approaching that of tilting-pad bearings. It is true that thermal effects of this kind are not wholly ignored in the book and that the mathematical work of Cope, which established the theory of the thermal wedge, is listed among the references, but no specific reference to Fogg's work is made and the author appears to doubt whether any permanently satisfactory lubrication and load-carrying capacity can be obtained by thermal dilatation of the lubricant.

If the fact be accepted that it represents only a part—albeit the most important part for the practising engineer—of the accumulated knowledge on lubrication, what there is in the book is excellently done. The physical properties of lubricants, viscous fluid-flow, sliding bearings, thrust bearings, journal bearings and rolling bearings are all, in turn, considered in detail, and the relevant theory and principles of design expounded lucidly with the aid of elegant mathematics and carefully-prepared diagrams and drawings. Most of the matter is not new and some of it has appeared in print a number of times, but it is well to have it collected together under one cover and set down in such an admirably connected manner by one who has made the subject a life study. From this point of view, the book will be as useful to the student as it will certainly be to the "practician."

The author's predilection for mathematics is evident throughout the book, but nowhere more so than in the first and last of the appendices, which contain new material. As has already been remarked, Mr. Michell clings tenaciously to hydrodynamic or fluent-film lubrication, in which viscosity plays the decisive rôle, as the only true form of lubrication, and regards the regime of boundary lubrication as nothing more than a transitional state between the fully lubricated and the wholly unlubricated conditions. It is one of the conclusions of the mathematical theory that, as the inclination of a bearing pad to the runner is reduced —as a result, for example, of a drop in the running speed or an increase in the load—the ratio of the tractive force to the load should diminish steadily. Experiment and practice, however, do not confirm this ; the coefficient of resistance reaches a minimum and, thereafter, increases with further reduction in the angle of the pad. In order to show that such a result is possible under conditions of fluid-film lubrication when the lubricated surfaces are not perfectly smooth, the author examines the case of a plane bearing where the surface of the pad, considered to have infinite width, is covered uniformly with a series of small sinusoidal corrugations parallel to its length, and proves, with the aid of much mathematics and a number of simplifying assumptions, that the resistance coefficient would vary with the inclination of the pad in accordance with the generally observed trend ; the resistance would increase at small angles but fluid-film lubrication would persist until the surfaces became parallel and the runner made contact with the pad along the crests of the corrugations.

Undoubtedly there is some satisfaction to be gained from a demonstration that results which might have been supposed due to some occult cause, such as a change in the characteristics of the lubricant or the nature of the lubrication, or the interplay of molecular forces, can be explained on the simple and likely hypothesis that the bearing surfaces are not perfectly smooth ; but the reader is likely to be left with an uneasy feeling that, despite both the fact that rugosities are always present and that the kind considered by the author may occur in practice as a result of machining, and the realisation that the author was obliged to limit his theory to a somewhat artificial case only in order to make his equations tractable, this is one instance in which mathematics has been overworked in the service of the cause. The same feeling persists after reading the other appendix, which treats of the rate of displacement of a ball or roller through the oil in a race, when subjected to a sudden load. The printing and production of the book are of Messrs. Blackie's customary high standard.

Mechanics Applied to Vibrations and Balancing.

By D. Laugharne Thornton. Second edition. Chapman and Hall, Limited, 37, Essex-street, London. W.C.2. [Price 50s. net.]

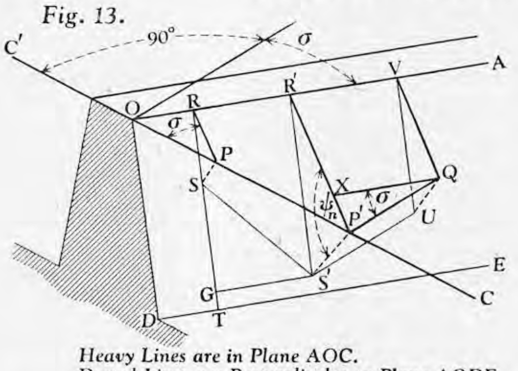
The first edition of this important treatise on vibrations and balancing was published in 1939 and was reviewed on page 162 of our 149th volume. It was noteworthy for the extensive application of more general dynamical methods, and, in particular, those associated with the names of Lagrange and Rayleigh, to actual questions that had arisen in the course of the author's wide consulting practice, rather than to the somewhat academic problems that are a familiar feature of the formal texts on dynamics. The main difficulty is, of course, to reduce the data of a complex engineering situation to a form that enables these more powerful methods to be employed, and considerable experience is required to pick out the details that are essential and to leave aside the circumstances that are mere accessory. On this score, Mr. Thornton's sure insight will be evident to the more mature readers, while the commendable care he has taken to set down all the relevant steps in the working out will be appreciated by those less mature.

For this second edition the first six chapters have been reproduced substantially as they appeared in the first edition, so that no further analysis of their contents is called for. Chapter VII is new and deals with the transmission of stress under conditions of rapidly applied loading, which the author refers to as "impact" loading, but which might equally well, or perhaps preferably, be termed "impulsive" loading. For large impulses of brief duration, typical instances of which are provided when ships or forts are subjected to the effects of explosions, the rate of change of strain may be of the order of a million times that obtaining in a normal test under static conditions, while the ensuing stresses are liable to result in plastic deformation. The propagation of plastic strain is much more complicated than that of elastic strain, and the manner of dealing with it was first formulated by Maxwell in 1868. It is shown that, when one end of a long bar is deformed at a rate greater than the permissible velocity of impact for elastic deformation, the velocity of transmission of stress is a function of strain. Moreover, though experiment tends to confirm the theoretical prediction that, in the vicinity of the yield point, damping increases with stress, attention is directed to the dearth of reliable experimental data on the behaviour of metals under high rates of change of stress. After working out the circumstances attending the reflection of a pressure pulse at an interface, and exhibiting graphically the changes in form that a pulse, the initial profile of which is rectangular, undergoes upon reflection, consideration is given to the effects of reflection in structural components having both ends more or less fixed. Interesting oscillograph records are reproduced relating to three test-pieces, furnished at either end with electrical resistance strain gauges, the first being continuous, the second having a riveted joint at mid-length and the third a welded joint at mid-length.

The general survey which forms the concluding chapter has been completely rewritten and some new material added. Attention may be directed to the deduction of the criterion of stability for a turbine wheel executing transverse vibrations, to an examination of the action of two alternative types of vibration absorber designed to minimise torsional vibration in an engine crankshaft, and to the investigation of the axial vibration of a close-coiled helical spring. Other topics on which the author writes with authority are the modes of vibration of various types of ships, and methods of building to counter the effects of earthquake shocks. The whole subject of vibrations arising from mechanical causes on land, at sea and in the air is treated in a comprehensive yet practical manner. Perhaps, in a future edition, space might be found for a discussion of the intricate problems of non-linear vibrations, which are assuming an ever-increasing importance.

TOOTH SURFACES OF CREEP-CUT HELICAL GEARS.

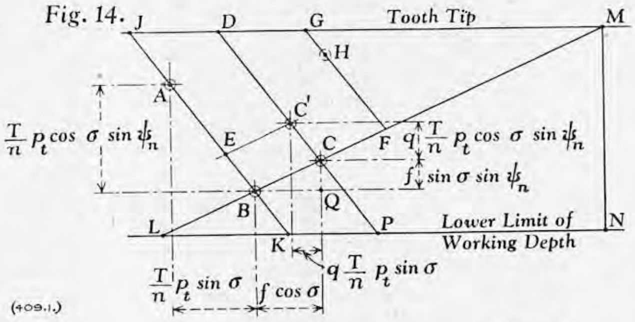
Fig. 13.



Heavy Lines are in Plane AOC.
Dotted Lines are Perpendicular to Plane AODE.
Other Lettered Lines are in Plane AODE.

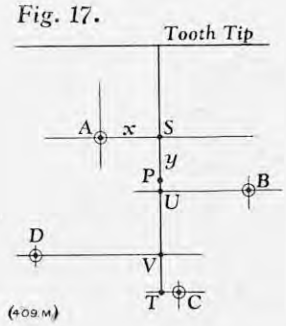
(409.H.)

Fig. 14.



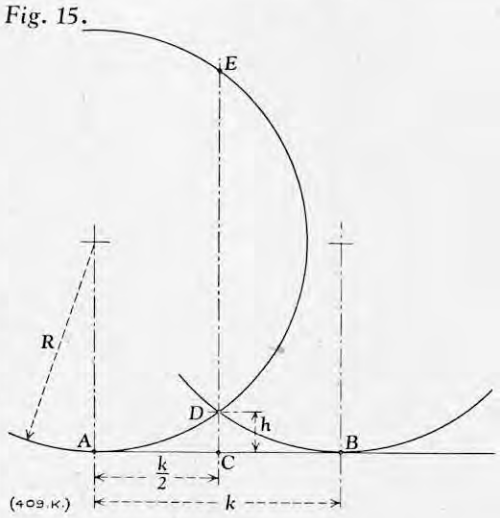
(409.I.)

Fig. 17.



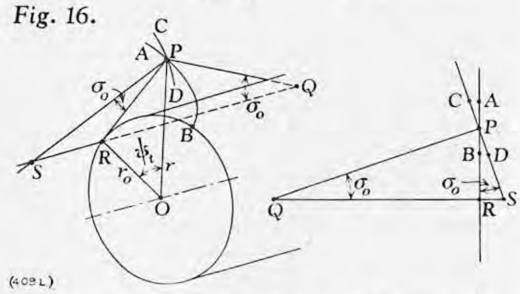
(409.M.)

Fig. 15.



(409.K.)

Fig. 16.



(409.L.)

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

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

(*Continued from page* 519.)

Appendix I.

Calculation of Positions of Low-Cuts. In Fig. 13 O is the tip of one of the tooth flanks at the side face of a helical gear mounted on a hobbing machine and C′OC is the path of O during the generating process. The tooth flank is regarded as plane over the area considered here. A pitch-point of engagement of gear and hob is P. The position of the point of contact of a hob tooth with the gear tooth is determined by drawing through P a line PS perpendicular to the tooth surface. (The common normal to tooth surfaces at a point of contact passes through the pitch point.) This is done by drawing PR perpendicular to OA and then drawing the plane PRT so that it contains PR and lies perpendicular to the plane OAED. In the plane PRT, PS is drawn perpendicular to RT and since the plane is perpendicular to OAED, the line PS is also perpendicular to it.

Now

$$\begin{aligned} \mathrm{OR} &= \mathrm{OP} \sin \mathrm{RPO} \\ &= \mathrm{OP} \sin \sigma \\ \mathrm{RS} &= \mathrm{PR} \sin \mathrm{RPS} \\ &= \mathrm{OP} \cos \mathrm{RPO} \sin \mathrm{RPS} \\ &= \mathrm{OP} \cos \sigma \sin \psi_n \end{aligned}$$

where

σ = helix angle of gear tooth, and
ψ_n = normal pressure angle of gear tooth.

If gear and hob are rotated so that the pitch-point of engagement moves to P′, the point S moves to S′. If S′G is drawn perpendicular to RT, then

$$\mathrm{S'G} = \mathrm{R'R} = \mathrm{OR'} - \mathrm{OR} = \mathrm{PP'} \sin \sigma \,. \quad (1)$$

Also

$$\mathrm{SG} = \mathrm{RG} - \mathrm{RS} = \mathrm{R'S'} - \mathrm{RS} = \mathrm{PP'} \cos \sigma \sin \psi_n \quad (2)$$

Hence

$$\tan \mathrm{SS'G} = \frac{\mathrm{SG}}{\mathrm{S'G}} = \cot \sigma \sin \psi_n.$$

Successive hob-cuts on a gear tooth thus lie on a straight line inclined to the tooth tip at the angle the tangent of which is $\cot \sigma \sin \psi_n$.

If

$$\sigma = 30 \text{ deg. and } \psi_n = 20 \text{ deg.}$$

$$\tan \mathrm{SS'G} = 1 \cdot 732 \times 0 \cdot 342 = 0 \cdot 592$$

whence

$$\mathrm{SS'G} = 30 \text{ deg. } 40 \text{ min.}$$

If the hob is traversed so that the pitch-point of engagement assumes a position Q such that P′Q is perpendicular to OC, then the point of contact moves from S′ to U the position of which is determined from Q in the same way as that of S was determined from P.

In the plane AOC, QX is drawn perpendicular to R′P′.

Now

$$\mathrm{R'V} = \mathrm{XQ} = \mathrm{P'Q} \cos \sigma \;. \quad . \quad . \quad . \quad (3)$$

$$\begin{aligned} \mathrm{VU} &= \mathrm{VQ} \sin \psi_n = (\mathrm{R'P'} - \mathrm{P'X}) \sin \psi_n \\ &= \mathrm{R'S'} - \mathrm{P'Q} \sin \sigma \sin \psi_n \end{aligned}$$

Hence

$$\mathrm{R'S'} - \mathrm{VU} = \mathrm{P'Q} \sin \sigma \sin \psi_n . \quad . \quad (4)$$

The tangent of the angle between S′U and R′V is

$$\frac{\mathrm{R'S'} - \mathrm{VU}}{\mathrm{R'V}} = \frac{\mathrm{P'Q} \sin \sigma \sin \psi_n}{\mathrm{P'Q} \cos \sigma} = \tan \sigma \sin \psi_n .$$

Cuts made on a gear tooth by the hob at intervals of one revolution of the gear thus lie on a straight line inclined to the tooth tip at the angle the tangent of which is $\tan \sigma \sin \psi_n$.

If $\sigma = 30$ deg. and $\psi_n = 20$ deg., this angle is 11 deg. 10 min.

In general, if the pitch-point of engagement of work and hob is displaced circumferentially by an amount c (corresponding to PP′) and axially by an amount f (corresponding to P′Q) then from (1) and (3),

displacement of contact-point measured parallel to tooth tip

$$= c \sin \sigma + f \cos \sigma, \quad . \quad . \quad (5)$$

and from (2) and (4),

displacement of contact-point measured perpendicular to tooth tip

$$= (c \cos \sigma - f \sin \sigma) \sin \psi_n . \quad . \quad . \quad (6)$$

For example, the displacement (measured parallel to the tooth-tip) of the contact point (B to C in Fig. 14) after exactly one revolution of the work is determined by writing $c = 0$ in (5) giving

$$f \cos \sigma \quad . \quad . \quad . \quad . \quad (7)$$

in which f is the axial feed of the hob during the revolution of the table.

The displacement measured perpendicular to the tooth-tip is determined by writing $c = 0$ in (6) giving

$$- f \sin \sigma \sin \psi_n . \quad . \quad . \quad . \quad (8)$$

Another important case is that of successive low-cuts produced by cyclic irregularity in the worm that drives the table wormwheel. If the number of revolutions made by the worm during one revolution of the table is n and the work has T teeth of transverse pitch p_t, then, during one revolution of the worm, the displacement of the pitch-point of engagement of work and hob is $\frac{\mathrm{T}}{n} p_t$.

The distances between the successive low-cuts produced at the beginning and end of this revolution are determined by writing $c = \frac{\mathrm{T}}{n} p_t$ in (5) and (6). The value of f may be written as zero as the axial feed of the hob during such a small rotation of the table is negligible compared with c.

Hence, distance between low-cuts (A to B, in Fig. 14)

(a) Measured parallel to tooth tip $= \frac{\mathrm{T}}{n} p_t \sin \sigma \quad (9)$

(b) Measured perpendicular to tooth tip =

$$\frac{\mathrm{T}}{n} p_t \cos \sigma \sin \psi_n . \quad (10)$$

The displacements given by (7), (8), (9) and (10) and indicated in Fig. 14 in connection with the points A, B, and C are for "non-creep" cutting conditions.

Creep Cutting. The effect of a worm creep fraction q is to cause the low-cut originally at C to occur when the pitch-point of engagement of hob and work is at a distance $- q \frac{\mathrm{T}}{n} p_t$ from that at which C was produced. Hence, from (9) and (10), the co-ordinates of C′ differ from those of C by $- q \frac{\mathrm{T}}{n} p_t \sin \sigma$ (parallel to tip) and $- q \frac{\mathrm{T}}{n} p_t \cos \sigma \sin \psi_n$ (perpendicular to tip). Other low-cuts on the line CD are spaced from C′ by distances that are integral multiples of AB.

Taking B as the origin of co-ordinates with x and y axes parallel and perpendicular, respectively, to the tooth-tip (the positive direction of x being to the right and that of y upwards), the co-ordinates of C′ are therefore

$$x = f \cos \sigma - q \frac{\mathrm{T}}{n} p_t \sin \sigma$$

$$y = f \sin \sigma \sin \psi_n + q \frac{\mathrm{T}}{n} p_t \cos \sigma \sin \psi_n$$

and those of all low-cuts on CD are

$$x = f \cos \sigma - q \frac{\mathrm{T}}{n} p_t \sin \sigma - \mathrm{V} \frac{\mathrm{T}}{n} p_t \sin \sigma$$

$$y = f \sin \sigma \sin \psi_n + q \frac{\mathrm{T}}{n} p_t \cos \sigma \sin \psi_n + \mathrm{V} \frac{\mathrm{T}}{u} p_t \cos \sigma \sin \psi_n,$$

where V is any whole number.

The low-cut H produced on the line FG (parallel to AB) at approximately one revolution of the work-table later than the production of C′ bears the same relation to C′ as C′ does to B. Hence the co-ordinates of H are

$$x = 2 \left[f \cos \sigma - q \frac{\mathrm{T}}{n} p_t \sin \sigma \right]$$

$$y = 2 \left[f \sin \sigma \sin \psi_n + q \frac{\mathrm{T}}{n} p_t \cos \sigma \sin \psi_n \right]$$

and those of other low-spots on FG are

$$x = 2 \left[f \cos \sigma - q \frac{\mathrm{T}}{n} p_t \sin \sigma \right] - \mathrm{V} \frac{\mathrm{T}}{n} p_t \sin \sigma \,. \quad (11)$$

$$y = 2 \left[f \sin \sigma \sin \psi_n + q \frac{\mathrm{T}}{n} p_t \cos \sigma \sin \psi_n \right] + \mathrm{V} \frac{\mathrm{T}}{n} p_t \cos \sigma \sin \psi_n . \quad (12)$$

For low-spots on other lines parallel to AB, the

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coefficient 2 is changed to other whole numbers. Hence, writing Z (any whole number) instead of 2 in (11) and (12), and rearranging, the co-ordinates of all low-cuts on the tooth surface are given by

$$x = \mathrm{Z} f \cos \sigma - (\mathrm{V} + \mathrm{Z}q) \frac{\mathrm{T}}{n} p_t \sin \sigma \quad . \quad . \quad (13)$$

$$y = \left[\mathrm{Z} f \sin \sigma + (\mathrm{V} + \mathrm{Z}q) \frac{\mathrm{T}}{n} p_t \cos \sigma \right] \sin \psi_n . \quad (14)$$

Low-cuts on any line parallel to AB have a common value of Z but different values of V. Low-cuts on any line parallel to BC′ have a common value of V but different values of Z.

Sign of Creep Fraction. The diagrams and formulæ in this Appendix relate to the condition in which the displacement of one line of hob cuts (e.g., DP, Fig. 14) relative to its immediate predecessor (JK) is in the same direction (left to right) as the displacement of a single hob cut (e.g., at A) relative to its immediate predecessor (at a point between A and J). This condition corresponds to normal gear-cutting practice, in which the hand of the feed-helix is the same as that of the tooth-helices. If the feed is reversed in direction without altering the direction of rotation of the work (as in "climb cutting"), the sign of q must be reversed when determining the distribution of low-cuts.

Appendix II.

Determination of Contours of Tooth Surface.—If on any plane perpendicular to the nominal flank of the gear tooth, the cuts appear as circular arcs of radius R varying gradually in depth over a range g in a distance k large compared with R, it will be clear from Fig. 2, page 484, *ante*, that the lowest points on the resulting surface lie on a smooth curve undulating over a height g and the high-spots lie on a very similar curve. Ignoring all but low-cuts, the height of the "cusp" produced by the intersection of two cuts spaced at distance k is determined by the geometry of chord and tangent to a circle of radius R.

Referring to Fig. 15, opposite, $\mathrm{CA}^2 = \mathrm{CD} \cdot \mathrm{CE}$. As C D is usually small compared with R, the length of D E is nearly equal to the diameter of the circle shown, i.e., 2 R.

Hence $\left(\frac{k}{2}\right)^2 = \mathrm{CD}\,2\mathrm{R}$ and so

$$\mathrm{CD} = \frac{k^2}{8\mathrm{R}} . \quad . \quad . \quad . \quad (15)$$

Whatever the nature of the cuts between A and B, the height at C cannot exceed this value of C D. The maximum height of the high-spot is therefore proportional to the square of the pitch of the low-cuts.

If k is large, the value of C D given by this expression is large, but, as already seen, the height of the resultant wave on the surface cannot in any case exceed g.

Although the maximum height of the undulations on the tooth surface can be determined exactly only by somewhat tedious calculation, it will be clear that it can never exceed the smaller of the quantities $\frac{k^2}{8\mathrm{R}}$ and g. By adopting a sufficiently fine feed in cutting the teeth, $\frac{k^2}{8\mathrm{R}}$ can be reduced to any desired amount and the particular machine error indicated by g need not therefore be allowed to control the roughness of the surface.

In order to obtain an adequate picture of the conditions it is necessary to examine the interaction of the straight cutting edge of the hob tooth and the slightly curved nominal profile of the gear tooth. The normal section of an involute helicoid gear tooth approximates to an arc of a circle of radius equal to the length of the tangent drawn from the mid-depth point on the profile to the section of the base cylinder by the plane concerned.

In Fig. 16, A B is a section of a tooth profile on a plane perpendicular to the axis of the gear. It contains a point P distant r from the axis. The ellipse in Fig. 16 is the oblique view of the section of the base cylinder by the plane that contains A B. P R is tangential to the base cylinder and S P Q is the plane that contains P R and touches the base cylinder in S Q. P Q is the line that generates the involute helicoidal tooth profile when the plane P Q S rolls on the base cylinder.

The right hand diagram in Fig. 16 represents the plane P Q S when viewed normally from the left. The transverse section of the tooth profile is represented by A B and the normal section by S D. The radius of curvature of the transverse section at P is P R and of the normal section is P S since R and S are the intersections of the planes concerned with the "rolling line" Q S. In the left-hand view, the right-angle triangle O P R shows that

$$\mathrm{PR} = \sqrt{(r^2 - r_0^2)}$$

and in the right-hand view the right-angle triangle P R S shows that

$$\mathrm{PS} = \mathrm{PR} \sec \sigma_0 = \sqrt{(r^2 - r_0^2)} \sec \sigma_0 .$$

Hence the radius of curvature of the normal section of the tooth surface at mid-depth is

$$\sqrt{(r^2 - r_0^2)} \sec \sigma_0 ,$$

where

r = distance of mid-depth point from axis of gear,
r_0 = radius of base cylinder, and
σ_0 = base helix angle.

For a gear of pitch diameter d, normal pressure angle 20 deg. and helix angle 30 deg., the radius of curvature of the profile at mid-depth is equal to about $0 \cdot 2d$.

The straight edge of a hob tooth that takes a light cut from the tooth-flank forms a chord of this circular arc. If the depth of cut is j, the length of the chord is $\sqrt{(8j \times \text{radius of arc})}$ and for a gear of diameter d the normal pressure angle 20 deg. this is about

$$1 \cdot 26 \sqrt{(j\,d)} . \quad . \quad . \quad . \quad (16)$$

This is the width of the single hob-cut measured perpendicularly to the tip of the tooth.

Over a small angle of rotation of the hob, the straight edge of a tooth sweeps the surface of a cone, the semi-angle of the vertex of which is the complement of the axial pressure angle of the hob tooth, i.e., very nearly the complement of the normal pressure angle of the gear teeth. The radius of curvature of the conical surface at any point is the distance, measured perpendicular to the generator, from the point to the axis of the cone, i.e., of the hob. For a point on a cylinder co-axial with the hob, the radius of curvature of the conical surface is thus the radius of that cylinder multiplied by the cosecant of the normal pressure angle of the gear teeth. For an average hob of about 6 in. diameter at mid-depth of its teeth, and 20 deg. normal pressure angle, this works out at about 8·8 in. This is the radius of the surface cut by the hob tooth when viewed along the cutting edge. The involute helicoid surface viewed in the same way appears as a very nearly straight line and is consequently the chord of an arc of radius 8·8 in. and height j. The length of the chord, which is the width of a single hob-cut measured parallel to the tip of the tooth, is therefore

$$\sqrt{(8j \times 8 \cdot 8)} \text{ or } 8 \cdot 4 \sqrt{j} . \quad . \quad . \quad (17)$$

The boundary of the surface of a shallow cut is therefore a closed curve of which the overall dimensions perpendicular and parallel to the tooth-tip are

$$1 \cdot 26 \sqrt{j\,d} \quad \text{and} \quad 8 \cdot 4 \sqrt{j}, \text{ respectively.}$$

If, for example, $d = 100$ and $j = 0 \cdot 001$, the "height" of the cut surface is 0·4 in. and the "width" 0·26 in. These lengths, perpendicular and parallel, respectively, to the tooth tip, are greater than the corresponding distances between the centres of low-cuts on an average gear tooth.

To obtain an estimate of the heights of the high-spots, it therefore becomes necessary to consider the intersections of the surfaces of the low-cuts. The height of any point P (Fig. 17, opposite) above the plane defined by adjacent low-spots A, B, C and D is the least of those defined by the location of P in respect to the low-cut surfaces corresponding to A, B, C and D. Of the four low-cut surfaces, the one that gives the least height at P obliterates the effects of the others at P.

Let the radius of curvature of each low-cut surface in a plane perpendicular to the nominal surface of the tooth and containing a straight line parallel to the tooth-tip be R_h and the corresponding radius in the perpendicular plane be R_v.

Then (cf. equation (15)) height of S above A = $\frac{\mathrm{AS}^2}{2\mathrm{R}_h}$ and height of P above S = $\frac{\mathrm{SP}^2}{2\mathrm{R}_v}$.

Hence the height of P above the common plane of the low-spots A, B, C and D is

$$h = \frac{\mathrm{AS}^2}{2\mathrm{R}_h} + \frac{\mathrm{SP}^2}{2\mathrm{R}_v} . \quad . \quad . \quad . \quad (18)$$

provided that it has not been reduced below this amount by a low-cut centred on any other point such as B, C or D.

Considering only the low-cut centred on A, all points at a height h above A have x and y co-ordinates with respect to A such that

$$\frac{x^2}{2\mathrm{R}_h} + \frac{y^2}{2\mathrm{R}_v} = h . \quad . \quad . \quad . \quad (19)$$

They therefore lie on an ellipse centred on A and having horizontal and vertical axes $\sqrt{(2\mathrm{R}_h\,h)}$ and $\sqrt{(2\mathrm{R}_v\,h)}$, respectively. A contour map of each low-cut is therefore a series of co-axial similar ellipses and the contour map of the whole surface may be constructed by drawing the interlacing contours of all the low-cuts and then deleting those parts of lines that lie between any line of smaller height and the low-spot on which it is centred. From the resulting map, the positions and heights of high-spots left within each parallelogram (e.g., A B C D) of low-spots may be determined. The high-spots will be found to lie on a system of straight lines parallel to those that define the low-spots, and so the easily-calculated distribution of low-cuts applies, with some linear displacement, to the "high-spots." This analysis takes into account only the low-cuts. The ignored high cuts and intermediate cuts may cause the height of the high-spots to be less than the analysis indicates (and this is especially the case if the machine errors are small) but they can never have the opposite effect. Thus the method can never underestimate the height of the high-spots however great the machine error.

Contour maps for a typical tooth surface produced on a machine the only error of which repeats itself in a cycle completed during one revolution of the dividing worm are reproduced in Figs. 18 to 22, page 552, for several values of q and f. The features of special interest are :—

(a) The small height of the roughness, which is not increased by any increase in magnitude of the machine error concerned.

(b) The production of separate high-spots instead of a high ridge by the change from $f = 0 \cdot 04$ to $f = 0 \cdot 08$ (Figs. 18 and 19).

(c) The reduction in height of high-spots by the change from $q = 0$ to $q = 0 \cdot 46$ with $f = 0 \cdot 04$ (Figs. 18 and 20).

(d) The increase in height of high-spots and marked change in contours by the change from $q = 0$ to $q = 0 \cdot 46$ with $f = 0 \cdot 08$ (Figs. 19 and 21).

(e) The situation of the high-spots of the creep-cut teeth on lines not parallel to the generator (Figs. 20 to 22).

(f) The change in contours (although there is no change in height of high-spots) by the change from $q = 0 \cdot 46$ to $q = 0 \cdot 54$ with $f = 0 \cdot 04$ (Figs. 20 and 22).

In Fig. 21 is shown the effect of repeating the conditions of Fig. 20, but with twice the feed. It will be seen that if f is increased from 0·04 in. to 0·08 in., the "pin-cushion" high-spots of Fig. 20 (height 0·00008 in.) are replaced by ridges exceeding 0·00030 in. in height. These ridges are inclined at a large angle to the generator and are nearly uniform in height. They may, therefore, be expected to produce smooth running but with relatively high stress concentrations as the generator must span valleys more than 0·00030 in. in depth. Figs. 23 and 24 show the contours produced by use of creep fractions 0·285 and 0·36, respectively, with the same feed of 0·04 in. per revolution of the work. Examination of Figs. 20 to 24 shows that, for a given feed, a creep fraction of about 0·5 results in the smoothest finish.

Note.—In the late Dr. Tomlinson's report on undulations on creep-cut gear teeth (N.P.L. No. 203), a creep fraction of about 0·46 is regarded as undesirable because it tends to produce teeth that show long waves on lines parallel to their tips. While this may be possible in certain circumstances, Fig. 20 shows that it is not always the case. In the example illustrated, which refers to a reasonable feed of 0·04 in. per revolution of the table, the

TOOTH SURFACES OF CREEP-CUT HELICAL GEARS.

Fig. 18. *Contours of Tooth Surface at 0·00004 In. to 0·00016 In. Above Low Spots*
Creep Fraction q = 0 Axial Feed f = 0·04 In. per Rev.

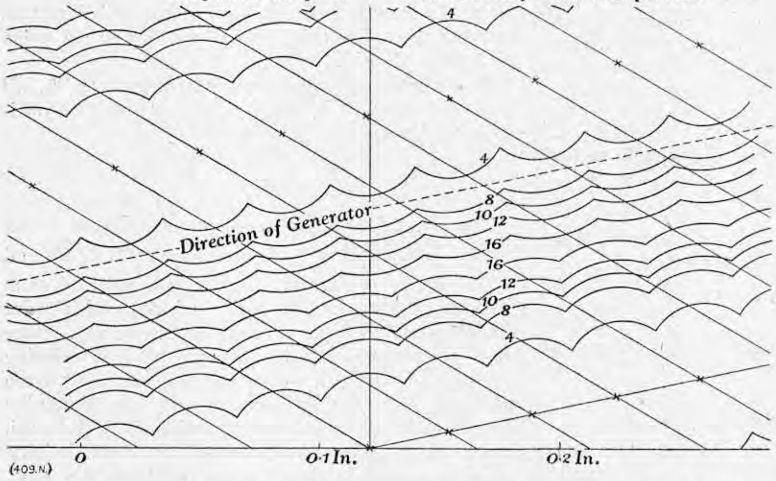


Fig. 19. *Contours of Tooth Surface at 0·00004 In. to 0·0002 In. Above Low Spots*
Creep Fraction q = 0 Axial Feed f = 0·08 In. per Rev.

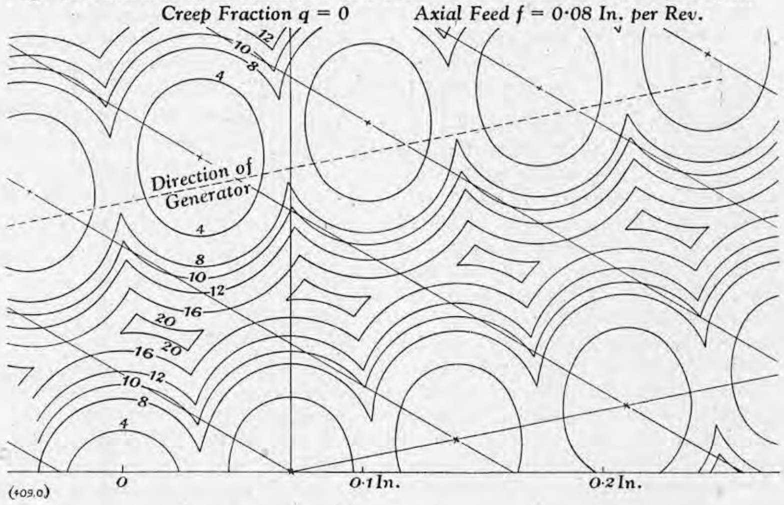


Fig. 20. *Contours of Tooth Surface at 0·00004 In. and 0·00008 In. Above Low Spots*
Creep Fraction q = 0·46 Axial Feed f = 0·04 In. per Rev.

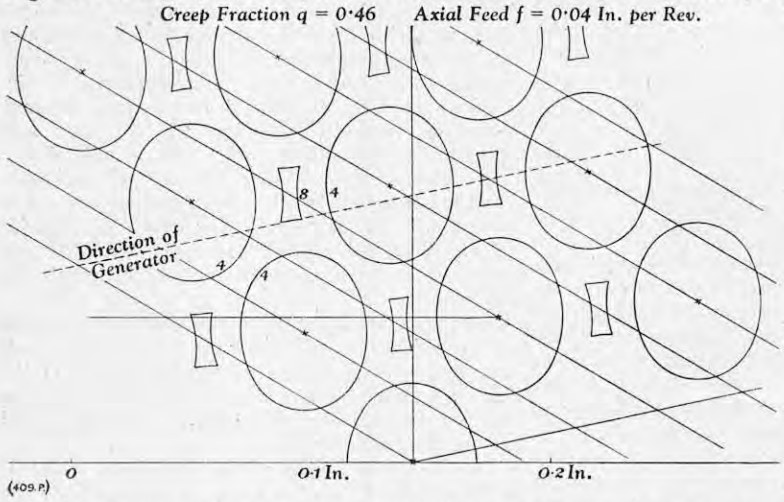


Fig. 21. *Contours of Tooth Surface at 0·00004 In. to 0·0003 In. Above Low Spots*
Creep Fraction q = 0·46 Axial Feed f = 0·08 In. per Rev.

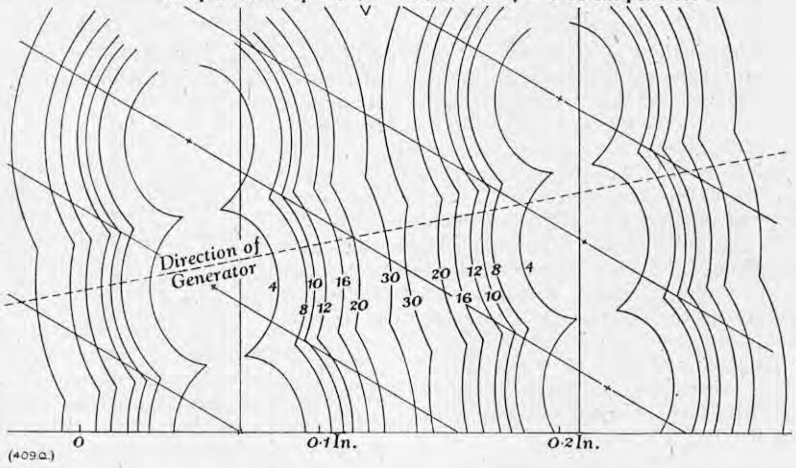


Fig. 22. *Contours of Tooth Surface at 0·00004 In. and 0·00008 In. Above Low Spots*
Creep Fraction q = 0·54 Axial Feed f = 0·04 In. per Rev.

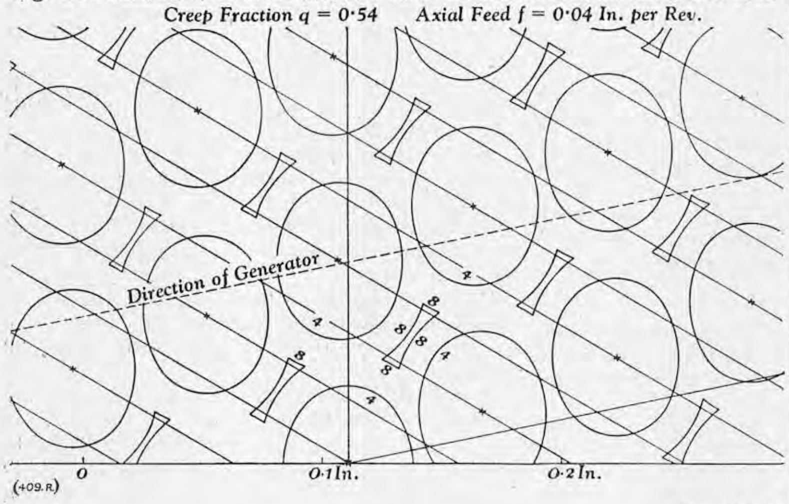
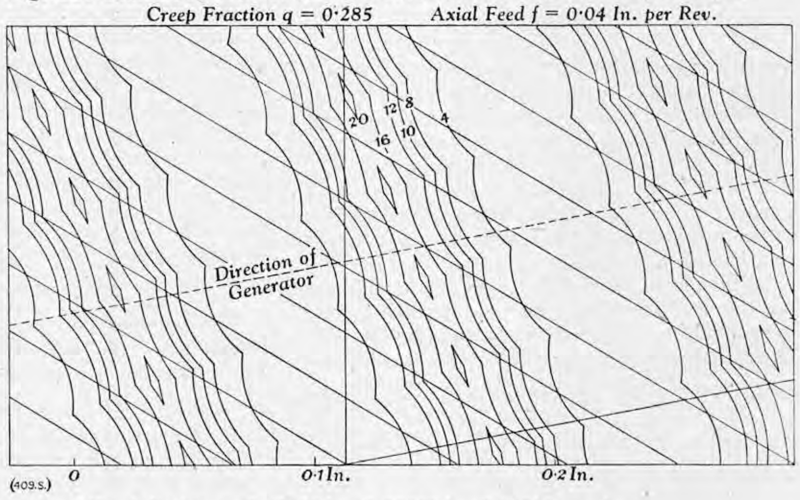


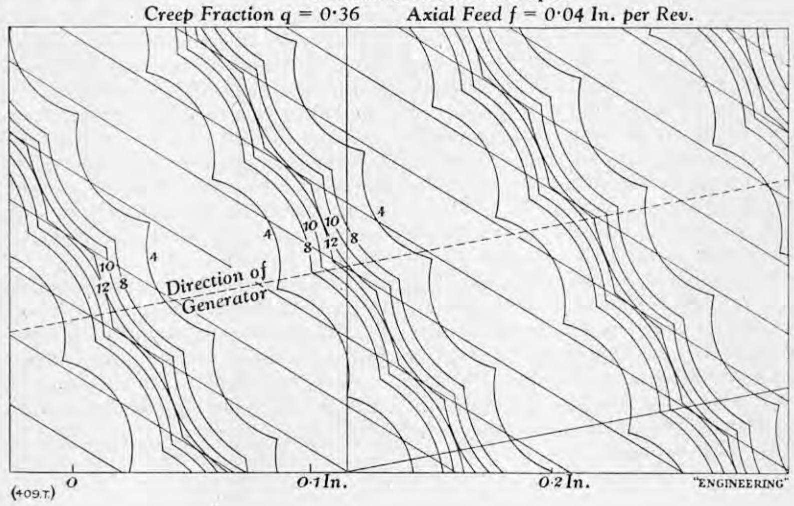
Fig. 23. *Contours of Tooth Surface at 0·00004 In. to 0·0002 In. Above Low Spots*
Creep Fraction q = 0·285 Axial Feed f = 0·04 In. per Rev.



surface is characterised by high spots of small linear dimensions compared with their spacing, which is of the order of 0·08 in. The only sense in which the tooth surface can be said to have a long wave on a line parallel to its tip is that the distance along such a line between the points at which it meets high spots in exactly the same way is many times the feed per revolution. Such a line (e.g., the one shown) meets high spots at distances equal to about twice the feed per revolution and it is seen, therefore, that in a practical sense, as distinct from a purely academic one, the value $q = 0 \cdot 46$ does not necessarily result in long waves on lines parallel to the axis. Fig. 21, on this page, shows the effect of increasing the feed rate from 0·04 to 0·08. This, it will be seen, produces a marked change in high-spot distribution, but there is still no long wave on a line parallel to the tooth-tip.

(To be continued.)

Fig. 24. *Contours of Tooth Surface at 0·00004 In., 0·00008 In., 0·0001 In. and 0·00012 In. Above Low Spots*
Creep Fraction q = 0·36 Axial Feed f = 0·04 In. per Rev.



METAL ECONOMICS.

(*Continued from page* 521.)

Continuing our report of the general discussion on "Metal Economics" held in London under the auspices of the Institute of Metals on Wednesday, October 17, we now deal with the afternoon session, which was on "Scrap Reclamation, Secondary Metals and Substitute Metals." As was the case at the morning session, short papers were presented, after which there was a general discussion restricted to the subject of the session. The short papers were five in number and the authors were, respectively, Mr. C. A. Bristow, Mr. A. J. Sidery and Dr. H. Sutton, of the Ministry of Supply; Mr. C. Dinsdale, of British Railways; Mr. F. Hudson, of the Mond Nickel Company, Limited; Mr. E. H. Jones, of Capper, Pass and Son, Limited; and Colonel W. C. Devereux, C.B.E., of Almin, Limited.

The Scope for Conservation of Metals.

When presenting their paper on "The Scope for Conservation of Metals, Ferrous and Non-Ferrous," Mr. C. A. Bristow, Mr. A. J. Sidery and Dr. H. Sutton stated that the continuance of any nation's existence and, indeed, the favourable development of civilisation as a whole, depended on the resolution of basic problems common to all nations. World population was increasing at a rate of about 1 per cent. per annum. Education brought with it an ever-increasing demand for improvements in standards of living, more and more people desiring better amenities all the time. In this movement metals were involved. For scientific and technical agencies connected in any way with metals there was a task of ever-increasing importance to ensure that metals were won, handled, used and re-used with the greatest care and with due deference to the fact that the future peace and comfort of the world's peoples were directly dependent upon the efficient use and conservation of metals.

An important part would be played in the future, as it had been in the past, by those concerned with the mining of metal-bearing minerals and their treatment. The approaching exhaustion of particular deposits had already accentuated the search for new sources and the exploitation of commercially less attractive ones. Critical shortages were with us already in respect of a number of common metals such as lead, copper and zinc. The contribution of scientists and technologists was involved not only in the discovery and appraisal of the minerals and raw materials, but in their treatment from the earliest stages. Present and future policies in mining and extraction were and would be increasingly concerned with metal economy and conservation.

In the handling of the metals as such there was great scope for the exercise of economy by the use of particular techniques of many kinds and varieties, in the production of semi-finished forms and of finished pieces. Design for production was much concerned here, and, especially in connection with pieces to be made in large quantities, the designer had great scope for influencing the metal-economy side of the project. Economic production called for the closest collaboration between designer, production engineer, and metallurgist. As regards metals in use, wear and tear, obsolescence and other causes brought the period of effective service to an end. Corrosion was one of the factors contributing to unserviceability, in many cases limiting the service life of metal articles. In some cases failure by corrosion led to great financial loss, as, for example, the penetration of buried pipes conveying water or gas. Corrosion control could contribute substantially to metal conservation.

Conservation by substitution offered considerable scope. As regards substitution of metals or alloys by others, it was important to recognise the impracticability of making new use on any considerable scale of one of the commoner metals already in short or insufficient supply. Non-metallic materials such as plastics, timber and impregnated timber represented an important field, but the direct replacement of metallic pieces by others made in such materials was by no means simple. These were, however, renewable resources and they would be needed increasingly in future years. In the field of metallic materials, the best prospects of substantial relief of present and approaching shortages were concerned with conservation and the better utilisation of supplies, with more efficient recovery of and from scrap for re-use, and with greater use of metals which were abundant in the earth's crust, notably aluminium, magnesium and titanium.

Economy by Standardisation and Reclamation of Scrap.

At the outset of his paper, "Economy by Standardisation of Alloys and of the Method of Reclamation of Scrap Metals," Mr. C. Dinsdale stated that British Railways were substantial users of many ferrous and non-ferrous metals. The nationalisation of British main-line railway companies made it essential to use standard metals and metallurgical practices in all regions. He proposed to indicate how this was being accomplished, and to discuss, in broad terms, the economies expected. The present annual consumption of non-ferrous metals for rolling stock alone was nearly 30,000 tons. In 1948 the Railway Executive Policy Committee had been set up to investigate and report on what non-ferrous metals were being used on rolling stock; and the extent of the reclamation of non-ferrous scrap; and to recommend future alloys and practices. The Committee's main findings and recommendations are indicated below.

The Railway Executive's 17 "brass" foundries, between them, were casting 11,000 tons of 37 different copper-base alloys, while a further alloy was used for purchased bearing-shells. Widely different alloys were being used in the regions for the same components. The five standard alloys, shown in Table I, were recommended and introduced for castings for rolling stock and machinery. The standardisation of use was also recommended and introduced. It was difficult to assess the savings which should follow standardisation, but metal-melting and scrap-segregation costs should be reduced and a potential saving of 175 tons of tin and 100 tons of lead against an increased consumption of zinc was estimated.

The Railway Executive owned from 6,000 to 7,000 tons of whitemetal. In 1948, 18 alloys, with 13 different compositions, were being used. Large variation in lining practice existed, for which no obvious reasons—except established practice—could be found. As a first step towards standardisation, the number of compositions had been reduced to four (Table II). The standardisation of the purposes for which the various grades were used was not yet accomplished, but extensive trials were being carried out, using whitemetals with lower tin content. For wrought metals and soft and brazing solders, the well-known British Standards were already used in all regions.

Much cast-iron and non-metallic packing was used, and seven non-ferrous alloys were replaced by the three standard alloys shown in Table III. The financial savings were not large as the quantities involved were small. Light alloys were little used at present in rolling-stock construction in this country. Specifications for several virgin metals purchased in ingot form for use in foundries and workshops had been issued, these being more detailed than formerly. British Railways found it necessary to draft specifications, as no British Standards existed for block tin, pig lead, phosphor-copper and antimony. British Railways differed from most engineering concerns, their metals being in constant circulation throughout their own system, returning periodically to their own workshops for re-use or scrapping. The re-use of as much non-ferrous metal scrap as possible was an economic proposition, and all the former railway companies carried out a varying amount of reclamation and renovation. A total of 27,000 tons of some 80 types of non-ferrous metal scrap was produced each year by British Railways as the result of machining operations and the breaking-up and repairing programme, 15,000 tons being re-used and 12,000 tons sold.

TABLE I.—Bronzes and Brasses for Future Use on British Railways.

Type of Alloy.	Nominal Chemical Composition, Per cent.					Main Uses.	Notes.
	Cu.	Sn.	Pb.	Zn.	Others.		
Phosphor-bronze	87·5	12	—	—	P 0·15 min.	Slide valves (superheated); unlined bushes; machinery bushes and details.	B.S. 1400—PB2
Leaded bronze ..	67·5	5	26	—	Ni 1·5	Slide valves (sat. engs.); regulating valves (grid type).	—
Leaded gunmetal	86	7	2	5	—	Steam and boiler mountings; axleboxes, lined bushes and brasses; carriage and wagon bearings, etc.	B.S. 1400—LG3
Yellow brass ..	66	—	2	32	—	Name and number plates; carriage fittings, etc.	B.S. 1400—B3
Brazing metal ..	90	—	—	10	—	Fittings which are to be brazed on to copper or steel pipes.	—

TABLE II.—Whitemetals (Chemical Composition).

Type of Alloy.	High-Tin Lead-Free.	High-Tin Low-Lead.	Lead-Tin Base.	Lead Base.
Tin, per cent.	84—86	80—85	58—60	11—13
Antimony, per cent.	9—11	9—11	9—11	12—14
Lead, per cent.	0·2 max.	0—5	27—29	73·5—75·5
Copper, per cent.	4—6	4—6	2—4	0—1
Maximum total impurities, per cent., of which:	0·30 (excluding lead)	0·30	0·35	0·40
Aluminium shall not exceed ..	0·05	0·05	0·05	0·05
Arsenic shall not exceed	0·10	0·10	0·15	0·20
Bismuth shall not exceed	0·08	0·08	0·08	0·08
Iron shall not exceed	0·08	0·08	0·08	0·08
Zinc shall not exceed	0·05	0·05	0·05	0·05

TABLE III.—Metallic Packing.

Type of Alloy.	Nominal Chemical Composition.		Typical Use.
		Per cent.	
Antimonial-lead	Antimony	20	Piston rod and piston-valve rod packing; saturated engines.
	Lead	80	
Copper-lead	Copper	37	Piston rod and piston-valve rod packing; superheated engines.
	Lead	61	
	Nickel	1·25	
	Sulphur	0·75	
Leaded-bronze	Copper	67·5	Piston rod, piston-valve rod and McNamee packing; superheated engines.
	Lead	26	
	Tin	5	
	Nickel	1·5	

Reclamation and renovation would continue to be carried out in Railway Executive shops. A second Policy Committee had been formed to recommend specifications for steels for rolling stock, etc., but, as most of the steels used previously were in accordance with British Standard specifications, the resulting standardisation was not so spectacular as in the case of some non-ferrous metals. Most grey cast-iron mixtures already included a high percentage of returned scrap (sometimes up to 95 per cent.). Further economies in this field were not expected to be great.

Influence of Specifications on Productivity.

Presenting his paper on "The Influence of Specifications on Productivity and the Economic Utilisation of Ferrous and Non-Ferrous Metals," Mr. F. Hudson said that, before maximum productivity could be obtained, in conjunction with the economic use of ferrous and non-ferrous metals, consideration should be given to the greater use of simplification, standardisation and specialisation methods, so that manufacturing operations could be properly planned. Simplification and standardisation, in particular, must go hand in hand, as too many standard specifications might be just as bad as none at all. At present, therefore, there was need for the more general use of a limited number of simplified standard alloys.

For example, British Standard Specification 1400-1948, covering copper-alloy ingots and castings, outlined 23 different alloys for castings. The bulk of industrial requirements could probably be met by 10 copper-base alloys, and these could be readily grouped into seven main types for production purposes. Agreement regarding tolerances on certain elements, normally considered as impurities, would reduce the number of alloys required still further. The simplification of alloys in this way assisted productivity and the subsequent reclamation of scrap.

Specifications only covered the quality of the metal in a test-bar, and this was of limited value to the engineer in designing a structure composed of rolled, forged, stamped or cast components. There was particular need for greater attention to be given to the quality of castings and for research on the relation between test-bar and casting. Designers and engineers to-day appreciated that neither integral, nor separately cast, test-bars normally exhibited mechanical properties representative of the casting. In many instances the properties of castings were below those obtained from test-bars. When designing castings the engineer therefore increased the sections to ensure an adequate factor of safety. This obviously increased the weight of the casting and the amount of metal required. The production of castings of the highest quality, and of known properties, would enable designers to reduce both section and weight, and lead to a substantial economy in the use of metal.

Where design, production, and supply conditions permitted, consideration could usefully be given to the greater use of high-strength alloys for the production of wrought and cast articles for the purpose of reducing weight and the amount of metal required.

Secondary Heavy Metals.

The paper on "Secondary Heavy Metals," by Mr. E. H. Jones, covered the recovery, in usable form, of copper, zinc, lead, tin and antimony from sources other than their ores. The author stated that the effect of the price was of importance. A price controlled at an artificially low level and a consumption controlled by rationing must, in secondary metals, produce a free market at higher prices, even if this were disguised by barter operations. If this did not happen, less metal would be recovered from dispersed sources than if the price were economically equitable. Since the dispersion of the metals in the form of salts exceeded that of even the lowest grade ore, recovery was obviously economically impossible in this case, but there was a possibility that substitutes might be found for such compounds as tetraethyl lead, white lead, lithopone and bluestone. The economics of the recovery of protective metallic coatings and their substitutes varied with the price and thickness of the coating. The inevitable mixing of scrap during use or collection had a great influence on the methods of recovery used, and stress should be laid on the importance of accurate analyses of impurities and the quantitative determination of their effects on properties. Low-grade scrap, and the residues from fabricating plants and primary smelting operations, were dealt with by special methods. The stage at which it was more economical to separate an alloy into its constituent elements and re-alloy, the economics of the sacrifice of one element to recover another, and the balance between the value of the work and the value of recovery were matters which had to be carefully considered. It was also interesting to note that some of these problems were in some respects common to both primary and secondary smelting.

Secondary Aluminium and Magnesium.

In his paper on "Secondary Aluminium and Magnesium," Colonel W. C. Devereux, C.B.E., dealt with the production of secondary light metals of high quality from scrap and waste materials. He traced the history of the secondary smelting industry from the early days of prejudice and discrimination against the use of its products, outlined the way in which these were gradually overcome, and referred to its rapid war-time expansion from 32,000 tons in 1940 to 85,500 tons in 1943 and its post-war consolidation and further expansion to 94,000 tons in 1950. The author stated that methods had been developed for the collection, sorting, analysis and blending of scrap and its melting and refining in furnaces, evolved for the removal of undesirable non-metallic constituents and oxides with the minimum loss of metal, to produce alloys equivalent to those made from primary materials. Methods of further refining secondary material to remove alloying elements either partially or completely, by distillation or electrolysis, had been introduced and were promising.

Of special significance to the industry were the war-time concentration of all light metals into aircraft and the present high rate of export of aluminium in finished products. The very heavy demand for light metals in the next few years and an anticipated shortage of scrap called for the maximum efficiency in collection and treatment. Both from the national and the light-metal industry's points of view, it was of the utmost importance that the maximum recovery should be achieved by the widest application of scrap segregation, by the diligent collection of scrap and by the fullest utilisation of the highly efficient resources of the secondary smelting industry. This, by its specialised processes and equipment and its scientific knowledge and control, was able to extract the last ounce of economically usable material from the scrap and waste available.

Discussion.

Mr. G. L. Bailey, who opened the discussion, said that the question of substitute metals should be carefully scrutinised. In the normal course of events—in the next five to ten years, say—it might be supposed that there would be available in the world more aluminium and more magnesium, and possibly more titanium than were now obtainable. As these materials became available, the price factor and the availability would both conspire to cause people to use them, perhaps for purposes for which, hitherto, other and heavier metals had been utilised. Substitution of that kind should be regarded as permanent replacement. There would be such changes, and they would be gradual, and a great deal of work would be done to establish the suitability of this or that material, or the action that was necessary to make a particular material suitable for a particular application. It was most inefficient and unpromising, however, to start trying to use materials just because there was a temporary shortage. To use certain materials in place of other materials, where their use was not likely to remain permanent, was unsatisfactory on a long-range basis. On a short-range basis, however, it probably would have to be done. Most substitution suggestions on a short-range basis had to face the fact that the substitution might well be uneconomic in money or in man-power, or in some other respect, and was only done because there was a temporary shortage.

On the question of secondary metals and scrap reclamation, it should be stated that metallurgists and engineers were all very impressed by what the aluminium industry had done in the re-use of secondary materials. The various methods of collection and the grading systems had done useful work of permanent value. It would be good to see the range of operations of the secondary-copper industry similarly increased—not to the same scale, because the metal was not available in the same quantity, but increased very largely. This subject however, had been much debated by many people in many places without getting very far in this country. There were some aspects of reclamation which had not been touched upon. Cases in point were reclamation from liquid residues, from pickling solutions, plating solutions, and so on. There was no doubt that a great deal of copper sulphate was still thrown down the drain in this country, and that this could be treated by electrolysis, which would not only permit the recovery of the copper, but make possible the regeneration of the sulphuric acid. This was being looked into, but it could be dealt with more thoroughly. Another matter which was also being investigated was the recovery of plating solutions which found their way into the drains in one way or another. One firm had recently installed plant for running its wash water through synthetic resins to recover an extremely valuable metal present in very small amounts, but which was of the greatest value. Moreover, drag out losses from plating tanks could be very considerable, particularly in the nickel-plating industry, and the recovery of such losses was quite an important matter.

Mr. Hudson had introduced into the title of his paper the influence of specifications on productivity, but he (Mr. Bailey) questioned whether he had not forgotten the value of productivity when he had spoken of using high-strength alloys instead of ordinary gunmetals. No doubt it was possible to make valves of aluminium-bronze instead of gunmetal with an economy in the weight of metal used, but this economy was probably offset by the loss of productivity, and, after all, man-power was still one of our most urgent questions, however short of metals we might be. The possibility, however, that working to a limited number of specifications could greatly increase the economic use of metals was undoubted, but when this was done, the right alloys, from the productivity point of view, as well as from the point of view of the availability of the metal, should be chosen. Mr. Dinsdale had spoken of the very successful efforts of the railways in this direction. He had said that they did not use the 85 : 5 : 5 : 5 Cu-Sn-Pb-Zn gunmetal as they did not find it satisfactory for all purposes. This was somewhat surprising, because, of the alloys which Mr. Dinsdale listed, it seemed that the 85 : 5 : 5 : 5 gunmetal would have been satisfactory for most of the applications for which the 86 : 7 : 2 : 5 alloy was suitable, and with considerable advantage in productivity as well as price. At present, efforts were being directed to save metal, not money, and it was questionable whether the railways were necessarily doing well if they wanted to use lead-rich bearing metals instead of tin-rich bearing metals, because, at present, there was more tin available than there was lead.

One of the most important aspects of the matter under discussion was the economic utilisation of what metals were available. There was still a great deal that could be done in this connection, and among the steps which could be taken were the reduction of machining tolerances by more accurate manufacture, and a reduction in weight by working to closer tolerances. A certain number of industrial products were over-size, and matters of that kind could be looked into with advantage in every section of industry. Quite apart from the question of the benefit to the community, if a manufacturer found that he could make 90 per cent. of what he used to make, though he only received 85 per cent. of his previous supplies of metal, he was obviously on the right side from every point of view, even though he could not manufacture everything that he would like to produce. Apart from this, there was the great urge to economy in the metal values themselves. Practice which was satisfactory and economical twenty years ago, when copper, for instance, was 41*l*. a ton, might well become quite uneconomic at present prices.

1,700-KV IMPULSE GENERATOR.

JOHNSON AND PHILLIPS, LIMITED, CHARLTON, LONDON.

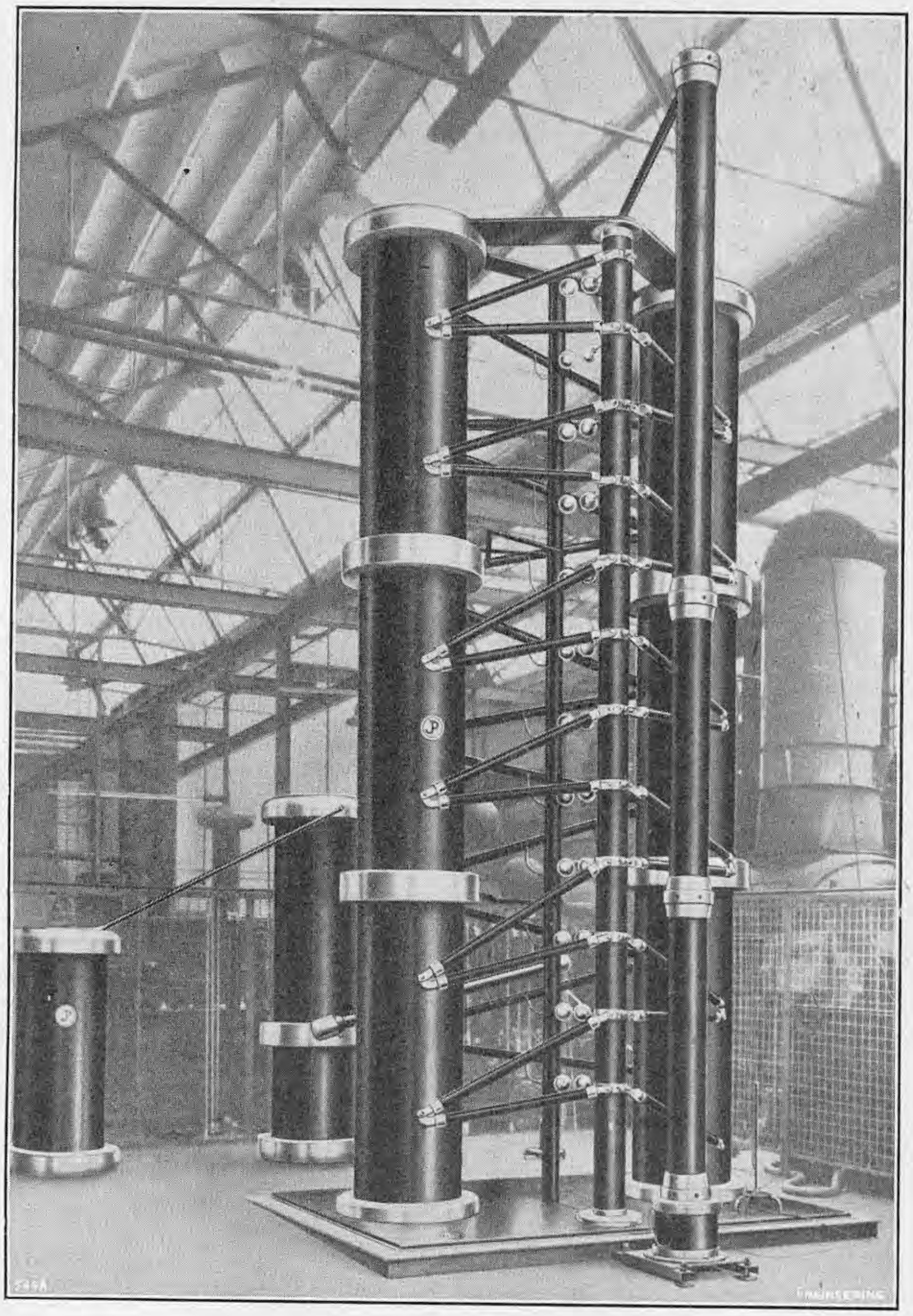


Fig. 1.

Fig. 2.

Fig. 3.

Looking at it in another way, while one could not afford, 20 years ago, to take certain measures to conserve or recover metal, now that copper was 227*l*. a ton the situation was very different. The argument had been used in industry that certain matters had been looked into before and it had been found that they did not pay. With present metal prices a good many of those matters were worth investigating again, and they might be found to pay much better now than when they had been last considered.

(*To be continued.*)

O.E.E.C. Mission on Oil-Field Equipment.—Representatives of some eight European countries left Paris by air for Washington on October 20, to form Missions Nos. 57 and 68, organised by the Organisation for European Economic Co-operation to study equipment for the oil industry. The missions will be divided into two groups, one particularly interested in refining equipment and the other in drilling equipment. The British contingent has been drawn from members of the Council of British Manufacturers of Petroleum Equipment, headed by the vice-chairman, Mr. Douglas Wilson, of the United Steel Companies, Limited. Those taking part will include Mr. Frank Kenyon, director of Wm. Kenyon and Sons, Limited; Mr. S. C. Mackenzie, field engineer, the Oil Well Engineering Company, Limited; and Mr. J. Steel, sales manager, Ruston and Hornsby, Limited. The itinerary of the mission will last until the end of November.

1,700-KV IMPULSE GENERATOR.

The 1,700-kV, 30-kW-second impulse generator, which has recently been installed at the Charlton works of Messrs. Johnson and Phillips, Limited, to ascertain the surge voltage characteristics of electrical apparatus and insulation, and for the routine testing of transformers, cables and switchgear, is believed to be the only one of its kind in Great Britain to be designed and built entirely by one firm. The equipment, of which a general view is given in Fig. 1, consists of a 200-kV direct-current charging unit; a twelve-stage two-column impulse generator; a capacitor screened resistance potential divider; a high-speed double-beam cathode-ray oscillograph with a recording camera; and a control desk. For the sake of uniformity and of appearance, the transformer, rectifier and generator capacitors are housed in black Bakelised-paper tanks, 23 in. in diameter, which are fitted with cast-aluminium end rings and corona shields.

The direct-current charging unit consists of a 6·6 kVA, 200-kV transformer, a 250-kV peak half-wave rectifier and a limiting resistor. The transformer was designed and manufactured in the company's transformer department and is housed in an oil-tight tank of black Bakelite. It is supplied from the 230-volt mains through a voltage regulator, and the output terminal which is directly connected to the rectifier, is the top corona shield. A tertiary winding is provided for cascade operation. The half-wave rectifier, which is of the copper-oxide type, is mounted on an insulated base, so that positive or negative direct current can be obtained by connecting the transformer to its top or bottom. The other end of the rectifier is then connected through the limiting resistor, which passes a maximum current of 30 milliamperes at full voltage to the first capacitor. A solenoid-operated earthing switch is placed at the output end of the limiting resistor and automatically earths the generator when the transformer is de-energised, either from the control desk or by opening any of the interlocked gates of the test area.

The impulse generator consists of twelve stages with one capacitor per stage. These capacitors, a view of one of which is given in Fig. 2, are arranged in two columns of three tanks, each tank containing two capacitors. They were designed and manufactured in Johnson and Phillips' capacitor department and each has a capacity of 0·255 microfarad and can be charged to a maximum voltage of 142 kV. With the twelve stages in series, the maximum output voltage of the generator is therefore 1,700 kV and the total energy output 30 kW-seconds. The capacitors are discharged by 12 pairs of spheres, which are 10 cm. in diameter and are mounted on two Bakelite cylinders between the capacitor columns. One of these cylinders is fixed, while the other can be rotated round its vertical axis by a lever and screw, driven by a small electric motor. The gap setting, which can be adjusted by push-button switches on the control desk, is indicated by a slide wire potentiometer operated by the lever.

The output from the final stage of the generator is taken through a damping resistor to the potential divider and thence to the test object. The output wave form is controlled at each stage by sets of resistors, which can be replaced to suit the load conditions.

HOT-DIP WIRE-GALVANISING PLANT AT MANCHESTER.

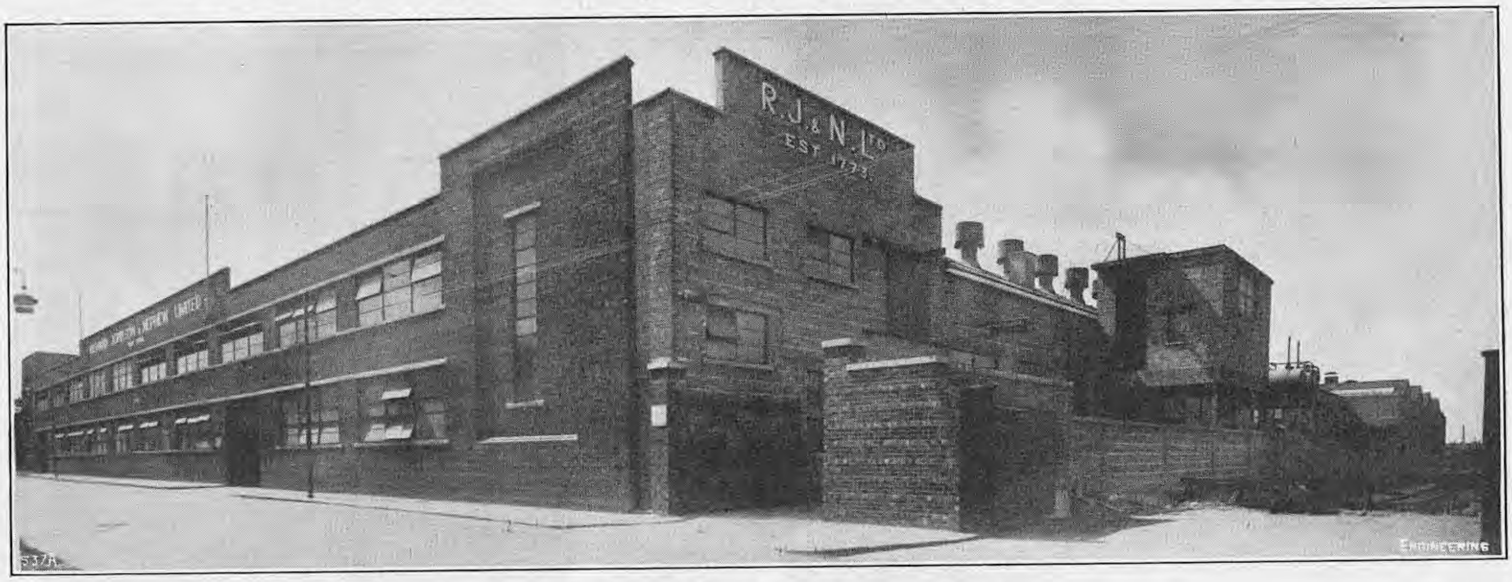


Fig. 1. Exterior View of Galvanising Plant.

The overall height of the generator is 18 ft., which is equivalent to 10·6 ft. per megavolt. The potential divider is of the single-resistance type and is surrounded by a tube of cylindrical capacitors, which screens the resistors and at the same time puts a small load on the generator, thus reducing the effect on the output wave form of variations in the test load. The surge is fed through a delay cable to the deflection plates of the oscillograph.

The high-speed cathode-ray oscillograph is of the sealed glass-tube type. It works at an accelerating voltage of 20 kV and incorporates two beams for simultaneously recording voltage and current surges. Sweep speeds from 0·3 to 1,000 microseconds are available, as well as timing " pips," covering a range of time intervals from 0·1 to 100 microseconds. Fixed calibrating voltages are provided for voltage measurements. The sweeps and brightening pulses are initiated by a valve relay, which is operated at the instant the first-stage gap is fired. A 35-mm. recording camera is used in conjunction with the oscillograph for obtaining permanent records of the tests. To enable the operator to monitor tests which are being photographically recorded, the instrument department of the firm is providing a 10-kV single-beam high-speed oscillograph.

The generator is operated from the control desk illustrated in Fig. 3, which is placed outside the test area. It houses the voltage regulator, the push-button switches and the associated contactors for energising the 200-kV charging transformer, as well as the push-button switches for adjusting the generator sphere gaps. Meters are provided for indicating the voltage and current input to the charging transformer, the gap setting and the mean stage voltage. The value of this voltage is indicated on a micro-ammeter, which is calibrated in kilovolts and is connected through a 3,000-megohm resistor to the high-voltage side of the first-stage capacitor.

As regards operation, for single surges the stages are charged to the required voltage and the gaps are closed until a discharge occurs. To make repetition " shots " at a constant voltage, the generator is charged continuously with the gaps set to flash over at the required voltage. To obtain chopped waves, such as are required in transformer tests, a standard rod gap for voltages up to 750 kV is connected in parallel with the generator. The three-electrode method of controlling the tripping of the generator is not used, but arrangements have been made so that it can be employed later.

" At the Turn of the Century."—The General Electric Company, Limited, Magnet House, Kingsway, London, W.C.2, who claim to be the largest British electrical manufacturing organisation, have issued a booklet, entitled " At the Turn of the Century," to their shareholders. This may be described as a running commentary on the electrical events of the past half-century, for it indicates in text, diagram and illustration the progress which has been made by the company during that time. For instance, the number of employees rose from 3,000 in 1900 to 57,800 in 1951, and the capital of the firm from 289,000*l.* to 37,250,000*l.* Numerous factories were opened and extended during the same period, and research, upon which 1,500,000*l.* per annum is now spent, was actively carried on. The overseas organisation is correspondingly extensive.

CONTRACTS.

The Hunslet Engine Co., Ltd., Leeds, 10, have received an order from the Ministry of Supply for 14 " Austerity " 48½-ton 0-6-0 tank locomotives with 18 in. by 26 in. cylinders.

British Polar Engines, Ltd., Govan, Glasgow, S.W.1, have received a number of orders for auxiliary marine machinery, propelling units, and generating sets. Among these are orders for a 230-b.h.p. and four 450-b.h.p. 600-r.p.m. auxiliary generating sets for a vessel for the New Zealand Shipping Co., Ltd., to be built by John Brown & Co., Ltd., Clydebank; one auxiliary 340-b.h.p. generating set, to run at 600-r.p.m., for each of five ships for the Anglo-Saxon Petroleum Co., to be built by Cammell Laird & Co., Ltd.; a 640-b.h.p. 250-r.p.m. marine propelling unit for a vessel for Henry McGregor, Ltd., to be built by Henry Robb, Ltd.; three 375-b.h.p. 500-r.p.m., auxiliary generating sets for W. Denny and Brothers, Ltd.; six 340-b.h.p. 600-r.p.m. generating sets for R. & W. Hawthorn, Leslie & Co., Ltd., and three 290-b.h.p. 600-r.p.m. auxiliary generating sets for the Burntisland Shipbuilding Co., Ltd. A 270-b.h.p. 600-r.p.m. alternator set has been ordered for Rizla Cigarette Papers, Ltd., for emergency generating purposes.

Balfour, Beatty and Co., Ltd., 66, Queen-street, London, E.C.4, have been awarded the first contract, amounting to approximately 6,000,000*l.*, for the construction of the Wadi Tharthar project in Iraq by the Development Board, on behalf of the Government of Iraq. The project, which is for flood-relief at Samara, on the River Tigris, diverts the flood waters into the Wadi Tharthar depression, and the first contract consists of the construction of a canal, 64 km. (40 miles) in length, and entails the excavation of 35 million cub. m. of material. The money required to pay for this and other projects will be derived from the oil revenues which, it is estimated, will reach a figure of over 50,000,000*l.* per annum after 1954.

Davy and United Engineering Co., Ltd., Park Iron Works, Sheffield, 4, have received a further large order for the Mo i Rana Works of the Norwegian Steel Company (A/S Norsk Jernverk), namely, a Morgan combination merchant-bar, wire-rod and strip rolling mill, capable of rolling speeds of over 4,000 ft. per minute. The mill is designed to produce 80,000 tons annually and will have an ultimate annual output of 150,000 tons. It will be complementary to the blooming, slabbing and section mill ordered from Messrs. Davy and United by Norsk Jernverk 14 months ago. The new Morgan mill will consist of a seven-stand roughing train complete with two vertical edging mills, a four-stand intermediate train with two further vertical edging mills, a two-stand looping train with skew tables and repeaters, and a six-stand rod-finishing train. The Morgan mill will produce coiled strip from 25 mm. to 265 mm. wide, merchant rounds, flats, angles, T-sections, beams, and 5-mm. to 9·5-mm. wire rods, in coils, starting from billets and slabs from 50 mm. square up to those measuring 65 mm. by 265 mm. The Davy and United Engineering Co. now have in hand orders valued at over 2,000,000*l.*, for Norsk Jernverk, which is an integrated iron and steel works. At the Mo i Rana Works, the iron will be produced from local ores by electric smelting instead of by conventional blast furnaces, the current being generated hydro-electrically.

HOT-DIP WIRE-GALVANISING INSTALLATION IN MANCHESTER.

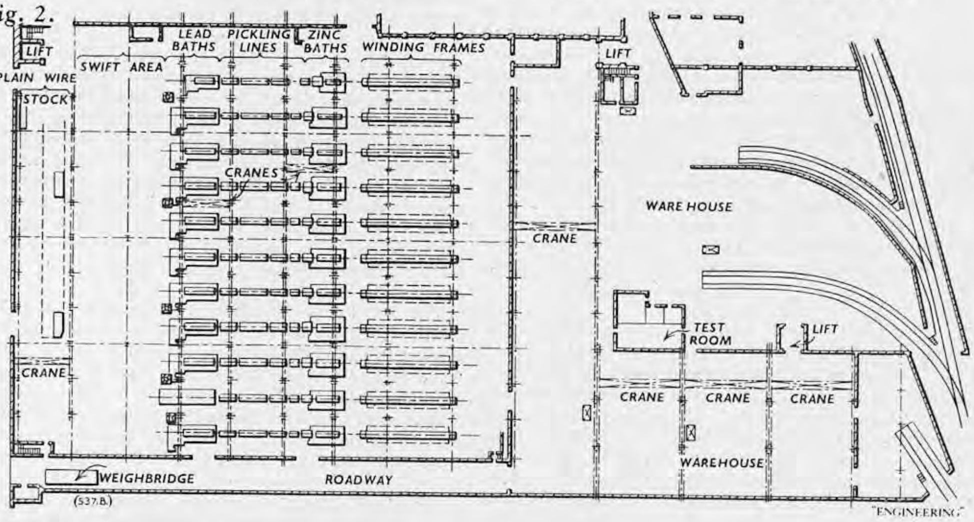
The firm of Richard Johnson and Nephew, Limited, wire manufacturers, Forge-lane, Manchester, 11, established in 1773, produce important tonnages of wire of many types and sizes for a variety of trades and industries. The production of galvanised wire by the continuous hot-dip process has been conducted since the introduction of the process, at the Forge Lane Works, by George Bedson, in 1861, and the latest development in this sphere of the company's activities has been the recent completion of a large new galvanising plant. This has involved a completely new lay-out of this portion of the works and the erection of new buildings, all of which has been carried out without hindering production by arranging the new construction in four sections. An exterior view of the new galvanising department is shown in Fig. 1, on this page. The new premises covers a floor space measuring 540 ft. by 270 ft.; a plan is reproduced in Fig. 2, on page 557. The roof is of the portal type and the distance from the ground level to the eaves is 24 ft. Roof glazing provides excellent lighting during the day and a system of fluorescent lighting is installed throughout the galvanising department to provide thoroughly adequate illumination for night work.

As will be seen in the plan, Fig. 2, there are 11 galvanising plants or lines, each of which consists, in sequence, of a lead annealing bath, a water-cooling bath, a hydrochloric-acid pickling bath, a water washing bath, a flux bath, a drying chamber, a zinc galvanising bath and a final re-winding or " take-up " frame. Throughout the installation, the fuel used for heating the various baths is town gas. Coils of plain wire from the wire mill are taken by electric truck, through a passage below the galvanising shop, to the base of two rectangular apertures in the shop floor. The position of these is shown in the plan, Fig. 2, and one of them, as may be discerned in Fig. 3, on page 557, is opposite bay No. 4. The overhead crane seen in Fig. 3 hoists the coils of wire and stacks them alongside the left-hand wall, as shown in Figs. 2 and 3. In front of the plain-wire stacking space is the swift area. A swift is a pay-off reel on which a coil is placed and from which the wire is uncoiled solely by the tension applied by the take-up or re-coiling frame placed after the galvanising bath. As may be seen in Fig. 3, the spindle of the swift is vertical and the coil is supported by cross arms or an annular plate.

Next in line in the production sequence is the gas-heated lead bath, which is held at a temperature of 730 deg. C., for soft wire and 400 deg. C., for high-tensile wire. To minimise heat losses the lead baths are covered with blocks of 90 per cent. magnesia. When operated at a temperature of 730 deg. C., the lead baths act as annealing units and completely remove the effects of cold work when the transit time through the molten metal is adjusted to allow for this. At 400 deg. C., little alteration to the hard-drawn properties occurs, but this low-temperature treatment is found to be beneficial, particularly where a figure for elongation is laid down in the wire specification. After the lead bath the wire passes through a water bath, where it is cooled before entering the hydrochloric-acid pickling bath. This cooling process is necessary as, if the wire entered the acid at too high a tempera-

WIRE-GALVANISING PLANT, MANCHESTER.

Fig. 2.



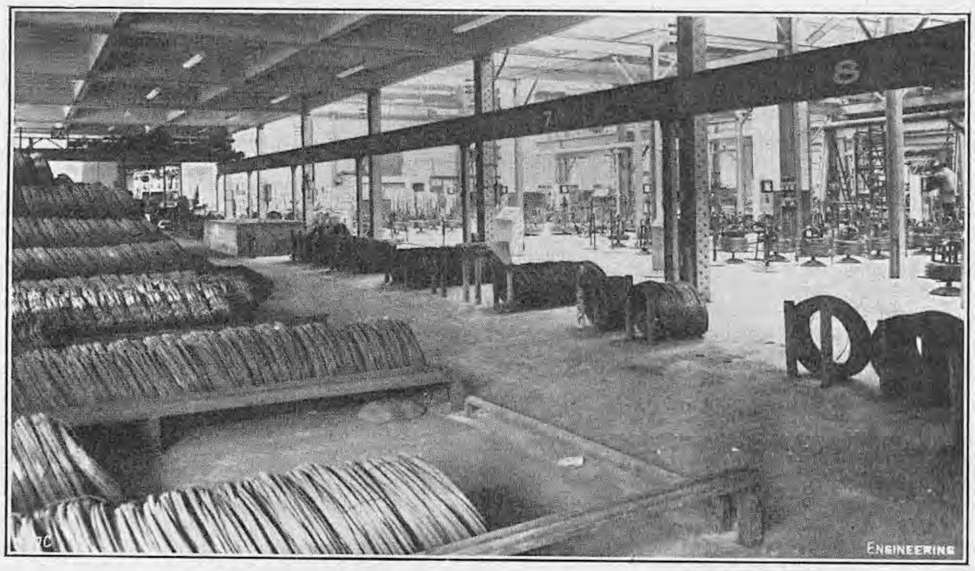


Fig. 3. Plain-Wire Stock and Swift Area.

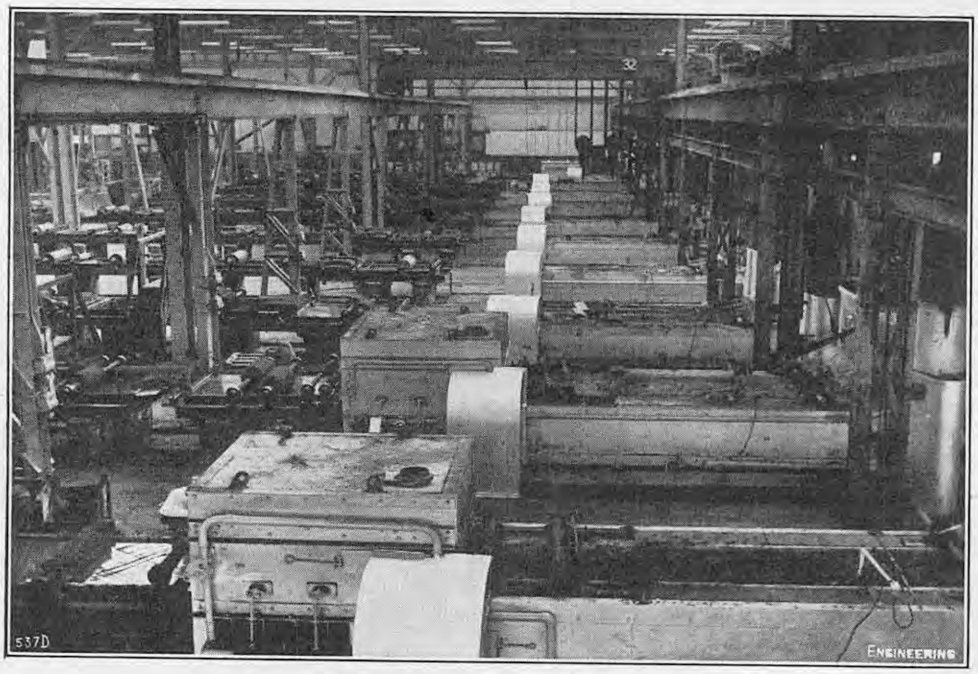


Fig. 4. Zinc-Bath End of Galvanising Department.

ture, it would drive off hydrochloric acid gas from the pickling liquor. After passing through the acid pickling bath the wire traverses a water washing bath and is then taken into a flux bath consisting of a solution of zinc ammonium chloride. Then, before entering the galvanising bath the wire is passed through a drying unit. This is a small gas-fired reverberatory chamber and is the box-like structure fitted with four lifting lugs seen in the left centre of Fig. 4, herewith. The flux carried on the wire is dried mainly by radiation during the rapid passage through the chamber, the aim being to remove all water and leave the flux unaltered by the action of heat. The chamber functions solely as a surface-film drier and very little sensible heat passes to the wire itself.

On the right of the drier in Fig. 4 is the gas-heated zinc bath, which is usually maintained at a temperature of 455 deg. to 460 deg. C. To minimise heat losses, the bath is covered with a layer of exploded vermiculite. In Fig. 4 it may be discerned that the wires are above the zinc bath, but this is merely due to the fact that the photograph reproduced in our illustration was taken during a week-end, when the plant was not working. In order to ensure that the coating of zinc on the wire is concentric, the latter invariably issues vertically from the zinc bath, by way of a seal of oiled charcoal which prevents oxidation of the zinc. The finished wire then passes on to the take-up or re-coiling frames, from which it is conveyed to the warehouse in coils each weighing about 350 lb. by electric-battery driven "poker" trucks. These, in effect, are fork-lift trucks fitted with a single prong. This takes the form of a very slightly tapered cylindrical and almost horizontal arm on which coils of a total weight of from 20 to 25 cwt. can be accommodated at one lift. The trucks not only convey the coils to the warehouse, but stack them in the allotted bays. After testing, the coils are tied up and labelled for dispatch.

Having thus briefly outlined the process, we will now deal in greater detail with some of the equipment employed. It will be seen from the plan, Fig. 2, and also from Fig. 4, that the lead and the zinc baths are arranged in two lateral lines and that each line of baths is served by an overhead travelling crane. These are capable of lifting a lead or a zinc bath, filled with metal, from its setting. Alongside each zinc and lead bath, sunk below floor level and covered with removable plates, is housed a spare bath so that, should a leak occur in a bath while in service, its molten-metal contents can be pumped at once into the spare bath, and metal losses reduced to the minimum. In practice, however, the baths are changed according to a tonnage schedule, and premature bursts are of comparatively rare occurrence. Hydrochloric acid for the pickling tanks is delivered to the plant by road tank wagons and their contents transferred by means of compressed air to two overhead rubber-lined steel tanks from which the acid is fed, by gravity, through measuring vessels to the individual pickling baths in each line. The compressed-air supply is coupled to a flange on the road tank wagon and the acid is, in effect, blown out of the mobile tank into the overhead storage tanks by way of a delivery pipe attached to another flange on the tank wagon. To ensure complete emptying, the delivery pipe carries a tube which extends to the bottom of the tank on the wagon. Throughout the installation, temperatures are pyrometrically controlled by means of thermocouples which operate recorder controllers of the "on-off" type. Experience has shown that temperatures are thereby held closely within the pre-arranged limits.

The basis of operation is continuous and the minimum campaign consists of a week of 120 hours, during which time the plant does not stop and the finished galvanised wires are continuously unloaded, as mentioned above, in coils, each weighing about 350 lb. The 120-hour weekly quantity of wire galvanised, when supplies of steel are adequate, is of the order of 1,500 tons and, when the quantity of zinc available is normal, all wire meets the minimum requirements of British Standard Specification No. 443 or similar overseas specifications. The diameters of the wires passed through the galvanising plant range from 0·028 in. to 0·324 in., and the tensile strengths vary from 25 tons to 100 tons per square inch. As a rule, each of the 11 galvanising plants deals with 32 wires, though this may be reduced to 20 in the case of heavy wires of diameters between 0·200 in. and 0·324 in. The galvanised wires produced by the firm cover most of the requirements of the cable industry, both for land and submarine cables, and a high tonnage of fencing and barbed wire is also manufactured. High-tensile wires for steel-cored aluminium conductors are among the many other types of wire produced for a multiplicity of industries.

Loan of H.M. Submarines to French Navy.—At a ceremony at the Royal Navy's submarine base at Gosport, on October 30, H.M.S. Statesman was handed over to the French Ministry of Marine on loan for four years, and was renamed "Sultane." Three other submarines to be transferred on loan at a later date are the Satyr, Spiteful and Sportsman, which will be renamed Saphir, Sirène and Sybille, respectively. The Parliamentary Secretary of the Admiralty said in the House of Commons on August 1 that these submarines were being refitted in the United Kingdom at the expense of the French Government.

Gas-Turbine Merchant Ship.—The Shell Petroleum Company's 12,000-ton tanker Auris, the first merchant ship in the world to be propelled by a gas-turbine, is now on her way to Tampico in the Gulf of Mexico. One of the ship's four Diesel-electric engines has been replaced by gas turbine, built by the British Thomson-Houston Company, Limited, Rugby. Mr. John Lamb, O.B.E., head of the Shell Marine Research and Development Department, has stated that no trouble was experienced during the trials, lasting 48 hours, off the Northumbrian coast.

NOTES FROM THE INDUSTRIAL CENTRES.

SCOTLAND.

COAL POSITION.—Coal stocks have derived much benefit from the mild weather this autumn, and, with space-heating requirements much below the average, industrial users are steadily strengthening their reserves. At October 13, these consumers held 484,000 tons, compared with 424,000 tons last year. Of that, iron and steel works accounted for 100,000 tons against 107,000 tons, but with steel-ingot output at only about 80 per. cent. of last year's production, their fuel position, on balance, is somewhat sounder. House coal is the most vulnerable category, with 165,000 tons against 234,000 tons, but people have become considerably more fuel-conscious after last winter's experience, and a good proportion of the increased disposals during the past few months is being put to private reserve. Electricity stations find stockpiling progress difficult because of the extra strain on fuel-fired installations brought about as a result of reduced water supplies for hydro-generation after the dry weather.

EFFECTS OF SHORTAGES OF SCRAP.—Concern is increasing among steel consumers at the absence of any improvement in supplies of scrap for steel-melting furnaces. Ingot stocks are well down after the cut in production since May, reserves of bars and billets at re-rolling premises are greatly diminished, and consumers of finished steel, in many cases, have also run down what stocks of material they had in hand for contingencies. The effect of reduced deliveries at all stages is being felt by shipbuilders, whose already bulging order books are steadily increasing in size. In one yard recently one or two departments were compelled to operate at only 50 per cent. of capacity because of diminished material supplies. Last week one re-rolling concern worked only three days. The older mills, having heating furnaces not possessing a pusher-bar installation, are slightly favoured, as they can more readily carry on with re-rolling scrap items such as rails and axles, but this material is in short supply.

RADIO WARNINGS OF POWER CUTS.—Beginning on Monday, October 22, the South-West Scotland Electricity Board are operating their own short-wave wireless system to warn certain industrial consumers, using receivers supplied by the Board, of impending electricity cuts. A rota system has been established, throughout the area, and this will enable industrial consumers to ascertain immediately from the radio messages whether their premises will be affected.

SHIPBUILDING ACTIVITY.—Contracts were announced yesterday for eight large cargo vessels and a small tanker for three shipbuilding firms in the Greenock and Port Glasgow area. Six of the new vessels are to be built by the Greenock Dockyard Co., Ltd. (four for Clan Line Steamers, Ltd., and two for the Pacific Steam Navigation Co.), two by Lithgows, Ltd., Port Glasgow (ore-carrying steamers for Scottish Ore Carriers, Ltd., Edinburgh), and one by George Brown & Co. (Marine), Ltd., Greenock (a tank lighter for the Anglo-Saxon Petroleum Co., Ltd.).

LOSSES DUE TO DRY ROT IN TIMBER.—The Forest Products Research Association (Department of Scientific and Industrial Research) recently estimated that the damage caused by dry rot in Great Britain amounted to 20,000,000*l*. per annum. Of this, 10,000,000*l*. occurred in Scotland, said Mr. E. H. Brooke Boulton, lecturer in forestry and timber at the University of Cambridge, addressing an audience of builders and architects in the Building Centre, Glasgow, last night. This high incidence had been caused by neglect of the fabric of buildings, particularly during the war.

AMATEUR RADIO EXHIBITION.—The Radio Amateurs of Glasgow are staging an exhibition, entitled "The Story of Amateur Radio," at the Engineering Centre, 351, Sauchiehall-street, Glasgow, C.2. It was opened by Sir Victor Warren, the Lord Provost, at 2.30 p.m., on Monday, October 29, and will continue until to-morrow, Saturday, November 3. The hours of opening are from 2 p.m. to 9 p.m., and from 10 a.m. to 9 p.m. on Saturday.

THE LATE MR. BARCLAY HOGARTH.—We regret to learn that Mr. Barclay Hogarth, chairman of the Clyde Navigation Trust, collapsed and died on October 27, while out shooting on the moors at Alexandria, Dumbartonshire. Mr. Hogarth, who was 63, was a partner in the Glasgow shipping firm of Hugh Hogarth & Sons, managers of the Hogarth Shipping Co., Ltd., the Kelvin Shipping Co., Ltd., the Iberia Shipping Co., Ltd., and Hogarth, Sons & Co., Ltd., shipbrokers, London, who together control one of the largest privately-owned fleets sailing from the Clyde. He was rear-commodore of the Royal Northern Yacht Club.

CLEVELAND AND THE NORTHERN COUNTIES.

IRON AND STEEL POSITION.—Business in the North of England iron, steel and allied trades has shrunk nearly to vanishing point. The suspension of Cleveland market operations is attributed to several disturbing influences, including the General Election, but the principal cause of business inactivity is the serious shortage of commodity outputs, which are insufficient to meet the urgent needs of customers. Home and overseas customers are prepared to discuss possible terms of new business, but at present both makers and merchants are unable to re-enter the market. Defence orders are now absorbing much of the distributable tonnage and these restrict the quantities which are wanted in very large parcels for shipment overseas.

MANUFACTURE OF JET ENGINES on WEARSIDE.—The manufacture of jet aircraft engines is to be commenced on the Pallion Trading Estate, Sunderland, in December, as a result of the signing of a contract between Sunex, Ltd., and the Bristol Aircraft Co., Ltd., whereby the former firm are to cede their factory at Pallion to the aeroplane company. Sunex, Ltd., are manufacturers of perambulators and tricycles, but have had difficulties, latterly, in obtaining adequate supplies of materials and especially of steel. The present 200 employees of Sunex, Ltd., are to be taken on by the new factory owners, and it is anticipated that when future extensions, on an adjoining site, are completed, employment will be found for some 3,000 persons, about 85 per cent. of whom would be men.

AIR SERVICES IN THE NORTH EAST.—In these notes, on page 462 of our issue of October 12, we referred to the impending visits of British European Airways Corporation representatives to airports on the North-East Coast to survey existing facilities and to hear evidence regarding the need for the introduction of air services to the Continent. The visit was made on October 22 and 23, and the facilities at Woolsington Airport, near Newcastle, and at Greatham Airport, between Stockton-on-Tees and West Hartlepool, were inspected, as well as the site of the proposed larger airport at Boldon, Co. Durham. Little seems to have emerged as a result of the visit, except that scheduled air services to the Continent would not be commenced for "some time yet" and that other regular services from the area might not be remunerative. It appears possible, however, that private companies, working on a charter basis, might be encouraged to undertake new services.

LANCASHIRE AND SOUTH YORKSHIRE.

IMPORTANCE OF SCRAP.—Mr. George Wood, C.B.E., chairman of Thos. W. Ward, Ltd., told the shareholders at the annual meeting of the company that the steel industry was in urgent need of more scrap, yet lying about the country were hundreds of thousands of tons of scrap in the form of derelict plant, obsolete equipment, waste material, etc. There should be an ever-present scrap-consciousness, he considered, even to the extent of its being looked upon as an offence to neglect sending scrap to the melting works. He urged that every ton of steel which could be produced was needed for the Defence programme and for the manufacture of export goods.

COURSE ON STEEL HEAT-TREATMENT.—Sheffield steel-workers are being encouraged to take a course of 20 lectures on heat treatment prior to a City and Guilds examination next March. Sheffield University has taken the novel course of holding the lectures in an East-End steelworks instead of in the University, some miles distant. Each lecture will be repeated in the subsequent week, so that shift workers need not miss a lecture.

THE LATE MR. A. E. HANCOCK.—We regret to learn, from the Hunslet Engine Co., Ltd., Leeds, of the death on October 11 of their service manager, Mr. Albert E. Hancock, who had been associated with the company for more than 20 years. His engineering training was received with the locomotive-building firm of Kerr, Stuart & Co., Ltd., at Stoke-on-Trent, whose business closed down during the industrial depression between the wars. He next spent some time with the North British Locomotive Co., Ltd., before joining the Hunslet Company, on whose behalf he had travelled widely in South America and the Middle East. In the British coalfields he was particularly well known, having been intimately concerned with the putting into service of flameproof mines locomotives.

THE MIDLANDS.

THE BRITISH INDUSTRIES FAIR BUILDING.—The frontage of the British Industries Fair building at Castle Bromwich, Birmingham, which, since the Fair was re-opened after the war, has consisted of camouflage netting on tubular scaffolding, is to be re-modelled. Brick, stone, and some other materials, not subject to licence or permit, will be used, and the entrance will be emphasised as a central feature in the facade.

MIDLAND FIRM'S NEW FACTORY.—The industrial estates sub-committee of Liverpool Corporation have approved arrangements for leasing 50 acres of land to the Standard Motor Company, Ltd., of Coventry. The land is on the Kirkby Trading Estate, East Lancashire-road, and the Standard Company plan to build a factory there to manufacture Diesel engines and spare parts for motor vehicles. The factory is expected to employ about 4,500 people, and, to provide for possible expansion, the company have taken an option for ten years on a further 86 acres of land.

THE "INDIAN" MOTOR CYCLE.—The Indian motor cycle, an American design commanding a good market in the United States, is to be made by a British firm, J. Brockhouse & Co., Ltd., of West Bromwich. Arrangements have been made for the Brockhouse Company to take over the Indian Motor Cycle Company's jigs, tools, designs and stocks, and to control manufacturing both in this country and in the United States.

AN OLD BARGE.—The old Stourport-built wooden barge Safety, registered at Gloucester, has come into the news after a life of 113 years. The Safety, built in 1838, was for over 90 years a sailing barge, and then took on a new lease of life when twin screws and Diesel engines were fitted. She sank at Lydney at the end of last year, but was raised and was found to be still fit for service. Now, after engine repairs, the Safety is again in commission. She is said to be the oldest trading vessel in the country, and is one of the few survivors, if not the only one, of the many craft built at Stourport in the first half of last century for trading on the river Severn.

THE LATE MR. REX NICHOLS.—The death occurred, on October 24, at Birmingham, at the age of 49, of Mr. Rex Nichols, originator of the Nichols nut-tapping machine, which uses the principle of the floating tap.

SOUTH-WEST ENGLAND AND SOUTH WALES.

WELSH COLLIERY INDUSTRY.—Production of coal in South Wales, which has been lagging behind requirements for a long time, showed a further drop last week. Two big football matches at Cardiff resulted in the loss of more than 10,000 tons of saleable coal. Only 106 pits in the coalfield worked the voluntary Saturday shift on that day, producing 20,868 tons of coal, compared with an average, in recent weeks, of well over 30,000 tons.

RIVER TAFF WORKS, CARDIFF.—A proposal for confining the course of the River Taff near its mouth at Cardiff between retaining walls has been approved by the Cardiff Port Development Association and will now be discussed with the Ministry of Transport, the Cardiff Corporation and the Docks and Inland Waterways Executive. This would provide navigational improvement in the Cardiff docks entrance channel, which has been subject to silting by the river. The new scheme would provide for the reclamation of land which could be used for industrial purposes.

PURCHASE-TAX EFFECT ON RADIO EQUIPMENT.—As a result of the effects of the 66⅔ per cent. purchase tax on radio equipment, about 400 of the 1,000 employees working at the Murphy Radio Company's factory at Hirwaun Trading Estate will become redundant in the next few weeks. A meeting of the employees concerned has invited the Members of Parliament for the neighbouring divisions to attend a meeting to discuss the position. The M.P.s will be asked to appeal to the Government to arrange to have electronic contracts placed in South Wales.

DIFFICULTIES OF MANUFACTURERS.—Shortage of materials has caused some redundancy at the Ammanford factory of Pullman's Spring-filled Co., Ltd., where many employees have been laid off. At its peak, the factory employed 1,100 people but this has fallen to about 700 in the past 12 months. At the Ammanford factory of Messrs. Dancer & Hearne Bros., chair manufacturers, 65 employees have been temporarily laid off because of the high cost of materials.

WELSH DIVISION OF THE FACTORY INSPECTORATE.—The Ministry of Labour have announced their decision to set up a separate division for Wales in the organisation of the Factory Inspectorate. Although the Inspectorate was organised on a basis of districts, grouped in divisions, there has never been a separate division for Wales. South Wales has been grouped with districts in the South-west of England, and North Wales with the West Midlands.

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.

Society of Engineers.—Monday, November 5, 5.30 p.m., Geological Society, Burlington House, Piccadilly, W.1. "Oilfield Operations," by Mr. L. H. J. Hersch.

Institution of Mechanical Engineers.—*North-Eastern Branch:* Monday, November 5, 6 p.m., Stephenson Building, Claremont-road, Newcastle-upon-Tyne. "New Engineering Laboratories, King's College, University of Durham," by Professor A. F. Burstall. *Southern Branch:* Wednesday, November 7, 7 p.m., Municipal College, Portsmouth. Film on "Raising H.M. Submarine Truculent," introduced by Mr. C. L. Black. *Scottish Branch:* Thursday, November 8, 7.30 p.m., Royal Technical College, Glasgow; and Friday, November 9, 7.30 p.m., North British Station Hotel, Edinburgh. Repetition of Presidential Address by Mr. A. C. Hartley. *Institution (Hydraulics Group):* Friday, November 9, 5.30 p.m., Storey's-gate, St. James's Park, S.W.1. "Design of Large Pumping Installations for Low and Medium Heads," by Mr. G. A. Wauchope and Mr. H. P. Humphreys. Automobile Division.—*Coventry Centre:* Tuesday, November 6, 7 p.m., Craven Arms Hotel, High-street, Coventry. Address on "Experiences During Twenty Years of Oil-Engine Development," by Mr. C. B. Dicksee, divisional chairman. *Western Centre:* Thursday, November 8, 6.45 p.m., Park Hotel, Cardiff. "Factors Governing Performance of Crankcase Lubricating Oils," by Mr. A. Towle.

Royal Aeronautical Society.—*Derby Branch:* Monday, November 5, 6.15 p.m., Rolls-Royce Welfare Hall, Nightingale-road, Derby. "Princess Flying Boat," by Mr. H. Knowler. *Graduate and Student Section:* Tuesday, November 6, 7.30 p.m., 4, Hamilton-place, W.1. "Production Research for Aircraft," by Mr. L. E. Bunnett.

Institution of Electrical Engineers.—*Mersey and North Wales Centre:* Monday, November 5, 6.30 p.m., Royal Institution, Colquitt-street, Liverpool. "Life and Work of Oliver Heaviside," by Professor G. H. Rawcliffe. *London Students' Section:* Monday, November 5, 7 p.m., Victoria-embankment, W.C.2. "Power Station Practice, with Reference to Earley Power Station," by Mr. J. E. G. Silvester and Mr. M. G. Nash. *South Midland Centre:* Monday, November 5, 6 p.m., James Watt Memorial Institute, Birmingham. "Economic Plant Sizes and Boiler-Set Groupings on the British Grid," by Mr. B. Donkin and Mr. P. H. Margen. *Measurements Section:* Tuesday, November 6, 5.30 p.m., Victoria-embankment, W.C.2. Discussion on "Measurements Involved in Testing of Protective Equipment," opened by Mr. H. S. Petch. *North-Western Centre:* Tuesday, November 6, 6.15 p.m., Engineers' Club, Manchester. "A Review of Research in Electricity Supply," by C. W. Marshall. *East Midland Centre:* Tuesday, November 6, 6.30 p.m., Loughborough College, Loughborough. "Development of the Vibrator as a Competitor of the Rotary Converter," by Dr. J. H. Mitchell. *Scottish Centre:* Tuesday, November 6, 7 p.m., 39, Elmbank-crescent, Glasgow; and Wednesday, November 7, 7 p.m., Heriot-Watt College, Edinburgh. "Planning of an Electricity Board's Distribution System," by Mr. G. O. McLean. *Southern Centre:* Wednesday, November 7, 6.30 p.m., Polygon Hotel, Southampton. "Electrical Control of Dangerous Machinery and Processes," by Mr. W. Fordham Cooper. *Institution:* Thursday, November 8, 5.30 p.m., Victoria-embankment, W.C.2. "The London-Birmingham Television-Cable System," by Mr. T. Kilvington, Mr. F. J. M. Laver and Mr. H. Stanesby.

Institution of Production Engineers.—*Liverpool Graduate Section:* Monday, November 5, 7.30 p.m., Electricity Showrooms, Whitechapel, Liverpool. Film, Evening. *Reading Section:* Tuesday, November 6, 7.15 p.m., Great Western Hotel, Reading. "Mechanical Handling," by Mr. F. T. Dean. *Halifax Section:* Tuesday, November 6, 7.15 p.m., George Hotel, Huddersfield. "Production of Steel and Bronze Castings," by Mr. G. L. Hancock. *Nottingham Section:* Wednesday, November 7, 7 p.m., Victoria Station Hotel, Milton-street, Nottingham. "The Lost-Wax Process," by Mr. A. Short. *Liverpool Section:* Wednesday, November 7, 7.15 p.m., Offices of North Western Gas Board, Radiant House, Bold-street, Liverpool, 1. "Accidents and Accident Prevention," by Mr. C. P. Gourley. *Western Section:* Friday, November 9, 7.30 p.m., Wheatstone Hall, Brunswick-road, Gloucester. "Mechanical Gauging and Inspection," by Mr. J. Loxham.

Junior Institution of Engineers.—*North-Western Section:* Monday, November 5, 7.30 p.m., 16, St. Mary's Parsonage, Manchester. "Modern Electric Traction," by Mr. J. K. Brown. *Institution:* Friday, November 9, 6.30 p.m., 39, Victoria-street, S.W.1. "The Engineer and Safety," by Mr. F. M. Panzetta.

Institute of Road Transport Engineers.—*Scottish Centre:* Monday, November 5, 7.30 p.m., North British Station Hotel, Edinburgh. "Pistons, Rings and Cylinder Liners," by Mr. G. W. Yarwood. *Eastern Group:* November 6, 7 p.m., Marshall's Airport, Cambridge. "Vacuum and Air Brakes," by Mr. S. H. Edge.

Institution of Works Managers.—*Notts and Derby Branch:* Monday, November 5, 7.30 p.m., Midland Hotel, Derby. *Wolverhampton Branch:* Tuesday, November 6, 7 p.m., Star and Garter Royal Hotel, Wolverhampton. "Why Nationalised Industry Cannot Be Efficient," by Mr. L. C. Ord. *Bristol Branch:* Thursday, November 8, 7.15 p.m., Royal Hotel, Bristol. "Factory Discipline," by Mr. J. Ayres.

Institute of British Foundrymen.—*Sheffield Branch:* Monday, November 5, 7.30 p.m., Royal Victoria Station Hotel, Sheffield. "Dust in Foundry Dressing Operations," by Mr. R. F. Ottignon and Mr. W. B. Lawrie (with film). *Slough Section:* Tuesday, November 6, 7.30 p.m., Lecture Theatre, High Duty Alloys, Ltd., Slough. "Practical Experiences in Producing Nodular Iron," by Mr. M. M. Hallett. *Lincolnshire Branch:* Thursday, November 8, 7.15 p.m., Technical College, Lincoln. "Production of Intricate Castings from a Durable Loam Mould," by Mr. J. Currie. *Newcastle Branch:* Saturday, November 10, 6 p.m., Neville Hall, Newcastle-upon-Tyne. "Dust in Foundry Dressing Operations," by Mr. R. F. Ottignon and Mr. W. B. Lawrie (with film). *West Riding of Yorkshire Branch:* Saturday, November 10, 6.30 p.m., Technical College, Bradford. Report of Sub-committee on "Synthetic Resins in the Foundry," presented by Mr. G. L. Harbach.

Chemical Society.—*Nottingham Branch:* Tuesday, November 6, 5 p.m., University College, Leicester. "Molecular Compounds," by Mr. H. M. Powell.

Institution of Civil Engineers.—Tuesday, November 6, 5.30 p.m., Great George-street, S.W.1. Presidential Address by Mr. A. S. Quartermaine. *Midlands Association:* Thursday, November 8, 6 p.m., James Watt Memorial Institute, Birmingham. "Water Supply," by Mr. Norman J. Pugh.

Institution of Chemical Engineers.—Tuesday, November 6, 5.30 p.m., Geological Society's Apartments, Burlington House, Piccadilly, W.1. "Mechanism of the Drying of Solids, with Special Reference to China Clay," Part III, by Mr. D. M. Newitt and Mr. M. Coleman.

Illuminating Engineering Society.—*Cardiff Centre:* Tuesday, November 6, 5.45 p.m., Offices of South Wales Electricity Board, Cardiff. "Lighting of Departmental Stores," by Mr. L. E. Gibbs. *Edinburgh Centre:* Wednesday, November 7, 7 p.m., 357, High-street, Edinburgh; and *Glasgow Centre:* Thursday, November 8, 6.30 p.m., 39, Elmbank-crescent, Glasgow. "Lighting for Indoor and Outdoor Sports," by Mr. D. E. Beard.

Institution of Engineers and Shipbuilders in Scotland.—Tuesday, November 6, 6.30 p.m., 39, Elmbank-crescent, Glasgow, C.2. "Some Aspects of Research on Friction and Wear," by Dr. F. T. Barwell.

Institution of Structural Engineers.—*Northern Counties Branch:* Tuesday, November 6, 6.30 p.m., Cleveland Scientific and Technical Institution, Middlesbrough. "Contrast and Similarities Between Ship and Land Structures," by Mr. G. M. Boyd. *Scottish Branch:* Wednesday, November 7, 6 p.m., Ca'doro Restaurant, Union-street, Glasgow. Chairman's Address, by Mr. R. Summers.

Institution of Heating and Ventilating Engineers.—*East Midlands Branch:* Wednesday, November 7, 6.30 p.m., School of Technology, Leicester. Ten-minute papers for John Hughes prize. *Birmingham Branch:* Thursday, November 8, 6.30 p.m., Imperial Hotel, Birmingham. "Design and Pipe Sizing for Small Hot-Water Systems," by Mr. S. F. Greenland.

Royal Society.—Thursday, November 8, 4.30 p.m., Burlington House, Piccadilly, W.1. "Science in the Coal Industry," by Sir Charles Ellis, F.R.S.

Institute of Metals.—*London Local Section:* Thursday, November 8, 7 p.m., Royal School of Mines, South Kensington, S.W.7. "Transformations in Metals," by Professor C. S. Barrett.

Institute of Marine Engineers.—Thursday, November 8, 7.30 p.m., Hull Municipal Technical College, Kingston-upon-Hull. "Construction of Marine Boilers," by Lieut.-Com. (E) A. P. Monk.

Royal Meteorological Society.—*Scottish Centre:* Friday, November 9, 5.15 p.m., The University, Drummond-street, Edinburgh. "Meteorological Research at Oxford," by Dr. A. W. Brewer.

Societe des Ingénieurs Civils de France (British Section).—Friday, November 9, 5.30 p.m., Institution of Electrical Engineers, Victoria-embankment, W.C.2. "Development of Hydraulic Power Production and High-Tension Transmission in France," by Mr. R. C. S. Walters.

North East Coast Institution of Engineers and Shipbuilders.—Friday, November 9, 6.15 p.m., Hall of the Literary and Philosophical Society, Newcastle-upon-Tyne, 1. Andrew Laing Lecture on "Shortcomings of Structural Analysis," by Professor J. F. Baker.

PERSONAL.

Air Chief Marshal Sir Alec Coryton, K.C.B., K.B.E., M.V.O., D.F.C., who was appointed Chief Executive (Guided Weapons), Ministry of Supply, in August, 1950, has joined the board of the Bristol Aeroplane Co., Ltd., Bristol, as managing director of the firm's engine division. It will be recalled that, as stated on page 463, *ante*, Mr. N. Rowbotham, C.B.E., Wh.Ex., F.R.Ae.S., M.I.Mech.E., M.I.P.E., has been obliged, for health reasons, to relinquish his appointment as divisional managing director of the engine division.

Sir George W. Barr, C.B.E., M.I.N.A., has relinquished his position as managing director and also his seat on the board of the Fairfield Shipbuilding and Engineering Co., Ltd., Govan, Glasgow, on medical advice. The secretary of the company, Mr. D. D. McPhie, and the shipbuilding manager, Mr. J. F. Barr, have been appointed to the board.

Dr. D. G. Sopwith, M.I.Mech.E., acting Director, Mechanical Engineering Research Organisation, Department of Scientific and Industrial Research, East Kilbride, near Glasgow, and until recently superintendent, Engineering Division, National Physical Laboratory, has been appointed Director of Mechanical Engineering Research in succession to the late Dr. G. A. Hankins. Since the death of Dr. Hankins in November, 1950, Dr. Sopwith has been acting Director at East Kilbride.

Sir James Moir Mackenzie, K.B.E., C.M.G., deputy director-general of the Federation of British Industries, 21, Tothill-street, London, S.W.1, has retired after 30 years of service.

Mr. C. C. Inglis, A.M.I.E.E., at present deputy chief scientific officer, Ministry of Supply, has been appointed chief research officer on the headquarters staff of the British Transport Commission, 55, Broadway, London, S.W.1, as from January 1, 1952, in succession to Dr. H. E. Merritt.

Mr. Georg Pfeiffer, who has been on the staff of Geo. Adlam & Sons, Ltd., Fishponds, Bristol, for several years, has been appointed chief engineer to the company.

Professor W. G. Holford, F.R.I.B.A., M.T.P.I., has been appointed chairman of the Advisory Committee on Buildings of Special Architectural or Historic Interest of the Minister of Local Government and Planning. Professor Holford, who has been a member of the committee since this was appointed in 1945, is succeeding the late Sir Eric Maclagan, K.C.V.O., C.B.E., in the chairmanship.

Mr. Arthur Parkinson, the only son of the late Mr. Frank Parkinson, has been appointed a director of Crompton Parkinson Ltd., Crompton House, Aldwych, London, W.C.2. He has been an executive director since 1946.

Captain R. P. Minchin, O.B.E., has joined Harry Ferguson Research Ltd., as general manager. Captain Minchin has been in charge of the police transport branch, at New Scotland Yard, for the past 17 years.

Mr. J. E. Price, A.M.I.E.E., who has been with Lancashire Dynamo & Crypto (Mfg.), Ltd., for 36 years has been elected a director of an associated company, Malcolm & Allen (London) Ltd., and will continue to operate from London. Mr. R. W. Ell, who has been appointed contracts manager of the Foster switchgear division of Crypton Equipment Ltd., will also operate from London.

Mr. Ben Smith has been appointed general secretary of the Association of Scientific Workers, 15, Half Moon-street, Piccadilly, London, W.1, in place of Mr. T. Ainley.

Smith's Electric Vehicles Ltd., makers of the N.C.B. electric vehicle, Princesway, Team Valley, Gateshead-on-Tyne, 11, have appointed Messrs. William Murphy, May-street, Belfast, and the Murphy Electric Co., Ltd., 7, Upper Stephen-street, Dublin, to be their distributors for Northern Ireland and Eire, respectively.

The Unit Dust-Collector Department of Dallow Lambert & Co., Ltd., has been transferred from the main works at Spalding-street, Leicester, to Barkby-road, Leicester, where modern new premises have been acquired.

On and after December 3, the address of the Building Centre will be Store-street, Tottenham Court-road, London, W.C.1. The present address is 9, Conduit-street, W.1.

Mr. R. H. Gray, O.B.E.: Erratum.—In the "Personal" Column in our issue of September 28, on page 399, *ante*, in a reference to the appointment of Mr. R. H. Gray, O.B.E., M.A., M.I.Mech.E., M.I.E.E., as deputy chief inspector in the Inspectorate of Fighting Vehicles, the words "War Office" were added. This, we are now informed, was incorrect, as the Inspectorate of Fighting Vehicles is part of the organisation of the Ministry of Supply.

TRENCHING BY EXPLOSIVES.

(*For Description, see Page* 567.)

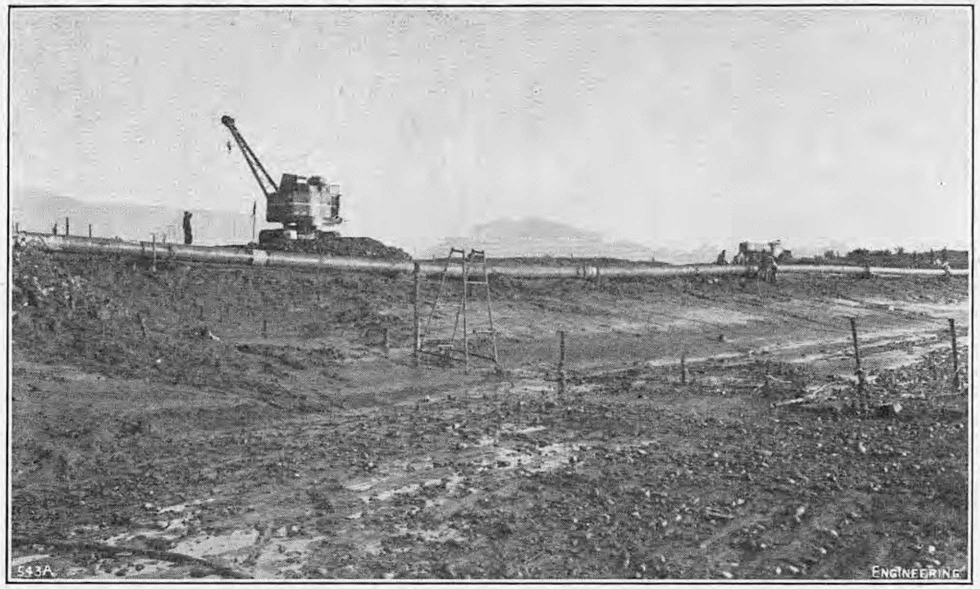


Fig. 1. Pipeline on River Bank.

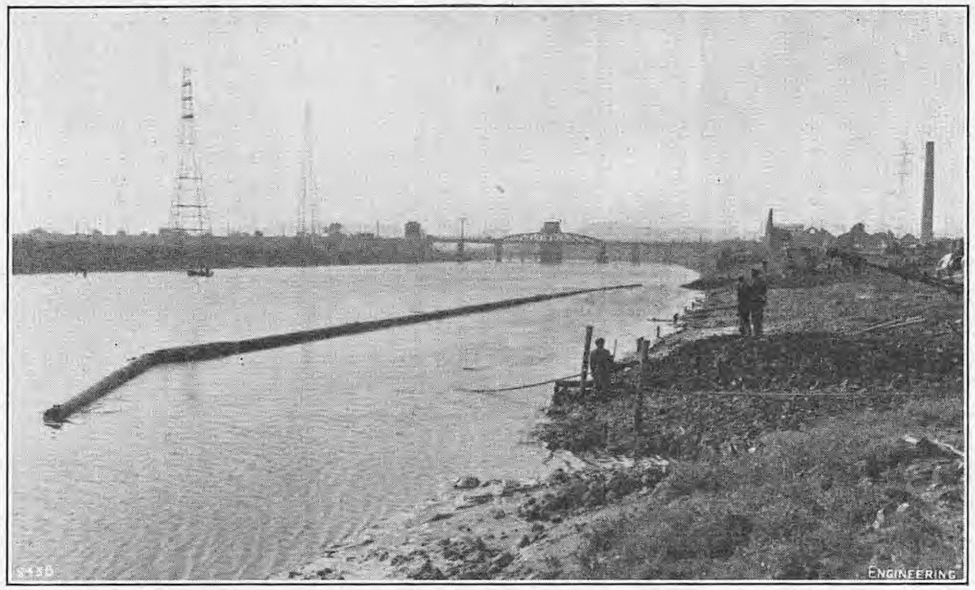


Fig. 2. Pipeline Afloat in River Neath.

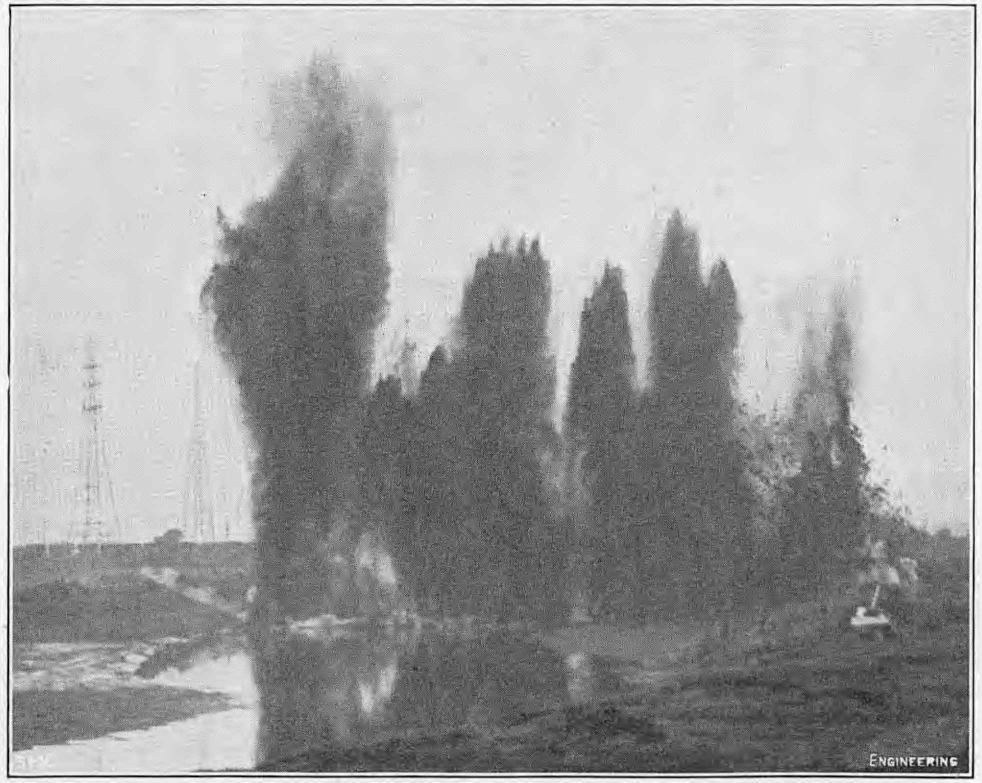


Fig. 3. Explosion of the Charges.

Fig. 4. Swansea end of Trench.

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.

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

For the United Kingdom and all places abroad, with the exception of Canada	£5 10 0
For Canada	£5 5 0

Subscriptions for periods less than twelve months are based on the price of a single copy, namely, 2*s.* 3*d.* 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 2¼ 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 10*s.* for the first four lines or under, and 2*s.* 6*d.* per line up to one inch. The line averages six words and when an advertisement measures an inch or more, the charge is 30*s.* per inch. If use is made of a box number the extra charge is 1*s.* 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 33⅓ 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.

CONTENTS.

ENGINEERING

FRIDAY, NOVEMBER 2, 1951.

VOL. 172. No. 4475.

THE ELECTION AND AFTER.

SINCE last week's issue of ENGINEERING went to press, the results have been announced of a General Election which may well have a more profound effect on the engineering industry than any event of recent years. On the face of things, it may seem a little difficult to understand why this should be so ; why the fact that some 14 million electors voted one way and much the same number another, on what are ostensibly purely political grounds, should have any marked effect on an industry in which, presumably, both sides are represented in about the same proportions as they are in any other section of the community. Reflection will show, however, that the engineering industry—with which, in this instance, we group that category of engineers which likes to regard itself as " professional," without always understanding exactly what that term might imply—is very deeply concerned ; for the simple reason that the difference between national solvency and insolvency, between prosperity and depression, between full employment and unemployment, between a more general enjoyment of " the kindly fruits of the earth " in the fullest sense and a perpetual state of grinding shortage, is a direct function of the extent to which humanity in general makes use of the specialised skills that the engineer has developed and the benefits that he alone can confer.

To realise the truth of this general statement, it is only necessary to consider the various Cabinet offices which Mr. Winston Churchill, as Prime Minister, has had to fill, and the means by which the holders of those offices can justify their appointments. The first eight appointments to be announced were those of Mr. Anthony Eden as Foreign Secretary ; Lord Woolton, as Lord President of the Council ; the Marquess of Salisbury, as Lord Privy Seal ; Sir David Maxwell Fyfe, as Home Secretary and Minister for Welsh Affairs ; Mr. R. A. Butler, as Chancellor of the Exchequer ; Lord Ismay, as Secretary for Commonwealth Relations ; Sir Walter Monckton, as Minister of Labour ; and Mr. Oliver Lyttelton, as Secretary for the Colonies. At a first glance, hardly one of them has any direct concern with engineering—except, perhaps, Mr. Lyttelton, in a private capacity which, as one of His Majesty's Ministers, he must now relinquish. A stronger case could be made out for another Minister, not included in the first eight—Lord Leathers, who has accepted the new appointment of Secretary of State for the Co-ordination of Transport, Fuel and Power ; but, in fact, he is no more deeply involved in engineering than are the others, not one of whom could exercise his functions with the speed and efficiency that modern circumstances demand, were it not for the facilities that the engineer has put at their disposal. It may be that they do not appreciate this as they should, but the fact is inescapable.

The Rev. Thomas Robert Malthus, rather more than 150 years ago, made that very mistake when he published anonymously his *Essay on the Principle of Population as it affects the Future Improvement of Society*, though there was more excuse for his failure to perceive the fallacy in his argument than there is for anyone at the present day. He foretold the eventual disintegration of the human race because they tended to multiply at a rate greater than the rate of increase in the means of sustenance. The argument might have been justified, had it not been that the engineer so greatly stimulated the production of the essential requirements of a civilised existence. He is still able and willing to do so, and, in fact, has done so in generous measure. It is not his fault that so many artificial restrictions on their beneficial distribution have been imposed by a succession of short-sighted idealists, ably assisted by a parasitic host of others whose ideals are more questionable, and whose myopia is even more pronounced. Meanwhile, the population of the world continues to increase, as a direct result of the additional resources made available by previous generations of engineers, for a tendency of this kind cannot be checked or accelerated in a mere decade or so ; and, as the population increases, the struggle for existence becomes intensified. The problem is not peculiar to any single nation, though it may appear so to the individuals comprising a nation that is suffering shortages because of it ; but it is one that is bound to become increasingly serious.

To return to the Ministers whom we have cited : the Foreign Secretary, who may reasonably regard his office as being one of a purely political character, is faced in fact with the results of a situation which the engineer can cure—or, at least, palliate—if he has a free hand to develop the natural resources which every nation possesses to some extent. The Egyptian Government, for example, have decided recently to expel from their borders the British engineers who, as successors to earlier generations of professional advisers, have rendered fertile many thousands of square miles of land which previously was arid and virtually useless, and who are prepared (and fully competent) to continue that beneficial work. If he fails in his task, the standard of life of thousands, and possibly millions, of human beings will be lowered ; and if he is to succeed, it can only be by the work of engineers in the long run.

Lord Woolton, as Lord President of the Council, has the responsibility of directing the industrial research policy of the Government. This is not, by any means, his sole responsibility, but it is one which, perhaps, has greater potentialities of ultimate benefit to the community than any other ; and, incidentally, one in which a mistaken policy of retrenchment might prove costly in the long run out of all proportion to any immediate saving that might accrue. The functions of the Lord Privy Seal, we must admit, do not appear to have any obvious connection with engineering activities ; but those of the Home Secretary, in his other capacity as Minister for Welsh Affairs, promise to be very closely bound up with engineering, for the future prosperity of Wales obviously depends upon industrial developments which are fundamentally of an engineering character. The Chancellor of the Exchequer, as the nation's financial director, will soon realise, if he does not realise already, that the engineering industry is at the root of all industrial prosperity, without which he is likely to be concerned mainly with bad debts; and the Secretary for Commonwealth Relations must know that, without a steadily increasing volume of mutual trade—only to be achieved through the medium of the engineer—his efforts will be in vain.

The Minister of Labour, who has perhaps one of the least enviable tasks, will certainly find himself in constant and close contact with the activities of the engineer, for it will be his function to promote, as far as in him lies, a greater freedom in the use of the nation's available manpower, and, by the encouragement of all practicable incentives, to increase the national level of productivity. If he can succeed in reducing the number and effect of the artificial restrictions on the use of every possible means to increase the productivity of the limited manpower of the nation, a long step forward will have been taken. There is no reason whatever to fear that unemployment will result, though he will not find it easy to convince to the contrary those who have a vested interest in opposing measures designed to enable one man to do as much work as formerly employed several. Hitler cured unemployment in Germany by substituting manual labour for the work of machines, but mere employment is not the main aim in a civilised life. The employment must be profitable, both to the individual engaged in it and to those who employ him; and one of the prime responsibilities of the Minister of Labour should be to convince the ordinary working man—and we do not mean only the manual labourer or artisan—of the difference between real wages and mere money wages. If he can do that, he will indeed deserve well of his country.

The Secretary for the Colonies will have, as one of his main pre-occupations, the task of helping the Colonies to help themselves, and of so developing their resources that they are able to make a real contribution to international trade. It may be that this can best be done by expanding their production of the raw materials needed by the home industries rather than by endeavouring to make each Colony self-supporting, at the expense of export trade, over a wide range of manufactured products. That is a matter for the experts in economics to decide in the light of individual circumstances; but whether they advise for or against the establishment of local industries in markets which formerly were supplied from the United Kingdom, there will be ample opportunities for British consultants and British engineering manufacturers to apply the experience that they have gained over so many years.

Eventually, however, the fruition of all the schemes and activities of the various Government departments will depend on the success or otherwise with which Lord Leathers accomplishes his function of co-ordinating the work of those concerned with transport, fuel and power; and even his best efforts will be useless unless the people as a whole can be brought to see that progress can never come from a state of artificially-induced semi-stagnation. The reports of the productivity teams that have visited the United States are unanimous in emphasising the benefits of ample power, and of a liberal provision of handling equipment, if these advantages are fully exploited. Henry Ford's dictum that burdens should be put on to machines rather than on men is the key to the productivity that Britain needs; but there must be an end to the practices of paying men to do nothing, and taking from them the tangible fruits of any additional efforts that they put forth.

THE CONSULTANT-INSPECTOR IN RAILWAY WORK.

By choosing the title "The Inspecting Engineer's Contribution to Railway Economy" for his presidential address to the Institution of Locomotive Engineers on October 17, Mr. Julian S. Tritton invited his audience to view that type of inspection work, of which he has long experience, as a means of saving money. The numerous advantages—to the contractor and consulting engineer, in addition to the client—can all, in the long run, be reduced to monetary terms. What, indeed, is engineering but man's most effective and widespread means of saving money—or man-hours, or other convenient yardstick? Independent inspection is simply one of the less obvious contributions to this aim.

In Mr. Tritton's experience, good inspection by a competent authority is generally welcomed by contractors. It reveals defects or mistakes at the earliest possible stage in production; experienced inspection engineers can give technical advice and raise the standard of workmanship in the shops; the moral effect assists the management in getting production; and a competent inspection authority acts as a buffer between the contractor and an exacting client. At least two of these points were brought out by a story he told of an incident which occurred early in his career. He had taken over the inspection of a locomotive contract abroad at the stage when the fourth or fifth tender was being tested hydraulically. The test was applied by erecting a 6-ft. stand-pipe over a hole on the tank top, filling up with water and looking for leaks. When the tank had been under pressure for about half an hour he was satisfied that the water level in the stand-pipe had not fallen, and he told the man in charge to dismantle the pipe. The man waited for Mr. Tritton to get off the tank top, explaining that he might wet his feet. When Mr. Tritton insisted on standing by, however, he noticed that it took four men closely bunched together to break the joint, and they did not seem to mind getting wet. When he asked to see the jointing washer at the foot of the pipe, the foreman took a long time wiping it. The jointing "washer" turned out to be a solid disc, and the foreman's delay had been due to his efforts to make a hole in it with his clasp knife. On being tested properly, the tank leaked badly. "I was not too popular," Mr. Tritton said, "when I called for a retest of the previous tanks which had been passed and which were standing loaded up for dispatch."

Not all incidents in an inspecting engineer's work, however, reveal such wilful subterfuge. Sometimes a genuine unforeseen difficulty arises which can best be solved by a decision from an independent authority. In a recent case of locomotive cylinder inspection, quoted by Mr. Tritton, porous patches were found when taking almost the finish boring cut in a pair of cylinders which had been welded together to form a monobloc unit. The inspecting engineer called for the patches to be chipped out down to sound metal, thus producing small cavities. He had no course but to reject the cylinders. The contractor, knowing the cylinders were worth about 800*l*. each, requested permission to fill the cavities by welding, pointing out that, had the porosity been detected in the steel foundry, the patches would have been cut out, and the casting annealed and accepted as sound. Unfortunately, however, the actual cylinders could not be annealed after welding without risk of distortion, and there was not sufficient metal left to clean up the bore. The cylinders were to be fitted with cast-iron liners, so that there was no question of welding the wearing surfaces, and examination showed that the porosity had not materially affected the strength of the casting. Theoretically, Mr. Tritton continued, it would have been perfectly safe to leave the cavities as they were, and, indeed, it was agreed that this was probably more desirable than setting up unknown stresses by filling the cavities with weld metal. On the other hand, if the cavities had been left, there would certainly have been a complaint from the purchaser when, some years later, on withdrawing the cylinder liners for renewal, the cavities would have been revealed. Such complaints could have been forestalled by signing a "qualified certificate," but it was considered better to take the risk of welding. The work was carried out very carefully in thin layers; the final skim cut was taken to clean up the surface, and when the job was done it was impossible to detect where the pockets had been.

Apart from the fact that the firm of inspectors may also be the consultants, their inspecting engineers are often required to perform subsidiary duties, such as submitting progress reports, forecasting the dates of delivery, advising the client on any unusual rejections and on suggested improvements in his specification, and assisting both the client and the contractor by "chasing" delayed material from sub-contractors. The chief advantages to the client, however, of employing independent inspectors are, as Mr. Tritton expresses it, mostly various forms of insurance: the operating departments want insurance against breakdowns in service, the legal department want insurance against accidents and claims which may arise from faulty materials or workmanship, and the purchasing department want insurance against the supply of unsuitable stores or spare parts. In addition, the accounts and audit department want certificates that the railway is getting what it is paying for, the shops want up-to-date progress reports so as to anticipate deliveries of materials and components, and the purchasing department wants information on the reliability and capacity of firms tendering.

On occasions, the inspector is in a position to refute allegations of bad workmanship or material, thus protecting the contractor against ill-founded criticism from the railway. Some time ago, Mr. Tritton recounted, a number of piston rods failed mysteriously at the section just before the taper portion that fits into the crosshead. A claim for replacement of the rods was submitted by the railway on the ground that the material was defective. The contractor rejected this, pointing out that the locomotives had been built under independent inspection. The inspector's certificates, indeed, showed that the material for all the rods had passed satisfactory physical and chemical tests and that the dimensions and fits of the rods in the crossheads accorded with the drawing. When a broken end was cut up, however, and etched for examination, it became apparent that the taper had been built up by welding. As the rods were of D-class steel, this accounted for the failure. On finding that the welding had been carried out by an enthusiastic mechanical officer, without authority from the chief mechanical engineer, the railway accepted full responsibility.

An inspecting engineer is not usually associated with the design staff, but as Mr. Tritton described, where he is part of a consulting engineer's organisation and the client relies on the consulting engineers for advice on design, then the dividing line between inspection and design is very flexible. This would seem to be a valuable feature of the consultant-inspector system that Mr. Tritton describes. The designer relies on the inspector not only to interpret and amplify his specification, but to check the results of his calculations by actual test, and a close liaison of this kind is something that is generally recognised as being desirable in the engineering industry, though it is not always achieved.

NOTES.

Princess Flying Boat: Final Stages of Erection.

On Tuesday, October 30, the first of the three 140-ton Princess transport flying-boats, which are under construction by Messrs. Saunders-Roe, Limited, Cowes, Isle of Wight, was transferred from the assembly hangar to the apron overlooking the River Medina prior to the final stages of erection; there is not sufficient space inside the hangar to allow the assembly of the outer wings, which span 210 ft. 6 in. with the retractable wing-tip floats down, and the top 7 ft. of the fin, which extends to a height of 55 ft. 9 in. It may be recalled that the Princess flying boat was ordered by the Ministry of Supply in 1946 and was originally intended as an air liner for the direct transatlantic service to New York. The British Overseas Airways Corporation have, however, abandoned the idea of using flying boats at present, and the three Princesses are now being adapted as troop-transport aircraft for the Royal Air Force, a role for which the flying boat, with its ability to operate from quickly-improvised water bases, is well suited. Each Princess aircraft will be able to carry 200 troops over a distance of 3,500 miles, and in one year, it is claimed, the three flying boats will be able to carry as many troops as could be carried by nine ordinary troopships on strategic trooping routes. The hull, the inner-wing structure, the tailplane, and as much of the fin as it has been possible to erect under cover, are now completed on the first Princess; the outer wings, the floats, and the top of the fin are ready and awaiting erection. In order to transfer the flying boat to the apron, the main beaching-chassis legs were fitted on each side of the hull mid-section joint, and the tyres of the eight 4-ft. diameter main-chassis wheels were inflated to raise the hull from the cradle. The hull was then propped up by jacks, and a two-wheel bow beaching chassis was fitted. So far, the engines have not been installed, and the aircraft was therefore ballasted by filling eight ballast tanks forward of the front spar with about 3,000 gallons of water. In order to clear the hangar roof trusses before towing the aircraft out, the tail had to be lowered; the aircraft was pivoted about the main chassis by winches attached to the after-mooring hook and to the front chassis, the forward winch cable being paid out to keep a constant load of about ½ ton on the winch as the tail of the boat was winched down. As the nose lifted, the movement of the ballast caused the machine to become slightly tail-heavy, and the tail end of the aircraft was attached to a weighted tail trolley. For wheeling the aircraft out, extra weight on the trolley was provided by pumping water ballast from the two forward tanks to two tanks in the rear of the hull. The main beaching chassis was then braced to the tail trolley by cables and the aircraft was towed out and swung round with the hull parallel to the hangar doorway. Before lowering the nose on to the bow chassis, the main-chassis wheels were chocked and the water-ballast was pumped back to the forward tank, so that the centre of gravity would return to the normal position as the nose was winched down. The second Princess hull, which is about six months behind the first aircraft, will now be transferred to the centre of the hangar for erecting the inner wings. It is hoped that the first Princess will be ready to fly towards the middle of 1952. After erecting the outer wings and the top fin, the four coupled and two single British Proteus propeller-turbine power plants will be installed; three of the coupled units have still to be delivered.

The Institution of Mechanical Engineers.

The first paper in the 1951-52 session of the Institution of Mechanical Engineers—apart, of course, from Mr. A. C. Hartley's presidential address—was presented at a meeting on Friday, October 26. The authors, Mr. W. C. F. Hessenberg, M.A., and Mr. R. B. Sims, B.Sc., A.M.I.Mech.E., in a paper on "Principles of Continuous Gauge Control in Sheet- and Strip-Rolling," gave an interim report on work that is being carried out by the British Iron and Steel Research Association. At present, they said, the usual method of controlling gauge was to measure the thickness of the strip continuously as it left the mill, at a point some distance away from the mill, and then to adjust the rolls whenever a persistent change of gauge was observed. After considering the causes of gauge variations, they described two methods of automatic gauge control which they are developing. In the "tension method," while the roll setting is not altered, corrections to gauge are made by varying the tension in the sheet or strip in accordance with the variations in the roll force, i.e., the load applied to the rolls through the screws. The load force inevitably varies due to changes in the thickness of the ingoing strip and to changes in the friction between the strip and the rolls. An automatic servo mechanism which controls strip tension according to roll force was described. The second, the predetermined-setting method, unlike the first, can be applied to hot-rolling as well as cold-rolling. Here, the gauge is controlled by adjusting the roll screws in accordance with the roll force, but so far only preliminary tests have been made with this method. The discussion was opened by Professor Hugh Ford, who mentioned the problem of the production of off-gauge strip during acceleration and deceleration of the mill. The proportion of off-gauge material could be lessened by reducing the acceleration and deceleration times, but this led to a larger mill and coiler motors. Mr. M. F. Dowding thought that it should now be possible to reverse the trend, evident in recent years, towards increasing the robustness of the mill housings; but mechanical engineers would have a problem in designing reels suitable for the increased tension, and electrical engineers would have to increase the power of the mill motors. Mr. G. R. Wilson pointed out that, to ensure the greatest success, automatic gauge control should be applied to the hot mill and the cold mill. Mr. E. A. Cooke advocated the use of an error-detecting device on the ingoing side; Mr. N. H. Polakowski was also in favour of a direct measurement of thickness. Mr. G. G. Nicholson, by citing a hypothetical case, showed that the power of the reel motors would have to be increased considerably. In reply, Mr. Sims said that when the paper was written he and his co-author had done no experiments on the speed effect on thickness, but some recent results showed that their method could control it. The speed effect would not be detected by a thickness gauge before the rolls. He agreed that manufacturers would have to choose between paying for a bigger motor or having off-gauge strip. The authors hoped to have a production machine with automatic control by the middle of next year.

Chemistry Research.

The study of the possibility of the production of suitable fertilisers from phosphate rock, by methods having as their object the replacement of sulphuric acid, in whole or in part, by nitric acid, has been under way for some time past at the Chemical Research Laboratory, Teddington, Middlesex. It is stated in *Chemistry Research*, 1950, which is the report of the Chemistry Research Board and of the director of the Chemical Research Laboratory of the Department of Scientific and Industrial Research, for the year 1950, that the study is now virtually complete and that details of the mixed nitric-sulphuric acid process are being supplied to the fertiliser industry. An important point is that laboratory studies indicate that the product has satisfactory storage properties. The corrosion of metals group at the Laboratory continue to receive satisfactory reports concerning the effectiveness of a corrosion inhibitor developed by them. This inhibitor consists of sodium benzoate, containing a small percentage of sodium nitrite, and it successfully prevents corrosion and rusting when added to ethylene glycol "antifreeze" solutions used in the cooling systems of motor vehicles. It is pointed out, however, that further investigations are necessary in the case of cooling systems in which aluminium is used in conjunction with other metals. The Pure Metals Committee have continued their work and the stock of metals available at the Laboratory now comprises antimony, cobalt, iridium, iron, lithium, potassium, silicon, sodium and vanadium in a satisfactory state of purity. Germanium in a very high state of purity has been prepared at the request of the Radio Research Board, tracer techniques being used to study the removal of the last traces of arsenic. In the programme of the organic group at the Laboratory, increasing importance is being paid to the preparation and distribution of standard reference samples of organic compounds of industrial interest, including hydrocarbons for the calibration of mass spectrometers. Microbiological investigations at the Laboratory were at one time concentrated on the study of sulphate-reducing bacteria with particular reference to their influence in the corrosion of buried pipes. On the basis of these investigations, advice and practical help is being given to engineers and municipal and local authorities on pipe-laying and protective measures, and on the treatment of malodorous pools. It is stated in the report, which is obtainable, price 3*s.* 8*d.*, post free, from H.M. Stationery Office, that developments in the work of the Laboratory require both additional staff and further accommodation. In this connection, the construction of a radiochemical building has been commenced; this will eventually alleviate some of the present difficulties of space.

Permanent-Way Mechanised Equipment.

At a time when there is much talk of restrictive practices, it is a change to learn, from an exhibition of permanent-way mechanised equipment, held at Marylebone station on Wednesday and Thursday this week, that the track maintenance men of British Railways are making good use of mechanical aids. Mr. J. C. L. Train, M.C., M.I.C.E., member of the Railway Executive, has stated that these machines lighten the heavy manual labour, compensate for man-power shortages, release man-power for less arduous tasks that cannot be carried out efficiently by mechanical means, and save time on the job, thereby allowing traffic to move more freely. The machines exhibited included some which have been described in Engineering, such as the Matisa ballast-cleaning machine; the Matisa ballast-tamping machine; the track-relaying unit of the Southern Region, consisting of two jibs projecting from one side of a flat bogie wagon; and the petrol-driven truck mover, which is controlled manually. Other machines and tools, some of which are common to many branches of engineering, included ballast scarifiers, mounted behind tractors; pneumatic and electric ballast tamping tools; a mobile crane for handling concrete sleepers four at a time, correctly spaced; rail barrows, which are used for lifting and traversing rails; pneumatic tools for driving elastic spikes; a rail-creep adjuster, which adjusts the gaps between rails; the Steenbrugge track slewing machine; a ½-ton frog hammer; and various power-driven saws, generators, drills, scythes and hoes.

Benevolent Fund of the Institution of Electrical Engineers.

The report of the Incorporated Benevolent Fund of the Institution of Electrical Engineers for the year ended June 30, 1951, contains the statement that "cases of hardship are likely to become more frequent owing to present-day conditions." As this is certainly true, there is one matter mentioned in the report which cannot be considered with satisfaction. This is the fact that, in the year covered, the number of contributions to the fund decreased by 95, although the membership of the Institution increased by 910 in the same period. There were probably two reasons for this, one being that a large proportion of the new membership was, no doubt, represented by students who felt that they could not be expected, or could not afford, to subscribe. The other reason may have been that some previous subscribers were themselves adversely affected by present conditions and ceased to subscribe for reasons of economy. Those who operate the fund would be glad, no doubt, if both these classes would remember that small contributions are welcome, as well as large, and that many small contributions will add up to a substantial sum. In spite of this feature of the year, the total amount received in subscriptions and donations amounted to 15,057*l.*, compared with 13,252*l.* in the previous year. The total income, however, was not greater as the 1949-50 year included the sum of 3,208*l.* arrears of income tax recovered. This item was not repeated. The amount paid out in grants, at

7,777*l*. was 1,381*l*. more than in 1949-50, grants being made to 115 beneficiaries and support being given to 91 of their dependants. The average amount distributed per beneficiary was 68*l*. This is a small sum by modern standards and no doubt the governors of the fund would like to increase it as well as adding to the number benefited. Their appeal for more donations may be warmly supported.

The World's Shipbuilding.

Statistics contained in Lloyd's Register quarterly Shipbuilding Returns, issued last week, indicate that the merchant ships of 100 tons gross and upwards, under construction in the shipyards of Great Britain and Northern Ireland on September 30, totalled 2,271,640 tons, representing an increase of 157,321 tons over the total for June 30, and the highest total recorded since December, 1921. The total of 2,271,640 tons comprises 117 steamers, making together 858,695 tons, and 250 motorships, aggregating 1,412,295 tons. The progress made during the September quarter is indicated by the fact that 75 vessels, comprising 423,602 tons, were commenced in the shipyards of this country; 51 ships, totalling 242,446 tons, were launched, and 53 vessels, aggregating 268,638 tons, were completed. Work has been suspended on five small ships, making together 1,350 tons. Shipping under construction in this country for registration abroad or for sale amounts to 119 ships of a total tonnage of 801,877. This constitutes an increase of 72,564 tons over the corresponding figure for June 30, and represents 35·3 per cent. of the total tonnage built in the United Kingdom. Oil tankers of 1,000 tons and upwards, under construction in Great Britain and Northern Ireland on September 30, totalled 108 ships, making together 1,255,754 tons. This was an increase of 73,999 tons, as compared with the total for June 30. The figure, 1,255,754 tons, represents 55·3 per cent. of the total tonnage under construction in this country. Abroad there were under construction, at the end of September, 834 ships, aggregating 3,192,862 tons, a decline of 24,033 tons compared with the total for June 30. As has been the case for some years past, figures are not available for China, Poland and Russia. France, with a total under construction on September 30 of 482,347 tons, is the leading shipbuilding country overseas, Japan is second with 448,135 tons, Germany third with 430,927 tons, the United States fourth with 377,315 tons, Sweden fifth with 335,494 tons, Holland sixth with 297,476 tons, and Italy seventh with 263,670 tons. The totals of other maritime countries were well below 200,000 tons. The progress made during the September quarter in overseas shipyards is shown by the fact that 166 ships, aggregating 546,508 tons, were commenced; 170 vessels, totalling 536,934 tons, were launched; and 197 ships, making together 536,401 tons, were completed. Oil tankers of 1,000 tons and upwards, under construction abroad, on September 30 totalled 91 ships, amounting to 988,235 tons, which total is greater by 123,653 tons than the figure for June 30. Oil tankers represent 31 per cent. of the total tonnage being built abroad.

Exhibition of Visual Aids to Industry.

Considerable advances have been made during recent years in the design and application of visual aids to industry, and their use is gaining steadily in popularity. To demonstrate the latest developments in this type of equipment, Messrs. Newton and Company, Limited, 72, Wigmore-street, London, W.1, and Messrs. John Saville and Sons, 4, Goodram-gate, York, have been holding this week, at the Hotel Metropole, Leeds, an exhibition of "Visual Aids to Industry," which will remain open until this evening. The equipment on view includes diascopes, epidiascopes, 16-mm. film projectors, a long-working-distance attachment for microscopes and a range of profile projectors. The use of film projectors for educational purposes is, of course, commonplace, but the benefits which may be gained by their intelligent use in factories possibly are not generally realised. By studying, for example, slow-motion films of assembly operations, it is often possible to effect improvements with consequent benefit to both operators and management, and it is this aspect that is stressed in the exhibition. Similarly with profile projectors; although they are used in many tool rooms, they have not been adopted widely for production purposes, probably because of the initial expense and the delicate nature of the earlier instruments. The profile projectors on view at the exhibition, however, are of moderate cost, exceptionally strong in construction, and have been designed from the outset for use in actual production lines. They are not affected by vibration and are constructed so that, if required, they can be locked to prevent tampering and pilfering. One of the instruments on view is equipped so that it can be used to check the concentricity of parts as well as their dimensional accuracy, the actual part checked being a small gearwheel as used in meters, etc. Another is set for ordinary dimensional checking and illustrates well the saving on gauges that can be effected by their use. The exhibition also includes a 50-way static-strain recorder together with an automatic plotting table. This equipment, which is being shown by Messrs. Savage and Parsons, Limited, Watford, uses electrical strain gauges of the resistance type, the plotting table being designed so that 50 different graphs may be obtained automatically without having to record manually a large number of readings.

OBITUARY.

SIR HENRY GRAYSON, BT., K.B.E.

We have learned with regret of the death, on October 27, of Sir Henry M. Grayson, for many years one of the most prominent figures in British ship-repairing, especially on Merseyside. He was 86 years of age.

Henry Mulleneux Grayson was a native of Liverpool, where he was born on June 26, 1865, and spent the greater part of his life in the family ship-repairing business, now nearly 200 years old, of H. and C. Grayson, Limited. In a succession of mergers with other Merseyside firms, it became part of Grayson, Rollo and Clover Docks, Limited, of which Sir Henry was chairman until a few weeks ago. He was educated at Winchester, and succeeded his father in the managing directorship of his firm in 1904. During the 1914-18 war, he was a member of the Admiralty's Shipbuilders' Advisory Council and, from 1916 until the end of the war, Director of Ship Repairs. He then entered Parliament as M.P. for Birkenhead West, representing that division for four years. He had been a member of the Institution of Naval Architects for 63 years, and was a liveryman of the Shipwrights' Company and an honorary lieutenant-colonel in the Royal Marines. For his war services, he received the C.B.E. in 1920, which was followed by the K.B.E. later in the same year and a baronetcy in 1922; and he was also a recipient of French, Belgian and Italian honours for his work in organising the Allied ship-repairing facilities during the 1914-18 war.

LETTER TO THE EDITOR.

SMOKE ABATEMENT.

To the Editor of Engineering.

Sir,—I was interested to read of Mr. J. Law's comments on the underfeed type of stoker, as reported in your note, on page 430, *ante*, on the National Smoke Abatement Society's Conference at Blackpool. At these meetings, manufacturers of coking and sprinkler stokers, of underfeed stokers and of chain-grate stokers each read a paper dealing with their own particular specialities. I would like to point out, however, that Mr. N. Higginson, of the National Coal Board, presented a paper dealing with "Policies for the Prevention of Industrial Air Pollution at the Collieries" in which he was quite as enthusiastic about the performance of the chain-grate stoker as was Mr. Law with the underfeed type.

Yours faithfully,
John Fox,
M.I.Mech.E., F.Inst.F.

Hove,
October 12, 1951.

SCIENTIFIC RESEARCH IN AUSTRALIA.

The appointment, in March, 1950, of its Advisory Council under the chairmanship of Sir David Rivett completes the transfer of State-sponsored industria research in Australia into the new form of organisation laid down by the Science and Industry Act of 1949. For the most part, the changes entailed have been nominal, and it is evident from the latest annual report* that all the programmes laid down by the now superseded Council for Scientific and Industrial Research have been actively pursued throughout the brief period of transition. As regards the relative importance of research subjects, the most notable development is a major re-organisation, during the year, of the work on wool textiles. Under the general oversight of a Wool Textile Research Committee, three separate laboratories are being set up at Melbourne, Sydney and Geelong, to deal, respectively, with fundamental chemical and biochemical studies, the engineering and physics of wool and wool-processing, and problems of immediate interest to the textile industry. One other particular development, consequent on the organisation's researches into minor element deficiencies in the Ninety-Mile Plain region of South Australia, is transforming into productivity a large proportion of some two million acres of land, formerly considered worthless, although it is well watered. Small amounts of zinc and copper applied with superphosphate to the light sandy soils of this region, are making it possible to grow remunerative crops of cereals, subterranean clover and other pasture plants.

Contrasting with the facilities available for large-scale field experiments in agriculture, the lack of suitable laboratory buildings for indoor work and the slow rate at which it is proving possible to provide them are seriously hampering the progress of new research programmes in the mechanical and physical sciences. The shortage of buildings generally, and housing in particular, has no doubt been influential in raising the former Building Research Section to the status of a Division which, in close collaboration with the Experimental Building Station of the Department of Works and Housing, and also with the building trade, is urgently attacking the problems of improving the quality of building materials so that maintenance can be minimised, and of enabling available materials to be more effectively and economically used. A variety of weathering studies includes work on the detrimental effects of solar radiation on building materials, surveys of building sands, and investigations of damp-proof course mortars. These last have revealed that water-repellent agents are much more effective in the case of mortars cast on absorbent materials, such as bricks, than when the mortar is cast in non-absorbent moulds. Other experiments are in progress to encourage local production of foamed concrete, prepared by mechanical and chemical processes, in which connection new chemical foaming agents are being tested; concretes ranging in density down to 15 lb. per square foot have been produced.

A survey of the heavy clay industry in Australia has revealed wide variations in the quality of products, and this is ascribed rather to lack of process control than to inferiority of raw materials. To support these constructive researches on clay building materials, therefore, the report urges the modernisation and mechanisation of many existing brick and tile plants, and the erection of new plants. Advice is offered regarding the properties of local clays, the design of machinery and new methods of production.

Research upon other building materials will be assisted by the recent establishment of a crystallographic laboratory, in which service failures of concrete and the nature of sulphide staining on fibrous plaster have already been investigated. For studying particle-size distribution in plaster powders, a gas-stream elutriator is in use, in which radioactive ionisation has proved a successful means

* *Second Annual Report of the Commonwealth Scientific and Industrial Research Organization for the Year Ending 30th June*, 1950. L. F. Johnston, Commonwealth Government Printer, Canberra. [Price 9s.]

of preventing electrostatic adhesion of fine particles to the glass walls of the apparatus. With the object of improving the service behaviour and durability of wall-surfacing materials, experiments are proceeding on such matters as weather-proofing, resistance to soap solution, decorative treatments and—in the case of fibrous plasters—the causes and prevention of mould growths. A general study of the conditions under which concrete floors can be made acceptable in domestic construction has included tests for coldness; and the effects of concrete flooring on the mechanics of walking are being analysed from measurements of instantaneous pressures at various parts of the sole of the foot, and of velocity changes in the shin and head of a person walking at different speeds over flooring of different materials. The results so far examined are negative, inasmuch as variations due to the individual and his speed are far greater than those due to the floor material. The purely structural aspects of flooring thus remain of primary importance, and experimental work continues on such aspects as resistance to dampness, abrasion and indentation.

Testing along somewhat similar lines, though with more emphasis on thermal and acoustic properties, is in progress on a variety of cheap walling and roofing materials. Somewhat more fundamental research on cement products is carried out by the Industrial Chemistry Division, and includes a study of the reaction between aggregates and cement in mortar, which has revealed that the expansion and degree of disintegration of mortar are increased as the size of particles of reactive aggregate is decreased. When, however, the particles can pass through a 300-mesh sieve the mortar does not expand, and the addition of such particles to an otherwise reactive cement-aggregate combination lowers its expansion.

The importance of timber throughout the building industry is further emphasised by some of the experimental work carried out by the Forest Products Division, which includes the development of accelerated seasoning processes and methods of utilising wood waste, mixed with synthetic resin or cement, in the form of moulded products. Endeavours to improve the equipment and manufacturing methods of sawmills and timber factories are also in progress on a considerable scale. Economy in another direction is exemplified by a range of investigations into the causes of failure of exposed timber and the merits of different preservative treatments: in which connection the construction of a new cylinder for the impregnation of karri and jarrah telegraph-pole cross-arms and of eucalypt timber sleepers, at pressures up to 1,000 lb. per square inch, is noteworthy. Australian railways consume some $2\frac{1}{2}$ million sleepers per annum, so that any significant extension of service life represents an economy that is worth investigation. The work that is being carried out on this subject has revealed that the prime causes of sleeper failure are mechanical rather than biological. Increasing attention, consequently, is being given to the effects of rail fastenings and to the value of surface protection and end coatings, without neglecting, however, the development of toxic protection against fungal and insect attack. A study of *lyctus* attack on timber generally, including plywood, has indicated that the momentary dip treatment of green veneer in basic acid or borax is very successful, and that copper naphthenate preservatives are more toxic than crude naphthenic acids.

A detailed aspect of the industrial applications of wood is exemplified by an investigation of the holding power of various types of nails used for assembling containers of radiatarpine, which has revealed that improvements in the wire of which nails are made has altered the relative holding power of different types of nails since previous experiments of this sort were made on hemlock wood nearly 20 years ago. The particular form of nail recommended for fastening a patented type of wood-framing anchor, which has been tested in connection with the use of timber for housing construction, was not available, and the substitute employed was found to be weaker than the anchor.

The more academic investigations of the mechanical properties of wood has included studies of the standard shear test, following a recommendation of the Empire Timber Mechanics Conference of 1948; and also the development of an impact hardness test in which the reciprocal of the area of the impression made by a falling steel ball is taken as a measure of the hardness of the wood specimen. This is a non-destructive test and can be used on hard fibre boards that are too thin for the ordinary timber hardness test. The variation in the mechanical properties of wood according to the height in the tree is being studied by compression and bending tests on specimens taken from a 150-ft. length of a single trunk of the species *Eucalyptus regnans*. This same species has been used to study the influence of growth cycles on mechanical strength of young wood, specimens of cross-section 1·5 mm. by 0·08 mm. being tested in a micro-tensile apparatus. Preliminary work on the alterations in the strength of wooden columns with duration of loading has shown that the most instructive results are obtained from measurements of central deflection and surface strains, under successive increments of load, from which Euler load, stiffness and elastic modulus can be estimated. For general timber testing, a 48-channel strain indicator has been built and its characteristics in combination with electrical resistance strain gauges are being explored by comparisons, under continuous loading conditions, with mechanical extensometers.

The value of this and other types of timber research to the economy of Australia is illustrated by a recent development in the processing of plywood. One good source of veneer-quality timber is the ash eucalyptus of south-eastern Australia, so far virtually untapped because of the refractory behaviour of this wood, particularly in the drying of the veneer. The difficulty was traced to the prevalence of collapse in these species, accentuated by wide variations in the susceptibility to collapse of the wood formed at different times of the year, which resulted in buckling, checking and splitting of the veneer while it was being dried. The solution was found to lie in correct peeling procedure, drying under carefully controlled conditions which have been determined, and re-conditioning of the dry veneer with a special steaming treatment. The industrial use of the laboratory technique has been demonstrated, and subsequently accepted as standard practice at a commercial plant, with the direct result that some 2,500,000 sq. ft. of veneer per annum is now being recovered, at this one plant, from previously discarded material on which some processing had been carried out. In another example, tests in co-operation with the Woods and Forests Department of South Australia have been made on a pilot plant to appraise the economic possibilities of using high-frequency dielectric heating for setting glue during the manufacture of fruit cases from narrow boards. The results were very successful and showed that the method is a better proposition economically than the mechanical jointer hitherto used.

From the engineering standpoint, some of the most interesting research within the organisation is that done by the Tribophysics Division on the fundamentals of friction and lubrication. Continued study of the formation and shearing of minute points of adhesion between materials in sliding contact has now revealed that, in the case of metals, such shearing of metallic junctions causes deformation extending below the surface, and that oxide particles originating at the surface are found at considerable depth. Evidence of the intense working in this zone has been obtained by comparing the frictional work with the work necessary to cause deformation. The relation between metallic hardness and friction has been investigated with copper-beryllium alloys, heat-treated to various extents, which exhibit a consistent reduction in friction as hardness increases. The influence on friction of superficial irregularities has also been measured in the case of gold surfaces ruled to a regular contour with a diamond tool, and also of nickel replicas of these contoured surfaces. The results of preliminary experiments are in agreement with theoretical calculations of the frictional effects.

The effectiveness of thin film lubricants has been investigated in the case of long-chain normal acids and paraffins, deposited on polished metal surfaces and subjected to sliding shears. Electron-diffraction examination has revealed no appreciable effect of applied pressure on subsequent film structure. In general, rubbed films comprise a tightly bound mono-molecular layer below excess material in the form of small crystals oriented according to the direction of rubbing. Such crystals have been observed to have their symmetry and cell dimensions deformed by sliding shear. The present conclusion drawn from this work is that the possibility of producing oriented crystals on top of an absorbed monolayer depends on the chain length and chemical composition of the long-chain compound, and on the nature of the underlying metal surface. The adsorption of long-chain polar compounds on metal surfaces from solution is being investigated with metals in finely-divided form, a sensitive technique having been developed to measure slight decreases in concentration of the solution. The presence of adsorbed films on a metal surface markedly affects the spread of lubricating oil over the surface, and may prevent it entirely, with advantage in cases such as instrument mechanisms, clocks and watches where the spread of lubricant may impair sensitivity. The manner and rate of spreading of various oils over clean polished metals, and the influence of adsorptions of long-chain polar compounds, is accordingly under examination.

An investigation having immediate engineering applications is being made upon the stability and form of the lubricating film between the piston rings and cylinder of a small petrol engine. The electrical resistance of the oil film is continuously measured and recorded under various operating conditions, particular attention being given to the state of lubrication during the running-in of new surfaces, and to the correlation between engine wear and film breakdown. In the case of whitemetal sleeve bearings, running tests have shown that the ability of a bearing to "run-in" is influenced by geometric errors of shaft and bearing rather than by normal variations in loading or in the ratio of length to diameter. Satisfactory machining techniques have been developed which avoid these geometric errors, and experiments are being continued to study the effects of clearance and of small length/diameter ratio.

Physical effects of industrial processes such as rolling, drawing, extrusion, and forging, associated with the metal rather than with the lubricant, are being studied under the two main heads of plastic deformation and phase-changes. For the first of these researches, calorimetric apparatus of extremely high accuracy has been devised to measure the energy stored in a metal during deformation. Other experiments, with copper-iron alloys, have confirmed that the harder of the two phases is deformed more heavily than the other when it is present in a greater proportion. This general influence of the volume proportion of the harder phase on the deformation of two-phase alloys is of industrial importance, since the majority of alloys contain at least two phases.

Another interesting effect of plastic deformation is the anisotropic increase of electrical resistivity due to rolling a sheet of metal, which has been found to vary with the direction of measurement in the sheet. Fundamental metallurgical processes will be clarified by a newly developed method whereby the growth of new crystals may be followed photographically during recrystallisation. Photographs of the recrystallisation of zinc have revealed erratic growth, attributed to the variation of internal stress from grain to grain and within individual grains. In the case of another metal—polycrystalline tin—radioactive isotopes have been recently brought into use to enable the rate of self-diffusion to be investigated qualitatively by the darkening of photographic film. As a comment on all this somewhat abstruse physical metallurgy, it is perhaps worth remarking that, since phase changes are accompanied by changes in the physical properties of metals and alloys, they are the basis of processes, such as heat treatment and age hardening, which underlie the production of specific qualities. Fundamental research may be expected, therefore, to have far-reaching results of potentially great importance to industry.

Research in physics of a more general character is undertaken by one of the three divisions which comprise the Commonwealth National Standards

Laboratory. The primary responsibility of the Physics Division is to maintain standards of measurement of heat and light, and electrical units of resistance, voltage and current. In some of the major standards laboratories of Europe and America, elaborate methods have been evolved, after years of research, for realising basic electrical quantities in terms of primary standards of length, mass and time. It is not considered necessary at present for the Commonwealth to go to such refinement, and their electrical standards are therefore maintained in the form of resistance coils and standard cells which are periodically compared with the similar material standards at the National Physical Laboratory in England.

In connection with the standardisation of heat and light measurements, however, a good deal of research of a very high class is carried on in Australia, and experiments directed towards the practical adoption of the International Temperature Scale have been actively pursued during the year under review. Apparatus has been set up for calibrating thermometric instruments over the range from 0 to −196 deg. C., while a sub-standard optical pyrometer used for temperatures above the "gold point" (1,063 deg. C.) has itself been re-calibrated. Research at temperatures approaching absolute zero, for which equipment has just been built, is a new undertaking in Australia. With its use, and the aid of nitrogen and helium as working gases, nitrogen has been liquefied at −196 deg. C. and helium reduced in temperature to −225 deg. C. For basic temperature measurements, a helium-gas thermometer has been constructed and calibrated. Mass spectrometers are used for detecting gaseous impurities in helium and for detecting leaks in low-temperature apparatus and vacuum equipment generally.

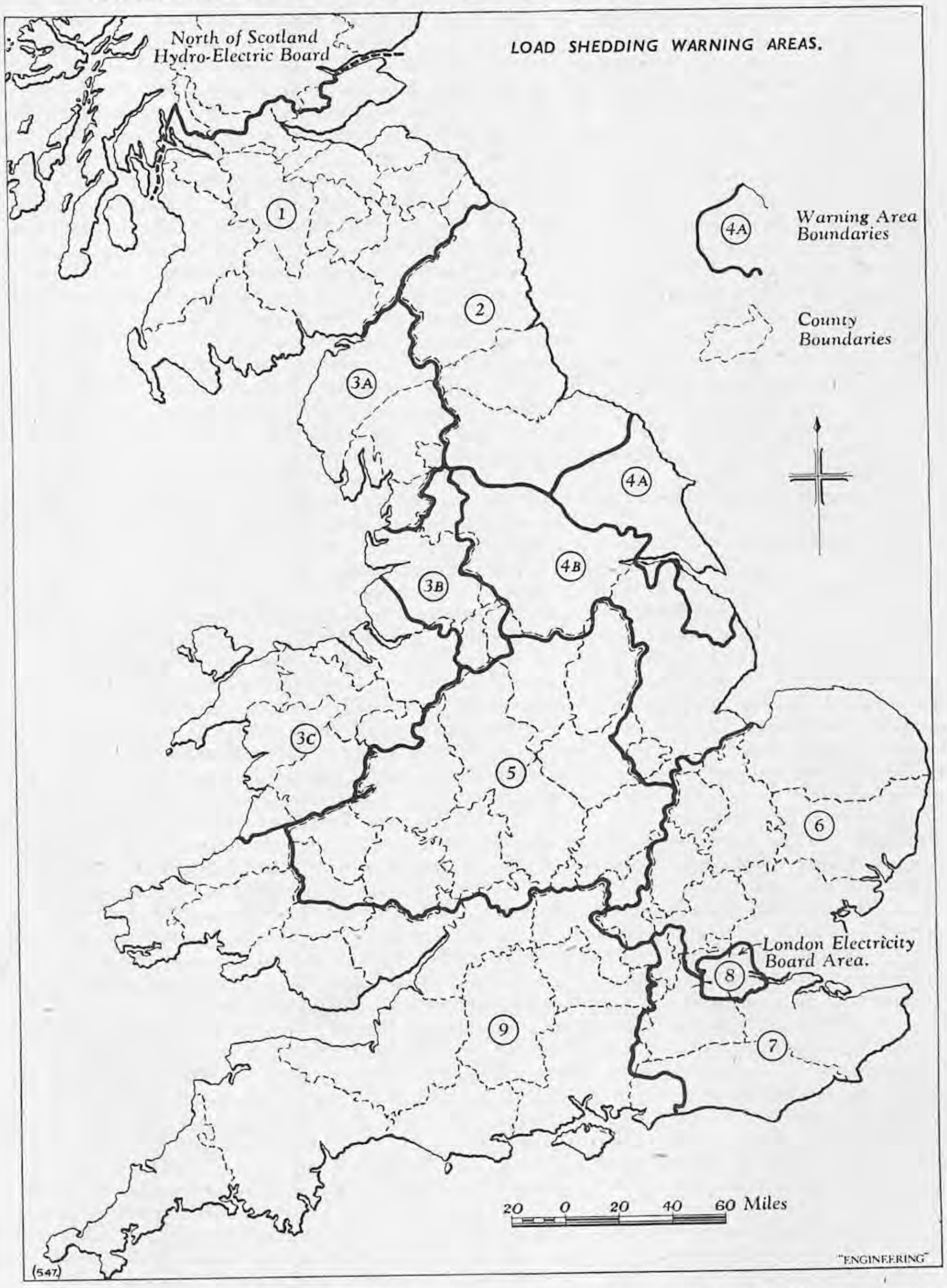
The section of the Standards Laboratory which deals with light has been mainly occupied throughout the year with techniques of photometric measurement, directed towards realising the candela, i.e., the recently adopted standard of illumination based on the radiation from a black body at the melting point of platinum. In addition to the establishment of the standard, the programme includes the development of sub-standards for the photometry of fluorescent lamps, and the provision of reproducible standards for industry and science throughout the whole field of photometry, colorimetry and spectrophotometry. The international adoption of a standard visibility relationship for the average eye has prompted the design of a precision spectrophotometer, the essential component of which is a polarising photometer. This apparatus, now in course of construction, will supersede visual methods by purely physical methods, for measuring and comparing luminous intensities. It will also take advantage of improved sensitivity of photoelectric cells, corrected to give the same spectral response as a standard observer, and with inherently better sensitivity than the human eye. A photometer capable of measuring to an accuracy of $\pm 0 \cdot 1$ per cent. is being designed on this principle. Meanwhile, an existing spectrophotometer has been used to examine and prepare standard samples of greasy wool for the use of the Gordon Institute of Technology, which is investigating the origins of discoloration in wool and its effect on the evaluation of the wool by buyers.

Among a variety of miscellaneous optical work, an especially interesting achievement is the manufacture of reflection microscope objectives, embodying the essential principles of those designed by Burch, in England, for use with ultraviolet light, but having spherical instead of aspherical surfaces. The great advantages of reflection objectives are their complete achromatism and larger working distance, both of which features are attractive to biologists. The Australian prototypes, having numerical apertures up to 0·85, have shown performances adequate for many purposes, though a little below that of aspherical objectives.

(*To be continued.*)

Diamond Tools.—A lecture on "Diamond Truing Tools for Grinding Wheels" will be delivered by Mr. N. Smith at the South East London Technical College, Lewisham-way, London, S.E.4, on Monday next, November 5, commencing at 7 p.m. This lecture is one of a series in a course on the technology of diamonds and other hard substances.

ELECTRICITY LOAD-SHEDDING AREAS.



BROADCAST WARNINGS OF ELECTRICITY CUTS.

The accompanying map shows the areas into which the country has been divided for the purpose of giving broadcast warnings of load shedding, the county boundaries also being indicated for the sake of clarity. As already announced, each area will be designated by a number and the extent of the shedding by numbered 5 per cent. stages. Important industrial consumers have already been 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. We hope that the publication of this map in Engineering will assist those smaller consumers who would otherwise have to apply to their local Area Boards for the full details applicable to them.

The arrangements for giving broadcast warnings of load shedding came into force on Monday last, October 29. Warnings will be given as and when necessary on the 1,500-m. wavelength (the long wavelength of the Light Programme) at any time between 7.30 a.m. and 12.30 p.m., and between 3 p.m. and 6 p.m. Monday to Friday. The warnings will be sent by teleprinter from the National Control Centre of the British Electricity Authority to Broadcasting House, and will be broadcast immediately. After they have been given, shedding will follow within a few minutes, in order to avoid widespread breakdown. To give the warnings, the normal programme will be interrupted, the only exception being the "Five to Ten" religious service and the gale warning to shipping. A typical opening will take the form of the announcement "Caution," followed by three seconds of the timing 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 involve a disconnection of supply, this will mean that a cut of 10 per cent. is about to occur in Area 2 and of 5 per cent. in Area 4. Urgent cuts may still, however, have to be made without warning, while on some occasions it may be impossible for technical reasons to carry out load shedding in small sections of areas for which warnings have been issued. In any event, the warnings will not apply to the Midland region.

"Launches and Trial Trips": Erratum.—In our issue of September 28, on page 395, *ante*, it was stated that the speed on trial of the M.S. Bernhard Hanssen, fully loaded, was 12¼ knots. This figure was supplied officially to us, but we have since been informed that it is incorrect; the speed actually attained was 13·45 knots.

Standard Goods Brake Vans.—Details of a second standard goods vehicle—a 20-ton goods brake van—have been issued by the Railway Executive. Experience during the war showed the advantage of a vehicle of this type which could run over any of the former railway companies' systems, and the companies were accordingly engaged on developing a design at the time of nationalisation. This work was continued, and the new design is based largely on the 20-ton brake van of the former L.N.E.R. A mass of concrete is used in place of the cast-iron weights formerly used to give the required tare weight. The Faverdale shops of the North Eastern Region are building 400 of the vans under the 1951 wagon building programme.

TRENCHING BY EXPLOSIVES.

An unusual method of trenching across the bed of a river, for the purpose of laying a portion of an 18-in. gas main forming part of the West Wales gas grid, was adopted where the main crosses the river Neath at a point about two miles downstream from the town of the same name. The main is intended to connect the Abbey Works of the Steel Company of Wales at Port Talbot, where coke-oven gas is available, with the Morriston gasworks, Swansea. The work was carried out for the Wales Gas Board under the direction of Mr. Ernest Ablett, O.B.E., the engineer and manager of the Swansea gas undertaking, and is illustrated in Figs. 1 to 4, on page 560, and Fig. 5, herewith.

The contractors, the United Kingdom Construction and Engineering Company, Limited, Hammond-road, Kirkby Trading Estate, Liverpool, were required to lay the pipe at a gradient of 1 in 50, falling from the Swansea side towards Neath, and the specification called for a minimum cover of 5 ft. below the river bed. At each end of the underwater length, as shown in Fig. 5, herewith, upward bends were necessary to bring the main above the river banks, and these had to be at different inclinations—1 in 2 on the Neath side, and 1 in 6 on the Swansea side—to suit the formation of the banks. The river is about 400 ft. wide at the point selected for the crossing. It is tidal, with depths of water ranging up to 19 ft. at spring tides; and there is a considerable current at certain states of the tide. For these reasons, conventional methods of making a trench in the river bed—by a grabbing crane, by dragline, or by building cofferdams and excavating within them—were either physically impracticable or too expensive to be considered. The use of cofferdams was also undesirable because of the present shortage of steel piling sections.

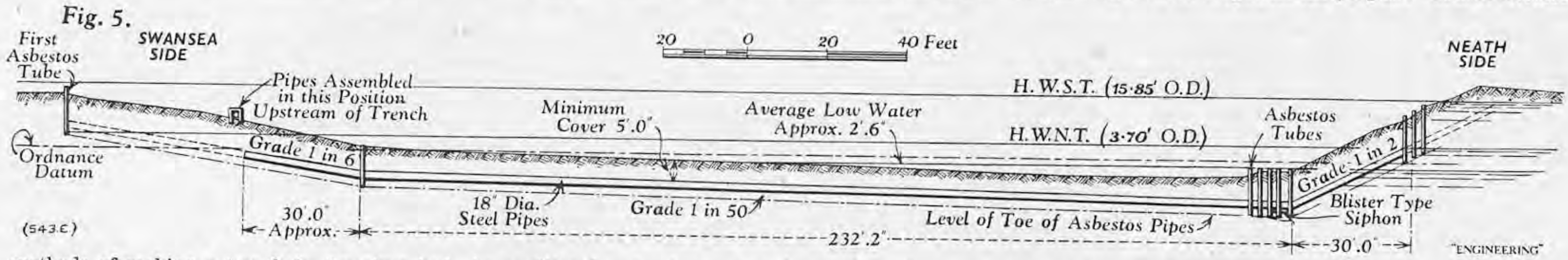
It was decided, therefore, to make the trench by laying two lines of explosive charges in the river bed and firing them simultaneously; the trench could thus be excavated instantaneously, and the pipe floated over it and sunk in position before the tides and the normal flow of the river could fill the trench with mud. A small-scale trial of the method was completely successful and work was begun, therefore, on the preparation of the site and the construction of the pipeline. The pipes were laid on timber supports on the Swansea side of the river, which has the more gently sloping bank, and where there is a road providing direct access to the site. In this position, a short distance above the eventual line of the trench, they were welded into a continuous length, as shown in Fig. 1, on page 560. As indicated in Fig. 5, the centre straight portion is 232 ft. long and the eastern and western "legs," respectively, 30 ft. and 52 ft. The pipeline was welded at a height of only 8 ft. above Ordnance Datum, so that it could be floated off on completion, the ends being left open meanwhile to prevent premature floating. The welding was undertaken, as a direct contract from the Wales Gas Board, by the Unit Superheater and Pipe Company, Limited, of Swansea.

On completion of the welding, some of the welds were given a supersonic test for soundness, and oil-impregnated mops were drawn through the pipeline to clean it. Cap ends, with valves, were then fitted, and the pipeline was given a test of 48 hours duration with compressed air at 100 lb. per square inch, which it passed without loss of pressure. The outside of the pipe was next wrapped with Denso plastic wrapping, supplied by Messrs. Winn and Coales, Limited, Terminal House, Grosvenor-gardens, London, S.W.1. A draw wire was left in the pipe to enable mops to be pulled through after it was laid in the trench. At a suitable high tide, the pipeline was drawn into the river by means of winches on the opposite bank, and moved downstream to a point clear of the trench site, where it was moored, as shown in Fig. 2, on page 560, to await the next stage in the operations.

Meanwhile, the shot holes for the trench has been prepared and charged. The explosive charges, contained in asbestos tubes, as indicated in Fig. 5, were laid in two lines, 2 ft. apart, the charges being staggered, with 4 ft. 6 in. between adjacent holes in the same line. The explosive was Submarine Polar blasting gelatine, made by Imperial Chemical Industries, Limited, in cartridges $2\frac{1}{4}$ in. in diameter and weighing $2\frac{1}{2}$ lb. each. In some parts, rock was encountered, and the shot-holes were prepared by pneumatic drilling; elsewhere, the cartridges were placed in position through a steel pipe, which was driven into the river bed, and withdrawn when the charge was correctly located. The average depth to which the charges were set was 9 ft. The weights of the charges were varied according to the nature of the ground at the particular spot. Altogether, about 120 were laid, the total weight of the explosives being about 1,000 lb.

Imperial Chemical Industries' Cordtex fuse was connected to the charges, and the length of fuse from each charge was itself connected to a further length leading to the shore. Just after low tide on October 9, a detonator and a short length of slow-burning fuse were attached to the shore end of the Cordtex fuse. In a further length of slow-burning fuse was inserted a detonator which would explode 15 seconds before the main charges, as a warning signal. When the charges were detonated, debris was thrown to a height of about 250 ft., as shown in Fig. 3, on page 560. Most of it fell back almost vertically, but clear of the line of the trench. A few stones were projected to a distance of 100 yards or so. The resulting trench being found satisfactory on inspection, the shore end on the Neath side, where the explosive charges had been made lighter because of the rather weak nature of the bank, was cleared out with the aid of a dragline. Fig. 4, on page 560, shows the Swansea end of the trench, at a point where it was partly filled with soft material which had fallen into it after the explosion. The pipe was floated upstream on a later high tide, and, when in position over the trench, was filled with filtered water from a nearby canal, and so sunk into position. Provision had been made for small adjustments in level to be effected by high-pressure water-jetting. Concreting, and backfilling with hard material from a barge, were done in the normal way.

Fig. 5.



THE IRON AND STEEL INDUSTRY IN 1895 AND TO-DAY.*

By Professor R. Hay, B.Sc., Ph.D.

Only once before, in the history of the West of Scotland Iron and Steel Institute, has the President been a person engaged in an academic occupation. My predecessor, four times removed, Professor Humboldt Sexton, was elected President in 1895. It occurred to me that it might be profitable to compare the background against which the Institute operated in those times with that of the present time, to see if any useful lessons can be learned for the future development of its work. The decision to form an Iron and Steel Institute in Scotland was taken at a meeting of 20 iron and steel makers held in Coatbridge in 1892. In October, 1893, the Institute was founded, with Mr. James Riley as its first President. Riley was works manager at Blochairn Works of the Steel Company of Scotland, which company, at its Hallside Works, was the pioneer of open-hearth steel production in Scotland. He was one of the foremost steelmakers of his time and in his early years had been manager at the Landore Works in Wales, where Siemens had installed his original steel-melting furnace. The original open-hearth furnaces had a capacity of 3 tons and later a larger furnace of 7 tons capacity had been built. Riley, when there, had drawn out plans for a much larger furnace of 12 tons capacity and had discussed his designs with Sir William Siemens. By 1895 a few large furnaces of 25 tons capacity had been built in different parts of the country.

The Bessemer process of steelmaking was never very fully developed in Scotland. After the unsuccessful attempt at making steel by this process about 1857 by Messrs. William Dixon, Limited, nothing further was done until 1861, when Rowan obtained a licence from Bessemer and built two 3-ton converters to use Cumberland hematite pig iron. This plant closed down in 1875. In the early '80's Merry and Cunningham, at Glengarnock, and the Glasgow Iron Company, Limited, at Wishaw, introduced basic-lined converters, the former erecting four 10-ton and the latter three 7-ton converters, the combined output of which was around 100,000 tons per annum. Steel was steadily replacing wrought iron at this period and we find such firms as D. Colville and Sons and Stewarts and Lloyds taking up the new process and gradually replacing puddling furnaces by open-hearth furnaces. At this time there were about 367 puddling furnaces in Scotland and of these about 260 were active, each producing about 730 tons per furnace per annum. The production figures in tons for 1895 for the whole country were as follows: converter ingots, acid, 1,093,675, basic, 441,550; open-hearth and acid basic, 1,724,737 and wrought iron, 1,148,012. We see from these figures that the three processes were producing very approximately the same order of tonnage.

The blast-furnace industry in Scotland was in a very different position. As the result of Neilson's epoch-making experiments at Clyde Iron Works in 1829 Scotland was placed in the forefront of pig-iron manufacture. Furthermore, arising from the discovery of Blackband ironstone in 1801, at Coatdyke, by David Mushet, who was at that time manager of the Calder Iron Works, and the successful utilisation of splint coal as the blast-furnace fuel that followed on Neilson's work, a special type of blast-furnace technique had been developed which was unique to Scotland. The furnaces, on an average, were about 65 ft. in height and about 16 ft. in diameter at the boshes. They were mostly closed at the top and the gases were scrubbed to recover the ammonia and volatile oils, special plants such as that of Alexander and McCosh having been developed for the purpose. It is of interest to note that one of the first attempts in Britain to collect and utilise blast-furnace gas was made at the Dundyvan Iron Works in 1845 on a 65-ft. furnace. The average production of iron was from 20 to 30 tons per cast of 24 hours, or about 200 tons per week. There were about 140 blast furnaces in Scotland; of these about 90 or more were in blast in 1895. These furnaces were located at Dalmellington, Ardeer, Kilwinning, Glengarnock, Lugar and Muirkirk in Ayrshire; Coltness, Clyde, Wishaw, Quarter, Summerlee, Langloan, Gartsherrie and Shotts in Lanarkshire; and Carron in Stirlingshire.

Thus, from the numerous blast-furnace plants, malleable-iron plants and the rising steel industry there was a large personnel from which to draw the early membership of the Institute. The technical staffs, at that time, would be among the most efficient in Britain as they had excellent opportunities of technical education in Glasgow. The Glasgow and West of Scotland Technical College (now the Royal Technical College) had been long established, being the successor of Anderson's University. This Institution was founded in 1796 and by 1895 the teaching of chemistry and engineering had been established in well-equipped laboratories. Both day and evening clases were available and practically all personnel in technical occupations had attended these classes. James Beaumont Neilson attended evening classes in mathematics and chemistry, and it was this foundation that made possible his work which led to the hot-blast technique in blast-furnace operation. In 1884 metallurgy was first taught in the College as an independent subject by Humboldt Sexton and in 1887 a chair was established of which he was the first incumbent. Thus, Glasgow Technical College, the Royal School of Mines in London (1851) and Sheffield Technical School (1886) were the only centres in Britain to have Professors of Metallurgy in 1895. The approach to metallurgy in those times was largely through analytical chemistry, and much of the student's time was devoted to chemical analysis of raw materials and finished products. A certain amount of attention was given to engineering and to drawing. The extraction of metals from their ores and the working and heat treatment of the finished product were largely arts handed down from early times, and instruction was of a descriptive character.

As would be expected, the papers presented to the Institute reflected the background of education and practice. Thus, in the session 1895-96, the chemistry of the open-hearth process was described from the angle of taking bath samples at different times, from melt-out to tap, but no attention was given to the composition of the slag and its influence upon the process. The estimation of sulphur was discussed and there was a descriptive paper on the puddling process. Another paper dealt with the composition of different types of refractory materials. MacFarlane, in this

* Presidential address delivered before the West of Scotland Iron and Steel Institute on Friday, October 19, 1951. Abridged.

paper, mentioned the use of carbon as a refractory material and suggested the use of carbon bricks in the bosh of the blast furnaces making grey iron. He stated that the experience of those who had used carbon bricks was that, when white iron was made, the carbon blocks disappeared owing to the absorption of the carbon by the metal. Sexton, in the same year, made reference to the importance of temperature measurement in the blast furnace and said that the time was at hand when temperature measurement would be regarded as being as important as chemical analysis and would become a daily routine of every works. He also said that managers were very conservative and did not care to introduce innovations. Another suggestive paper by the same author dealt with gas analysis. In it, he mentioned an apparatus which was designed and used by G. Craig of the Lugar Iron Works, for the continuous measurement of the amount of CO_2 in waste gases. Sexton pointed out that the working of the blast furnace depended largely on the ratio between the CO_2 and the CO in the gases and stated that this could be determined easily. However, there is no record of this having been achieved in practice.

The early meetings of the Institute showed a great deal of liveliness. The discussions were very good and a considerable amount of hard hitting took place. Possibly the method by which the Institute conducted its meetings helped considerably towards this end. A paper was read one evening and the next meeting of the Institute opened by discussing this paper and then the next paper was read. This meant that a month elapsed between the reading of a paper and the discussion. Admittedly, this would present difficulties with visiting lecturers, but in those days most of the papers were contributed by the members themselves. Printing, of course, did not offer the difficulties it does to-day and it was possible to have the paper in print before the next meeting of the Institute; in fact, it was laid down in the Constitution that the *Proceedings* were to be issued monthly. Not all papers were published in full; if a paper was not very important it was published in an abridged form with the discussion.

The position in the industrial and academic worlds to-day in Scotland are very different from the conditions just depicted. The puddling process is almost extinct and consequently receives little attention from metallurgists. In fact, the elementary descriptions which occur in many text-books are misleading. The fundamental principles underlying this process were not understood at the time of its extensive practice, and, to-day, although of great academic interest, they receive scant attention. Of the many blast-furnace plants which were in existence in 1895, only four remain in operation, namely, Clyde, Govan, Gartsherrie and Carron, with a combined total of nine furnaces in blast. All operate on coke, so that the unique practice of Scotland is now defunct due to lack of splint coal. Three plants still use the small hand-charged furnaces which were used in the old Scottish practice, but the old Clyde furnaces have been completely replaced by modern mechanically-charged furnaces. This plant has also been developed into an integrated plant by amalgamation with the adjacent steel works at Clydebridge. Clyde Iron Works are again making history by being the first plant in Britain to instal high top-pressure practice. Unfortunately, on this occasion it is only employing a practice already established in the United States of America and not developing a novel idea of its own, as was the case in 1829 when the hot-blast was developed there. In steel practice, many of the old firms have been amalgamated into large combines, but the individual plants continue to operate to a large extent independently, while others have been closed down or are in process of closing down. With the development of large furnaces, up to 300 tons capacity, the number of furnaces at each works has been greatly diminished. Other marked changes have been the cessation of Bessemer practice, the extension of basic-steel manufacture and the decrease of acid-steel manufacture by the open-hearth process.

(*To be continued.*)

Diamond Jubilee of the "Electrical Times."—Our contemporary, the *Electrical Times*, was first published on October 22, 1891, and we may therefore now congratulate it on attaining its sixtieth anniversary. The occasion was marked by the publication in the issue of October 25, 1951, of an article by Mr. R. W. Hughman, who joined the staff before publication and served in various capacities for 56 years, until his retirement as managing director in 1946. He describes not only the condition of the electrical industry in those early days, but amusingly indicates that the electrical journals were not then the "fraternity" they have since become. He also brings out the important fact that this "United Nations" idea has since extended to other branches of the industry, with benefit to all concerned. We have no doubt that, in the future, the journal will maintain the prestige that it has achieved.

LABOUR NOTES.

Restrictive practices by workpeople, and their opposition to the introduction of labour-saving devices, were criticised by Sir John Anderson, G.C.B., the chairman of the Port of London Authority, in an address delivered in London on October 24. Referring to an article written recently by Sir Hartley Shawcross, while President of the Board of Trade, Sir John said that if Sir Hartley thought that all was well with production in Britain, he should examine the situation in the building industry and the rate of discharge of ships in British ports compared with, for example, Rotterdam. During a tour of the port of Marseilles a short time previously, Sir John continued, he had seen a warehouse stacked to the roof with goods neatly arranged, obviously with fork-lift trucks, and wished that similar methods could be employed at the Port of London. Unfortunately, employees there seemed unwilling to agree to the appropriate reduction in the strength of gangs, and only such a course would justify the use of the expensive equipment involved. Apart from the speed with which goods could be handed by such methods, and speed of handling was vital to Britain's competitive position, the saving of physical effort to the men concerned would be immense.

At the Royal docks in London, there was a floating grain elevator, Sir John stated, which had been purchased at a cost of 150,000*l*. This worked so fast that the men complained that it was taking the bread out of their mouths, and they had demanded rates of pay which would make its use uneconomic. As a consequence of this attitude, the elevator was idle and three grain ships were waiting to be unloaded. The situation seemed to Sir John to be reminiscent of the days when the Luddites went about wrecking mills and machinery. He emphasised that he was not criticising the trade-union leaders or the individual employees. The authority of the leaders had been weakened in the eyes of the men by their close association with the Government. The unions had also lost the assistance of some of their most responsible officials, who had been taken away to perform other work. In connection with Sir John's remarks, it may be mentioned that the floating grain elevator at the Royal Docks ceased to be operated by the dock employees as from mid-October. It had then been in service for rather less than two months but the men complained that some of them would be rendered redundant by its continued use.

There has been some worsening of the position in connection with the two disputes in progress at the London docks during the past week. Employees at Tilbury docks decided at the beginning of October to adopt a policy of banning all overtime and of working to rule. These restrictions, which have been in force since October 5, were introduced as part of a protest by the dockers against the engagement of additional men on a permanent basis by one of the larger firms of master stevedores. It is understood that the extra men taken on in that way were later returned to the dock labour pool, but the other dock employees have remained dissatisfied. One of their main grievances appears to be that they have been unable to obtain from the firm of master stevedores concerned an assurance in writing that no more attempts will be made by the firm to increase the number of their permanent staff.

It may be recalled that two strikes took place at Tilbury docks during the past summer on the question of whether it was permissible to employ men on a permanent basis from the dock labour pool. The National Joint Council for the Port-Transport Industry investigated the position after the first strike had ended and decided that the employers had the right to engage men on a weekly basis, if they so wished, and that this was in accordance with the terms of the dock labour scheme. After discussions between rank-and-file dockers and their trade-union leaders, the men subsequently agreed that a limited number of dockers should be placed on a permanent basis of employment with stevedoring firms. Attempts were made in September by one firm of master stevedores to put the agreement into practice and these, unfortunately, led to a second strike taking place. The men returned to work later in order to enable negotiations on the dispute to take place between the employers' organisation and the unions concerned. It was reported at the beginning of October, however, that the negotiations had broken down.

On October 23, the London shipowners' dock labour committee condemned the work-to-rule policy and the overtime ban as an "unofficial and irresponsible" go-slow movement and insisted that the men had acted without warning after the employers had offered a "substantial" compromise on the question of the engagement of dockers on a permanent weekly basis. The employers felt that they could no longer employ men who were using "obstructive tactics" to delay the work of the port or who were not prepared to act in accordance with the normal practice of the port. As from that date, all men continuing to ban overtime or persisting in working to rule would be returned to the dock labour pool. These warnings were rejected and the men's working policy was continued. Relatively small numbers of men were, in fact, returned to the labour pool, but without effect. In some cases, the men concerned were re-engaged by other firms and even, in some instances, by their own previous employers. During the early days of the past week there have been even fewer instances of men being returned to the labour pool, but the overtime ban and working to rule have remained in force.

Similar working-to-rule methods, accompanied by a ban on overtime, were put into operation by lightermen at the Port of London early in October, in order to enforce a claim for increased remuneration. A committee of investigation set up by the Ministry of Labour had previously decided that the men's demands for a daily contingency payment of 1*s*. 6*d*. had no justification. Refusal to undertake a reasonable amount of overtime constitutes a breach of agreements formulated under the dock labour scheme and the lighterage firms have been returning men to the dock labour pool for not working in accordance with the practice of the port. The employers have affirmed that they are fulfilling the recommendations made by the committee of investigation and that they are willing to commence negotiations on a claim for a day bonus of 3*s*. 4*d*. in one section of the industry. Lightermen returned to the pool have not, in the main, been re-engaged and are reported to be drawing only their attendance money. In all, nearly six thousand dock employees are involved in the two disputes now in progress at the London docks.

Suggestions that the extension of compulsory education up to the age of fifteen and the introduction of modern methods of training rendered long periods of apprenticeship unnecessary, were made by Sir Godfrey Ince, K.C.B., K.B.E., Permanent Secretary to the Ministry of Labour and National Service, in an address delivered at the annual meeting of the British Association for Commercial and Industrial Education, in London on October 22. Sir Godfrey, who is also a member of the Economic Planning Board, spoke on the necessity of skilful training in order that the best use of the nation's man-power might be obtained. In his view, it would be only by making the most efficient use of man-power that increased production would be obtained. Training to achieve this end would have to be concentrated on works study and communications. He inquired why young men had to be trained for one job only, when, by the introduction of intensive methods, it would probably be possible to train them in two skilled crafts in the same amount of time.

Some 1,238,000 workpeople in the United Kingdom received increases in their weekly full-time rates of wages during September. These increases amounted to a total of 350,000*l*. a week net, according to the *Ministry of Labour Gazette* for October, and the principal groups of workpeople benefiting from them included manual employees in the service of local authorities in England and Wales, persons engaged in the cotton industry, and employees in the iron and steel industry. During the first three quarters of the present year, some 9,230,500 workpeople have received increases in their weekly-wage rates, amounting in all to over 3,983,000*l*. net. In the corresponding months of 1950, there was a net increase of 603,000*l*. in the weekly full-time wages of 3,278,500 persons.

Industrial disputes in progress in the United Kingdom during September numbered 173, and, in these, 33,300 workpeople were involved and some 109,000 working days were lost. In the preceding month, there were 165 disputes in progress, in which 22,500 persons were concerned and about 73,000 days lost. The comparative figures for September, 1950, were 129 stoppages in progress, 43,800 persons involved, and about 154,000 days lost. During the first nine months of this year, there have been 1,318 strikes, against 1,049 during the corresponding period in 1950. There were about 307,000 persons involved, and 1,444,000 days lost during the first three quarters of 1951.

Claims for certain increases in wages were considered by the National Joint Industrial Council for the Gas Industry at a meeting in London on Tuesday last. It was announced subsequently that the Council had agreed to increase the standard scheduled rates of pay for all adult manual employees in the industry by twopence an hour as from Sunday, November 4. It is estimated that about 100,000 manual employees will benefit from the award.

CHEMISTRY IN METAL EXTRACTION.

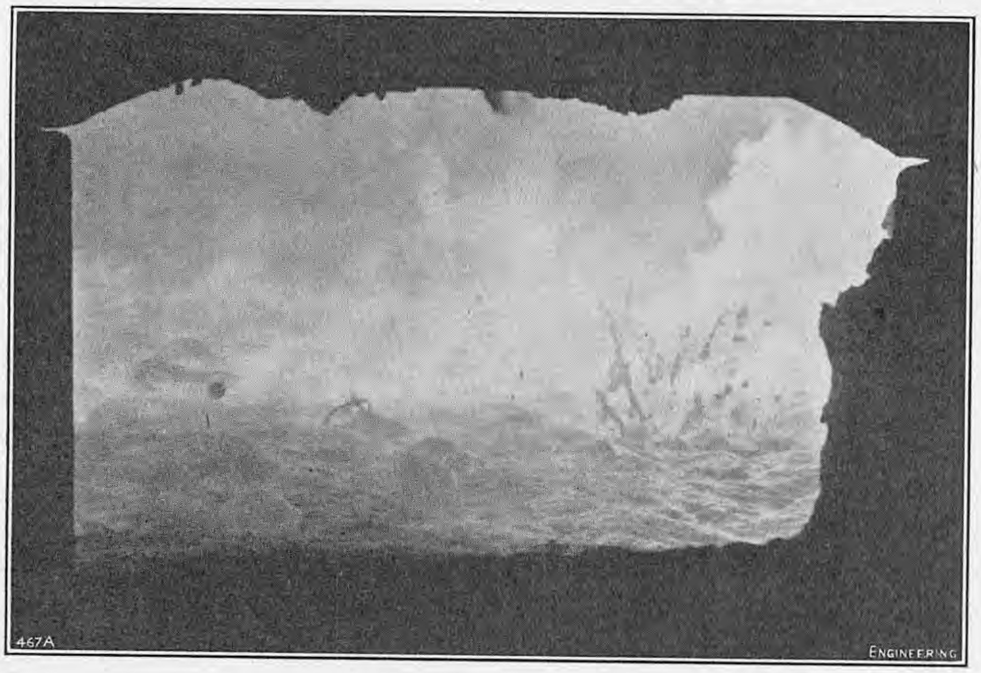


Fig. 1. Interior of Open-Hearth Steel Furnace.

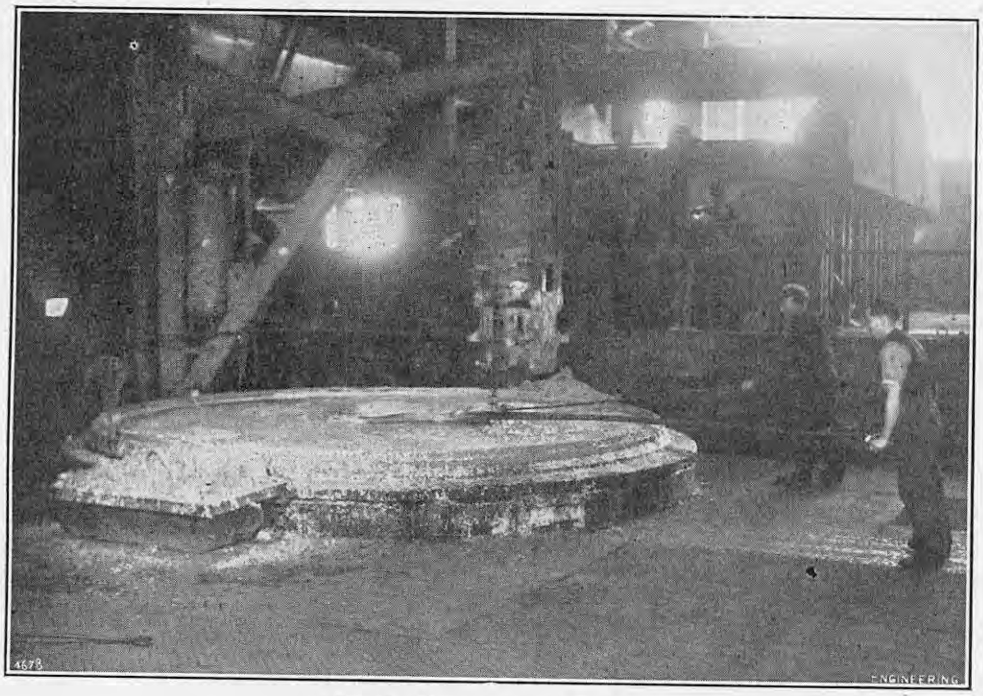


Fig. 2. Desilverising Lead.

CHEMISTRY IN METAL EXTRACTION.*

By F. D. Richardson, Ph.D.†

Chemistry enters into almost every phase of metal extraction. The chemist and the chemical engineer are familiar with and have contributed greatly to those processes which are conducted at normal temperatures. In contrast, the smelting and refining of metals at high temperatures has so far been left almost entirely to the metallurgist. This is so even on the research side, the chemist, I believe, being daunted by the difficulties inevitably associated with accurate investigations at high temperatures.

In these processes, commonly termed pyrometallurgy, the metals, slags, mattes and speisses which take part are usually molten. The temperature range is wide. Steel, for example, is made at 1,650 deg. C., and this high temperature is the cause of many practical difficulties. It is also the reason why steelmaking (Fig. 1) is the most spectacular chemical process in common use. The photograph, reproduced by courtesy of the United Steel Companies, shows the interior of an open-hearth steel furnace seen through one of the doors. Carbon monoxide is bubbling out of the bath as carbon in the iron is oxidised away. In marked contrast, lead is refined at about 400 deg. C. and this operation (Fig. 2) appears prosaic and easy by comparison. The lead is treated in iron pots (called kettles) and is pumped conveniently from one to another through iron pipes. The photograph, which shows desilverising in progress is reproduced by courtesy of the Britannia Lead Company and Johnson, Matthey and Company.

The broad chemical basis of smelting and refining is simple enough. The elements combined with the metal in the ore have to be torn away from it by combination with other suitable added substances. Oxygen, for example, is most commonly removed from oxide ores by combination with carbon to form CO and CO_2, as in the making of iron and lead. Sulphur is removed from sulphide ores by combination with oxygen to form SO_2, as, for example, with copper and nickel. Although some of the unwanted elements can be removed as gases, most of them have to be collected into a liquid product known as slag. This consists of the lime, alumina, magnesia and silica, which combine together to form a molten mixture. This is immiscible with metal and normally floats on top of it. The smelting slag need not be merely a passive collector of the worthless constituents of the ore; it may also be an active solvent for the impurities which can dissolve in the metal. In iron making, for instance, the sulphur which comes from the raw materials fed into the blast furnace is partitioned between the slag, and the metal, so that the former carries about 2 per cent. sulphur, and the latter about 0·1 per cent.

In order that the subsequent refining may be made as easy as possible, it is obviously desirable for the slag to be a good solvent for impurities. Since the slag can always dissolve the metal to some extent as oxide or sulphide, and the slag ultimately goes to waste, it is important that it should be a poor solvent for the metal. The smelter therefore tries, as far as practicable, to adjust the composition of his slags to obtain these properties. Molten slags are also used for refining, and in this case are designed specially to collect and retain the impurities from the metal. The materials from which they are made cost money, and it is expensive to heat and melt them. It is therefore important that their bulk should be kept as small as possible, and that they should hold the impurities at as high concentrations and as low chemical potentials as possible. It is also desirable that they should not absorb much of the metal, as oxide or sulphide, in order that re-smelting the slag to recover the metal may be avoided.

A slag and metal react together at the interface where they meet. The temperatures are usually so high, and the chemical reactions therefore so rapid, that equilibrium is established almost instantaneously in the neighbourhood of this interface. The rates of slag-metal reactions are therefore controlled by the rates of movement of reactants and products to and from the interface. They are thus dependent on stirring conditions and on the diffusion coefficients of the participating species in the slag layer, where movement is normally slowest. Since slag and metal are always in equilibrium at the interface, it follows that equilibrium considerations, and hence the thermodynamics of slag and metal solutions, are of paramount importance to the smelter and refiner.

In spite of its importance, the chemistry of molten metals and slags is a relatively new subject. In the last decade, however, knowledge has advanced considerably, so that a useful picture can now be drawn of the nature of these two interesting liquids. I will not refer again to mattes or speisses, that is, to sulphide, arsenide or antimonide mixtures, as the knowledge of their chemistry is still fragmentary. The bulk of the research so far done is related to iron and steel making and springs directly from the pioneer work of Schenck in Germany, Chipman in the United States and McCance in Britain. Most of my examples have, perforce, to be drawn from solutions in liquid iron and iron-making slags. The principles, nevertheless, are applicable to all metals.

There has been a regrettable attempt to explain the thermodynamic behaviour of molten metal and slag solutions in terms of the formation of molecular compounds which obey Raoult's law. This has led, and still leads, to the postulation of compounds, which cannot be reconciled with our knowledge of the structures of these melts obtained from other sources. Furthermore, these alleged compounds even differ widely for similar solutions. In my view, our atomic models of molten metals and slags should be based broadly on our knowledge of chemical structure. These models may then be developed in detail in the light of thermodynamic information as it becomes available. They should find their greatest value as a guide to show how far existing thermodynamic knowledge can safely be extrapolated beyond the range of conditions over which it has been established.

A molten metal is very like a solid metal, for the expansion on melting is only 2 to 4 per cent. It consists of metal atoms closely packed together, but lacking the long-range order peculiar to the crystal. Each atom has between six and twelve other metal atoms immediately surrounding it, and it interacts strongly with each of them. Other elements dissolved in metals can be pictured as foreign atoms dispersed among the metal atoms and also interacting strongly with their six to twelve nearest atom neighbours. The foreign atoms may be distributed randomly throughout the melt or they may cluster together in some degree, depending on how far the energies of interaction between unlike atoms differ from those between the two sets of like atoms.

There is an interesting form of clustering which is important in more complex solutions. The behaviour of oxygen in iron containing chromium, and of sulphur in iron containing manganese, provides strong evidence for clustering between pairs of solutes. The chromium case is illustrated by Fig. 3, on page 570, which shows how the nearest neighbours surrounding any oxygen atom can be richer in chromium than the bulk of the solution. In the diagram the oxygen concentration has been exaggerated about twenty times beyond that

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CHEMISTRY IN METAL EXTRACTION.

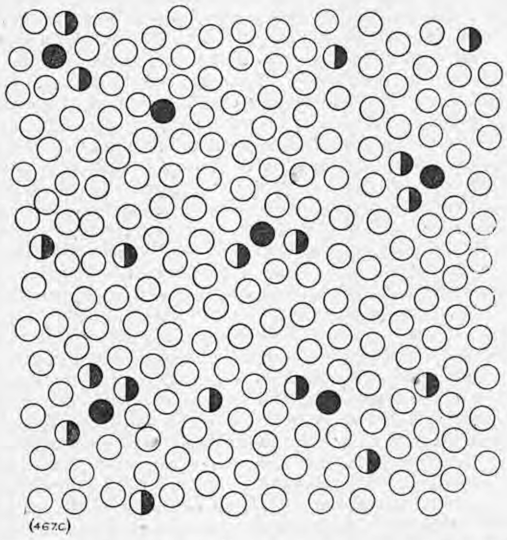

FIG. 3. SCHEMATIC REPRESENTATION OF LIQUID IRON CONTAINING CHROMIUM.

NOTE.—Iron atoms shown white, oxygen black and chromium black and white.

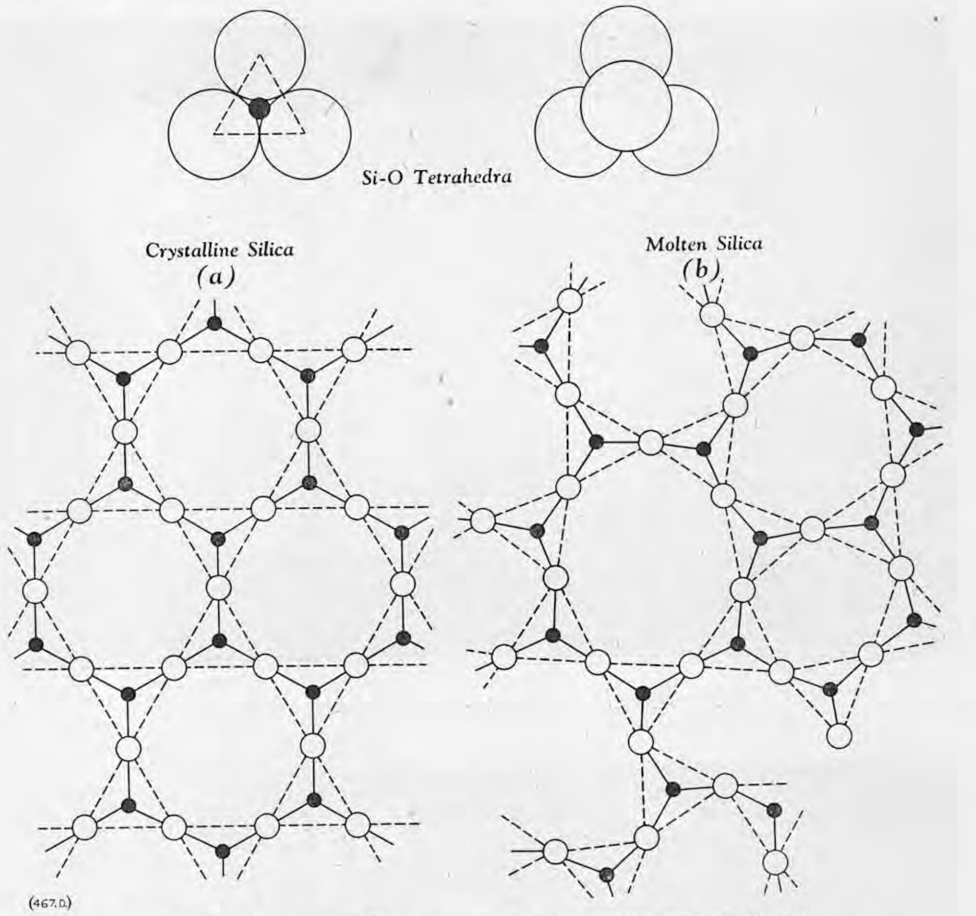

FIG. 4. SCHEMATIC REPRESENTATION OF STRUCTURE OF SILICA.

NOTE.—Oxygen atoms are shown white and silicon atoms black. The Si–O tetrahedra, above, are drawn on the same scale as the silica networks, but the atoms in them are shown with their ionic radii.

possible at 1,600 deg. C., in order to illustrate the statistical nature of the clustering. A similar diagram would apply to the case of manganese and sulphur. In each case the alloying element, manganese or chromium, lowers the activity coefficient of the other solute markedly. The reverse effect is found in iron containing both sulphur and carbon, for the sulphur and carbon atoms keep as far away from each other as possible. In this case, the carbon markedly raises the activity coefficient of the sulphur, and vice versa.

Such mutual interactions may influence greatly the behaviour of both impurities and alloying elements, and part of the art of smelting and refining is to make the best use of such effects. Other things being equal, it is easier to remove the impurities when their activity coefficients are greatest.

Most metallurgical slags are mixtures of molten silicates and, being so, are of great interest to the geologist and glass technologist as well as to the metallurgist. Their structure is extremely interesting and they constitute as remarkable a group of synthetic solvents as exists in chemistry. The name "slag" is, in some ways, unfortunate. It smells so strongly of the dump and the waste heap that it seems to have prevented the chemist from taking any interest in these mixtures. Indeed, I well remember that when I first started work in this field, I could only interest research chemists in slags when I referred to them by the chemically exciting term "ionic melts."

Our understanding of the atomic nature of slags is founded essentially on the X-ray studies which have been made on the structure of silica and of silicate glasses by Bragg, Warren and others. The fundamental building unit in silica and all silicates is the silicate tetrahedron consisting of four nearly close-packed oxygen atoms or ions, surrounding a small silicon atom. This tetrahedron is represented, as viewed from above, at the top of Fig. 4. In the left-hand tetrahedron the apical oxygen atom has been omitted so that the central silicon atom is revealed. The oxygen atoms at the corners of a tetrahedron have a residual valency each, so that an SiO_4 group on its own carries four negative charges—one associated with each oxygen. These tetrahedra can share corners but not edges with each other, so that when every corner (that is every oxygen) is shared, the substance formed has the stoichiometric formula SiO_2. In crystalline silica the tetrahedral groups are distributed in regular array, sharing all their corners in a manner which may be represented two-dimensionally as in Fig. 4 (*a*). Here, for the sake of clarity, only the atom centres are shown and the apical oxygen atoms which lie alternately above and below the plane of the paper have been omitted. In molten or vitrous silica, all or nearly all corners remain shared, albeit with some distortion. The long-range order has disappeared, however, and we have the three-dimensional network represented in Fig. 4 (*b*). Being tightly linked in all directions, the melt has a high viscosity. Fig. 5 shows what happens when a metal oxide, such as CaO or MgO, is added to molten silica. The oxygen atoms from the added oxide join into the silicate tetrahedra, with the result that a shared corner is freed at every point at which an oxygen is added. This can be represented by an equation such as:—

$$\rangle Si - O - Si \langle + CaO =$$
$$\rangle Si - O' + O' - Si \langle + Ca^{\cdot\cdot}.$$

The oxygen atoms at such breaks each carry a negative charge, and the cations $Ca^{\cdot\cdot}$ or $Mg^{\cdot\cdot}$ are localised near the break, being accommodated in holes in the network. As such oxides are added in increasing concentrations, the silicon-oxygen network is increasingly broken down and the viscosity falls correspondingly. Finally, the stage is reached at which no corner is shared. The structure of the liquid is then a disordered version of that which has been established for the crystalline compound Mg_2SiO_4 and is represented in Fig. 6. Further addition of oxide results in a melt containing $(SiO_4)''''$ groups and oxygen ions (O''), together with the equivalent number of cations. It must not be supposed, however, that there are no O'' ions in slags containing more silica than corresponds to the stoichiometric composition $2MO.SiO_2$, e.g., Ca_2SiO_4. At any instant, there will be a proportion depending on the thermal dissociation of the silicate chains as might be represented by the equation,

$$2\left(\rangle Si - O'\right) = \rangle Si - O - Si \langle + O'',$$

and one such group is shown in Fig. 5 (*b*).

The proportion of such groups is smallest in extremely silicous slags and increases as the metal oxide content is increased. An equilibrium of this type is probably of great importance in the iron blast furnace, where it seems that sulphur is retained in the slag as sulphur ions (S''), the sulphur equilibrium between slag and metal taking the form,

$$[S]_{metal} + 2\left(\rangle Si - O'\right) = \rangle Si - O - Si \langle$$
$$+ S'' + [O]_{metal}.$$

The solvent powers of slags are remarkable; so much so that no inert containers can be found for many of them. Such behaviour is hardly surprising, for many silicates are, in a sense, solvents even in the solid state, in spite of the stringent packing rules which have to hold. Phosphorus, for example, can frequently substitute for silicon in the tetrahedral silicate group provided an anion, such as F', is added simultaneously to balance the charges. Similarly, aluminium can substitute for silicon if a cation, such as $Na^{\cdot}$, is added at the same time. Again, a whole range of stable structures exist which are in a sense mixtures of Mg_2SiO_4 and $Mg(OH)_2$.

What effect has physical chemistry and research, of the kind described here, had on metal extraction? The newer metals such as titanium, zirconium and uranium are now produced by methods developed in the laboratory by the application of physical chemistry. With the older metals, such as steel, copper and lead, the story is different. These have been in bulk production for many years by methods which have been developed empirically with great success. Research has been aimed at establishing the why and wherefore of existing processes rather than in developing new ones; in a sense, the physical chemist has been struggling to catch up with the practising metallurgist. The older metal industries do nevertheless show many improvements which have followed from a better understanding of what goes on in the furnaces of the smelter and refiner. In particular, the techniques of refining have been progressively improved to meet the continuing demand for purer metals with lower and lower concentrations of deleterious elements.

I will conclude with an example of how such improvements may come about. I will take the risk of describing some current possibilities which may become important, as they concern that topical element sulphur. Although the scarcity of sulphur causes a headache to the Government and to chemical industry, a surfeit of this element is a headache to the metallurgist and especially to the makers of iron and steel.

I have already explained how sulphur is divided in the blast furnace between the slag, which commonly holds 2 per cent., and the metal, which retains about 0·1 per cent. Even the latter is objectionable to the steelmaker, who has to remove most of it by the use of large quantities of a strongly basic refining slag. Recent laboratory studies by Hatch and Chipman have shown that the partition of sulphur in the blast furnace is nowhere near as favourable as can be obtained under equilibrium conditions. This is probably due to bad mixing between slag and metal in the furnace. A tenfold improvement appears possible

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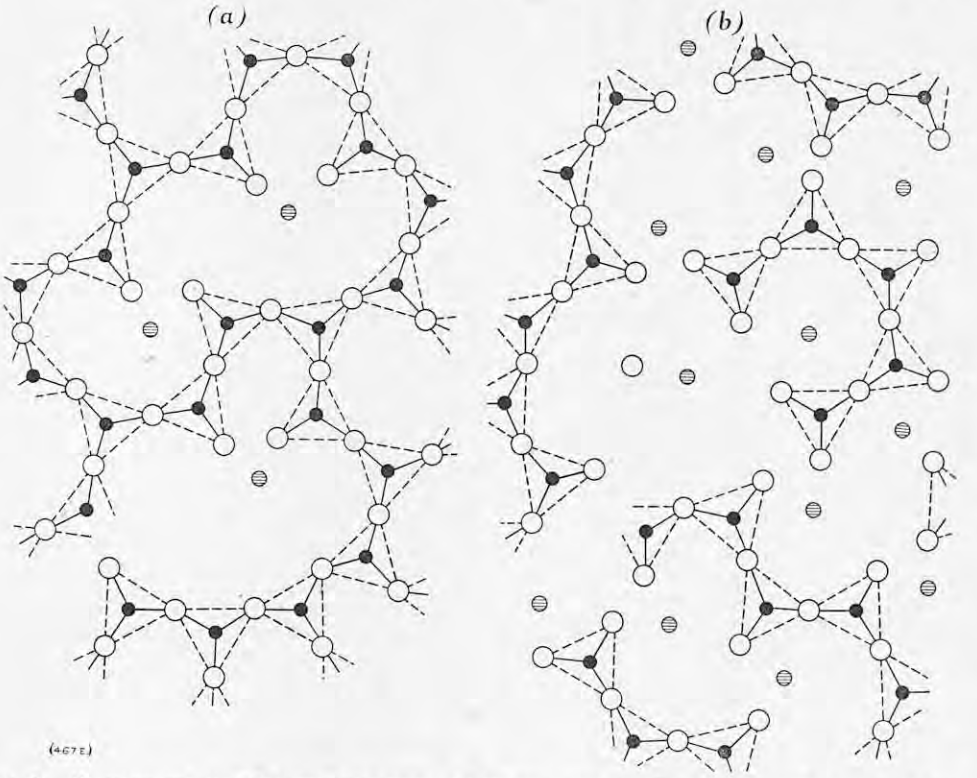


Fig. 5. Structures of Molten Mixtures of Silica and the Oxide of a Divalent Metal.

Note.—The metal ions are represented by shaded circles, and their concentration increases from left to right.

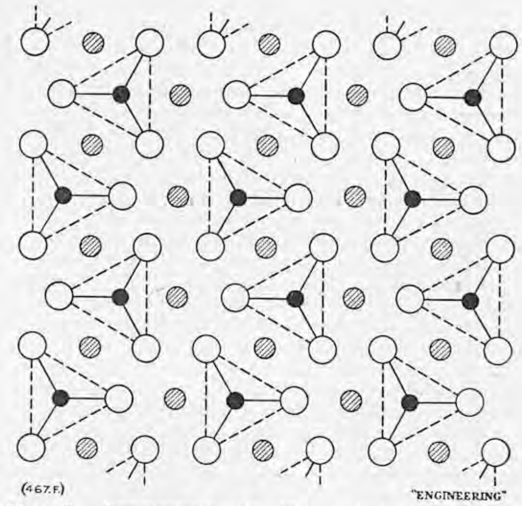


Fig. 6. Structure of Crystalline Mg_2SiO_4. Notation as in Figs. 4 and 5.

under laboratory conditions, so that a threefold improvement might reasonably be expected in works practice provided slag and metal can be adequately mixed together. This could be done, for instance, by running the metal continuously through the slag during or after tapping. In this way iron containing 0·03 per cent. sulphur might be consistently obtained.

There are, however, other possibilities. If the equilibrium between slag and metal with respect to sulphur can be represented by the equation given above, that between slag and gas may be written,

$$\rightarrow Si - O - Si \leftarrow + S'' + \tfrac{1}{2}O_2 = 2\left(\rightarrow Si - O'\right) + \tfrac{1}{2}S_2.$$

It follows that sulphur may be removed from slag by blowing it with an oxidising gas mixture. This would normally convert the sulphur to sulphur dioxide. A process to make sulphur dioxide in this way, for the production of sulphuric acid, was developed by Diehl and used in Germany in the 1914-18 war, when her supplies of pyrite were cut off. It was later abandoned as uneconomic. This method of removing sulphur might be used on all or part of the slag prior to mixing with the metal, in order to improve its desulphurising action.

Under present conditions the blowing of slag could again become a worthwhile method of making sulphuric acid. The iron maker to-day complains of the increasing sulphur content of his raw materials and particularly of his coke. If he were to accept raw materials richer in sulphur, he might make slags containing 3 or 4 per cent. of sulphur and at the same time still produce a satisfactory low-sulphur metal by mixing slag and metal as already suggested. To-day the recovery of 3 to 4 per cent. sulphur from slag should be economic. In that event the 7,000,000 tons of blast-furnace slag which are made annually in Britain, and even to-day contain about 100,000 tons of sulphur, might become a valuable source of that much needed element.

In so short an address I have had to be very brief. I hope that I have been able to show the chemist that the behaviour of molten metals and slags is worthy of his interest. I hope also that I have been able to show the metallurgist that if he wants to understand and control his slags and metals better, he must use the tools, and especially the thermodynamic tool, which the physical chemist has already made available.

The Institute of Physics.—Mr. N. Pentland, Mr. W. C. Price, and Mr. J. Yarwood, of London, Mr. W. G. Darvell, of Salford, and Mr. S. L. Martin, of Australia, were elected Fellows of the Institute of Physics, London, on October 11. Thirteen associates, 41 graduates, 10 subscribers and 14 students were elected at the same meeting.

MEASUREMENTS ON POWER-TRANSMISSION SYSTEMS.*

By F. J. Lane, O.B.E., M.Sc.

In relation to the power-transmission system, measurement can be subdivided into research, design, operation, and planning. Research is directed to determining the properties of the materials to be employed, to prescribe the mathematical and mental processes by which one proceeds from the small effect to the great, and, by correlation of data, to assist in the solution of special problems. Design is concerned with the specification of those measurements and tests which will ensure that a product or an arrangement will give satisfactory service. In operation, measurement seeks to obtain indications of the continuing reliability and efficient utilisation of all the equipment employed. In planning, it is important to have available data collected in any of the above stages, and to use them as a means of forecasting the form and plan which future development can take.

The effect of atmospheric conditions on insulators and overhead-line conductors, the measurement of corona levels and radio interference, the determination of the characteristic impedances and losses of lines and cables, and the exploration of the noise problem with transformers are contributions that have been and are being made by research towards the achievement of the present high standard of security in supply. It is clear, however, that with the expansion of systems, the higher voltages of transmission, and the closer control of equipment design which will be necessary to keep down capital costs, its scope must be expanded if the measurements involved are to be really valid for practical networks. For example, the increasing need for the transmission of large blocks of power over great distances or in circumstances where the overhead line is not a desirable or practicable solution is inevitably causing supply engineers to look at the possibility of using direct-current transmission. Although, however, research has produced solutions on small-scale equipment and at low powers at voltages up to 50 kV, and has indicated to a limited extent the way in which the problems of rectification and conversion, switching and protection can be solved at high voltages and large powers, there cannot be sufficient assurance of practicability until there has been a painstaking attempt at a major direct-current transmission project. Until that can be effected, however, the practical solution of any supply circuit problem must be an alternating current one.

In specifying electrical equipment it is necessary to define the service conditions, both normal and abnormal, and to devise tests which will ensure as far as is reasonably practicable that the apparatus will continue to work in all service conditions without failure. There are three classes of tests which are generally recognised as necessary to-day—type tests to prove the design, and routine and sample tests to check uniformity of production.

Routine tests, which are carried out on every unit in the particular contract and designed to ensure that there has been no grave departure from an accepted standard, present no serious difficulty. Sample tests represent a simplification of routine tests where large quantities of a product are involved. It may, however, be necessary to combine them with special tests which involve extra high stresses, even up to breakdown point.

Type tests are much more subject to discussion. Both the manufacturer and the user have a common concern to achieve the most economic design consistent with good service, but they may have very different opinions as to the degree to which abnormal system conditions in particular should be withstood, and even as to what are the magnitudes involved in abnormal conditions. The user will naturally have regard for the fact that, once a design is accepted as a result of type tests, there is little likelihood that these can be repeated except at appreciable cost, or if some change in essential features is proposed. Consequently, he will require them to have sufficient margin to secure that the validity of the design is not affected by any normal vagaries of the routine manufacturing processes, and may also seek to obtain adequate data on the basis of which different designs can be compared. The manufacturer, while actively interested in meeting the requirements of the home market, has also to consider the needs of the export market, in which the test specification is often easier than that which is justified by British measurements and experience. Any standard or agreed set of test conditions, therefore, tends to be a compromise which is not completely satisfactory to either party. Generally, however, an intermediate position between the user's requests, which err on the generous side, and the manufacturer's recommendations, which tend to be more restricted, produces a design which is workable and reasonably economic.

One factor which has led to an important change in type tests during the last few years has been the growing appreciation of the importance of safeguarding against the surge conditions set up by atmospheric storms and switching operations. Manufacturers and users have been devoting time to the specification of the criteria which determine insulation and air clearances. The subject is of vital importance, since its objective is to set practical limits to what the equipment is expected to do and consequently to permit the most efficient use of insulating materials. In outdoor substations the clearances have a major influence on the dimensions of the layout and therefore on the cost of the assembly, particularly at the higher voltages. It is characteristic of this type of problem, however, that the research methods for ascertaining basic data often do not correspond sufficiently closely to the conditions appertaining to service installations. There are test figures which show, for example, that the breakdown voltage of sphere-plane gaps (curved 'busbars against plates, perpendicular conductors) may be lower than that of a point-plane gap—a phenomenon which is not explicable on the basis of geometry and field strength. In the design of a substation, therefore, there will be a tendency to err on the safe side and thus to incur greater expense than would be necessary

* Chairman's address to the Measurements Section of the Institution of Electrical Engineers, delivered on Tuesday, October 23, 1951. Abridged.

if sufficient data were available to associate clearance and impulse level more precisely. There is also a real need for more data on the insulation level which is essential for a given system arrangement. Since impulse testing was introduced there has been a certain progressive reduction of the impulse levels appropriate to particular system voltages, not because there has been any material increase in the knowledge of measurement of the voltages which may be imposed, but because of service experience. Experience alone, however, is an unreliable basis on which to make a change, because trial-and-error methods must be taken to the stage where they include errors the cost of which with the large-scale apparatus involved, is high enough to be a deterrent. Effective measurement of the surge conditions encountered in a system would require extended and expensive installations of measuring equipment and would absorb much expert engineering time, but the collection of reliable data might be amply repaid by economies in plant design.

While transformers were subjected only to power-frequency over-voltage tests, protection against surge conditions consisted mainly of reinforced insulation on the end-turns. The introduction of impulse testing as a means of checking the security of the design, and the later employment of the recurrent-surge oscillograph for analysing the conditions at all parts of the winding during a voltage surge, immediately opened the eyes of the designers to the shortcomings of existing practice and pointed the way to the shielded and distributed-capacitance windings which are now general. Impulse testing of transformers is still regarded with suspicion by many, not only because it falls in the "make-or-break" category, but also because of the fear that the tests, particularly the chopped-wave tests, may over-stress the insulation in a manner which will not be apparent until a breakdown occurs in service. However, tests carried out as type tests, and ultimately to breakdown, on typical coil assemblies, and the extension of "withstand" tests to occasional units selected at the option of the purchaser have been fully justified by the resulting detection of both defective design and defective manufacturing technique. Where failure has occurred, the indication has been quite positive and there has been no suspicion of incipient undetected breakdown on any occasion.

Cathode-ray oscillography is also a vital adjunct for showing the magnitude and effect of the rate of rise of restriking voltage—an important controlling factor in the performance of a circuit breaker. A serious difficulty here is the problem of relating test performance to service requirements. As a means of obtaining improved indication of the relation between calculated and actual rates, the Electrical Research Association are making, in co-operation with the British Electricity Authority's staff, a number of tests at selected 66-kV and 132-kV substations. Short-circuit duties are not difficult to calculate, but there is very little factual information about conditions which are actually experienced in service. Some such data can be obtained from the high-speed ammeters which are now being included in every 132-kV transformer neutral, and the wider installation of Masson "perturbographs" should permit of further analysis.

The functions of measurement on the transmission system in operation are to facilitate utilisation of the equipment with the maximum economy, to assist in the detection of weaknesses before breakdown occurs, and to provide means for analysing the conditions consequent on breakdown. The ammeter indicates the thermal margin available between the operating condition and the full-load condition. This was quite satisfactory when circuits were fairly simple units and full-load operation was rare. At the present time, however, circuits may include switchgear, transformers, cables and overhead lines, each item having a different thermal characteristic and rating. Further, with the present shortage of transmission equipment in relation to load, a much more accurate knowledge of thermal ratings is desirable, and it is necessary to consider whether the magnitude of the current is a satisfactory criterion of the ability of a circuit to carry the load. The latest practice on transformers suggests that a better guide is the temperature. All larger transformers have therefore been fitted for years past with thermometers for indicating oil temperatures and possibly winding temperatures. These have frequently been provided with contacts suitable for automatic control of cooler pumps and fans or for giving alarm and trip signals. It was soon found, however, that it was not possible to obtain the correct relation between cooler operation and the alarm and trip signals if these functions were separately allocated to the oil thermometer and the winding thermometer. Present practice on new grid transformers requires the provision of duplicate winding thermometers to give better control of the thermal operation and protection of the transformer.

The winding-temperature indicator is a capillary thermometer with its bulb in an oil pocket on the top of the transformer. A heater strip round the pocket or the bulb is energised from a current transformer in one of the phases. In theory, the characteristics of the current transformer and heater and the location of the bulb are such that the effect of the heater added to the top-oil temperature reproduces the temperature in the hottest part of the winding. In practice, the heater may be unsuitably located in relation to the thermometer bulb, its time-constant may be different from that of the winding, and the accuracy of the thermometer may be poor. Only within the last few years has the design of these "thermal images" received serious attention, and the older types are highly suspect. This state of affairs makes it difficult to apply the theory that a transformer should be loaded according to its temperature. When it is remembered, however, that the British Standard design is based on a mean ambient temperature of 35 deg. C., and that in general the peak loads occur in winter and are of relatively short duration, it is clear that the margin of load transfer security can be reduced at points of supply and that transformer reinforcements can be postponed if full advantage is taken of the thermal capacity. General calculations, based on an average daily load cycle, indicate that it should be safe in emergency to operate transformers in conditions where the peak demand exceeds the rated capacity by some 30 per cent. The adoption of such a basis of operation, however, presupposes that steps are taken to improve greatly the reliability of the winding-temperature devices. In this connection, a further improvement would be the provision of a winding-temperature dial on the control panel where the attendant can see it. Normally, the scale and contacts of the thermometer are mounted in a kiosk alongside the transformer, and operation through a capillary tube is satisfactory up to distances of 200 ft. For greater distances some other method of measuring temperature is necessary. The thermocouple has too low an output for satisfactory operation on transformers. One method successfully uses a platinum resistor mounted in the oil pocket and heated by winding current with an auxiliary supply connected so that the current through the thermometer resistor and the current through a fixed resistor are compared in a crossed-coil instrument.

The British 132-kV grid system, which has been operated successfully as a fully interconnected system since 1939, has become more and more dependent on centralised measurement of supply quantities as operating technique has improved. There are now eight Area control rooms, each responsible for the detailed operation of the system in its own part of the country, and one National control room responsible for co-ordination of the area controls and inter-area transfers. The equipment is, however, becoming impossible to maintain and highly expensive to extend. It has therefore been decided to replace all the old control-room equipment during the next five to eight years on the following lines: the "sent-out" active power and reactive power of each generating station of over 20-MW capacity will be transmitted to and indicated on a "loading desk" at the control room for that area. The initiating meters will be of the rotating type provided for tariff purposes. These will impulse to the usual summator, which in turn will transmit impulses to Area Control over a Post Office line. At the control room, the incoming impulses will be converted to direct-current to energise a milliameter, which will act as the generated-load indicator for the corresponding generating station. Summation of the direct-currents will give total area generation for transmission to National Control. On the loading desk also, there will be indication of the net inter-control area transfers of active and of reactive power. Associated with each generating station and inter-area meter will be an instruction device, so that area control will be able to see immediately what was the last instruction given, what is the present response, and, by means of an additional hand-set pointer, the available generating plant. On a loading wall-diagram, feeder flow will be displayed in terms of "MW" and "MVAr" on the more important lines or transformer feeders from the large generating stations.

The initiating devices for all these indications will be rotating meters—tariff-type meters for generation, and single-phase meters with three-point commutator contacts for feeder flow. The feeder-flow meters will rotate in either direction according to the direction of load transfer, the three-point contact arrangement permitting "import" or "export" to be determined from one meter. Frequency indication will be given from not more than five points in the control area. The initiating device will be a newly developed rotating frequency meter with a straight-line impulsing characteristic starting with zero impulses at 45 cycles. The error will be within $\pm$ 0·1 cycle under mains supply conditions varying between 44 and 52 cycles and between 180 and 260 volts. Standard time, frequency time, rate of frequency change and time-error indications will be provided in each control room. Except for the standard-time indicator, these will be energised from a local mains supply with a back-up supply locally generated, but controlled by system frequency signalled over a private wire from a suitable grid station.

It is most important to have such records as will permit day-to-day conditions and any emergency conditions to be analysed, and for these purposes a continuous record has definite advantages over logged readings. The following quantities will therefore be recorded: any one of not more than five system voltage telemeter indications; any one of the frequency telemeter indications; system frequency; rate of frequency change; time error; MW net inter-area transfer; MVAr net inter-area transfer; MW total generation; and MW total load for the Area, if practicable.

Two designs of pen-type recorder are favoured—one with the chart driven by a seven-day hand-wound spring and balance-wheel escapement, and the other driven by a synchronous motor connected to the mains. The first has the advantage that it is independent of mains time-keeping or mains failure. The charts of both types are small and not always linear, and the time ordinate may be radiused to suit the instrument movement. A more accurate type of instrument is the wide-scale slide-wire potentiometer-type recorder. This has a 10-in. scale with straight-line ordinates and has been found satisfactory down to 10 or 20 millivolts for full-scale deflection. The instrument is very suitable for the direct summation of a number of total-generation telemeters, but it is expensive and heavy and is dependent on the mains for operation and time-keeping. Recording instruments should be suitable for the removal of the previous day's record, and a well-designed tear-off bar is a desirable detail.

Secure operation of the supply system is dependent in the first place on good design and construction, but insulating materials may deteriorate, corrosion may affect conductors and contact surfaces, and apparatus may be misapplied and misusesd. Quite apart, therefore, from the possibility of accidental or deliberate damage to equipment, the risk of breakdown is always present, and early detection of any tendency towards failure is a real contribution to reliable supply. Devices for testing the condition of insulating materials and bushings and for detecting high-resistance line conductors and joints have received much attention, particularly with a view to obtaining ease of handling by "non-research" engineering staff, and in the result have been highly successful. The analysis of conditions consequent on a system fault requires a thorough consideration of the load- and fault-current distribution, the significance of relay indications, and the value of the reports of witnesses. The Masson "perturbograph" has provided an excellent basis for examining the 50-cycle conditions prior to and during a fault, but even with fourteen of these instruments distributed throughout the country the individual records will often be so localised as to have a restricted analytical value. Accurate fault location can save appreciable line inspection time, and can thereby speed up repairs and restoration to service. The method of location by reflected-pulse technique has been successfully demonstrated both here and on the Continent, and an extended trial is to be made by the South Western Electricity Board. For the 132-kV system very satisfactory results have been obtained for many years by measuring the transformer neutral currents over a short fixed interval, and calculating the fault position by reference to the zero-phase-sequence impedances of the system involved.

The many measurements involved in preparing for the design of equipment, in obtaining efficient operation and in checking reliability, all combine to form the basis from which springs the plan for the future. Knowledge of the factors affecting one voltage level give some confidence for a venture to the next level. Information on the transmission of to-day's loads is used to justify proposals for dealing with those of to-morrow. The final test will be in the building and operating of the new system, but considerable guidance can be obtained from the model system—the network analyser. The direct-current analyser permits a first-approximation analysis of load flows and short-circuit conditions. The alternating-current analyser carries the precision one stage farther and allows a step-by-step examination of system operation and stability. More recently, the *micro-réseau* of Électricité de France has provided a scale model of a machine system, both mechanically and electrically, which demonstrates realistically the effects of load variation and fault conditions.

Conference on Organisation of Research.—The Department of Scientific and Industrial Research announce that an international symposium on the organisation of scientific and industrial research is to be held in London from November 12 to November 15, 1951. The sessions will be held in the Council Room at Lancaster House, London, S.W.1, except for Session III, on "Sponsored Research," which will be at the National Physical Laboratory, Teddington. Representatives from Canada and the United States and from 11 European countries will attend.

AIRCRAFT STRUCTURAL PROBLEMS

Fig. 1. SANDWICH SKIN.

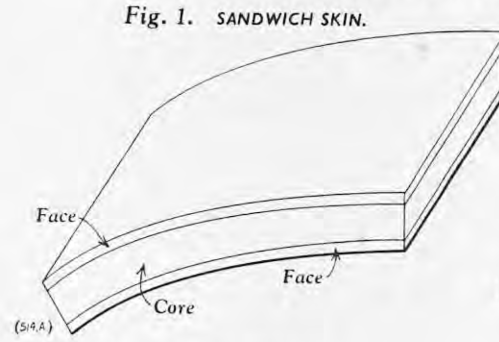


Fig. 2. HONEYCOMB SANDWICH CONSTRUCTION.

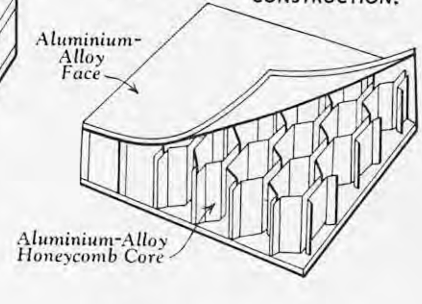


Fig. 3. INTEGRAL STIFFENER CONSTRUCTION.

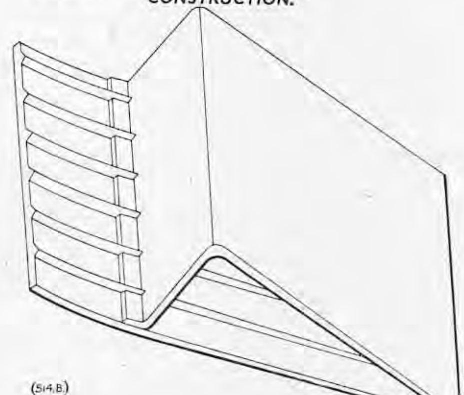
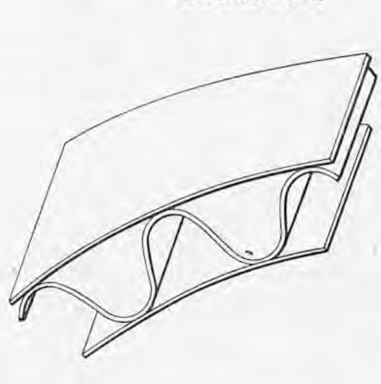


Fig. 4. CORRUGATED SHEET CONSTRUCTION.



STRUCTURAL PROBLEMS OF FUTURE AIRCRAFT.*

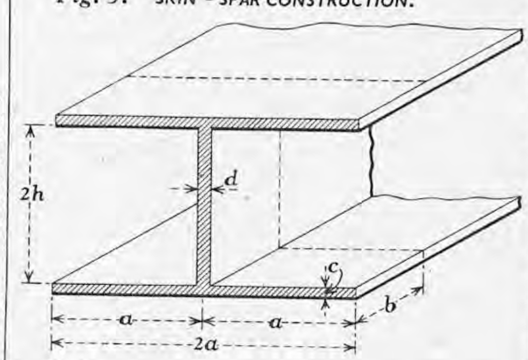
By N. J. Hoff, F.R.Ae.S., A.F.I.Ae.S.

As flying speeds have increased, structural designers have had to face difficulties. The introduction of the laminar flow wing requires unusual accuracies in the manufacture of the wing. Any deviation from the prescribed contour due to elastic deformations during the manufacturing process, wrinkling of the skin under loads, or dimples around rivet heads, is likely to cause turbulence, with a substantial increase in the drag. Manufacturing companies have installed heavy erecting jigs to avoid elastic deformations and have adopted hand-milling tools to shave off carefully all excess material in countersunk rivet heads. The second difficulty has been experienced with the control surfaces. Control-force reversals, jamming, and vibrations have been attributed to small changes in the external shape under aerodynamic loads and to the insufficient torsional rigidity of the structure. Thirdly, there has been a steady trend of increasing loads and decreasing wing thicknesses. The effect is an increased weight of structural material necessary to support the loads, and an increasing flexibility of the structure. The flexible wings cannot be analysed as rigid bodies because of the strong inter-action between aerodynamic, elastic, and inertia forces.

The principal structural difference between subsonic and supersonic wings is the vastly increased importance of a small wing thickness in the latter type. In the subsonic region the drag of the aerofoil increases slowly with thickness. In the supersonic field, the minimum drag coefficient corresponding to zero incidence increases with the square of the wing thickness. Consequently, in supersonic flight, the minimum drag of a 12-per cent. wing is four times that of a 6-per cent. wing. In contrast, in the subsonic region the increase is only 14·5 per cent. when the 6-per cent. wing is replaced by the 12-per cent wing.

A wing of the thin-walled monocoque type consists of a thin sheet of aluminium alloy shaped to form the correct contour and reinforced internally by longitudinal and transverse stiffening elements known as stringers and ribs, respectively. Since the sheet used to be only 0·02 in. to 0·032 in. thick, it buckled and became slightly wavy under ordinary conditions of flight. The waves were fully elastic and they disappeared when the aeroplane landed. The consequent unevenness of the wing surface was not objectionable so long as the flying speed was less than 300 to 400 miles per hour. In the transonic region, buckling of the wing skin cannot be tolerated. Moreover, several manufacturers have found it impossible to construct

Fig. 5. SKIN - SPAR CONSTRUCTION.



thin-walled monocoque laminar-flow wings with the required small tolerances. The skin and the stiffeners are so flexible that the shape of the wing alters when it is removed from the erection jig. Finally, the decreasing wing thickness has resulted in increased loads in the upper and lower reinforced skin surfaces, because the couple of these forces must remain unchanged for reasons of equilibrium. Ordinary thin-walled monocoque panels can carry efficiently loads up to about 2,000 lb. per inch of the width. When this loading is exceeded, other types of panel construction are preferable.

The first new type of skin introduced in aircraft construction was the sandwich skin, consisting of two thin but strong external layers between which is sandwiched a thick, ultra-light-weight and weak middle layer known as the core (Fig. 1). This construction was first adopted in the mass production of aircraft by the de Havilland Aircraft Company, Limited. In the United States it has been used extensively for the main structural elements of aeroplanes built by the Chance-Vought Company. Whereas in the de Havilland Mosquito aircraft the material of the sandwich was spruce plywood and balsa, in the Chance-Vought "Metalite" the faces are 0·01 in. to 0·024 in. aluminium-alloy sheets and the core is balsa wood with its grain arranged perpendicular to the faces. Experimental fuselages and wings built by the Air Materiel Command at Wright Field had Fiberglas textile faces and cellular cellulose-acetate core. Fiberglas cloth, woven from a yarn spun of extremely thin glass fibres and afterwards impregnated with a synthetic resin, has good mechanical properties and weighs about 86 lb. per cubic foot. Cellular cellulose acetate, an expanded resin, is very weak but weighs only from 4 to 10 lb. per cubic foot. The Glenn L. Martin Company has successfully developed a honeycomb-type core in resin, is very weak but weighs only from 4 lb. to 10 lb. aluminium-alloy foil 0·002 in. to 0·004 in. thick (Fig. 2). The company are now using the honeycomb sandwich for wing ribs, ailerons, flooring, bulkheads and elevators. Synthetic glues have been developed for reliably bonding any of these faces to the cores. Considerable design, production, and service experience has been accumulated, but more development work must be done before the potentialities of sandwich construction can be fully realised.

One method of reducing wrinkling and increasing the load carried per inch run is to use sheet of heavier gauge for the skin and to reinforce it with more closely spaced stiffeners. The Bristol Aeroplane Company, in investigations for the design of the Brabazon trans-Atlantic transport aeroplane, found that this system worked very efficiently at loadings of 8,000 to 14,000 lb. per inch. The National Advisory Committee for Aeronautics found that, with sheet thicknesses of the order of $\frac{1}{8}$ in., the most efficient stringers were thinner than the skin and were closely spaced. Another solution of the skin problem proposes the rolling of integral stiffeners into the sheet (Fig. 3). This procedure, of which little is yet known, eliminates the majority of the rivets which tend to disrupt the smooth air flow. Instead of the continuous sandwich core, a corrugated aluminium-alloy sheet can be chosen to connect two flat sheets to form a rigid sandwich-like skin (Fig. 4). This skin can carry loads of 15,000 to 35,000 lb. per inch.

When the wing is very thin and the bending moment it carries is large, the only structural solution is the use of a thick skin. Considerations of weight economy lead then to tapered skins. The Bell XS-1 experimental supersonic aeroplane has a skin tapering from $\frac{1}{2}$ in. at the wing root to $\frac{1}{8}$ in. at the wing tip. Knowledge of the buckling loads of variable-thickness panels of arbitrary plan form is still limited. The next step is to build solid wings; this has been done for some guided-missiles. The calculation of the stress distribution in solid wings of variable thickness and arbitrary plan form is another problem awaiting a rigorous solution.

It has been found that the heavy skins, as well as the sandwich or corrugated-sheet panels, are rigid enough to maintain the wing shape, with ribs only at positions where concentrated loads are introduced into the wing structure. The buckling loads of the skin panels are increased if the panel width, measured in the chordwise direction, is reduced. For this reason many modern wings have several shear webs and a reduced number of ribs. The opposite is true of the Saunders-Roe S.R.A.1 jet-fighter flying-boat, which has a single wing spar, no additional shear webs, and heavy ribs spaced only 6 in. apart.

In highly swept-back and delta wings, bending and torsion are intermixed; a low aspect-ratio supersonic wing is a plate-type structure rather than a beam. For its analysis new methods must be developed and checked against experimental results. The biplane arrangement should be suitable for supersonic aeroplane design. The structural rigidity inherent in the biplane permits a drastic reduction in the wing thickness. Part of the interference drag which made biplanes objectionable in the subsonic range, would be absent in supersonic applications because of the concept of the "zone of silence."

No really new structural problems seem to arise in connection with the fuselage of the transonic, supersonic, and very large aeroplanes contemplated for the future. The maximum load per inch of the fuselage circumference has stayed within the limits of 1,000 lb. and 4,000 lb. per inch. The best solution of the fuselage design problem is probably the thin-walled reinforced monocoque when wrinkling of the skin is not considered objectionable, and the sandwich skin when wrinkling must be prevented. The greatest problem in connection with the fuselages of supersonic aeroplanes is the excessive size they must have in order to accommodate the large amounts of fuel for jet or rocket propulsion. A strength problem arises in connection with the strength and stability of the walls of ducts and tanks subjected to extreme external or internal pressures, as well as to excessive temperature gradients.

Even the best riveting technique has been found lacking from the standpoint of surface smoothness. Moreover, it is difficult to maintain the exact contour wherever heavy internal stiffening elements are riveted to the skin. The problem of riveting does not exist in sandwich construction where faces and core are cemented together by synthetic adhesive. Another design in which rivets are not needed was introduced by the de Havilland Aircraft Company, who are gluing aluminium-alloy stiffeners to the aluminium-alloy skin. Redux, the bonding agent used, was developed by Aero Research Limited, Duxford, Cambridgeshire. Spot welding also has the advantages of better surface smoothness and lower cost than riveting. The industry, however, is reluctant to accept spot-welded structures because of the difficulties of checking the reliability of the joint.

The importance of thermal effects in aircraft has changed materially in the past four or five years. Jet engines mounted completely inside a fuselage

* Paper presented at the Third Anglo-American Aeronautical Conference at Brighton on September 4, 1951. Abridged.

AIRCRAFT STRUCTURAL PROBLEMS.

Fig. 6. TEMPERATURE OF SPAR CAP.

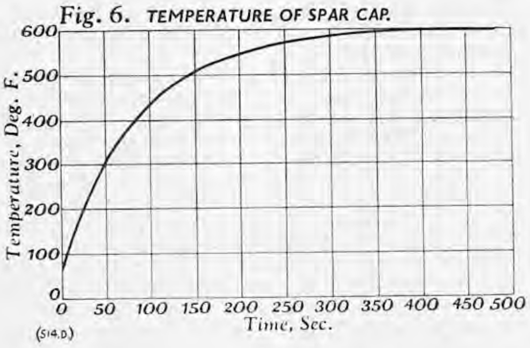
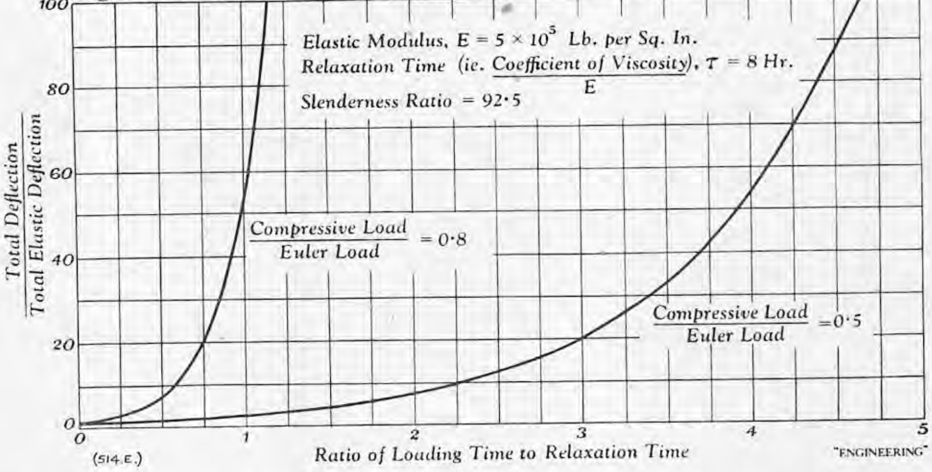


Fig. 7. BEHAVIOUR OF VISCO-ELASTIC COLUMN.



may heat adjacent aluminium-alloy structural elements sufficiently to decrease their load-carrying capacity. Another effect which is now causing fundamental changes in design is the aerodynamic heating. The boundary layer round a wing travelling at a supersonic speed is heated to an elevated temperature.

At a height of 50,000 ft. the steady-state temperature of the aeroplane is computed as 240 deg. F., 630 deg. F., and 1,180 deg. F., at Mach numbers of 2, 3, and 4, respectively. At sea level, the steady-state temperatures are 470 deg. F., 980 deg. F., and 1,700 deg. F., at the same three Mach numbers. There are few experimental or theoretical data on the heating effect at extreme heights where radiation is an important factor, and the laws of the aerodynamics of *continua* do not hold. By the methods of the kinetic theory of gases, steady-state skin temperatures have been calculated for heights up to 150 miles. At a speed of 20,000 ft. per second and at a height of 75 miles the temperature was estimated to be of the order of 1,000 deg. F. Above 150 miles, steady-state skin temperatures do not seem to be very critical for speeds foreseen for missiles, although meteorites are known to burn up after entering the atmosphere of the earth at much higher speeds. High temperatures, however, will be reached by high-altitude missiles during their travel through the lower atmosphere. Steady-state skin temperatures of 2,000 to 4,000 deg. F. have also been predicted in the not too distant future.

The strength of aluminium alloy 24S-T, which is 68,000 lb. per square inch at 75 deg. F., decreases to 10,000 lb. at 700 deg. F., whereas a medium carbon steel which has a strength of 75,000 lb. per square inch at 75 deg. F., shows a strength of 42,000 at 900 deg. F. The use of metals having very high melting points offers one possibility of obtaining materials of construction suitable for supersonic flight. Tungsten has the highest melting point of any metal, a little over 6,000 deg. F.; its specific gravity is high (19·1). Another possibility is K-Monel, which consists of two-thirds nickel and one-third copper, with a specific gravity of 8·47. It is manufactured by the International Nickel Company. Its tensile strength is 160,000 lb. per square inch at a temperature of 75 deg. F., falling to 95,000 lb. per square inch at 1,000 deg. F., and 21,000 lb. per square inch at 1,600 deg. F. The development of titanium and its alloys for structural purposes promises a solution of the problem for some time to come. Titanium has a higher melting point (3,270 deg. F.) than iron, nickel, and cobalt, from which present commercial heat-resisting alloys are made. Its ore reserves on the North American continent are very large. Moreover, it has a low specific gravity, 4·5. This places it between iron (7·8) and aluminium (2·8).

At room temperature, unalloyed titanium has a strength of about 85,000 lb. per square inch and an elastic modulus of 15×10^6 lb. per square inch. This compares favourably with stainless steel (85,000 and 29×10^6) and aluminium alloy (82,000 and $10 \cdot 3 \times 10^6$). Titanium alloyed with manganese, manganese-aluminium, iron-chromium, or chromium-aluminium has strength values ranging from 150,000 lb. per square inch to 200,000 lb. per square inch. In the limited number of tests performed, the fatigue strength was found to be good; the endurance limit was over 50 per cent. of the ultimate tensile strength. Titanium appears to have as good creep properties at 1,000 deg. F. as the best aluminium alloy at 600 deg. F. Many problems of production, alloying, shaping, welding, and design must yet be solved before titanium alloys can be used on a production scale for the structural elements of aircraft.

A development programme has been going on for some time at the National Bureau of Standards in Washington, D.C., to produce ceramics for the linings of rocket engines and for buckets of gas turbines. The best properties were obtained, at 1,800 deg. F., with oxides of beryllium and of zirconium with slight additions of other oxides. The bulk density of the former is 3, that of the latter 4·9. The modulus of rupture in bending and the modulus of elasticity in bending were in the neighbourhood of 15,000 lb. per square inch and 25×10^6 lb. per square inch, respectively, with the former and 25,000 lb. per square inch and 20×10^6 lb. per square inch, respectively, with the latter. The ceramics are stronger for a given weight at such extreme temperatures than any metals now available, but they are very brittle and cannot be used structurally at present. When applied in thin layers as a coating, they may have important applications in jet engines and on the surface of wings as a protection from oxidation.

Stainless steel and K-Monel, although heavy, are satisfactory materials for aeroplanes flying at supersonic speeds when the skin is subjected to high loads per inch width. For more lightly-loaded elements the sandwich skin should become attractive if suitable heat-resisting materials could be made available for its construction. The faces can be made of stainless steel, K-Monel, or possibly of Fiberglas textile. The difficulty lies in the core and in the bonding agent. A silicone rubber developed for use as a gasket in engines is manufactured by the Plastic Division of the Chemical Department of the General Electric Corporation, Pittsfield, Massachusetts. It has a specific gravity of 1·422 and stands continuous exposure to 325 deg. F. and short-time exposure to 520 deg. F. It is likely that it could be developed as a foamed core for sandwich construction having satisfactory strength properties at high temperatures. A silicate glue is now manufactured by the Union Carbon and Carbide Corporation which might serve as a highly-heat-resistant bonding agent for sandwich construction.

From consideration of the heat-conduction equation, it appeared likely that thin-walled aeroplane structures do not rapidly attain a uniform temperature when travelling at a constant speed and at a constant height. The temperatures in a somewhat idealised aeroplane wing spar were therefore investigated. It was assumed that a rocket-propelled parasite aeroplane was launched from a "mother aircraft" at a height of 50,000 ft. The speed of the aeroplane was assumed to correspond to a Mach number of 3·1 during the entire flight. The elimination of the period of acceleration simplified the calculations without impairing the significance of the results obtained. The wing construction chosen for the example incorporated a heavy wing skin, a number of shear webs, and comparatively light spar flanges. It was reasonable to assume, therefore, that the skin and flange temperatures were equal. The simplified structure, representing a shear web and adjacent portions of the cover-plate, is shown in Fig. 5. The variation of the flange temperature with time after launching was calculated and is plotted in Fig. 6. It takes about 6 minutes for the flange to approach closely the boundary-layer temperature of 600 deg F., which was assumed to be somewhat smaller than the stagnation temperature corresponding to a Mach number of 3·1. Large variations in temperature exist in aeroplane structures even after several minutes of uniform supersonic flight. The middle of the shear web was found to have a temperature of 260 deg. F. after 400 sec. when the border of the web attached to the flange had already attained practically the boundary layer temperature of 600 deg. F.

In the foregoing calculations it was assumed that heat was transferred from the cover-plates to the web by conduction only. In reality, the hot cover-plates heat up the air inside the wing and the hot air in turn transmits heat to the webs. Unfortunately the great wealth of empirical data on convection was obtained almost exclusively on individual flat plates and tubes, and no information is available on convective heat transfer inside a box such as the space enclosed by the cover-plates and the shear webs of a wing. A rough approximate calculation indicated that the rate at which the web is heated by convection should be of the same order of magnitude as that obtained for conduction. A rough check of the heat transfer by radiation in the wing of the numerical example proved it to be insignificant.

In an actual wing, conduction, convection and radiation take place simultaneously and the problem of calculating the temperature distribution is further complicated by internal installations obstructing air flow and radiation inside the wing, as well as by joints between structural elements offering additional resistance to heat flow by conduction. Much more theoretical and experimental work is required, therefore, before the temperatures in a supersonic wing can be calculated with engineering accuracy.

Because of the non-uniform expansion due to non-uniform temperatures, thermal stresses are set up in the web of the wing spar. The stresses are also influenced by the spar flanges, where the temperature must be sensibly equal to that prevailing in the edges of the web to which they are attached. The thermal stress problem of the spar web can be separated into two parts, the determination of the stress distribution in sections of the web far from the two ends of the spar, and the local disturbances arising at the end points of the actual spar of finite length. The first part of the problem was solved rigorously by means of the theory of plane stress. It was found that very high stresses develop after only 50 seconds of flight when the maximum temperature in the web is only 300 deg. F. At first the stresses increase with time. They reach their maximum values after about 200 seconds. When the flight is continued farther, the stresses decrease because the maximum temperature in the web remains approximately constant and the temperature over the web becomes more and more uniform. After an extended period of time the entire wing structure must attain practically the same constant temperature. When this steady-state condition is reached, there cannot be any thermal stresses in the structure.

It is of interest to observe the influence of the ratio of flange cross-section to web cross-section upon the stress distribution. When the flanges are absent, the ratio is zero. In this case, large compressive stresses develop in the edges of the web, while the middle portions are subjected to tension. As the ratio increases, the tension also increases and the compression in the edges diminishes. This is because the compressive force required for equilibrium is furnished to an increasing degree by the flanges. When the ratio becomes infinite, i.e., the flange cross-section becomes very large compared with the web cross-section, the entire web is in tension. According to the results, the maximum thermal stress is 44,100 lb. per square inch after 50 seconds, 80,200 lb. per square inch after 200 seconds, and 61,800 lb. per square inch after 400 seconds. At these values of stress and temperature, structural steel no longer behaves as the perfectly elastic material it was assumed to be in the calculations. It can be concluded that the thermal stresses arising in a steel spar of a wing flying at a Mach number of 3·1 at a height of 50,000 ft. are most likely to exceed the elastic limit and even the yield point, of the material after two or three minutes of flight.

Without further calculations, the same conclusion can be drawn regarding the stresses arising at the ends of the actual finite wing. It is known from the theory of elasticity that the stress developing at the corner of a finite heated plate attached to an unheated rigid wall is infinitely large, i.e., some yielding is bound to take place. The region in which the material becomes plastic is limited in this case, whereas in the problem discussed earlier the plastic region extends throughout the entire length of the plate. For this reason the stress concentration at the corner point of the plate represents a lesser danger to the safety of the structure than the large thermal stress inside the web. The theoretical infinitely large value is naturally reduced when the perfectly rigid wall is replaced by an elastic flange.

In supersonic aircraft, the range of stress in which the inelastic deformations are negligible is reduced to such an extent at high temperatures that permanent deformations will have to be tolerated under the working stresses. This will involve a revision of the concepts of safety. At high temperatures the instantaneous elastic, or possibly plastic, deformations caused by the application of a load are likely to be followed by slowly increasing additional deformations. These deformations, representing the effect of creep, have been studied in the past 30 years in connection with the design of gas and steam turbine blades, and the rate of creep was generally listed in units of 1 per cent. reached in 10,000 hours. It is unavoidable that much higher rates of creep will be tolerated in structural elements of supersonic aircraft and for this reason the study of creep phenomena will have to be extended. One interesting effect of creep can be observed in the behaviour of viscous columns. Since every real column deviates from perfect straightness, the initial deflections are magnified under the action of a constant end load until the column fails, even though the end load is smaller than the Euler load. Fig. 7 shows the deflections, plotted against time, of the mid-point of a column of linearly viscous material such as certain high polymers. After about six or eight hours the column becomes crooked when loaded with eight-tenths of its Euler load, even though at the outset its maximum deviation from straightness was only one-hundredth of the radius of gyration of its cross section. Metals behave in a much more complex manner and are likely to buckle suddenly rather than in the gradual fashion indicated by the curve. It will be necessary to study creep buckling in detail in order to safeguard the integrity of columns at high temperatures.

It has long been recognised that defining the safety of a structure by a safety factor based on rather arbitrarily specified maximum loads and on minimum strength requirements for the materials of construction has not much physical significance. The rationalisation of the safety concept becomes unavoidable for supersonic aircraft when safety against creep must be compared with safety against exceeding an elastic or plastic stress limit. Official civil-engineering circles of France are now making a determined effort to introduce probability calculations in the evaluation of the safety of civil-engineering structures. They want to establish probability curves for the stresses induced in structures by dead and live loads. At the same time the strength of the structural materials will also be expressed by curves of probability. On the basis of this information the probability of the actual stress exceeding the strength of the structure can be calculated rationally. An interesting feature of this approach is that the probability of failure cannot be zero but it should be a very small number. What actual value should be considered satisfactory might be determined from an analysis of structures that have done satisfactory service. In the evaluation of the stresses caused by the loads in the structures, stress concentrations due to holes, sharp edges, etc., can be taken into account just as well as reductions in the stress values because of plastic deformations.

It is suggested that future aircraft be classified, from the standpoint of safety, in three categories—non-expendable, semi-expendable, and expendable. All aeroplanes flying at present are non-expendable, and should remain safe to fly for many years. They are generally replaced by new aeroplanes when progress renders them obsolete, and not when their lifetime is exhausted because of attrition, or mechanical or structural failure. The other extreme is represented by a guided missile which is used for only a single flight of short duration. Its structure need only be strong enough to withstand the loading incurred in one flight.

Although the distinction between expendable and not-expendable structures is not very important in slow subsonic flight, it attains great importance at Mach numbers above 2·0, because of the effect of aerodynamic heating upon the behaviour of metals. When the structure is heated to high temperatures, inelastic permanent deformations take place which increase in magnitude with time and eventually lead to failure. Obviously it would be senseless to make use of special materials and excessive wall thicknesses in order to ensure a life of 1,000 hours for a guided missile, when the warhead will explode after 30 minutes of flight.

The phenomenon of creep, which becomes increasingly noticeable as the structure is heated, necessitates the introduction of the semi-expendable class for piloted aeroplanes. It will not be possible to design aeroplanes to fly efficiently for an indefinitely long period of time at Mach numbers of 3 or 4. Inelastic deformations are bound to take place and a thorough understanding of the phenomena will be needed in determining just how long a particular aeroplane will remain safe. When a consistent theory corroborated by experiment is available, the crew and the passengers will trust the supersonic semi-expendable aeroplane just as much as the non-expendable subsonic aeroplane. Even to-day's transports might be classified as semi-expendable: consideration of fatigue implies the estimation of the life of the aeroplane, and such a process is characteristic of the design of aeroplanes belonging to the semi-expendable class. Nevertheless, there is a great deal of difference between designing a subsonic transport aircraft for a life of, say, 10,000 hours of flight with due consideration of fatigue, and ascertaining that yielding and creep will not cause failure in a supersonic fighter in perhaps 100 hours of service.

NOTES ON NEW BOOKS.

Thermodynamics.

By Professor George A. Hawkins. Second edition. John Wiley and Sons, Incorporated, 440, Fourth-avenue, New York, 16. U.S.A. [Price 6·50 dols.); and Chapman and Hall, Limited, 37, Essex-street, London, W.C.2. [Price 52*s*. net.]

In spite of the generality of its title, the contents of this book are confined almost exclusively to those parts of thermodynamical theory that students of engineering are expected to acquire. Within this field the author, who is professor of thermodynamics at Purdue University, has covered much the same ground as other exponents of the same subject, proceeding from the elementary concepts to the working cycles of heat engines, refrigerating machinery and gas turbines, and including also chapters on combustion and heat transference. The treatment is essentially theoretical, no kind of apparatus being illustrated except in a purely diagrammatic form, and perfect reversibility generally being postulated for all processes, including even polytropic compression and expansion. The ordinary British units of weight and measure are used throughout, for, though the reader is told that the unit of mass is called a "slug," this name is happily disregarded as completely in the text as it is everywhere else outside the walls of a few class-rooms. In accordance with modern American practice, the single letter "B" is used to symbolise British Thermal Units. Another novelty for English readers is the description of a constant-volume process as "isovolumic"; an adjective which has perhaps the advantage of being immediately self-explanatory to the average student, though it may offend the pedant.

Electricity in Transport.

By H. H. Andrews, M.I.Loco.E. The English Electric Company Limited, Queen's House, Kingsway, London, W.C.2. [Price 12*s*. 6*d*. net.]

The title of this book is wider than its contents altogether justify; nevertheless, it is worthy of study, since it gives an account of the achievements of the English Electric group in transport engineering during the past 67 years. It may be recalled that the English Electric Company was formed in 1918 by acquiring control of Dick, Kerr and Company, Limited, Preston; Willans and Robinson, Limited, Rugby; and the Phoenix Dynamo Manufacturing Company, Limited, Bradford. They also purchased the Stafford works of Siemens Brothers' Dynamo Works, Limited. At that time, the first and last of these firms had for long been engaged in traction work, the latter having equipped the first electric railway in the British Isles, between Portrush and Bushmills, in 1883, and the former having been responsible for the electrification of many tramway systems, while both were contractors for the rolling stock of the Waterloo and City Railway in 1898. Dick, Kerr and Company subsequently equipped the first main line in Great Britain to be electrified—that between Liverpool and Southport—as well as supplying the first trolley 'bus in 1910 and equipment for the first 3,600-volt direct-current electrification in the world—that between Bury and Holcombe Brook—two years later. Coming to more recent times, the English Electric Company provided the electrical equipment for the rolling stock for the Liverpool Street–Shenfield line, after having supplied numerous motors for the widespread Southern Railway electrification, including those for the locomotives used for hauling freight traffic. Much equipment has also been exported to railways abroad. Further, the company has made a notable contribution in the field of Diesel-electric traction, being responsible for a 500-h.p. four-coach train which was put into service on the London Midland and Scottish Railway in 1928, and five years later for a 300-h.p. Diesel-electric shunting locomotive on the same system. In 1947, they collaborated in the construction of two 1,600-h.p. main-line locomotives which are now doing good service on important expresses. Again, similar equipments have been exported to other countries. The descriptions of all this plant are clear and concise, and the whole book is excellently illustrated. It forms an interesting record of what one of the best-known British firms have done in improving transport by electric railway.

Differential Equations.

By Professor H. B. Phillip, Ph.D., LL.D. Third revised edition. John Wiley and Sons, Incorporated, 440, Fourth-avenue, New York 16, U.S.A. [Price 3 dols.]; and Chapman and Hall, Limited, 37, Essex-street, London, W.C.2. [Price 24*s*. net.]

There are several English works on differential equations which have enjoyed a reputation among British students for many years. This book, by a professor emeritus of the Massachusetts Institute of Technology, is presumably a favourite in the United States, since it is now in its third edition and first appeared as long ago as 1922. The title is somewhat misleading in that a prospective reader or purchaser might reasonably expect to find some account of partial differential equations in the book. Closer scrutiny, however, reveals that only ordinary equations are considered, a restriction which ought to be indicated clearly in the main title. Although the problems involved in the solution of the ordinary equations are generally simpler than those associated with partial differential equations, they often demand considerable ingenuity, as every student of the subject knows; and skill in their solution can only be acquired by thorough practice. The author has aimed at providing the student with opportunities for such practice by including numerous problems for solution and has drawn largely on the familiar fields of mechanics, physics and engineering for the purpose. The text is said to have been carefully revised and a few sections rewritten in this third edition, and the numbers of exercises for solution and of illustrative worked examples have been increased. The standard theory has been set out clearly and concisely, but the book does not appear to contain any textual matter which is novel or not already available to British students in books of a similar character at a lower price.

Construction with Moving Forms.

By L. E. Hunter, M.Sc., A.M.I.C.E., M.I.Struct.E. Concrete Publications Limited, 14, Dartmouth-street, London, S.W.1. [Price 7*s*. 6*d*.]

In this book, one of the "Concrete Series" on concrete and cement, the author describes, from a basis of first-hand experience, the continuous method of constructing silos, bunkers and other tall concrete structures of uniform cross-section in plan, by the use of moving forms which are raised as pouring proceeds. The method has its inherent limitations, one of the chief of which is the prior requirement that the plan must not vary with height, but within that limited field of applicability it has great advantages, which the author brings out very clearly. In a given time, he states, four times as much height of wall can be concreted with moving forms as with fixed shuttering; but he also quotes details of the labour required to construct a batch of 70 square bins of 15 ft. side—224 men with moving forms, as against 59 men with fixed shutters. The method requires, moreover, that the work should continue day and night without interruption, even for meals, of more than a few minutes; but, even so, it shows considerable economic benefit in suitable circumstances. The author shows clearly how these are to be evaluated, and illustrates his points with many examples drawn from his personal experience. This is a thoroughly practical book, and the inclusion of a chapter on the cognate subject of horizontally-travelling shutters for quay walls, etc., considerably extends its usefulness.

Transatlantic Paddle Steamers.

By H. Philip Spratt, B.Sc., A.S.M.E. Brown, Son and Ferguson, Limited, 52–58, Darnley-street, Glasgow, S.1. [Price 7*s*. 6*d*. net.]

Mr. Spratt is one of the foremost authorities on the early days of steam navigation and has earned that position by a great deal of painstaking research among original records. In this book, he divides what he terms "the paddle era of the Atlantic" into three periods: the "spasmodic pioneers," in which steam propulsion was auxiliary to sail; the period of "sustained steam power," made possible by the invention of the surface condenser; and the period in which the transatlantic paddle steamer reached the peak of its development. As a chronicle of carefully sifted facts, well annotated, and summarised in four excellent folding tables at the end, the book is to be commended; it is, indeed, remarkably good value for its modest price. The illustrations are not numerous, but three of them—those of the Savannah and her machinery, and the Dutch steamer Curaçao of 1825—are likely to be new to most readers. The book would be even better, in our opinion, without its concluding reference to the "clumsy honest old paddles." A factual history is not helped by false sentiment, and there is nothing inherently dishonest about a screw propeller.

Technical Sketching.

By E. F. Waller, A.M.I.E.D., A.M.S.E. Sir Isaac Pitman and Sons, Limited, Parker-street, Kingsway, London, W.C.2. [Price 6s. 6d. net.]

Changing industrial circumstances, and the effect of two world wars, have wrought more fundamental changes in engineering drawing-offices than their present occupants commonly realise. In one particular: they have expelled, almost with ignominy, the last pretensions to artistic finish in drawings. The result has been a certain saving of time; but the draughtsman who could produce a drawing which was also a picture was likewise capable of neat and effective sketches, from which his juniors, too, learned to express their ideas with corresponding neatness and effect. Mr. Waller, in the preface to his book, comments on the fact that the amount of space devoted to sketching in the average text-book on drawing is so scanty; but there was little need for such instruction to be included in text-books when every draughtsman could sketch and most engineering students were given a good grounding in solid geometry. Now, apparently, there is such a need, and Mr. Waller has striven to meet it. His methods, if carefully and conscientiously followed, should produce beneficial results; but we fear that the type of youth who needs the instruction most is hardly the type to absorb it from books.

SPONSORED RESEARCH IN GERMANY.

During 1948 the Department of Scientific and Industrial Research, in consultation with the Foreign Office, placed several contracts for engineering research work to be carried out in Germany. The contracts have now been concluded, and translated reports are available from the Department, Charles House, 5-11, Regent-street, London, S.W.1. In some cases, no final conclusions have been reached, since the work was of short duration. Reports Nos. 1, 2, 3, 4, 5, 6, 11 and 13 were issued earlier this year, and were listed on page 303 of our 171st volume. Thirteen further reports have now been published, as follows:—

No. 7 shows how the rolling strength of gear flanks, plotted against their normal life, increases in proportion to the viscosity of the lubricant used. The effect of viscosity on pitting is also considered.

Nos. 8, 9 and 10 contain the results of a theoretical investigation of the oil pressure between rollers for both constant and pressure-dependent viscosity.

No. 12 describes pulsator tests on gears of mild, heat-treated, and case-hardened steels with different tooth shapes. The effects of differences in pressure angle, radius of tooth root, tooth form, heat treatment, polishing, etc., on the root strength are investigated.

No. 14 presents numerical and graphical results of a computation of the pressure distribution and load in a 180-deg. journal bearing.

Nos. 15 and 16 are a continuation of Nos. 3, 4, 5, and 6, a theoretical investigation of the deformation of loaded gears.

No. 17 describes apparatus for measuring the density and viscosity of oils at pressures up to 2,000 kg. per square centimetre, and a capillary viscometer for use with both liquids and gases under pressure. The results for 50 different oils are given. The refractive index, conduction of heat, and boundary-layer tension are also considered.

No. 18 describes a disc tester with variable slip for investigating fatigue rolling strength under various conditions of lubrication.

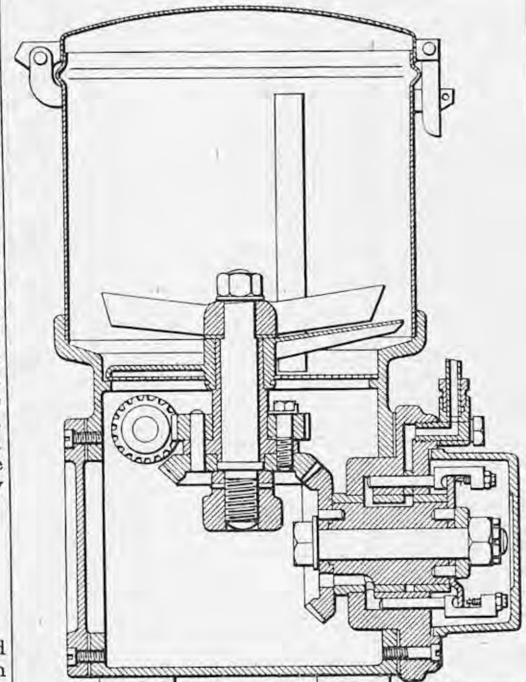
No. 19 presents the results of a short preliminary test to find the order of magnitude of, and factors affecting, the slip between friction wheels of hardened steel.

No. 20 gives the results of experiments to determine rolling strength, using rollers of ball-bearing steel and Nitrodur in linear contact with hardened test pieces.

No. 22 describes a method for determining tooth-profile errors by measuring the tooth deformation under load. Some results are given.

MULTI-POINT GREASE LUBRICATOR.

The drawing reproduced in the accompanying figure shows the construction of one of a range of Staufferlube "Multigreasors" which have been introduced recently by Messrs. Trier Brothers, Limited, Caldew-street, Camberwell, London, S.E.5. The lubricator was demonstrated at the Engineering, Marine and Welding Exhibition in London this year. The special virtue of these grease lubricators, which have up to 24 outlets, is the absence of springs and separate valves. The three principal types of lubricator are the Model FD, which is hand-operated, with a maximum of 16 outlets, and suitable for pressures up to 450 lb. per square inch; the Model FZ, with rotary or ratchet drive, up to 12 outlets, and a maximum pressure of 750 lb. per square inch; and the Models FWA and FWB, which differ in grease capacity, but have up to 24 outlets and are designed for a maximum pressure of



1,500 lb. per square inch. It is one of the latter models, with 12 outlets, that is shown in the drawing; an additional 12 outlets would be provided by fitting another pump unit on the side of the body that is shown blanked off by a cover. These models are suitable for rotary, ratchet or motor drive.

The drive to the pump plungers and the control of the inlets and outlets are combined in the following manner. The plungers are actuated by a swash plate, and the travel of each is adjustable by means of the screw in one end. As will be seen, the swash plate is driven through a worm and worm-wheel and a pair of bevel gears. Grease is admitted to each plunger bore through a hole in the main shaft and bevel gear, as shown in the lower part of the pump unit, admission and cut-off being controlled by the rotation of the shaft in its bearing. The path of the delivered grease is shown in the upper part of the pump unit; it is through a passage in the main shaft and thence to the outlet. The arrangements for propelling the grease through a sieve into the lower part of the unit, and other details of the design, will be clear from the drawing.

International Congress of Industrial Heating.—The fourth International Congress of Industrial Heating and Applied Thermodynamics is to be held at the Conservatoire National des Arts et Métiers, Paris, from September 29 until October 4, 1952, under the auspices of the Comité Consultatif de l'Utilisation de l'Energie, and the patronage of the President of the Republic and other high officials of State. An Exhibition of Industrial Heating is being arranged at the Parc des Expositions de la Ville de Paris, at the Porte de Versailles, from September 27 until October 12, 1952, and further particulars of this may be obtained on application to the Commissaire Général de l'Exposition du Chauffage Industriel, 66, rue de Rome, Paris (8e). A preliminary programme of the Congress, which will cover fuels, control measures, standardisation, steam and its utilisation, internal-combustion engines, high-temperature applications of heat, and other subjects, is available, and copies of this and of applications to take part in the Congress may be obtained from the secretariat, 2, rue des Tanneries, Paris (13e). The general secretary of the Congress is Mr. Henry Cassan, directeur-général of our contemporary *Chaleur et Industrie.*

BOOKS RECEIVED.

Garcke's Manual of Electricity Supply. 1950-51. Compiled under the supervision of Frederick C. Garrett. Electrical Press, Limited, 23, Great Queen-street, London, W.C.2. [Price 70s. net.]

The African Press and Advertising Annual. 1951. Edited by Chas. R. Pask and Baron V. M. Frederickesz. The African Press and Advertising Annual, 604, Boston House, Strand-street, Cape Town, South Africa; and the African and Colonial Press Agency, Limited, 8, Red Lion-square, London, W.C.1. [Price 20s. post free.]

Sell's National Directory and British Exporters' Register. Aviation Supplement. 1951. Business Dictionaries, Limited, St. Dunstan's House, 133-137, Fetter-lane, London, E.C.4. [Price 10s.]

University of London. University College Calendar. 1951-52. University College London, Gower-street, London, W.C.1. [Price 8s. 6d.]

Elektrische Maschinen. By Professor Rudolf Richter. Volume I. *Allgemeine Berechnungselemente. Die Gleichstrommaschinen.* Second revised edition. Verlag Birkhäuser, Basle, Switzerland. [Price 49·40 Swiss francs bound, 45·25 Swiss francs in paper covers.]

Chill-Cast Tin Bronzes. By Professor D. Hanson and Dr. W. T. Pell-Walpole. Edward Arnold and Company, 41, Maddox-street, London, W.1. [Price 75s. net.]

Unesco. International Conference on Science Abstracting, convened by the United Nations Educational, Scientific and Cultural Organization, in Paris, from 20 to 25 June, 1949. Final Report. [Price 12s. 3d. net.] *Report on Interlingual Scientific and Technical Dictionaries.* By Dr. J. E. Holmstrom. [Price 1s. 6d. net.] *Bibliography of Interlingual Scientific and Technical Dictionaries.* By Dr. J. E. Holmstrom. [Price 4s. net.] H.M. Stationery Office, Kingsway, London, W.C.2.

Theory of Elasticity. By Professors S. Timoshenko and J. N. Goodier. Second edition. McGraw-Hill Book Company, Incorporated, 330, West 42nd-street, New York 18, U.S.A. [Price 9·50 dols.]; and McGraw-Hill Publishing Company, Limited, Aldwych House, Aldwych, London, W.C.2. [Price 81s.]

Industrial Piping. By Charles T. Littleton. McGraw-Hill Book Company, Incorporated, 330, West 42nd-street, New York 18, U.S.A. [Price 8 dols.]; and McGraw-Hill Publishing Company, Limited, Aldwych House, Aldwych, London, W.C.2. [Price 68s.]

Aircraft Engines of the World, 1951. By Paul H. Wilkinson. Sir Isaac Pitman and Sons, Limited, Pitman House, Parker-street, Kingsway, London, W.C.2. [Price 50s. net.]

Traffic Control and Road Accident Prevention. By Captain Athelstan Popkess. Chapman and Hall, Limited, 37, Essex-street, Strand, London, W.C.2. [Price 37s. 6d. net.]

Patents, Designs and Trade Marks. With Supplement Containing the Changes of Patent and Design Registration Law under the 1949 Acts. By Charles S. Parsons. The Technical Press, Limited, Gloucester-road, Kingston Hill, Surrey. [Price 14s. net.]

Machinery's Yellow Back Series. No. 2A. *Air-Operated Production Aids.* No. 27. *Compound Change Gear and Indexing Problems.* By H. W. Hardy. The Machinery Publishing Company, Limited, National House, West-street, Brighton I. [Price 3s. 6d. each.]

Vacuum Physics. A Symposium held by the Midland Branch of the Institute of Physics in Birmingham on 27 and 28 June, 1950. Journal of Scientific Instruments Supplement No. 1. The Institute of Physics, 47, Belgrave-square, London, S.W.1. [Price 15s.]

The Autobiography of Robert A. Millikan. Macdonald and Company (Publishers), Limited, 16, Maddox-street, London, W.1. [Price 21s.]

TRADE PUBLICATIONS.

Alternating-Current Vane Relays.—Two-position and three-position alternating-current vane relays, designed for use either on the track or the line, are fully described in a leaflet issued by Metropolitan-Vickers-GRS, Ltd., 135, Long Acre, London, W.C.2.

Brush-Ljungström Turbo-Generators.—Full details, both practical and theoretical, of the Ljungström turbo-generators manufactured by them are given in a well illustrated pamphlet received from the Brush Electrical Engineering Co., Ltd., Loughborough.

Fork Truck with Crane and Shovel Attachments.—Mathew Bros., Sandy Lane North, Wallington, Surrey, have issued details of a crane attachment and a bucket-shovel attachment which they now make for their Matbro fork truck. The crane is in the form of a short jib with a hook attached directly to it; the jib is moved up and down like the fork which it replaces. The bucket-shovel is applied in a similar manner, and is particularly useful for moving fuel from dumps to hoppers.