HYDRAULICS IN AGRICULTURAL ENGINEERING.

By H. J. HAMBLIN, B.A.

THE world-wide acceptance of the use of hydraulics for controlling agricultural implements is not surprising in view of the advantages offered. Hydraulics provide a means of obtaining precise finger-tip control of movements, some of which could scarcely be obtained mechanically, with the further advantage that control is dissociated from forward travel. These are considerable advantages and it is not surprising that hydraulic control has found favour alike with designers and operators because it does, in fact, simplify both the development and the use of agricultural equipment. It is remarkable what progress has been made, however, considering that the development of this entirely new application of hydraulics has taken place over the comparatively short period since the second half of the 1930's. This rapid rate of development has, as might be expected, led to a wide diversity of results and, in attempting to survey the present state of affairs, it is difficult to do more than indicate some of the more interesting results and trends. The alternative, to attempt a classification by groups, is probably more misleading in the long run because it is almost bound to lead to over-simplification in a field where nearly every example is unique.

Probably as good an introduction as any is to describe the working principles of the first system to appear on the British market and of an early American system. The American system, the International Harvester Company's Lift-All, although chronologically the later of the two, will be described first because it was designed to do the more obvious job and therefore makes a better introduction. The primary function of the Lift-All system is to raise the toolbars on Farmall tractors at each end of the field without stopping the tractor and without appreciable effort on the part of the operator. The mid-mounted toolbar is in two parts, lifted by two hydraulic cylinders, one on each side of the tractor, while the rear bar is continuous and lifted by a single cylinder; hydraulic power is delivered to the cylinders from a self-contained unit mounted inside the transmission housing. With this system, movement of a control lever to the "lift" position, where it is held by a catch, closes a by-pass from a gear-pump so that oil is delivered, through non-return valves, to the three cylinder hoses. The rear cylinder hose is closed by a spring-loaded valve attached to the cylinder and, in the first place, only the front cylinders operate, lifting the mid-mounted toolbar. When this has been raised, the pressure rises to about 450 lb. per square inch and oil passes the spring-loaded valve into the rear cylinder. When the rear toolbar has been fully lifted, a further pressure rise to 750-800 lb. per square inch takes place and lifts a ball relief valve, releasing the locking catch and allowing the control lever to be returned by a spring to its neutral position; both toolbars now remain lifted, because of non-return valves in the control unit, and the pump by-pass is opened. The reason for the delayed lift of the rear toolbar is to allow the tractor to travel forward the appropriate distance while the mid-mounted toolbar is being lifted, so that the rear toolbar commences to lift only when it has reached the end of the row. A similar delay on entering a row is introduced by means of successive lifting of the non-return valves holding the mid-mounted and rear toolbars as the control lever is moved to the "drop" position.

The first British system, the Ferguson, differs fundamentally from the Lift-All in that it does not simply raise and lower an implement, but continuously controls the way in which it works. The implement is carried at the rear of the tractor on three links, as shown in Fig. 1, herewith, and the top link acts as the controller during work. There is a transverse rocking shaft, rotated by oil pressure through a piston and push rod, and connected by arms and links to the two lower links between the tractor and implement. Fluid under pressure is supplied by a submerged four-cylinder pump in the transmission housing with a control valve, the position of the latter being determined by a hand control lever on the operator's right and the movement of the anchorage of the top link. When the hand control lever is in any given position, the implement will run so that the force in the top link, which is related to the draught of the implement, acting through the compression spring to be seen in Fig. 1, tries to maintain the control valve in an equilibrium position where oil supply to the pump is cut off and the oil in the lifting cylinder is trapped. If the draught of the implement increases, the control valve is moved so that oil is admitted to the pump and allowed to pass from the pump to the lifting cylinder, the implement, as a consequence, being raised until equilibrium is again reached. If the draught decreases, oil is released from the cylinder and the implement's working depth allowed to increase. The implement is raised out of work by pulling the hand control to the limit of its travel when the pump lifts the implement until movement of the lifting piston moves the control valve to the equilibrium position. If the implement strikes a substantial obstacle, the compression spring is suddenly fully compressed and the larger forward movement of the top link anchorage moves the control valve and releases the oil pressure in the cylinder. This relieves the tractor of all downward forces produced by the implement and thus makes it likely that slip of the rear wheels will prevent any damage.

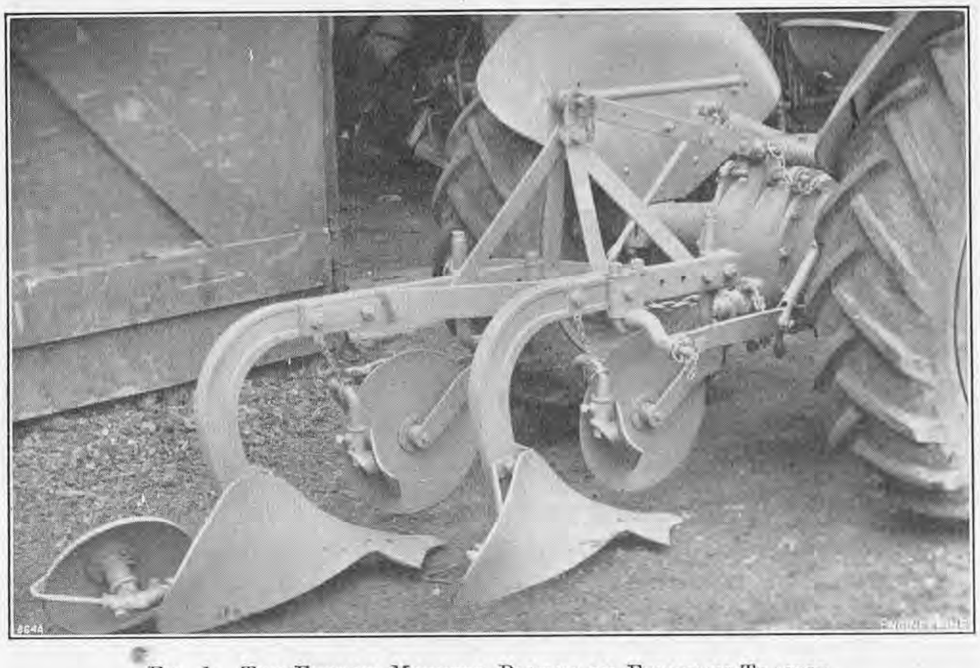

FIG. 1. TWO-FURROW MOUNTED PLOUGH ON FERGUSON TRACTOR.

It is, perhaps, a trifle misleading to couple these first two systems, because they represent two very different things. The International Harvester system was a straightforward alternative to hand or mechanical means of lifting toolbars; the Ferguson was the essential controlling element in what was, at the time, a new approach to tractor implements, namely, making the implement an integral part of the tractor. Nevertheless, they are well considered together, because between them they exhibit most of the features shown in subsequent systems except for the most recent ones. For example, the pressure relief valve on the Ferguson system is set at 2,000 lb. per square inch, compared with 700 to 800 lb. per square inch on the Lift-All, and most systems operated within this range up to about two years ago. Again, the use of hydraulic power to operate a rocking shaft in bearings rigidly secured to the tractor and thus raise or lower mounted implements coupled to the tractor by an arrangement of three, or sometimes four, links became common practice on the Continent as well as in Great Britain and America. The hydraulic system used in most of these applications, however, has been more on the lines of the Lift-All in its functions; that is, to raise the implement or allow it to drop, the depth of working being determined independently by means of depth wheels or alteration of the hitch point. The degree of refinement varies. For example, the end of the lifting phase of the cycle may be, as with the Lift-All or, for that matter, the Ferguson, a release of pressure in the pump occurring simultaneously with trapping oil in the lifting cylinder, or it may be simply the partial uncovering of a port by the lifting piston and spillage of oil continuously supplied. Differences of this nature, however, will immediately occur to any engineer and are hardly worth specific mention. One system introduced in 1949, namely, that on the Allis-Chalmers WD tractor, makes provision for a draught control of mounted implements. the main obvious differences between this and the Ferguson system being that control of the oil is obtained by bringing into operation in sequence one or more of the four plungers of an in-line pump instead of throttling the total supply to a four-cylinder pump arranged in horizontally-opposed pairs. The mounting linkage also is quite different.

At this point it may be of interest to consider briefly the advantages and disadvantages of draught control as compared with the use of depth wheels on mounted implements. One obvious advantage of draught control is that the operator has no depth wheel to adjust when setting the implement and his task is lightened; but it must not be overlooked that there may be other adjustments to be made, such as levelling a plough and it would be wrong to imagine that he will necessarily have nothing to do other than move a single lever. Another point is that, as the implement is always suspended from the tractor, any resultant vertical downward force on the implement is taken on the tractor, increasing its effective weight; a tractor intended for draught-controlled implements of a given size, therefore, can be lighter, an advantage which is particularly noticeable in hilly country and is, of course, in general, a good point. Against these advantages there is the criticism that a lazy operator is more likely to do an unsatisfactory job with a draught-controlled implement because the implement, if left to itself, will dodge a tough patch, coming to a shallower depth as the soil resistance, and the draught, increase; the operator should, of course, move the control to an increased draught setting for the tough patch. In practice, it would appear that either method of control is, in fact, acceptable and it seems likely that the two will continue to exist side by side. Draught control has obvious advantages for hilly country; depth-wheel control is probably to be preferred in very patchy land because, on the whole, the operator is likely to have a more straightforward job. For innumerable other circumstances it would be difficult to make an incontestable case for or against draught control.

There is one other type of control of mounted implements, namely, a direct positional control relative to the tractor. This is effected by the

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FIG. 2. NUFFIELD TRACTOR FITTED WITH STRIPPING FORK.

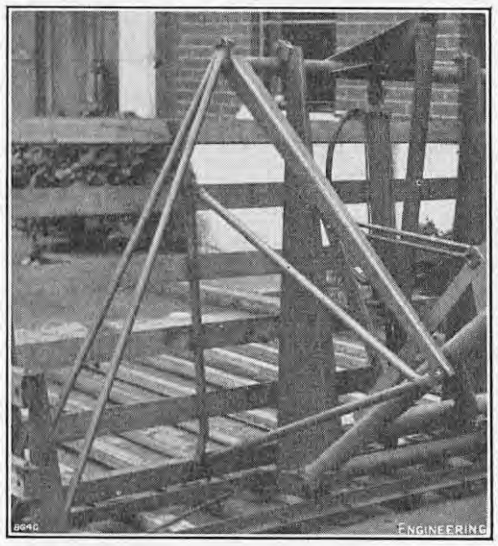


FIG. 3. STRIPPER IN RETURNED POSITION.

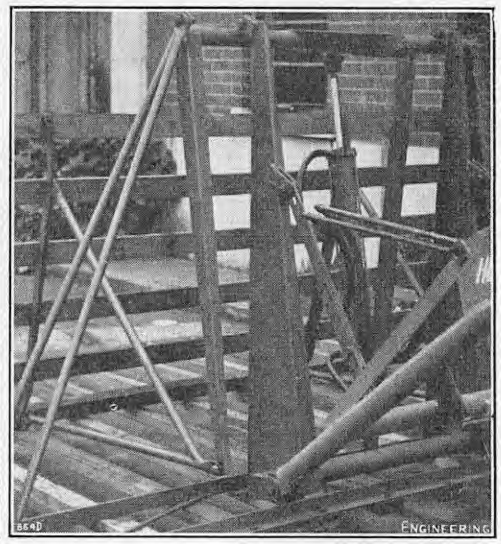


FIG. 4. STRIPPER EXTENDED.

FIG. 5. FERTILISER-PLACING MACHINE WITH HYDRAULICALLY-ACTUATED CRANKED AXLE.

Touch-Control system which is available for the smaller Farmall tractors. The system provides means of rotating, and hydraulically locking, either or both of two independent rocking shafts. The rocking shafts are actuated by independent double-acting pistons, each controlled by a separate lever, with a hunting control so that any given position of either lever corresponds to a definite position of the corresponding rocking shaft. A single gear pump supplies oil to each operating cylinder. The method of use of this system depends on the implement. A plough, for example, is mounted so that one rocking shaft controls the height of the hitch point and thus governs the depth of working by controlling the pitch, while the other raises and lowers the implement. One limitation of the system is immediately apparent: the method of mounting the plough would not be suitable for two-furrow and three-furrow ploughs, so that in its present conception the system would appear to be applicable only to small tractors such as those for which it has been designed, but within its limitations the system obviously combines some of the advantages of both methods of control previously considered. There are two particularly interesting details in this system. One is that movement of either control lever does not produce any result unless the engine is running. This is because the appropriate check valve through which oil must pass as an implement is lowered will not open until sufficient pressure is applied by oil acting on the other side of the piston; it means, of course, that the accidental dropping of an implement, such as may be caused by children playing, is impossible. The other feature which this system has in common with, for example, the John Deere Touch-o-matic system, and the Hanomag and Vevey tractors, is that the oil pump is mounted on the engine and not, as with many systems, driven from a shaft behind the main clutch; this is an obvious advantage.

During the past few years, the range of tractor-mounted equipment has grown much beyond the ploughs, cultivators and toolbars of the late 1930's and early 1940's. Drills, manure distributors, saw benches, hammermills, cutterbars and other equipment are commonly available in tractor-mounted versions for attachment to hydraulically-operated linkages. Some of the new applications have led to advances such as that embodied in the Nuffield system which provides for a main lift to a rocking shaft and two auxiliary pressure lines, one in series with the main lift (quite a common practice) and the other absolutely independent. This is useful for an application such as the front loading fork shown in Fig. 2, herewith, where the fork-stripper is connected into the independent subsidiary line so that the fork may be stripped as the lift is going upwards or downwards. The fork-stripper is shown separately in Figs. 3 and 4, Fig. 3 showing it in the "returned" position and Fig. 4 in the extended position. In this system there are two control levers, one for the main lift and its associated subsidiary and the other for the independent subsidiary. Either system can be lifting or lowering, according to the position of the appropriate lever, without reference to the other except that a reduced rate of lift is obtained when both are working together.

As well as being applied to an ever-increasing range of mounted equipment, tractor hydraulic systems are being used to operate trailed implements. This is an application which is still relatively uncommon, particularly in Europe. Provided it is equipped with a hydraulic cylinder actuating a cranked axle, all three of the control systems outlined so far could be used to raise and lower a trailed implement by taking oil under pressure from the tractor along a hose to the implement. An early example of this use is the fertiliser-placing machine shown in Fig. 5, herewith. This was a piece of equipment built in 1945 by the National Institute of Agricultural Engineering for the use of the Rothamsted Experimental Station. The chassis was lifted by a hydraulic cylinder actuating a cranked axle, using oil from a David Brown tractor hydraulic system, and the arrangement was entirely successful; but it should be noted that the chassis was always lowered to a fixed position relative to the land wheels. There is no difficulty about this; complications only arise when a variable relation is required between the working position of the chassis and the wheels, as, for example, in controlling the depth of working of a plough. In such cases there are three possible solutions. The simplest is to replace the mechanical lift by a hydraulic cylinder, but to retain all the original controls, such as the depth-regulating and levelling mechanisms on a plough. With this arrangement, using hydraulics to raise and lower the implement will not affect its normal working at all, but it is possible to raise it slightly, to get over a difficult patch; this is quite a worthwhile advantage, because it is not possible to use a mechanical lift in this way as it will always bring the implement right out, since, once in operation, it cannot be disengaged. Another possibility is to use a simple hydraulic system wherein the oil in the line to a lifting cylinder on the implement can be held by a valve, and then to discard the depth-regulating mechanism. This is not a good solution, because the operator has to judge the depth of working each time the implement comes into work and again whenever he adjusts it. Presumably, if this system were used in practice, some means such as a pointer on the quadrant would be provided to help the operator. Even with this, however, the system is not a good one, although it would probably not be too difficult to operate with an implement, such as a sugar-beet harvester, carrying its own operator, provided that he, and not the tractor driver, had control of the hydraulics.

The third solution is a refinement of the second. It consists of using a double-acting system with or without an adjustable stop to limit the power-cylinder stroke. If the nature of the work is such that the implement may be lowered to a pre-determined position, this is done; if not, any position may be selected, but this, of course, requires the operator's judgment on each occasion. One advantage to be obtained with a double-acting system is shown in the John Deere Power-Trol system, which is used to operate either a rockshaft or a remote power cylinder. In this system, provision is made for the return flow of oil from the power cylinder to pass through a check valve capable of allowing a free flow or a considerably restricted flow, according to the position of the control lever. By this means, a fast or slow rate of lifting or lowering may be selected, the slow rate being obtained with the control lever in the position where the check valve restricts the return flow. Thus, with this system, the operator can lower the implement quickly into work or raise it at the boundary of a field, minor adjustments to the working depth being made at a suitably slower speed.

At first sight, it would appear that there is, in general, not much to be said in favour of a double-acting system applied to a trailed implement. It is sometimes suggested that a double-acting system can be useful in helping to force a trailed implement into the ground, but a little consideration will show that, if the implement is designed, as presumably it always could be, with practically all its weight built into a tool-carrying chassis, and relatively light axles and depth wheels, then a double-acting system offers little advantage over a single-acting one as regards forcing the implement into work because the only additional weight available for this purpose is that of the depth-controlling wheels. Consideration of other purposes for which hydraulic power can be used, for example, for adjusting the angle between the gangs of a set of disc harrows, also leads to the conclusion that a single-acting system will give the required results. Nevertheless, it is quite obvious that there is a trend nowadays towards the use of double-acting systems and this has to be noted. Presumably, it is largely a result of the incidental advantages that can be obtained, such as those noted for the two double-acting systems mentioned, coupled with the undeniable fact that a double-acting system will certainly provide a better control of lowering.

Whether or not the trend towards double-acting systems continues, there is no doubt that the use of some form of hydraulic control for trailed implements will spread, and it is to be hoped that there will be rapid development of this application in equipment manufactured in this country. A wider use of hydraulics with trailed implements will be assisted by the recent introduction of standards, both in the United States*† and in this country.‡ The standards should ensure that any tractor hydraulic system, eventually, will be capable of controlling any trailed implement. Hydraulic cylinders are treated as part of the tractor, as, of course, they must be, because there has been no attempt at standardising operating pressures. Indeed, it would appear unlikely that any such attempt would be successful, as there are at present two quite incompatible trends among designers. Some prefer to use moderate pressures with gear pumps, while others are using pressures which can only be achieved with plunger pumps: for example, the Allis-Chalmers draught control system referred to has a relief valve set at 3,500 lb. per square inch. There does not seem to be any conclusive reason for preferring high or low pressure systems, any more than there is for accepting that all the complexities of the latest systems are necessarily worth while. It must be accepted that the use of hydraulics for implement control is a relatively recent innovation, and that the only certain feature is that it has come to stay, both for mounted and trailed machines.

(*To be continued.*)

* *S.A.E. Handbook*, 1950, page 995, SAE-ASAE Standard, "Hydraulic Remote Control, Farm Tractors and Trailing Implements."

† *Agricultural Engineering*, vol. 32, page 328, "Application of Hydraulic Remote Control to Farm Tractors and Trailing-type Farm Implements" (1951).

‡ B.S. 1773: 1951, "Hydraulic Lifts for Agricultural Trailed Implements."

LITERATURE.

Servomechanisms.

Selected Government Research Reports, vol. 5; issued by the Ministry of Supply. H.M. Stationery Office, York House, Kingsway, London, W.C.2. [Price 63s. net.]

AMONG the advances in engineering during the recent war, few were more remarkable than those in automatic control mechanisms, centred round such urgent requirements as automatic tracking by radar, and the automatic laying and gyroscopic stabilisation of guns. The problems that arose required a wide range of investigations, from the building up of appropriate mathematical methods to particular problems like the suppression of ripple-voltages in direct-current dynamos. The reports that arose during this war-time development were subject to secrecy restrictions and so were not published. It is to be welcomed that it has now been found possible to publish, in this volume, 17 reports, first circulated in 1943-46, relating to servomechanism development.

Only two of these reports, both written by the late Professor P. J. Daniell, deal with the general theory of servo-systems. There are three papers (C. Mack and A. Porter) on methods of solution of algebraic equations of high order. These relate to servo-systems only in so far as the finding of the roots of a high-order polynomial may be required in the exact solution of the equations of a servo-system. These three papers are of value to applied mathematicians generally. It might have been preferable to publish them as a separate brochure. The remaining papers deal with specific elements and computational devices. So far as concerns elements of servo-systems, there are papers on the velodyne, on a sense-detecting rectifier circuit, on the effect of air in the oil of hydraulic transmission systems, and on the linearity of direct-current tachometer generators. The remaining papers include descriptions of a differential analyser using velodynes, an apparatus for computing serial correlations, and accounts of several particular devices or systems of servo type.

The volume will be of value to engineers concerned with practical servo development. It contains a wealth of ideas that are both interesting and stimulating, and it should find a place in every library that serves the needs of servo engineers. It is not intended as reading for students, or for those seeking a broad introduction to the subject. The papers that deal with general theory cover the general principles of the Nyquist diagram and the use of the Laplace transform, but these topics have been more fully developed and are presented in a manner suited to students' needs in the text-books that have appeared in recent years. In making these papers available the Ministry of Supply has provided not only a permanent record of some of the past steps in an important phase of engineering development, but has provided a volume that will be of use in future developments and a source of stimulus to workers in this field.

Triaxial Testing of Soils and Bituminous Mixtures.

Special Technical Publication No. 106 (1951). American Society for Testing Materials, 1936, Race-street, Philadelphia 3, Pennsylvania, U.S.A. [Price 3·50 dols.]

THIS publication is a symposium of papers dealing with the use of various forms of triaxial test for soils and bituminous mixtures. In this type of test, best known for its application to soil mechanics, a steadily increasing compressive load is applied axially to a cylindrical specimen, while a uniform lateral fluid pressure is maintained. Several of the papers are by members of the Triaxial Institute, an informal group of American engineers. This group was formed in 1947 with the objects of clarifying the fundamental mechanics of granular particles combined with viscous binders, of investigating the triaxial compression test as a means for measuring mechanical properties, and of considering specific procedures for conducting the triaxial test. Later, the group became a project committee of the American Society for Testing Materials. As the Triaxial Institute, the group is interested in all aspects of triaxial testing, but in its capacity as an A.S.T.M. committee its scope is limited to bituminous materials.

The book opens with an introduction by W. G. Holtz, head of the Earth Materials Laboratory, Bureau of Reclamation, Denver, Colorado. This includes short summaries of all the papers. The first three papers, dealing with bituminous mixtures, were presented at the First Pacific Area National Meeting of the A.S.T.M., held in San Francisco, in October, 1949. Of these, the first, by V. A. Endersby, gives a review of the development of the triaxial test for road materials. Nine papers, some of which are concerned with soil testing, were presented at a meeting of the society in Atlantic City, New Jersey, held in June, 1950. Finally, there is a paper by W. S. Housel, on "Interpretation of Triaxial Compression Tests on Granular Materials," which was originally presented before the Association of Asphalt Paving Technologists. Short discussions on the various papers are interspersed throughout the book.

The book contains much information which will be of use to those interested in soils and road materials, but it is, as indicated on the cover, merely a compilation of papers. No attempt has been made to draw any general conclusions from the somewhat diverse data presented. The method of approach in which attention is centred on the triaxial test appears to be rather a narrow one. In investigating the properties of these materials, it would seem more rational to approach the subject from a wider standpoint, envisaging, in addition to the triaxial, other forms of test which might provide the necessary data.

Building and Civil Engineering Plant: Its Purchase, Application and Operation.

By SPENCE GEDDES, E.S. Diplomate, R.T.C., Glasgow. Crosby Lockwood and Son, Limited, 39, Thurloe-street, London, S.W.7. [Price 30s. net.]

ONE of the most notable features of civil-engineering contracting since the recent war has been the rapid increase in the capacity, versatility and usage of power-driven appliances for earth-moving and the general handling of materials; a trend which has been remarked repeatedly by visitors to the outdoor exhibits at the British Industries Fair at Castle Bromwich. Concurrently, the capital cost of the plant has risen to an extent that obliges the contractor to engage in much more detailed economic studies than previously before deciding what type of plant to adopt, and to reconsider, in many cases, the former practice of selling off much of his portable plant on the completion of a big contract and buying new plant for the next one. There is, therefore, a field for a book such as this one by Mr. Spence Geddes which did not exist before the war.

The book is arranged in 23 sections, of which the first four deal in a general way with the principles involved in the selection and operation of plant.

The remaining sections are devoted, respectively, to particular categories of plant, starting with one on agricultural equipment; an item which is not so out of place as it might seem, as many large engineering contracts—e.g., reservoirs, dams, and the restoration of opencast coal workings—bring the contractor into fairly close touch with the work of the agriculturalist. The following sections deal with air compressors and pneumatic tools, angledozers and bulldozers, mixers for asphalt and macadam dressings, concrete mixers, concrete vibrators, and conveyors. At this point there appears a certain discontinuity, as the next chapter, on cranes, is followed by one on crushing and screening plant which it might be thought, would be better considered before the concrete mixers rather than after them. Elevators, excavators and loading shovels each have their sections, in that order; after which the author turns to pile-drivers, platform hoists, pumps and rollers before returning to the subject of "muck-shifting" with a section on tractors and scrapers, another on transporting plant, and a final one on trenching machines. It would seem, therefore, almost as though the book had grown to its eventual scope by a process of accretion rather than as a planned whole; but, as each section is self-contained, the disadvantage to the reader is rather imaginary than real.

A useful feature of the book is the considerable number of tables presenting in convenient form the capacities, power requirements, and proportions of labour gangs needed for the different classes of plant described. Some of these tables go into a great deal of detail, though there are others—for instance, the table showing the weights of different materials which can be handled by power-driven hoists—in which the blank spaces are almost as numerous as the items given. Much of the information, obviously, has been derived from makers' catalogues, but it has been selected with some care and the book, as a whole, forms a compilation that should be of considerable use as a work of reference.

THE IRON AND STEEL INSTITUTE.

(*Continued from page 592.*)

THE afternoon session on the first day of the annual general meeting of the Iron and Steel Institute, held in London on April 30 and May 1, was devoted to the discussion of four papers.

COLD WORKING OF STEEL.

The first three of the four papers on the agenda dealt with the cold rolling of steel. The fourth concerned the softening of metals during cold work, and all four were taken together for the purpose of discussion. The first paper was entitled "Cold Rolling with Strip Tension. Part I. A New Approximate Method of Calculation and a Comparison with other Methods," by Professor H. Ford, Mr. F. Ellis and Mr. D. R. Bland. The second paper, on the "Effect of Tension on Torque and Roll Force in Cold Strip Rolling," was by Mr. W. C. F. Hessenberg and Mr. R. B. Sims, and the third, on "Pressure Distribution between Stock and Rolls in Hot and Cold Flat Rolling," was by Dr. C. L. Smith, Dr. F. H. Scott and Mr. W. Sylwestrowicz. The fourth paper bore the title "Softening of Metals during Cold Work," and was by Mr. N. H. Polakowski. It constituted an Andrew Carnegie Research Report.

In the first paper, which was presented by Professor Ford, the authors, who are on the staff of the Mechanical Engineering Department at Imperial College, London, showed that, by making certain approximations to Dr. E. Orowan's general theory of rolling, it was possible to calculate roll force and torque by a method which was both rapid and easy to apply, using the basic information on the yield-stress characteristic of the material to be rolled, the coefficient of friction, and the dimensions of the pass. The roll force and roll torque functions utilised in the calculations had been set out in graphical form, the particular values required being read off from the curves in terms of the pass dimensions. Various methods of calculating these quantities for strip rolling with tension had been put forward previously and the methods of Dr. E. Orowan, Dr. R. Hill, Mr. E. Siebel, Mr. A. I. Tselikov and Mr. A. Nádai had been examined and compared with the new method, for a wide range of tensions. It was concluded that the new method could be applied more quickly than any of the others examined.

The second paper, on "The Effect of Tension on Torque and Roll Force in Cold Strip Rolling," by Mr. W. C. F. Hessenberg and Mr. R. B. Sims, was presented by Mr. Hessenberg. The authors stated that they had studied the rolling of mild-steel strip, with front and back tension, on the B.I.S.R.A. experimental rolling mill, to determine the effect of tension on the roll force and torque and, if possible, to suggest quantitative relationships between these variables. Simple approximate formulae for calculating the effect of tension on roll force and torque had been deduced and comparisons made between calculated and experimental results. The energy of rolling was composed of the energy required to deform the strip and the energy absorbed in overcoming friction between the strip and the rolls. Since the former depended only on the properties of the strip and the amount by which it was deformed, any effect of tension on the energy of rolling must arise from changes in the frictional component. In most cases, this was relatively small, and the experiments had confirmed that the total energy of rolling, for all practical purposes, were unaffected by the tension.

"Pressure Distribution Between Stock and Rolls in Hot and Cold Flat Rolling" was the title of the third paper, contributed by Dr. C. L. Smith, Dr. F. H. Scott and Mr. W. Sylwestrowicz. It described work carried out between 1946 and 1949 in the Cavendish Laboratory, University of Cambridge. Dr. Smith presented the paper. The authors stated that they had studied a method of measuring the pressure distribution over the area of contact between the roll and the rolled stock. In this method, a photoelastic dynamometer, inside the lower roll, measured the normal force exerted on a small 0·7 mm. diameter tungsten radial pin inset into the roll, the surface of the pin being flush with the roll surface. Devices for applying back tension to the rolled strip, and for measuring the back tension and the total force separating the rolls, had also been installed. Annealed copper strip, 2 mm. thick by 40 mm. wide, had been subjected, by cold rolling, to reductions of from 5 to 50 per cent. and, by hot rolling, to reductions of 18, 26 and 36 per cent. The most important feature of the experiments was the good agreement, in all cases, between the curves calculated by the Orowan method and those observed experimentally. Other noticeable features were the manner in which the total roll load fell as back tension was applied.

The last paper, on "Softening of Metals During Cold-Working," was by Mr. N. H. Polakowski, who had been studying the deformation of metals at the University College, Swansea. He stated that steels and non-ferrous metals, initially overstrained by tension, torsion, or drawing, were progressively compressed in a direction opposite to that of the initial flow. In each case not only was a Bauschinger effect observed, but also an initial gradual decrease of the indentation hardness (by amounts up to 10 per cent.) before it increased. Both effects were reproducible and were more pronounced in the higher-carbon steels. Bauschinger had discovered that the effects of cold work were directional and that plastic deformation which raised the yield stress in the direction of flow reduced it in the opposite direction, when tension followed compression or vice versa, when torsion was followed by reversed torsion. The Bauschinger effect was explained by the action of internal stresses locked up in a cold-worked metal. As a result of the present work, a theory relating indentation hardness and the energy stored in a cold-worked metal was put forward as a tentative explanation of both the Bauschinger effect and work softening. To satisfy this theory, quenched and tempered steels should soften during the early stages of cold-working, and experiments had shown that such was the case. This energy concept accounted for the low rate of work-hardening during the reversed-rolling and cross-rolling of sheets, during reversed deep drawing, and during the cold-working and fatigue testing of heat-treated steels in the sorbitic and troostitic condition. The softening effect provided an explanation of the recrystallisation and mechanical properties of single-crystalline and polycrystalline metals after reversed deformation.

DISCUSSION.

Mr. W. C. F. Hessenberg, who opened the discussion, said that there was much to be learned here, and he very much hoped that the author would go on with his work. He felt, however, that Mr. Polakowski had been rather too precipitate in trying to discover an explanation for what he had found by a review of other people's work and by his own experiments.

Dr. D. V. Wilson, who was the next speaker, observed that Mr. Polakowski had shown that the Bauschinger effect and the related "work-softening" effects were general properties of cold-worked metals which might be of considerable practical importance. Mr. Polakowski did not discuss the influence of metallic structure in any detail, however, although it was clear that this would affect the possible magnitude of the effects which he had described. The Bauschinger effect was generally considered to arise as a result of the inhomogeneous character of plastic deformation. The pattern of the plastic inhomogeneities and that of the consequent internal stress system could vary very widely, both in scale and intensity, with the material and with the method of working. Some experiments which he (Dr. Wilson) had made on steel suggested that, as might be expected, the finer the carbide-particle size in a given steel, the higher was the level of the internal stresses which might be locked up in the cold-worked material. Moreover, it appeared that, in the case of a cold-worked steel of fine microstructure, the residual strain in the cementite particles might reach very high values, probably in excess of 1 per cent. mean strain. It was not surprising, therefore, that a larger Bauschinger effect was obtained with medium-carbon and high-carbon steels than with low-carbon steels or with one-phase alloys.

Professor H. O'Neill stated that he thought that Mr. Polakowski had made a discovery. If any metallurgist had been asked a year or two ago "Do you believe that cold-working a metal will soften it?" he would have said "No, I do not believe it," yet, apparently, there were members here, and he was one of them, who believed now that, in certain circumstances, there was evidence that a cold-worked metal could be softened by more cold work. A problem created by this phenomenon, however, was the effect which it had upon the mechanics of hardness-testing itself, because the usual deformation and indentation hardness tests naturally applied cold work to the metal. If the specimen to be tested was already cold-worked, then the actual indentation operation might produce some work-softening within the specimen. The effect of this phenomenon upon fatigue would have to be considered. Failure by fatigue was very much "in the air" at the present time. If it were confirmed that cold working under certain conditions produced work-softening, it might be that it produced a lowering of the fatigue value. There was, moreover, the question of the Meyer hardness analysis, which might have to be reconsidered. Sometimes in the cold working of copper, for instance, a stage was reached early in the progressive deformation at which the Meyer n value reached its lower limit and indicated that the metal could not be strain-hardened any more. Copper reached this limiting n value at about 30 per cent. reduction, and yet, after that, the copper would go on strain-hardening. That was a conflict which had never been resolved, and it might be that work-softening effects had something to do with it.

Professor H. Ford made a few remarks on the paper by Mr. Hessenberg and Mr. Sims. He stated that, in view of the expense of carrying out such tests as these, and the organisation and background of experimental knowledge which were required, it was unlikely that other information of this sort would be forthcoming from any other source, either here or abroad, for some years. The figures furnished contributed the first set of comprehensive results of tension rolling tests which had been put forward, and, consequently, they were of considerable importance. It was a pity, therefore, that more space in the paper had not been given to the experimental results, as compared with the theoretical speculations, and that other metals, and notably copper, had not been used in the tests.

Mr. M. F. Dowding said that, from the mill builder's point of view, he congratulated both Professor Ford and his colleagues, and Mr. Hessenberg and Mr. Sims, on producing most useful contributions to the very difficult problem of computing roll load and torque for any given reduction when it was necessary to take all variables into account, including forward and back tension. At first sight, the theoretical proof that both back and front tension reduced rolling load seemed welcome news to the mechanical designer, because if he found that a pass which he was asked to take was going to overload either the mill bearings or the roll necks, he could apply tension and reduce the load to bring it within the capacities which he had available. In theory, that was all right, but, in practice, it was probably necessary to sound a note of warning. There were times when one could apply front and back tension and times when one could not. The condition prevailing when the rolling-mill operator found it advantageous to apply heavy tension back and front was when the metal was soft and thick. Taking, for example, the rolling of thin gauges, say, a tin-plate gauge on a reversing mill; in the early passes it was possible to put the tension on fairly heavily front and back, but by the last pass, when the metal was hard and, perhaps, a reduction of about 35 per cent. was left, no more front tension should be used than was needed to keep the coil from collapsing. On the other hand, as much back tension as possible should be applied. It might be concluded, therefore, that the methods of calculation presented in the papers were proving useful, but in applying them to mill design, operating conditions other than the loading of the mill or the motor must be taken into account, and it would be interesting to hear what those other conditions were in more detail from persons who were actually rolling strip.

Mr. N. H. Polakowski said that the three interrelated papers on cold rolling offered an opportunity for comparing some aspects of the mathematical theories of rolling, put forward in recent years, with the experimental results obtained either in works or during laboratory tests. In this connection, the paper by Mr. Hessenberg and Mr. Sims was particularly valuable, since it offered a realistic basis for discussion. The circumstance that the rolling results reported by these authors had been obtained at speeds much below those used commercially did not detract from the value of the work, though a few comparative tests at, say, 200 to 300 ft. per minute would have been welcome. They had done particularly good work in making measurements of forward slip as well. The salient feature of their results was the remarkable constancy of the energy consumption figures for any given percentage draft, irrespective of the combination of tensions used. The authors' statement that rolling with back tension was actually less efficient than without it obviously applied only to single-stand mills with drag generators. In tandem mills and some single-stand installations the tension work was completely recoverable.

Dr. B. B. Hundy said that Mr. Polakowski's results agreed with some work of his on the softening of copper during cold rolling. He had taken some copper and given it a reduction of 6 per cent. in two passes, keeping the direction of rolling the same for each pass. Hardness measurements had shown a surface hardness of about 77 and a core hardness of 70. He had then taken another sample of the same copper, with the same reduction, also in two passes, but this time had reversed it, end to end, before the second pass. In this case, the core hardness was about the same, but the surface hardness was only 71. It seemed that reversal of rolling gave a product having lower hardness than ordinary straight rolling. Another point was that he had found that it was possible to twist some specimens of Armco iron to a shear strain of about 3·5, if it were twisted in one direction only. If, however, the direction of twist were reversed, it was possible to twist to a shear strain of about 2·5, and then twist it all the way back again before any fracture occurred, a total strain of 5 as opposed to 3·5.

Professor H. Ford, in reply to the discussion, said that the point he wished to make was that, as far as he could judge from the comparison which Mr. Hessenberg and Mr. Sims had made between their method and the experiments which they had carried out, the errors were of the order of ±20 per cent. for roll force. On the whole, they were better than that, but that was the main "spread" of the results. A possible error of ±10 per cent. on the nomogram, added to ±20 per cent. in the estimation of the results, led to an overall possible error of ±30 per cent., and for many purposes, if it were a serious question of the assessment of power, for example, in a multi-stand mill, that would not be sufficiently accurate. It seemed, therefore, that where a question arose where it was necessary to make a calculation, it was possibly more advantageous to go back each time to the basic equation, which meant to go back to a non-dimensional plot and ensure that, within the accuracy of that method, one could feel fairly confident of the results.

Mr. W. C. F. Hessenberg, in the course of his reply, stated that it was possible to submit many pages of experimental results in a paper such as theirs, but there were space limitations to consider, and if their graphs had been reproduced to a much larger scale (as they would have liked), they would have presented a complete picture to support their thesis that these formulæ were useful and reasonably accurate. Mr. R. B. Sims, who also replied, said that he would like to make a few comments, chiefly on the question of accuracy and also on the philosophy of these rolling calculations. There were two forms of calculating methods. There was the method for the student who would sit and ponder, and there were the methods for the mill engineer. If an accurate method were needed, Professor Ford's was employed, and if not, their method was adopted. He did not think that the methods proposed by the two sets of authors overlapped; one was for the man who wanted to be accurate and the other was for the practical man. They had carried out their tests at a low speed of 50 ft. per minute, merely because the instrumentation of the mill was difficult enough to cope with at that speed, and much more difficult at 300 ft. per minute. When they embellished their equipment to operate at 2,000 ft. per minute on their new experimental mill, they would in due course publish the results.

Dr. C. L. Smith, who replied in his turn, agreed with a point made by Mr. Hessenberg, namely, that several of their graphs had been reproduced, in their printed paper, on a very small scale, and it would be difficult to take accurate readings from those curves in order to check any further calculations which might arise at a later date. Mr. N. H. Polakowski, in a brief final reply, stated that it was very gratifying that most of those who had done similar experiments had found that their results bore out his own. It was necessary, however, to draw a dividing line between the physicist and the mechanical metallurgist. He had dealt mostly with bulk effects.

(*To be continued.*)

FIRST RUTHERFORD SCHOLARSHIP.—The Council of the Royal Society have appointed Mr. E. M. Gunnersen, a graduate of Melbourne University, as the first Rutherford Scholar, for three years from October 1, 1952, to carry out work in nuclear physics at a university in the United Kingdom.

TELEPHONE STATISTICS OF THE WORLD.—According to a detailed statement published in *Electrical Communication* for March, 1952, there were about 74·8 million telephones in use in the world on January 1, 1951, an increase of 4·5 million, or 6·4 per cent., over the previous year's total. Of these, the United States accounted for just over 43 millions and Europe for 21·3 millions. Asia had 2·6 millions and Africa only 895,200. Only ten countries were served by more than one million telephones: the United States, the United Kingdom, Canada, Germany, France, Japan, Sweden, Russia, Italy and Australia. Six countries had more than 15 telephones for each 100 of their populations: the United States (28·1), Sweden (23·9), Canada (20·8), Switzerland (19·1), New Zealand (19·1), and Denmark (16·9). The United Kingdom had 10·7.

THE THERMODYNAMICS OF HUMID AIR.

By BORIS N. COLE, Ph.D., Wh.Sc.

WHEN it is realised—to quote a random example—that the total heat (reckoned above 32 deg. F.) of 1 lb. of completely humid air at 100 deg. F. and 14·7 lb. per square inch is 3·3 times that of 1 lb. of dry air at the same temperature and pressure, it becomes apparent that there may be many circumstances in which it is wrong to employ the equations for a dry and a perfect gas for the calculation of wet-air behaviour. That the total-heat ratio of wet to dry air may so considerably exceed unity is, of course, due to vapour latent heat; and the fact that such latent heat may actually be released during an adiabatic expansion is a matter of common observation, for the exhaust of a pneumatic machine is frequently visible due to the presence of condensed vapour particles.

Clearly, the greater the humidity the greater the amount of latent heat that may be released, and the greater accordingly—as confirmed by a wide range of practical observation—may be the departure of the behaviour of the humid air from that of a perfect gas. In order to develop this theme as usefully as possible, the topics selected for discussion in the following are: "conventional" humidity corrections, and their limitations; isentropic expansion with vapour equilibrium, with mention of the piston-motor; acoustic velocity in wet air; steady flow through a convergent nozzle with vapour equilibrium, having special reference to flow measurement; and finally, the same, but with condensation shock.

The following symbols are employed:

P = absolute pressure in lb. per square foot.
ρ = density in lb. per cubic foot.
T = absolute temperature in deg. F.
C_v = specific heat at constant volume
= 0·171 for dry air.
C_p = specific heat at constant pressure
= 0·239 for dry air.
R = gas constant in ft.-lb. per lb. per deg. F.
= 53·2 for dry air.
$\gamma = \frac{\mathrm{C}_p}{\mathrm{C}_v} = 1{\cdot}4$ for dry air.
J = Joule's equivalent
q = heat quantity
n, m = expansion indices.
ϵ = mass humidity in lb. vapour per lb. dry air.
x = vapour dryness fraction.
ρ'_w = dry saturation vapour density, so that, in general

$$\rho_w = \frac{\rho'_w}{x}.$$

ϕ_l = liquid entropy per lb. H_2O at saturation temperature.
ϕ_L = evaporation entropy per lb. H_2O.
a = propagation velocity of a small sound wave, ft. per second.
w = gas particle velocity, ft. per second.
M = Mach number.
C = dimensionless criterion of mass-flow.

Of the suffixes used, a denotes air; w denotes water vapour; 1 denotes initial state, and 2 denotes final state.

Conventional Humidity Corrections.—"Conventional" corrections are here regarded as those which take no account of vapour latent heat, being thus based solely on the laws of partial pressures and densities. Any such correction is fundamentally an adjustment to the general gas law for air; for, if ϵ be known, a corrected mixture density, ρ, may be determined so that, for any given net pressure, P, and temperature, T, the effective value of the gas constant may be computed according to

$$\mathrm{R} = \frac{\mathrm{P}}{\rho \mathrm{T}} \quad . \quad . \quad . \quad (1)$$

This equation, which is virtually exact for the case of a superheated vapour content, remains quite acceptable for the case of a wet vapour content, provided, of course, that the wetness fraction is not excessively high. Most usually, any attempt to deduce a corrected value for the isentropic index, γ, of humid air is based on an equation for the mixture of two perfect gases, which here is quoted in the form

$$\gamma = \frac{1 + \epsilon \frac{\mathrm{C}_{pw}}{\mathrm{C}_{pa}}}{\frac{1}{\gamma_a} + \frac{\epsilon}{\gamma_w} \frac{\mathrm{C}_{pw}}{\mathrm{C}_{pa}}} \quad . \quad . \quad . \quad (2)$$

This equation is also virtually exact for the case of a superheated vapour content, the appropriate value of γ_w being 1·3. A limited, and rather questionable, allowance for the case of a wet vapour may be made by using for C_{pw} a mass-mean value of the specific heats of the dry saturated (quasi-superheated) vapour and the liquid, and by taking for γ_w a value calculated in accordance with the prevailing dryness fraction from Zeuner's equation. In either event—save for extremely high wetness fractions in the latter case—the departure of γ, so calculated, from γ_a is usually so slight as to be negligible. Strictly, it should be noted, the application of equation (2) to the case of a wet vapour content can only relate to conditions of small and rapid pressure change, as in the propagation of a sound wave, small both in wavelength and amplitude, through an infinitely divided fog. For such conditions, there is no time for interchange of vapour latent heat; and, in fact, it is well known that the correction to the propagation velocity may be included almost entirely in the correction to the gas constant, as defined in equation (1), the "γ" correction being negligible in comparison. Propagation velocity would thus be calculated according to the standard expression

$$a = \sqrt{\gamma_a\, g\, R\, T}. \quad . \quad . \quad . \quad (3)$$

However, for slower rates of pressure change, for which the vapour content would remain in equilibrium, it is important to emphasise the impossibility of "forcing" equation (2) to take account of latent heat interchange. In such a process, the term C_{pw} would have to be contrived so as to include a component for latent heat; but, inasmuch as, fundamentally, $C_p = \left(\frac{\partial q}{\partial T}\right)_P$ where q signifies externally added heat, it is evident that, P and T both being constant over the evaporation range, C_{pw} thus described would assume an infinite value, so that equation (2) would be reduced to an indeterminate form. An entirely different approach is therefore necessary if vapour equilibrium is to be taken into account.

Isentropic Expansion of Humid Air with Vapour Equilibrium.—While this problem has already been considered by Binder and others,* it is the object here to develop a solution in a form suitable for the analysis of compressible steady flow.

It is assumed that the expansion is slow enough to prevent supersaturation of the vapour content; and, inasmuch as the release of latent heat cannot begin until the dew-point is reached, it is convenient to assume that the vapour content is initially dry-saturated, i.e., that the initial relative humidity is 100 per cent. For adiabatic and frictionless conditions, the process is isentropic; hence, the entropy loss associated with the partial release of latent heat from ϵ lb. of vapour must reappear as an entropy gain for 1 lb. of dry air.

The initial vapour dryness fraction, x_1, being unity, the entropy loss for the vapour content in expanding between temperatures T_1 and T_2 will be

$$\epsilon\,(\phi_{l1} + \phi_{L1} - \phi_{l2} - x_2\,\phi_{L2}) \text{ units.}$$

in writing down an expression for the numerically equal entropy gain for 1 lb. of dry air, great ultimate advantage accrues from the assumption that the air content expands according to the reversible polytropic law $\frac{P}{\rho^m}$ = constant, in which, implicitly, it is anticipated that m may be approximately constant; specimen calculations, quoted later, justify this step. Hence, on this basis, the entropy gain for the air may be expressed according to the standard result as

$$C_v \frac{\gamma_a - m}{m - 1} \log_e \frac{T_1}{T_2}.$$

At the lower temperature, $\rho_{a2} = \rho_{a1}\left(\frac{T_2}{T_1}\right)^{\frac{1}{m-1}}$ and mass humidity, which remains constant throughout, $= \epsilon = \frac{\rho_{w1}}{\rho_{a1}} = \frac{\rho_{w2}}{\rho_{a2}} = \frac{\rho'_{w2}}{x_2\,\rho_{a2}}$; hence

$$x_2 = \frac{\rho'_{w2}}{\epsilon\,\rho_{a1}}\left(\frac{T_1}{T_2}\right)^{\frac{1}{m-1}}. \quad . \quad . \quad . \quad (4)$$

The governing equation for the isentropic expansion of the mixture thus becomes:

$$C_v \frac{\gamma_a - m}{m - 1} \log_e \frac{T_1}{T_2} = \phi_{l1} + \phi_{L1} - \phi_{l2} - \frac{\rho'_{w2}}{\epsilon\,\rho_{a1}}\left(\frac{T_1}{T_2}\right)^{\frac{1}{m-1}} \phi_{L2}. \quad (5)$$

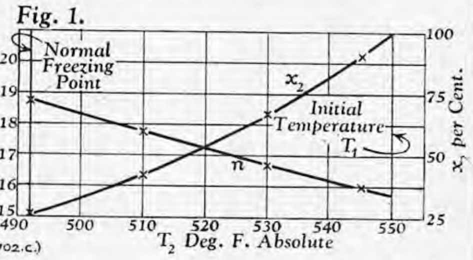
in which T_1 and T_2 (being the only quantities common to both air and vapour) are to be regarded as determining the expansion, so that m is the only unknown term. Various approximations may be applied in order to determine m explicitly for limited temperature drops, but the most accurate method is clearly to plot the two sides of the equation against m, the point of intersection giving the final solution.

Having once found the value of m for an assumed $(T_1 - T_2)$ interval, a modified expansion index, n, applying to the mixture as a whole, may be found from any one of the expressions

$$n = \frac{\log\left(\frac{P_1}{P_2}\right)}{\log\left(\frac{\rho_1}{\rho_2}\right)}, \quad \frac{n-1}{n} = \frac{\log\left(\frac{T_1}{T_2}\right)}{\log\left(\frac{P_1}{P_2}\right)}, \quad \frac{1}{n-1} = \frac{\log\left(\frac{\rho_1}{\rho_2}\right)}{\log\left(\frac{T_1}{T_2}\right)},$$

in which P and ρ are of net value, i.e., $P_1 = P_{a1} + P_{w1}$; $\rho_1 = \rho_{a1} + \rho_{w1}$, etc. Due to the slight variation of R for the mixture during the expansion, it is found that these expressions yield, respectively, values of n that are slightly greater than, slightly less than, and practically equal to, m. The last of these recommends itself as a natural choice for a mean value of n, which thus may be taken without serious error as being equal to m.

Fig. 1.



To illustrate the foregoing theory, Fig. 1 shows the small variation of n with T_2 for assumed initial conditions of P_1 = 30 lb. per square inch absolute, T_1 = 90 deg. F. (550 deg. F. abs.), and 100 per cent. relative humidity (so that $\epsilon = 0{\cdot}014817$). Also shown on the same base is the variation of dryness fraction x_2. The index n may be regarded in two ways: either, properly, as an approximate isentropic index for wet-saturated air; or, artificially, but very conveniently for the analysis of flow problems, as a reversible polytropic index for a perfect gas to which an amount of external heat, $\Delta\,q$, is added according to the standard expression

$$\frac{\Delta q\, J}{R\, T_1} = \frac{\gamma - n}{\gamma - 1}\left(\frac{1 - \frac{T_2}{T_1}}{n - 1}\right). \quad . \quad . \quad (6)$$

$\Delta\,q$, thus expressed, is consistent with the origin of the left hand side of equation (5), and corresponds, of course, to the quantity of latent heat which is released in the actual case. It should be understood clearly that, regardless of its interpretation, the index n will relate to a reversible process, being equally applicable to the adiabatic compression of foggy air up to the threshold of vapour superheat.

To find the appropriate value of n for a change of known pressure ratio, an approximate value of n should be guessed, and the corresponding value of T_2 calculated; using the equivalent of Fig. 1 for the initial conditions obtaining, the corrected value of n should then be read off, and the process repeated—though a single iteration is usually sufficient—until the value of n stabilises. In some problems, however, the small variation of n with T_2 may be considered negligible.

By way of practical example, it is interesting to note that if an air motor expanded air from the initial conditions assumed for Fig. 1 down to 15 lb. per square inch absolute, the effective value of n would be 1·188, resulting in an increase of more than 5 per cent. theoretical indicated horse-power relative to the normal dry-air calculation.

Acoustic Velocity in Wet-Saturated Air.—Before the foregoing theory can be applied safely to any analysis of gas flow, it is necessary to understand distinctly what may be meant by the term "acoustic velocity" for the case of air in which the vapour content is wet-saturated. Firstly, as already mentioned, if a small-amplitude sound wave be of short length, then any elementary mass of wet air will be embraced by the wave for so short a time that vapour equilibrium, with consequent interchange of latent heat, cannot be maintained. In these circumstances, the propagation velocity may be described as of "normal" value, being calculated in accordance with equation (3). By contrast, however, a long sound wave of very shallow profile may be conceived, for which the pressure change of an elementary mass would be slow enough for vapour equilibrium to be preserved. In this case, it is only consistent to suppose that the isentropic index n, as distinct from γ, would apply, so that what may now be termed the "equilibrium acoustic velocity" would be calculated according to:

$$a = \sqrt{n\, g\, R\, T}. \quad . \quad . \quad . \quad (7)$$

TABLE I.—CHARACTERISTIC RATIOS FOR MAXIMUM AND SONIC FLOWS.

Ratio.	Isentropic Flow (Maximum and Sonic).	Reversible Polytropic Flow.	
		"Equilibrium" Sonic and Maximum Flow.	"Normal" Sonic Flow.
$\frac{T_2}{T_1}$	$\frac{2}{\gamma + 1}$	$\frac{2}{n + 1}$ (= 1 for n = 1)*	$\frac{2n}{n(\gamma + 2) - \gamma}$ (= 1 for n = 1)*
$\frac{P_2}{P_1}$	$\left[\frac{2}{\gamma + 1}\right]^{\frac{\gamma}{\gamma - 1}}$	$\left[\frac{2}{n + 1}\right]^{\frac{n}{n - 1}}$ (= 0·606 for n = 1)*	$\left[\frac{2n}{n(\gamma + 2) - \gamma}\right]^{\frac{n}{n - 1}}$ (= $e^{-\frac{\gamma}{2}}$ for n = 1)*
C	$\left[\frac{2}{\gamma + 1}\right]^{\frac{1}{2}\left(\frac{\gamma + 1}{\gamma - 1}\right)}$	$\sqrt{\frac{n}{\gamma}}\left[\frac{2}{n + 1}\right]^{\frac{1}{2}\left(\frac{n + 1}{n - 1}\right)}$ $\left(= \frac{0{\cdot}606}{\sqrt{\gamma}} \text{ for } n = 1\right)^*$	$\left[\frac{2n}{n(\gamma + 2) - \gamma}\right]^{\frac{1}{2}\left(\frac{n + 1}{n - 1}\right)}$ (= $e^{-\frac{\gamma}{2}}$ for n = 1)*
$\frac{\Delta q\, J}{R\, T_1}$	0	$\frac{(\gamma - n)}{(\gamma - 1)(n + 1)}$ (= ½ for n = 1)*	$\frac{\gamma(\gamma - n)}{\gamma^2(n - 1) + \gamma(n + 1) - 2n}$ $\left(= \frac{\gamma}{2} \text{ for } n = 1\right)^*$

* These isothermal limits may be derived either by considering isothermal flow from first principles, or by applying the method of l'Hospital to the general forms of the ratios—other methods of limit evaluation giving anomalous results.

* *Trans. A.S.M.E.*, March, 1941.

THE THERMODYNAMICS OF HUMID AIR.

Fig. 2.

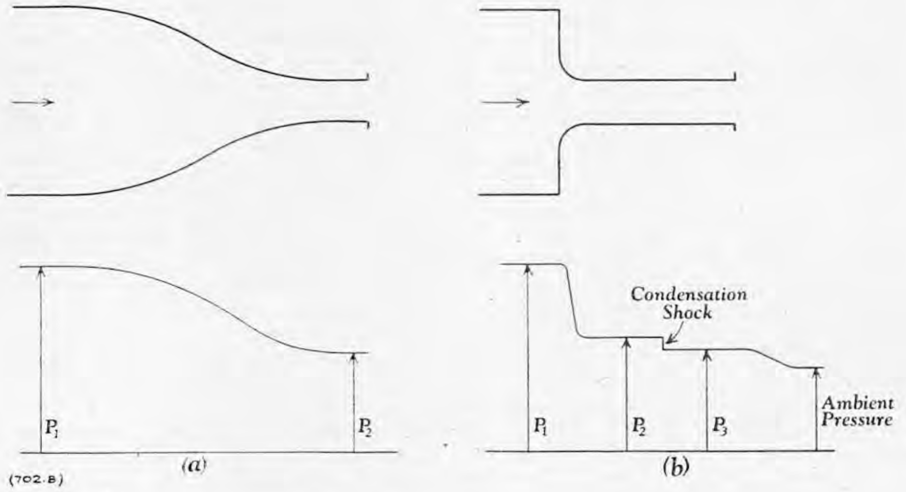


Fig. 3.

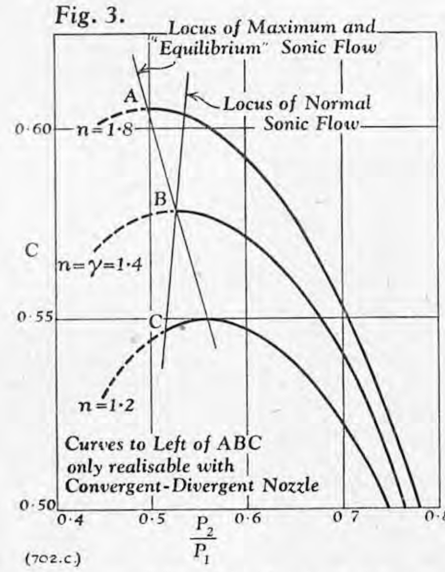
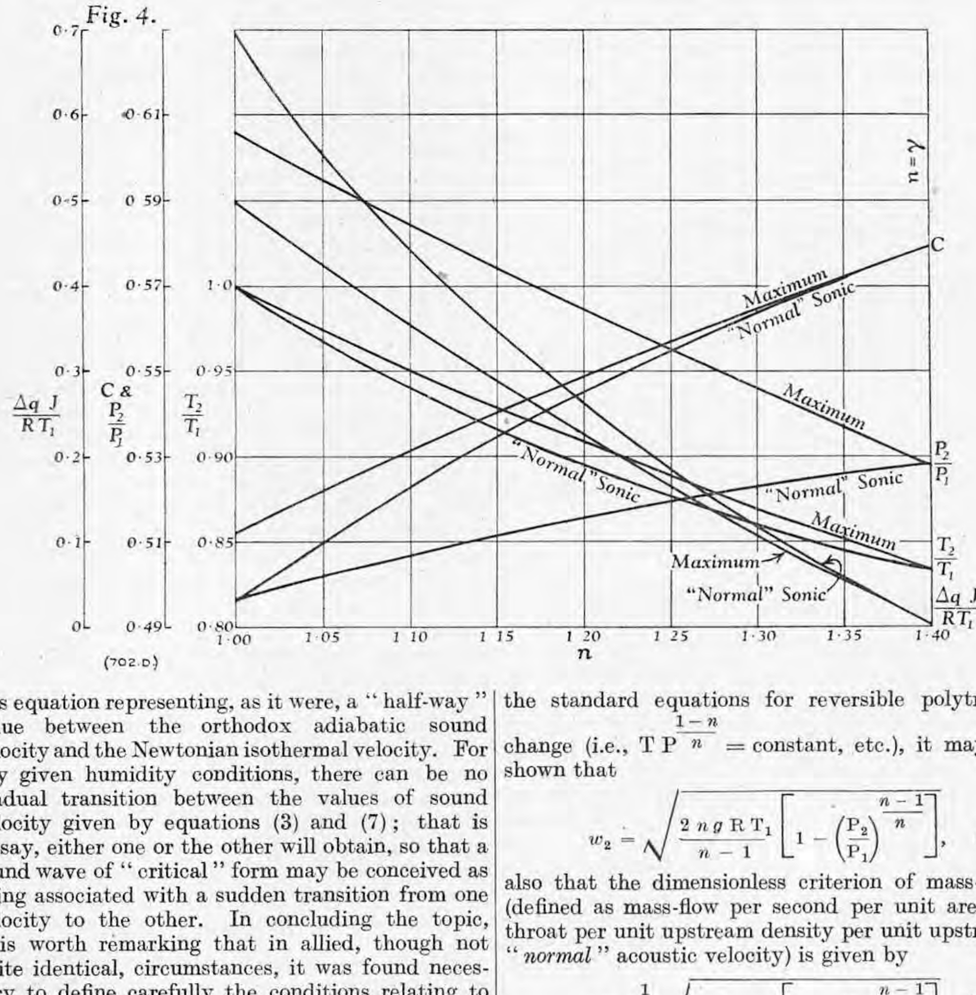


Fig. 4.



this equation representing, as it were, a "half-way" value between the orthodox adiabatic sound velocity and the Newtonian isothermal velocity. For any given humidity conditions, there can be no gradual transition between the values of sound velocity given by equations (3) and (7); that is to say, either one or the other will obtain, so that a sound wave of "critical" form may be conceived as being associated with a sudden transition from one velocity to the other. In concluding the topic, it is worth remarking that in allied, though not quite identical, circumstances, it was found necessary to define carefully the conditions relating to a specific acoustic velocity.*

Isentropic Steady Flow with Vapour Equilibrium.—The analysis of isentropic steady flow for initially saturated air is most conveniently performed in terms of the equivalent reversible polytropic flow of a perfect gas. Considering a convergent nozzle, as shown in Fig. 2*a*, the rate of convergence being slow enough to ensure vapour equilibrium in the actual case, suppose that Δq heat units per pound per second are supplied to the gas between sections 1 and 2. Neglecting velocity of approach, the energy equation may thus be written as:

$$\frac{\gamma}{\gamma - 1} \mathrm{R\,T}_1 = \frac{\gamma}{\gamma - 1} \mathrm{R\,T}_2 + \frac{w_2^2}{2g} - \Delta q\,\mathrm{J}, \quad (8)$$

where w_2 is the particle velocity at the throat, γ is regarded as equal to γ_a, and R is corrected for actual conditions 1 according to equation (1). Combining this equation with equation (6), and using the standard equations for reversible polytropic change (i.e., $\mathrm{T\,P}^{\frac{1-n}{n}} = \text{constant}$, etc.), it may be shown that

$$w_2 = \sqrt{\frac{2\,n\,g\,\mathrm{R\,T}_1}{n-1}\left[1 - \left(\frac{\mathrm{P}_2}{\mathrm{P}_1}\right)^{\frac{n-1}{n}}\right]}, \quad (9)$$

also that the dimensionless criterion of mass-flow (defined as mass-flow per second per unit area of throat per unit upstream density per unit upstream "*normal*" acoustic velocity) is given by

$$\mathrm{C} = \left(\frac{\mathrm{P}_2}{\mathrm{P}_1}\right)^{\frac{1}{n}} \sqrt{\frac{2\,n}{\gamma\,(n-1)}\left[1 - \left(\frac{\mathrm{P}_2}{\mathrm{P}_1}\right)^{\frac{n-1}{n}}\right]}. \quad (10)$$

Equations (9) and (10), duly modified by the condition that $n = \gamma$, will represent the case of isentropic flow of a perfect gas, for which it is a standard property that maximum flow (i.e., maximum C) and maximum throat velocity, w_2, are attained coincidently when the latter is sonic (i.e., when $w_2 = \sqrt{\gamma\,g\,\mathrm{R\,T}_2}$); the resulting characteristic ratios of temperature, pressure, etc., are quoted in the second column of Table I, opposite.

In what follows now, the basic physical argument is adopted that, for frictionless convergent flow, the particle velocity at the throat cannot exceed the prevailing local acoustic velocity. If, with reversible polytropic flow, the transition from the sub-sonic state to the sonic be made rapidly, then the oscillatory pressure wave in the throat, which is the actual means of such transition, will be of relatively steep profile, possessing, in the actual case of wet-saturated air, the "normal" propagation velocity. The condition that $w_2 = \sqrt{\gamma\,g\,\mathrm{R\,T}_2}$ will therefore still hold, the resulting characteristic ratios being as in the fourth column of Table I.

If, however, the transition from sub-sonic to sonic flow be made very gradually, then the oscillatory pressure wave will be of shallow profile, involving, in the actual case of wet-saturated air, the "equilibrium" value of propagation velocity. In these circumstances, "equilibrium" sonic flow will obtain, according to the condition that $w_2 = \sqrt{n\,g\,\mathrm{R\,T}_2}$. Independently of the prevailing type of sound velocity, maximum mass-flow will be represented by the condition that $\frac{d\mathrm{C}}{d\left(\frac{\mathrm{P}_2}{\mathrm{P}_1}\right)} = 0$, as applied to equation (10); the resulting characteristic ratios will, in fact, be found to be identical with those for "equilibrium" sonic flow; and these are given in the third column of Table I.

Taking the case of air, for which $\gamma = 1{\cdot}4$, Fig. 3 illustrates, on a dimensionless mass-versus-pressure basis, the distinction between the "equilibrium" and "normal" sonic states of flow; the case of $n > \gamma$ is, of course, purely imaginary so far as present problems are concerned. Finally, and again for air, Fig. 4 illustrates the variations of the ratios given in Table I, for the range $1 < n < \gamma$.

Adiabatic Steady Flow with Condensation Shock.—By contrast with the requisite condition for the last analysis, the expansion of humid air within a small convergent nozzle of normal proportions will take place very rapidly, so that supersaturation of the vapour content may be expected to occur just as in a steam nozzle. Hence, for any elementary mass, reckoning from the onset of expansion from pressure P_1, there will be a definite time lag prior to the abrupt reversion of the vapour to thermal equilibrium, this process creating what is usually called "condensation shock." In certain cases, it might be necessary to extend the parallel bore of the nozzle (assumed frictionless) to ensure that equilibrium was reached within its length, and not in the atmosphere beyond; for this reason the configuration is shown in its most general form in Fig. 2*b*.

The sudden release of latent heat will create a discontinuity in the flow within the throat, causing changes in pressure and particle velocity. If the assumption be retained that the air-vapour mixture behaves substantially as a perfect gas to which a sudden addition of heat, Δq units per pound per second, equivalent to the actual latent heat release, is made from an external source, it is clear that the problem resolves to that of the idealised parallel-sided combustion chamber.* This approach has been adopted by Lukasiewicz† and others for the

* "Compressibility Effects in Two-Phase Flow," by R. F. Tangren, C. H. Dodge and H. S. Seifert, *Jl. Applied Physics*, vol. 20, No. 7, page 637 (1949).

* See "On the Addition of Heat to a Gas Flowing in a Pipe at Sub-Sonic Speed," F. V. Foa and G. Rudinger, *Jl. of the Aero. Sc.*, February, 1949. An extensive bibliography is included.

† "Effects of Air Humidity in Supersonic Wind Tunnels," J. Lukasiewicz, *Proc. 7th Internat. Congress of App. Mech.*, 1948, vol. 2.

case of supersonic flow in a convergent-divergent nozzle.

The basic equations for continuity of energy, mass-flow, momentum and state are, respectively

$$\frac{\gamma}{\gamma - 1} \mathrm{R\,T}_1 = \frac{\gamma}{\gamma - 1} \mathrm{R\,T}_2 + \frac{w_2^2}{2\,g}$$
$$= \frac{\gamma}{\gamma - 1} \mathrm{R\,T}_3 + \frac{w_3^2}{2\,g} - \Delta q\,\mathrm{J}, \quad (11)$$

mass-flow per unit area of throat

$$= w_2\,\rho_2 = w_3\,\rho_3, \quad . \quad . \quad (12)$$

$$\mathrm{P}_3 - \mathrm{P}_2 = (\text{mass-flow per unit area}) \frac{(w_2 - w_3)}{g}, \quad (13)$$

$$\frac{\mathrm{P}_1}{\rho_1^\gamma} = \frac{\mathrm{P}_2}{\rho_2^\gamma} \neq \frac{\mathrm{P}_3}{\rho_3^\gamma}. \quad . \quad . \quad (14)$$

—the equality sequence of the last being broken due to the sudden gain of entropy at the effective plane of heating. The term "acoustic velocity" will now relate to the "normal" type, as given in equation (3), with R duly corrected according to the terms of equation (1).

For simplicity, only those developments of the above equations will be quoted which relate to sonic flow, i.e., to the condition of $w_3 = \sqrt{\gamma\,g\,\mathrm{R\,T}_3}$. In drawing up a method of calculation, it is convenient to work in terms of Mach number $\left(\text{defined as } \frac{\text{particle velocity}}{\text{local acoustic velocity}}\right)$; the equations quoted hereafter incorporate the substitution $\gamma = 1 \cdot 4$, as for air. Procedure is thus as follows:

(1) For the given upstream conditions 1—and there is no longer any special advantage in assuming these to include 100 per cent. relative humidity—the ambient pressure being low enough to ensure that the mach number M_3 is unity, assume a value for M_2 slightly less than unity.

(2) Hence calculate $\Delta\,q$ according to

$$\Delta q = \left[\frac{(5 + 7\,\mathrm{M}_2^2)^2}{24\,\mathrm{M}_2^2\,(5 + \mathrm{M}_2^2)} - 1\right] \frac{5\,a_1^2}{2\,\mathrm{J}}. \quad . \quad (15)$$

(3) The amount of heat (as latent heat) released per pound of H_2O per second under actual conditions will thus be:

$$\Delta_q' = \frac{\Delta q\,\epsilon}{1 + \epsilon}. \quad . \quad . \quad . \quad (16)$$

(4) For the above value of M_2, calculate also

$$\mathrm{T}_3 = \mathrm{T}_1 \sqrt{\frac{5}{5 + \mathrm{M}_2^2}} \left(\frac{5 + 7\,\mathrm{M}_2^2}{12\,\mathrm{M}_2}\right). \quad . \quad (17)$$

and

$$\mathrm{P}_3 = \mathrm{P}_1 \left(\frac{5}{5 + \mathrm{M}_2^2}\right)^{\frac{7}{2}} \left(\frac{5 + 7\,\mathrm{M}_2^2}{12}\right). \quad . \quad (18)$$

(5) For the above value of T_3, read off from steam tables the values of L_3 (latent heat per pound of H_2O), P_{w3} (saturation pressure) and ρ_{w3}' (dry saturation density).

(6) Hence determine the dryness fraction x_3 according to

$$x_3 = 1 - \frac{\Delta_q'}{\mathrm{L}_3}, \quad . \quad . \quad . \quad (19)$$

also

$$\mathrm{P}_{a3} = \mathrm{P}_3 - \mathrm{P}_{w3}, \quad . \quad . \quad (20)$$

so that

$$\rho_{a3} = \frac{\mathrm{P}_{a3}}{\mathrm{R\,T}_3}. \quad . \quad . \quad . \quad (21)$$

(7) Finally, calculate the corresponding mass humidity, ϵ, according to

$$\epsilon = \frac{\rho_{w3}'}{x_3\,\rho_{a3}} \quad . \quad . \quad . \quad (22)$$

—which, if M_2 is correctly chosen, will check with the value initially adopted for upstream conditions.

It is difficult to suggest any simplification to the above procedure, and successive values of M_2 must therefore be chosen until the final check is satisfied. When this is achieved, the value of P_2 may be found according to

$$\mathrm{P}_2 = \mathrm{P}_1 \left(\frac{5}{5 + \mathrm{M}_2^2}\right)^{\frac{7}{2}}, \quad . \quad . \quad (23)$$

so that the pressure drop $(P_2 - P_3)$ within the throat of the nozzle may be estimated.

Numerical Examples.—Assuming the same initial conditions as for Fig. 1, the four possible theoretical states of sonic flow are summarised in Table II, comprising "equilibrium" and "normal" sonic flows for the quasi-polytropic condition; sonic flow with condensation shock; and sonic flow calculated as for dry air. Inspection reveals that the mass-flow calculated on the last basis is 6·6 per cent. and 7·2 per cent. in excess of those for the first and second cases respectively, although the excess relative to the third is negligible. Equally notable are the variations in pressure and temperature between the four cases, while, with condensation shock, the disturbance within the throat is particularly striking, involving a pressure drop of over 1 lb. per square inch and a temperature rise of nearly 36 deg. F. Such considerations are of special interest in relation to flow measurement, inasmuch as a sonic-flow nozzle is frequently used for such a purpose. While making the cautionary statement that ". . . gases with substantial moisture content cannot, without special information, be measured below the critical pressure ratio . . ." the British Standard Code on Flow Measurement (B.S. 1042 : 1943) does not actually develop the theme in any way, and it has thus been one of the objects of this article to suggest possible theories as to what such "special information" may involve and lead to.

Since the instrumentation of a small sonic-flow nozzle is extremely difficult (for example, the introduction of a pressure search-tube, even of the axial type, can seriously affect the very phenomena which it sets out to measure), reliable experimental tests of the theoretical topics discussed above can only be done if sufficient compressed air is available for reasonably large-bore ducts.

TABLE II.—*Comparative States of Sonic Flow.*

Upstream Conditions: P_1 = 30 lb. per square inch abs. T_1 = 550 deg. F. abs. 100 per cent. relative humidity. R for dry air = 53·2; R (corrected) = 53·67.

—	Reversible Polytropic Flow. "Equilibrium" Sonic and Maximum Flow.	Reversible Polytropic Flow. "Normal" Sonic Flow.	Condensation Shock.	Dry Air.
n	1·182	1·186	—	$n = \gamma = 1 \cdot 4$
P_2, lb. per sq. in. abs. . .	17·04	15·47	16·89	15·85
P_3, lb. per sq. in. abs. . .	(= P_2)	(= P_2)	15·82	(= P_2)
T_2, deg. F. abs.	504·1	495·5	466·8	458·3
T_3, deg. F. abs.	(= T_2)	(= T_2)	502·7	(= T_2)
Mass-flow in lb. per sec. per sq. in. . .	0·6390	0·6356	0·6796	0·6814

The author's own experimental work, in the Mechanical Engineering Department of the University of Birmingham, has perforce been done on a small scale, with only ⅜-in. bore nozzles, and although striking humidity phenomena were noted,* the difficulties of instrumentation prevented any completely satisfactory conclusions being reached. He would mention, however, a graph published in ENGINEERING in 1950,† which showed that, for sonic flow with constant upstream pressure, the measured throat pressure decreased as upstream relative humidity decreased, finally and abruptly reaching a stable value as soon as it was no longer possible—such was the inference—for latent heat to be rejected. Inasmuch as the associated variation in mass-flow criterion (C) was found to be negligible, these characteristics could be explained adequately by the theory of condensation shock, assuming that the throat pressure-tapping was recording the pressure P_2 as distinct from P_3.

The author also carried out tests with slowly-convergent nozzles after the pattern of Fig. 2*a*, but was unable to record any phenomena that could be described in terms of the "quasi-polytropic" flow theory. However, for small-bore nozzles, it was worthless to employ extremely slow rates of convergence in view of the frictional reheat effects that could only obliterate the effects under pursuit; no definite conclusions can therefore be offered. Nevertheless, the "quasi-polytropic" state of flow undoubtedly remains a technical possibility, and it is suggested that such a state might well be realised in large-scale sonic ducts, particularly in the region of the flow-axis, where the disturbing effects of wall friction would be least.

* See communication by B. N. Cole on "The Low Pressure Air-Driven Air Ejector," by L. J. Kastner and J. R. Spooner, *Proc. I. Mech. E.*, vol. 162, No. 2 (1950).

† "Recent Developments in Gas Dynamics," by B. N. Cole, ENGINEERING, vol. 170, page 277 (1950).

THE BRITISH INDUSTRIES FAIR AT BIRMINGHAM—III.

(*Continued from page* 579.)

ANOTHER selection of exhibits which have been on show during the past fortnight at the Castle Bromwich section of the British Industries Fair is covered in this, the third, article. The Fair closes, in London and Birmingham, to-day.

25-TON INCLINABLE GEARED PRESS.

The main products of Messrs. Turner Brothers (Birmingham), Limited, Cliveland-street, Birmingham, 19, are press tools, jigs and fixtures, and the exhibits on their stand include a large selection of pressings, die castings and plastic articles made from tools which they have supplied. Their exhibits also include representative examples from their range of inclinable power presses and one of these, namely, the model G425, is illustrated in Fig. 54, opposite. This press is capable of exerting a pressure of 25 tons at the bottom of the stroke and is one of a series of three, the other two models exerting pressures of 20 tons and 30 tons, respectively. The body of the machine is built up from solid-steel side frames and the entire assembly is of screwed and dowelled construction, there being a complete absence of welding. A high-tensile steel crankshaft is fitted and this is connected to the flywheel by a sliding-key type of clutch. The ram has a stroke of 4 in. and the design is such that it does not recede into the slide on the return stroke, thereby enabling full use to be made of the tool space. A single-stroke mechanism prevents the occurrence of repeat strokes when the treadle is held in the depressed position, but the machine can easily be changed to continuous running when required. The standard machine is provided with a scotch plate which prevents accidental depression of the treadle but specially-designed interlock guards which meet the requirements of H.M. inspectors of factories can be fitted. These presses can also be supplied with the manufacturer's standard roll feeds and adjustable-stroke mechanisms, the latter being of robust construction with the adjustment positions clearly marked. Screw-jack inclining gear is fitted and the press can be fixed rigidly either in the upright position or inclined at 12 deg. 30 minutes or 25 deg., no adjustment to the treadle mechanism being necessary when in the inclined positions. The press is driven by a 3-h.p. motor, the drive being transmitted through multiple V-belts, as shown in the illustration. All presses, it should be added, are made from jigs, so that where batteries of these machines are installed tools can be changed over without alteration. Other presses on the stand of Messrs. Turner Brothers include their TBG 315 geared inclinable press and their TB 26 machine, also inclinable, the former having a capacity of 15 tons and the latter a capacity of 6 tons.

60-TON PRESS BRAKE.

One of the exhibits on the stand of the Bronx Engineering Company, Limited, Lye, Worcestershire, is the 60-ton press brake illustrated in Fig. 55. This machine is of all-welded steel construction and has a capacity of 8 ft. by ½ in. thick mild-steel plate. It is driven by a 5-h.p. motor, the drive being taken by V belts to a pulley integral with the flywheel, clutch and brake assembly fitted to the first-motion shaft, which is carried by ball and roller bearings. The drive is transmitted to the second-motion shaft, also supported by ball and roller bearings, by helical gearing, and double-reduction spur gearing at each end of the frame takes the drive to the twin eccentric shafts. These are machined from solid-steel forgings and are carried in the crown of the machine by large phosphor-bronze bearings. Cast-iron pitman arms fitted with phosphor-bronze worm wheels and high-tensile spherically-ended screws are used to transfer the power from the twin eccentric shafts to the top beam. The screws and their associated worm-wheels are, of course, provided for adjustment of the top beam, and to render this operation easier the worm wheels are power driven by means of a 2-h.p. electric motor. This is mounted on a bracket

EXHIBITS AT THE BRITISH INDUSTRIES FAIR, BIRMINGHAM.

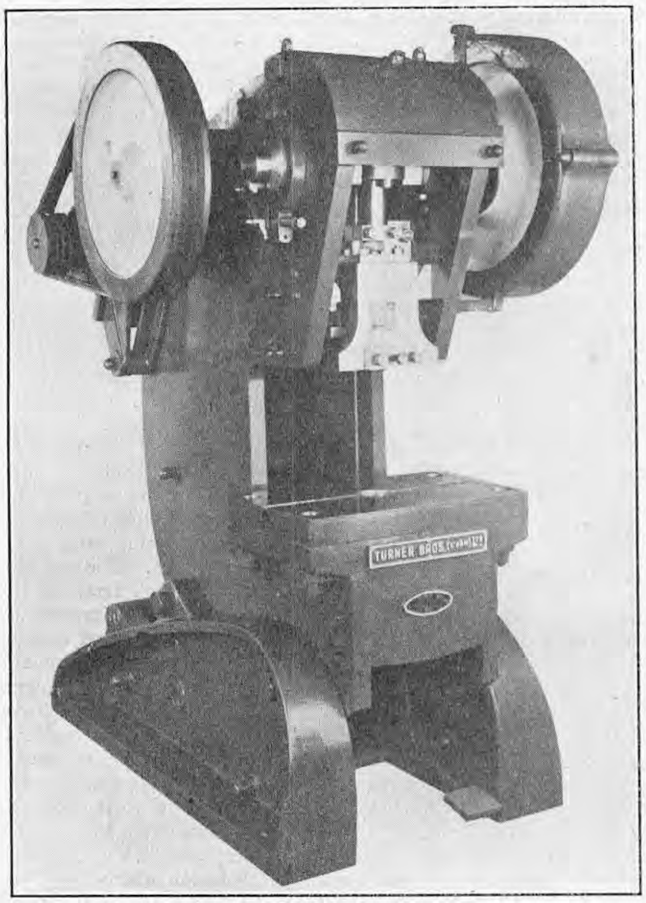


FIG. 54. 25-TON INCLINABLE PRESS; TURNER BROTHERS (BIRMINGHAM), LTD.

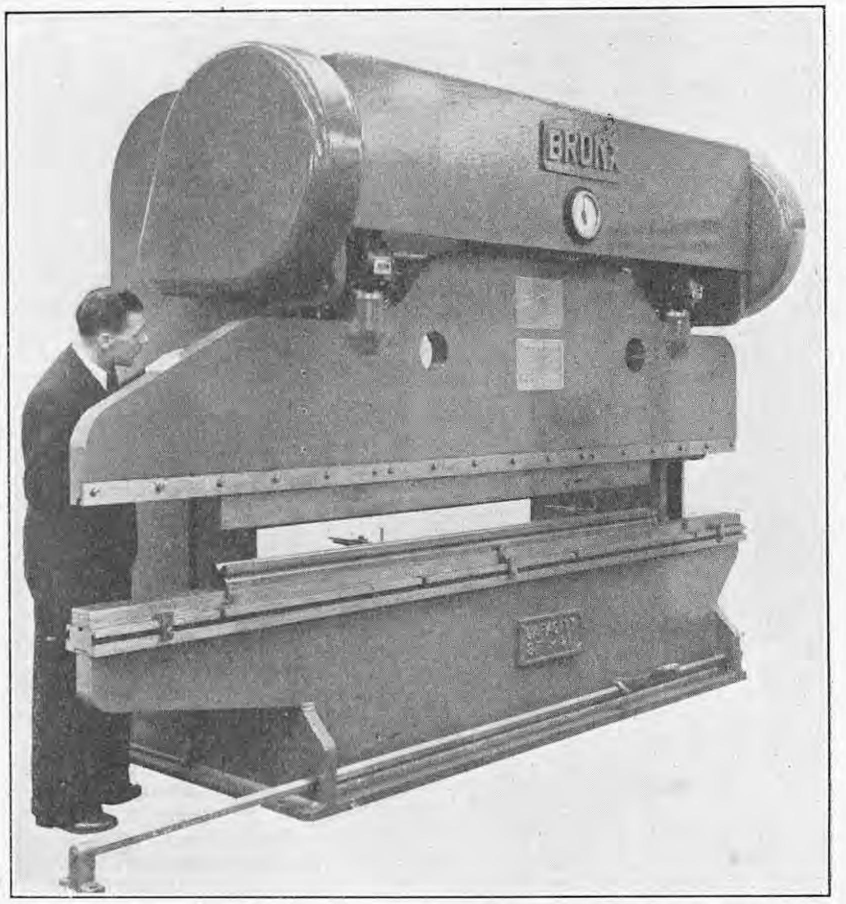


FIG. 55. 60-TON PRESS BRAKE; BRONX ENGINEERING CO., LTD.

integral with the left-hand connecting rod, safety limit switches being provided to prevent over-run of the top beam when being moved for tool adjustment. A ram-stop mechanism is fitted so that the press can be used for single-stroking, coming to rest each time automatically at top dead centre. The operator has good control over the top beam, the mechanism being arranged so that inching can be carried out at any position of the cycle. Bottom dead centre is indicated by a large dial-type indicator let into the crown of the machine. As previously indicated, the machine is capable of accepting work up to a width of 8 ft., the distance between the columns being 8 ft. 4 in. The stroke of the top beam is 3 in. and the maximum speed of working 30 strokes per minute. The gap in the columns is 12 in. and the overall length of the beam is 10 ft.

SHEARING AND CROPPING MACHINE.

The exhibits on the stand of Messrs. F. J. Edwards, Limited, 359-361, Euston-road, London, N.W.1, include a number of metal-working machines not previously shown at any exhibition. One of these, namely, the Besco Model G.A.7, shearing, section-cropping and notching machine is illustrated in Fig. 56, on Plate XXX. This machine has been designed to meet the needs of the constructional engineer and has been designed so that it can be transported easily to building sites. It is of strong construction, the body being built up from heavy-section steel castings which are bolted together. The shearing mechanism is operated by a hand lever arranged so that the pull is direct for light work and through a system of gearing, with a ratchet action for maintaining pressure, for heavier work, the change-over from one method to the other merely requiring the disengagement of a plunger and engagement of two pawls. Alloy-steel blades capable of splitting mild-steel plates up to a thickness of $\frac{1}{2}$ in. are fitted. An adjustable hold-down clamp comes into operation in advance of the blades to ensure that the material is held securely during the actual cutting operation. The notching head is arranged above the plate shear and is suitable for notching angles and T-sections up to a capacity of 2 in. by 2 in. by $\frac{1}{4}$ in. at one stroke. Four notching tools designed to cut rectangular notches are supplied as standard equipment, but triangular-shaped tiols for forming mitred notches in plates, angles, T-sections, etc., are available. The flanges of angles and T-sections may also be notched in a series of cuts taken at the end of the shearing blades, the maximum thickness that may be dealt with in this manner being $\frac{9}{32}$ in. The angle and T-section cutting mechanism is located centrally in the frame and consists of two sets of blades, one for gripping the material and the other for cutting. Gripping of the material takes place automatically on the downward movement of the ram and the machine is capable of cutting sections up to $2\frac{3}{4}$ in. by $2\frac{3}{4}$ in. by $\frac{3}{8}$ in. at right angles and mitring sections up to 2 in. by 2 in. by $\frac{1}{4}$ in. The cropping device for rounds and square sections is situated at the rear end of the machine. Suitable "slip-in" blades are supplied as standard equipment and the machine will crop round bars up to a diameter of $1\frac{3}{8}$ in. or square bars up to $1\frac{1}{4}$ in. Other sections, such as channels and joists, may also be cut, provided blades having suitable apertures are installed. An adjustable hold-down is provided, but the blades are not secured in any way. They are merely slipped into position in their holders and the one set of blades serves to cut both round and square sections, being reversed when the duty is altered.

PRESS BRAKE.

The press brake illustrated in Fig. 58, on Plate XXX, is also being shown by Messrs. F. J. Edwards for the first time. Known as the Besco Model 60 Mark II, this machine is intended for fabricating shapes in mild-steel sheet up to a capacity of 48 in. by 12 gauge or 60 in. by 14 gauge. It is capable of carrying out bending and forming operations, including corrugating, beading, wiring and seaming, and can also be used for punching, blanking, notching and piercing or embossing, pressing, straightening and shearing. All these operations can be performed individually, progressively or in multiples by using single or combination dies and ancillary attachments. In general, the design of the machine follows that of its predecessor, namely, the Besco No. 60 press brake, but it incorporates certain important modifications based on experience. The main frame, which is of welded steel construction, is provided with a number of bracing bars, which are adjusted during assembly to eliminate deflections at maximum loadings. Spirit-level strips have been added, and the side frames, which are open at the ends to enable the work to be passed through, have a gap of 6 in. The bed now forms an integral part of the main frame and the ram adjustment has been altered to $2\frac{1}{4}$ in. The ram operates between bronze-lined V-shaped guides and adjustment is effected through threaded pitman arms in the usual manner, the mechanism being actuated by a detachable cranked handle fitted to the right-hand side of the machine. The machine is driven by a 2-h.p. electric motor, the transmission group consisting of multiple V-belts between the motor and flywheel and gearing between the flywheel and the main crankshaft. A multi-plate dry-type clutch is used and this is controlled by a treadle, an automatic brake being fitted to ensure that the beam stops immediately the treadle is released. The bed has an overall length of 5 ft. and the maximum distance between the top beam and the bed is $9\frac{3}{4}$ in. The maximum stroke of the top beam is 2 in., and the maximum exerted pressure 17 tons.

DOWEL AND END-FORMING MACHINE.

Messrs. F. J. Edwards are also showing a selection of woodworking machinery, those on view including the dowel and end-forming machine illustrated in Fig. 57, on Plate XXX. Known as the Besco Valjoh, this machine has been designed for the manufacture of such items as dowels, rollers, cricket stumps, flag-staffs and other round articles from $\frac{1}{4}$ in. to $1\frac{3}{4}$ in. diameter. It is fitted with self-feeding gear and a self-aligning headstock, both being driven by a 5-h.p. motor. Safety guards are fitted throughout and the feed pressure and timber release are controlled by small hand levers. The cutter boxes are easily interchanged and it is equally simple to fit a Morse-taper boring attachment.

Turret Saw Bench.

The woodworking machinery being shown by Messrs. F. J. Edwards, Limited, also includes the 24-in. rise-and-fall turret saw bench illustrated in Fig. 59, on Plate XXX. This machine incorporates several new developments and is capable of cross cutting, ripping, grooving, planing, mortising, rebating, moulding and boring. The base may be considered as consisting of two parts, namely, a cast-iron plinth and, superimposed on this, a heavy turret-shaped body member designed so that it can be swivelled through 360 deg. on the plinth. This arrangement enables the machine to be swung round and set so that obstructions such as stanchions, etc., can be avoided when cutting exceptionally long baulks of timber, the machine being locked in the required position by a clamp fitted to the body. The normal working area of the sawing table has a length of 38 in. and a width of 24 in. while the height from the floor is 30 in. It has a machine-cut groove running the full length to permit fine setting of the mitre fence and work stop, and is provided with an extending rip fence. An auxiliary table can be clamped to the side of the main table when cutting wide pieces of timber, the auxiliary table being supported on rubber castors so that it can turn easily with the sawing table. A two-speed rise-and-fall spindle mounted in dust-proof ball bearings is provided, the higher speed of 3,000 r.p.m. being used with saw blades of 10-in., 12-in. and 14-in. diameters and the lower speed of 1,700 r.p.m. for saws from 16 in. to 24 in. in diameter. The rise-and-fall movement of the spindle is obtained by means of a small hand-wheel, the mechanism being designed so that the tension in the driving belts remains constant regardless of the height of working. The maximum depth of cut with a 24-in. diameter blade is 9¼ in. and grooves can be cut to this depth. A boring attachment is fitted to the end of the rise-and-fall spindle; this consists of a chuck designed to accept boring bits up to a diameter of ½ in., which works in conjunction with a separate rise-and-fall table, the height of which is adjusted by a separate hand-wheel.

Electrical Thermal-Storage Plant.

The major exhibit on the stand of G.W.B. Electric Furnaces, Limited, Dibdale Works, Dudley, Worcestershire, is a complete thermal-storage plant of the type illustrated in Fig. 60, on Plate XXX. It comprises a 200-kW Autolec water heater, storage tanks, auxiliary pumps, control valves and control panel, and is suitable for heating buildings of various types. It is designed so that the electrodes are placed inside the boiler shell and the water used as a resistance for passing the current from one electrode to another. This arrangement, it is claimed, gives an efficiency of 98 per cent., the 2 per cent. losses being accounted for by radiation and convection. There are two separate controls, a master rating control and a temperature control. The rating is governed by shrouds which move over the electrodes to expose the lengths necessary to give the desired output. Normally, the position of the shrouds relative to the electrodes is adjusted manually by turning a handle at the top of the boiler, but on the automatic type of unit this function is carried out by hydraulic means, the shrouds automatically being brought to the correct position when the master-rating control is moved to the required setting. The temperature control consists of a two-position rheostat, one position being set 5 deg. above, and the other 5 deg. below, the required temperature. These automatically lower the shrouds when the temperature tends to rise above the requirements and raises them when the temperature falls.

Reduction Gears.

Many different types of reduction-gear units are being shown by Messrs. David Brown and Sons (Huddersfield), Limited, Meltham, Yorkshire. These include a hypoid axle-drive unit for tramway-cars and a 24-in. turbine reduction gear unit. The hypoid axle-drive unit is illustrated in Fig. 61, on Plate XXX. It consists of hypoid gears of 2·75 diametral pitch and 2½-in. face width with the pinion offset by 1¾ in. Both the pinion and crownwheel are mounted on taper-roller bearings and the unit has been designed for a life of approximately 625,000 miles. It is of the type supplied for Rotterdam's new fleet of tramway cars and, although slightly smaller, is generally similar to the axle drives which Messrs. David Brown and Sons have been commissioned recently to supply for the Toronto Transport Commission's new fleet of subway cars. The 24-in. turbine reduction-gear unit is illustrated in Fig. 62, on Plate XXXI. It is being shown with the top cover removed so that the gear-tooth finish obtained by the shaving process, and the independent bearing caps, can be displayed. This latter feature is now standard for all such David Brown units of 17-in. centres and upwards. The unit illustrated has a reduction ratio of 11 to 1 and a weight of approximately 4½ tons and has been designed for use in a generating set having a rating of 2,000 kW. Other transmission assemblies being shown by Messrs. David Brown and Sons include a number of Radicon worm-reduction units, rear-axle spiral-bevel, hypoid and worm drives and a spiral-bevel unit capable of transmitting 15 h.p. at 500 r.p.m.

Die-Casting Machinery.

Messrs. Alfred Herbert, Limited, Coventry, are exhibiting a number of die-casting and plastic-moulding machines and, on a separate stand, a wide range of measuring equipments. The die-casting machines on view include the IMP-96 impact machine manufactured by Die Casting Machine Tools, Limited, and the Herbert-Reed-Prentice 1½ G machine. The former is illustrated in Fig. 64, on Plate XXXI. It has a casting capacity of 12 oz. and is operated by compressed air at a pressure of 80 lb. per square inch, consuming only 0·55 cub. ft. of free air each cycle of operations; it is only necessary, therefore, to install a small compressor in a works where compressed air is not already available. The machine is fitted with pilot-operated impact-type injection equipment, the operating mechanism incorporating a safety-interlock valve arranged so that metal injection cannot take place before the dies are closed completely. A new design of double-toggle air-operated die unit is incorporated, the resultant die-locking pressure being 12 tons. The die plates measure 9 in. by 6 in. by 1½ in. thick and the mould can be cut either directly in these or in steel pads fitted to the plates; the maximum area of casting is 12 sq. in. The fixed die plate is water-cooled to counteract the heat radiated from the pot, and injector pins are arranged in the die which, on the opening stroke of the toggle lever, are pushed forward to eject the casting. A 1¼-in. diameter plunger is fitted as standard and the resulting pressure on the metal when using compressed air at 80 lb. per square inch is 1,620 lb.

The Reed Prentice 1½ G machine is illustrated in Fig. 63, on Plate XXXI. It is a cold-chamber machine designed for producing die-castings from aluminium, brass and magnesium alloys. The machine is operated hydraulically and is arranged for both manual and semi-automatic operation. For semi-automatic action the dies are closed by operating the push-buttons on the lower control panel, after which the operator ladles in the metal and steps on the foot control to move the plunger forward. The remainder of the cycle is automatic and is controlled by an adjustable electrical timing device, the plunger remaining forward until the dies open, when it travels an additional 3½ in. to eject the "slug" before returning. When the machine is operated manually, the four push-buttons on the upper control panel are used, the two left-hand buttons opening and closing the dies and the other two buttons actuating the plunger. To eliminate any possibility of the metal being shot into the dies before the die-plates are closed securely, the machine is electrically interlocked and the design is such that the castings are ejected automatically at the end of each cycle. The plunger, which is water-cooled, is fitted with a Nitralloy tip and is joined to the piston rod through a self-aligning coupling. A 2-in. diameter plunger is fitted as standard but other rams from 1½ in. in diameter, and increasing by increments of ⅛ in. to a maximum of 2½ in. in diameter, are available. When fitted with the standard plunger, the capacity is 23½ cub. in., the corresponding capacities for the 1½-in. and 2½-in. plunger being 13 cub. in. and 37 cub. in., respectively. The total plunger pressure available is 28,000 lb. and the resultant pressure on the metal is 9,000 lb. per square inch with the standard plunger, 16,000 lb. per square inch with the 1½-in. diameter plunger, and 5,700 lb. per square inch with the 2½-in. diameter plunger. The die plates are 29 in. square, the die movement 10 in., and the locking pressure 130 tons. The time to close the dies is 3 seconds and the cycle time 15 seconds.

Bore Profilometer.

The measuring instruments being shown by Messrs. Alfred Herbert, Limited, include the bore profilometer illustrated in Fig. 65, on Plate XXXI. This instrument was produced by Messrs. Hilger and Watts, Limited, Camberwell, London, and is intended primarily for the inspection of the bore profiles of wiredrawing dies and to detect and measure the deformities arising from use. The inspection is carried out by means of a pivoted probe to which a mirror is attached so that any angular displacement of the probe can be detected by an auto-collimator. The instrument is of strong construction, consisting of a cast-iron base provided with rigid head and tail stocks. The component to be checked is held by a chuck arranged in the headstock so that it can be rotated, a simple dividing head enabling the chuck to be located accurately at 6 deg. intervals. Two hardened-steel rods form the ways for the measuring carriage, the carriage being traversed horizontally by a 1-in. micrometer screw. Contact between the carriage and micrometer spindle is maintained by a light spring and the carriage is set carefully during manufacture to ensure that its motion is parallel to the axis of the chuck. A vertical spindle supported by the carriage has two degrees of freedom, namely, a vertical sliding motion and a limited rotation about the vertical axis. The vertical sliding motion is imparted to the spindle by a micrometer acting through a lever, the micrometer being located horizontally within the bed. A mirror is provided to assist in reading this micrometer and, for convenience of handling, the spindles of both micrometers are extended so that they can be operated by two external knurled drums. These two drums can be seen in the illustration just behind the tailstock.

The probe unit is fitted to the top of the vertical spindle, the probe being carried by the end nearer the chuck and the mirror by the opposite end. The probe is free to move about the horizontal axis at right angles to the axis of the chuck, and a counterweight is provided so that it can be used to bias the probe towards either the top or the bottom of the bore as required. The counterweight is placed on a small hook adjacent to the mirror and is shown in use in the illustration, the probe, as a result, being biased towards the top of the bore. When the counterweight is removed, the weight of the probe and its holder causes the unit to be biased towards the bottom of the bore. The auto-collimator is supported by the tailstock and is provided with a reflector set at 45 deg., which receives the reflections from the small mirror at the rear of the probe unit. When the instrument is used, the probe is inserted in the bore of the die and the auto-collimator adjusted until the image received from the reflector on the probe unit appears in the field of view of the eyepiece. The vertical spindle which supports the probe unit is then rotated about its axis until the probe lies on the lowest part of the bore, this condition being indicated by a reversal in the direction of movement of the image in the auto-collimator.

After the probe has been located in the correct position, the carriage is traversed horizontally by means of the micrometer screw; this brings the probe on to a different portion of the profile and if there is any variation of the diameter the reflector on the probe unit is tilted. If tilting occurs, then the other micrometer is adjusted until the reflected image from the probe is restored to its original position, after which the reading of the micrometer is noted. This process is repeated as required and values of the "vertical" and horizontal micrometers are plotted to obtain the profile.

(*To be continued.*)

EXHIBITS AT THE BRITISH INDUSTRIES FAIR, BIRMINGHAM.

(*For Description, see Page* 612.)

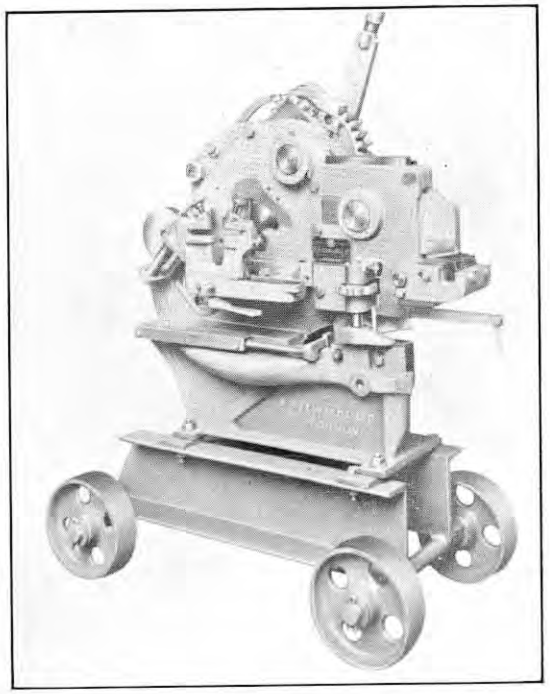


FIG. 56. SHEARING AND CROPPING MACHINE; F. J. EDWARDS, LTD.

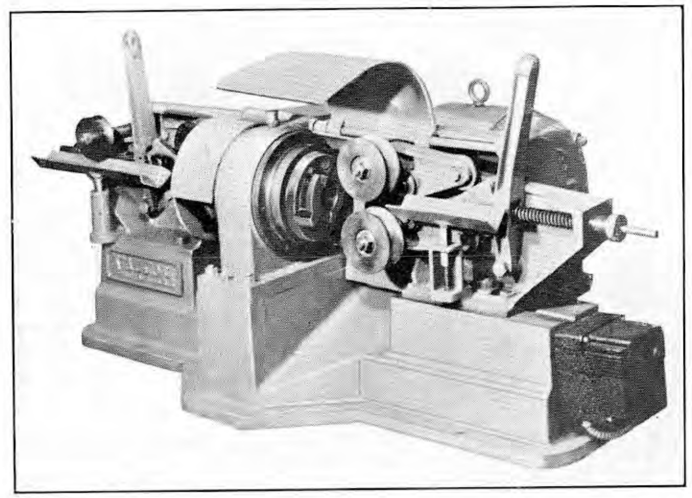


FIG. 57. DOWEL AND END-FORMING MACHINE; F. J. EDWARDS, LTD.

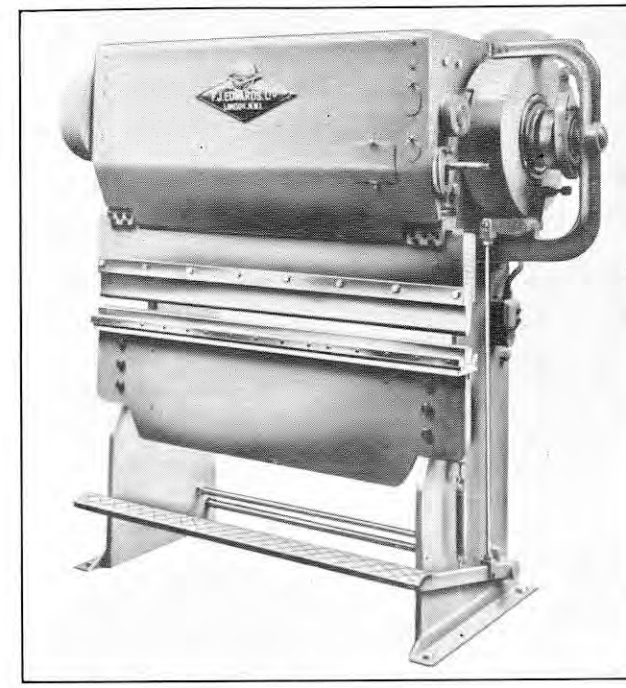


FIG. 58. 17-TON PRESS BRAKE; F. J. EDWARDS, LTD.

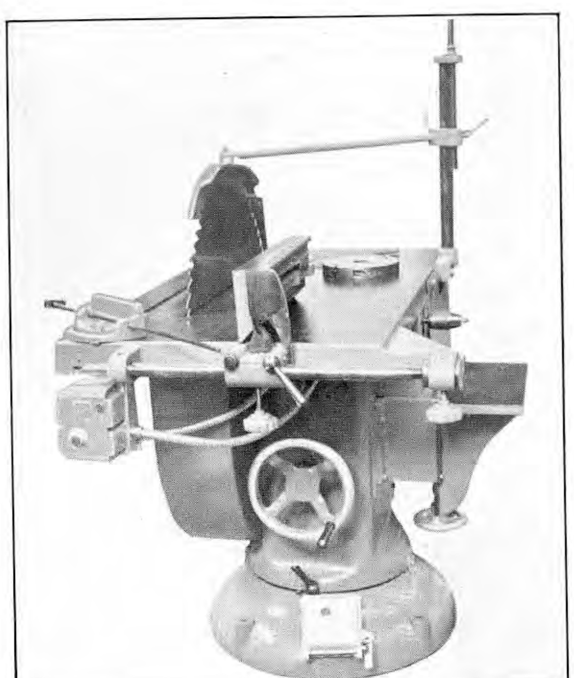


FIG. 59. TURRET SAW BENCH; F. J. EDWARDS, LTD.

FIG. 60. ELECTRICAL THERMAL-STORAGE PLANT; G.W.B. ELECTRIC FURNACES, LTD.

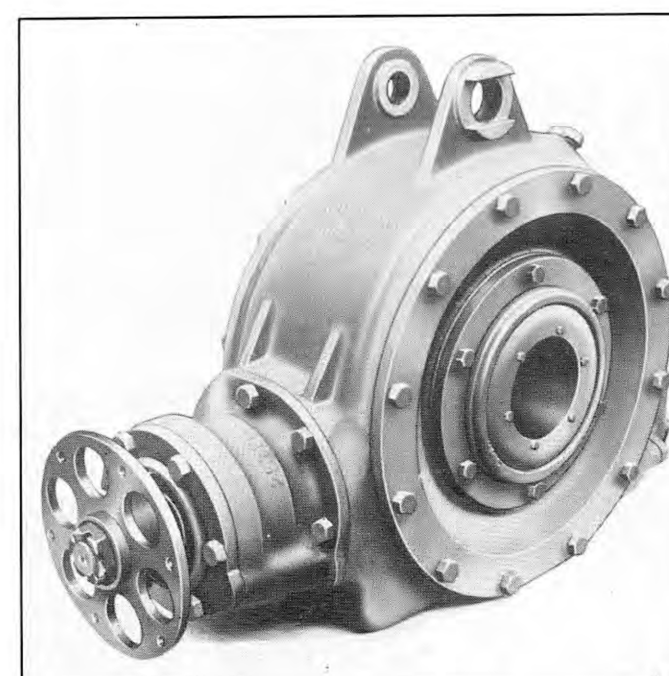


FIG. 61. HYPOID AXLE-DRIVE UNIT; DAVID BROWN & SONS (HUDDERSFIELD), LTD.

EXHIBITS AT THE BRITISH INDUSTRIES FAIR, BIRMINGHAM.

(*For Description, see Page* 612.)

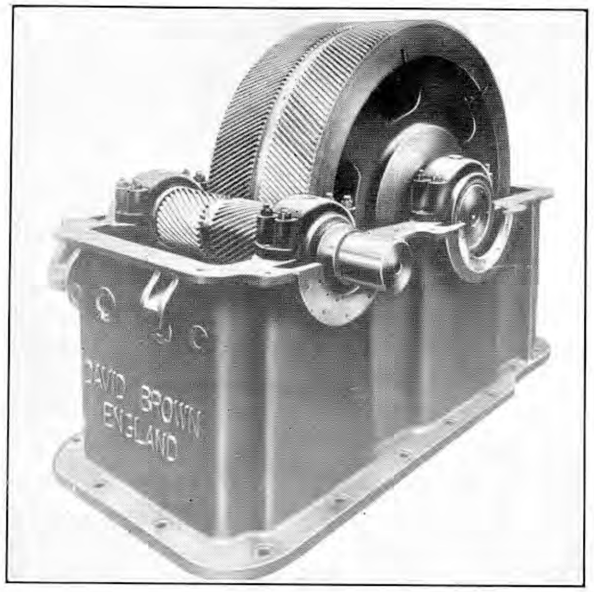


Fig. 62. Turbine Reduction Gear; David Brown & Sons (Huddersfield), Ltd.

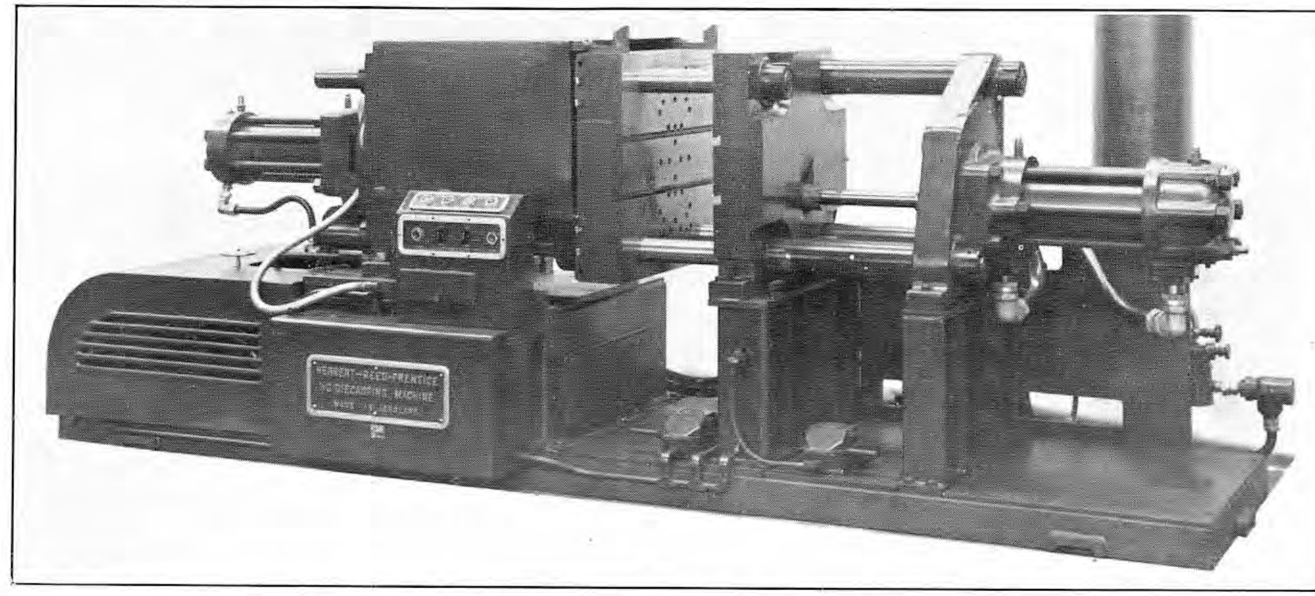


Fig. 63. Herbert-Reed-Prentice Die-Casting Machine; Alfred Herbert, Ltd.

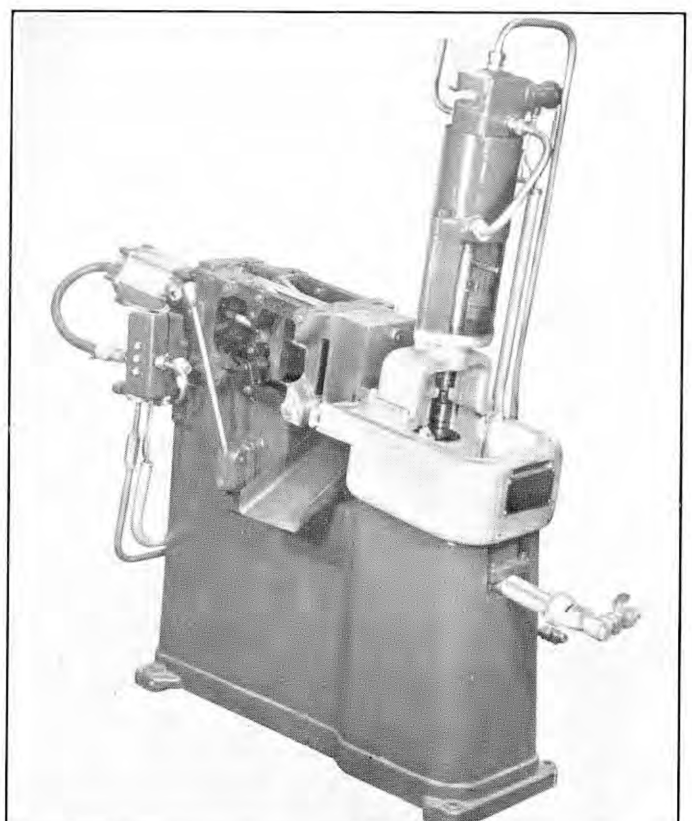


Fig. 64. IMP-96 Die-Casting Machine; Alfred Herbert, Ltd.

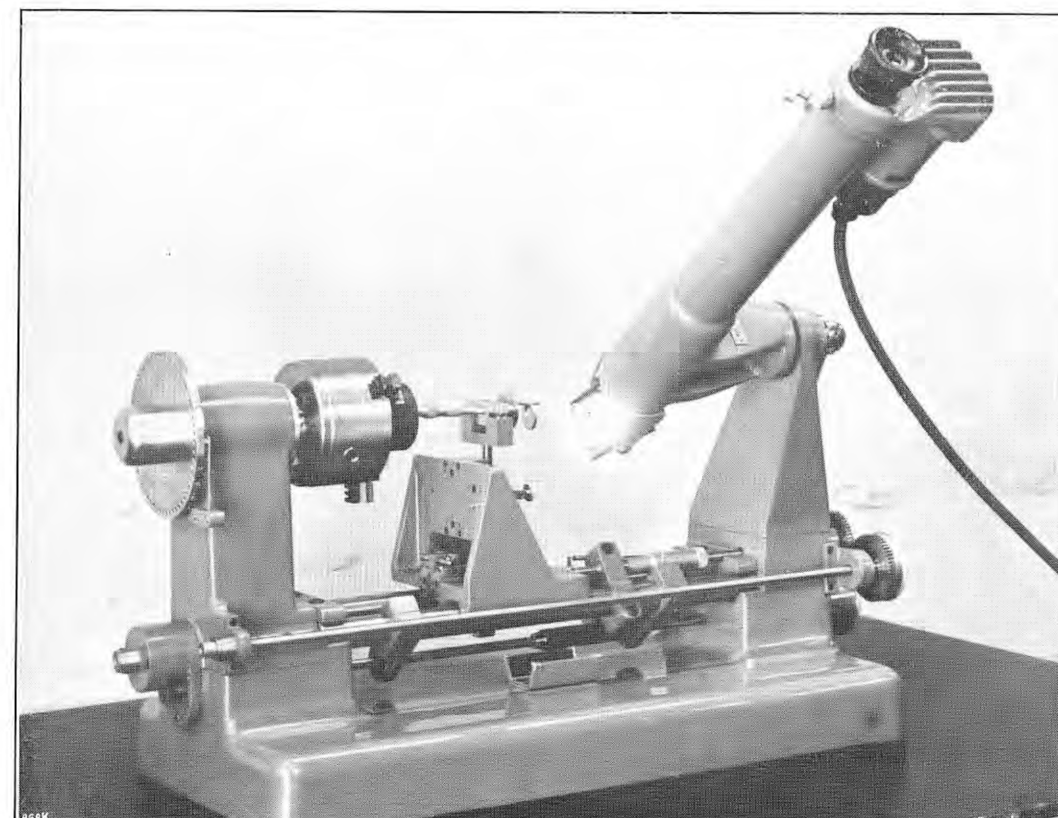


Fig. 65. Hilger and Watts Bore Profilometer; Alfred Herbert, Ltd.

THE INSTITUTION OF NAVAL ARCHITECTS.

(*Continued from page* 583.)

SIR CHARLES LILLICRAP, K.C.B., took the chair at the morning session on the third day (April 4) of the 1952 Spring Meeting of the Institution of Naval Architects. Two papers were presented and discussed in that session, the first of them dealing with "Structural Strength Investigations on the Destroyer Albuera." It was contributed by Mr. D. W. Lang, B.Sc. (Eng.) and Mr. W. G. Warren.

STRUCTURAL STRENGTH OF DESTROYER "ALBUERA."

The tests described in the paper were carried out at H.M. Dockyard, Rosyth, by the staff of the Naval Construction Research Establishment. The original intention was to test a welded vessel also, but none was available. The Albuera, of the "Battle" class, was chosen as representing a modern design of riveted hull. Three major trials were planned, namely, a series of loadings to subject the ship to hogging and sagging moments sufficient to produce a maximum stress of about 5½ tons per square inch in the main hull structure; a similar series of loadings during which the stress distribution at the break of the forecastle was measured; and a test with the ship supported at two positions amidships and subjected to an increasing hogging moment until major structural failure occurred. There were also several subsidiary objectives, one being to compare the actual load at collapse with the values obtained by the use of various theories. No allowance was made for rivet holes in calculating the moment of inertia of the hull section, and all continuous longitudinal material was assumed to be fully effective. It was concluded that the simple beam theory gave correct values for mean stresses, but underestimated the stress near the deck edge and overestimated the stress near the centre line. The paper dealt mainly with the third of the major trials, in which the vessel was loaded to the point of collapse while in dock. The stress in the keel at the time of failure was calculated to be 17·08 tons per square inch. Good agreement was observed between the theoretical and the measured deflections over the early stages of loading, but at the higher loadings the measured deflections tended to be more than the theoretical values, the difference increasing as the load increased. The loading was applied partly filling the compartments with water ballast and partly by lowering the water level in the dock.

DISCUSSION.

Mr. V. G. Shepheard, Director of Naval Construction, who opened the discussion, said that the Albuera trial differed from all others previously carried out in Britain in that it was planned to continue right up to the point of major structural failure. The experimenters had available to them the valuable knowledge of the technique of instrumentation used in the Neverita and the Newcombia. All the post-war trials owed most of their advance over earlier experiments, such as those on the Wolf, to the improvements in instruments and recording techniques. A word of warning was necessary; it was easier to record stresses, or rather strains, than to interpret them, and there was a temptation to take thousands of readings so that the task of analysis became almost impossible. Professor J. H. Biles, in his 1905 paper on the Wolf experiment, said that, "Within the limits of elasticity, it would probably be more nearly accurate to make no deduction for rivet holes." In the Albuera, the rivet holes were neglected in calculating the inertia of the test section and, as the authors stated, there was excellent agreement between observed stresses and those calculated by the simple beam theory. Recent stress-analysis work by photo-elastic and similar methods had also justified that assumption. In the Wolf experiments, the agreement with theory was not as close as was considered desirable, and the discrepancy was explained by adopting a value for Young's modulus different from that found for the steel in an ordinary tensile-testing machine. In 1925 and again in 1928, Mr. G. Hoffman endeavoured to show that the discrepancy was not due to Young's modulus at all, but was due to wrong assumptions in calculating the moment of inertia. The Neverita, Newcombia and Albuera results all seemed to show that there was no significant discrepancy between measured strains and those predicted by the simple beam theory.

Another interesting feature of the Albuera experiment was that there was no observable rivet slip, and that the readings remained linear up to stresses of about 10 tons per square inch. Even beyond this and right up to collapse, only compressive members showed departure from linearity, and that was only slight. The compressive stress in keel failure was about 17 tons per square inch, and the tensile stress in the upper deck about 18 tons per square inch. The average yield stress of the steel was about 23 tons per square inch, although a value as low as 18·4 tons per square inch was found in one plate. The variations between maximum and minimum values were somewhat disturbing for steels made to the rigorous specifications and inspections of the Admiralty. In some ways, the results were comforting, but in others they indicated that there was no cause for complacency. The paper dealt, in the main, with mean longitudinal stresses taken at a section especially selected to be in a region of general continuity; but, apart from the wide departures which were to be expected due to stress concentrations at discontinuities, it must be remembered that the results were "heart of plate" stresses. It would be informative if the authors could give a few typical and some extreme cases of the differences between surface stress and "heart of plate" stress. It would also be of interest to compare the direction and magnitude of the maximum principal stresses with the mean longitudinal stresses.

Dr. S. Livingston Smith said that, on the subject of thermal effects, experience in the British Shipbuilding Research Association had shown that, in addition to thermal stressing (which, in the tests described, would appear to have been small), it was necessary, in tests of that nature, to correct for differential temperature effect between the strain gauges and the plating. The strain gauges were of very low heat capacity and, if there was a change of temperature, they changed very rapidly, and the plating to which they were attached could not change so rapidly. To meet that situation, thermocouples were attached in pairs, one on a gauge and one on the adjacent plate at a number of representative positions. Could the authors state whether they had tried to make any such corrections? Although, no doubt, there was a good reason for it, he found it difficult to understand why it was decided to test the ship to destruction in the hogging condition. There were certain features about the manner of loading described which made the failure conditions very unlike those which might be experienced under the worst service conditions. From the curves of loading, shearing force and bending moment in the final condition, the manner of supporting gave an unusual distribution of shearing force and bending moment, the maximum bending moment and the maximum shearing force being nearly coincident. If the vessel had been sagged with the supports towards the extremities of the ship, it would appear to have been possible to obtain a more conventional type of loading over the centre length of the ship. Was consideration given to the direct measurement of the loads on the supporting towers by the use of hydraulic capsules? Were any measurements made with the direct object of actually measuring rivet slip, bearing in mind how small it might be? Collapse of the structure occurred in the region of maximum bending moment. He thought that the statement might have been qualified by saying that failure also occurred in a region of maximum shearing force. With regard to stress distributions, purely symmetrical loading was always difficult to achieve, and he felt that more gauges on the starboard side of the ship would have added to the value of the results. It would be interesting to see diagrams giving the distribution of transverse and shearing stress and the principal stresses with their angles of orientation. Were all the longitudinal stresses computed with due regard to transverse strains?

Professor A. M. Robb also commented on the remark that collapse occurred in the region of maximum bending moment; a statement which was true, but only half the truth, because the collapse of the structure occurred in the region of maximum shearing force. Thus they were left with the problem, whether the collapse of the structure was associated with buckling under local load or breaking under shearing force. There was evidence to show that shearing force or shearing stress did enter largely into consideration. In the authors' introduction and summary, it was stated that all continuous longitudinal material could be considered as fully effective. Unfortunately, that statement was not supported by the evidence. The diagrams showing the distribution of longitudinal stress showed that, in the hogging condition, the stress at the centre line was actual stress, and was rather less than one-fifth of the calculated stress; in the sagging condition, the stress at the centre line was about a quarter of the calculated stress. The other stress distributions indicated that there was an effect from a hatchway plate. It seemed that the modern development of the destroyer had gone slightly astray from the structural point of view. The forecastle had become longer and longer until there was a severe discontinuity at about the region of maximum bending. It seemed that the forecastle must be made much stronger, or other measures must be adopted.

Professor E. V. Telfer found himself in very substantial agreement with Professor Robb. He thought it strange that Mr. Shepheard could consider that the experiments provided a reasonable confirmation of the simple beam theory; the deck stresses showed that there was absolutely no agreement with it. They were in much better agreement with the early work of Dr. Lockwood Taylor; and a grave omission from the paper was an example showing how the Taylor calculation would have helped to explain the actual stress distribution across the deck. A good point was made by Professor Robb when he suggested that the loss of stress towards the centre line might have been due to a hatchway. If so, Professor Telfer suggested, it was wrong to have made experiments in way of such a marked discontinuity; they should have replated the hatchway if that were the only suitable place for an experiment of that nature. The authors made no comment on what was the actual structure modulus. There was another experiment that they could have made before placing the vessel in dry dock; it would have been useful to have borrowed the vibration exciter from Lloyd's Register and to have made the ship vibrate, to arrive at the modulus by experiment.

Mr. I. M. Youille said that, of the three conclusions drawn from the main part of the experiments, two needed no comment. The third one stated that "The simple beam theory gives correct values for mean stresses, but underestimates the stress near the deck edge and overestimates the stress near the centre line." That matter had been raised by Professor Robb and Professor Telfer. The authors, and also Professor Telfer, suggested that modifications to the simple beam theory to include the effects of shear might account for that; but he suggested that such might not be the case. There was a slight increase of stress at the deck edge and a considerable decrease of stress near the centre line. That was not what would be expected from shear lag; it would be expected that the shear would modify to give a peak at the deck edge and a gradual falling off of stress towards the middle. It was noticeable, also, that all three of the stress distribution plots show the same general distribution of stress across the deck. In the first two plots, the section under consideration and the vicinity of that section did not experience any change in load, and it might be expected that modifications due to changes along the deck would be very great. They might be carried over from the shear changes farther along the ship, but that would not account for all the changes in stress across the deck. He supported Professor Robb in inquiring whether the comparable discontinuity in the deck near the hole for the funnel might account for that.

Mr. L. Woollard thought that the authors had not got out of their results everything that was to be got. They had given results obtained with the test pieces of materials, but he had not noticed that they give the Young's modulus for those test pieces. Mr. Shepheard had said that the Young's moduli, deduced from the ship by two distinct methods, were in agreement with each other. He would like to have the figure so as to compare the two results.

Mr. B. N. Baxter remarked that the authors' results showed beyond any doubt that no allowance need be made for rivet holes in the calculations for moment of inertia. They showed also that the simple beam theory gave correct values for the mean stresses, but underestimated stress values at the deck edge and overestimated them at the deck centre. Referring to the first of the longitudinal stress distribution plots, the stress at the deck edge, using the simple beam theory, was 4 tons per square inch. The additional stress, as calculated by the shear lag theory, he found to be 0·17 tons per square inch, i.e., an increase of about 4·3 per cent. However, the mean stress as measured by the gauges was about 5·6 tons per square inch when extrapolated to the deck edge, an increase of 40 per cent. This indicated that the additional stress due to shear strain in that type of structure was not important. At the deck centre, the measured stress was much smaller than the theoretical stress, and he suggested that this large reduction was due to the proximity of the centre plates to the funnel opening. He would like to know whether the authors found the electric resistance strain gauges to be as satisfactory as the acoustic strain gauges, and, in particular, if there was any trouble due to zero drift. It seemed safe to predict that never again would a British destroyer be broken in peace time, and, therefore, during that unique opportunity for measuring the stresses, it was reassuring to see that the compressive stress in the keel at failure was as high as 17·08 tons per square inch.

Mr. A. J. Merrington remarked that the authors had stated in their paper that, after collapse, there was no evidence of rivet slip. He asked whether, before that stage was reached, there was any evidence of overstraining at the joints. When designers planned for very high working stresses, it was not unknown that difficulties arose at sea during prolonged periods of heavy weather. During the war, some British cruisers, which did extremely heavy service in the North Atlantic, gave trouble in their double bottoms and there was contamination of the fuel. In the trials described in the paper, was there any evidence of that stage arising before collapse—before, in fact, the 17 to 18 tons per square inch collapsing stress was obtained ? Presumably, it would show itself in the upper deck. From that point of view, Dr. Livingston Smith's suggestion that the trials might have been carried out under sagging rather than hogging conditions was interesting, for that might well have provided more information about the working conditions in a ship subjected to prolonged heavy strain. The stress at collapse was given as 17 tons per square inch; and he thought that the Director of Naval Construction himself had said there was 18 tons tensile on the upper deck. Would the authors give the results for the sort of standard conditions usually covered in calculations ? That would give an interesting comparison between design stresses and those applied in the trials.

Captain J. P. Thomson found the paper of extreme interest. Which of the two stresses was the greater, the hogging stress or the sagging stress ? He had had experience of tankers for a number of years, and had been warned by the builders that, when there was an empty tank, it should be in the centre; in other words, there would be 9,000 tons on each side of the empty tank. Apparently, it was easier to damage the ship by hogging than by sagging. What took place during the trials provided a warning to the man whose duty it was to load a ship.

Mr. Warren, replying to the discussion, expressed his gratitude to Mr. Baxter, in particular, for his remarks concerning the effect of shear lag; they coincided with the official findings. The suggestion to carry out vibration trials was extremely interesting. It was, in fact, the intention at the Royal Naval Research Establishment to carry out vibration experiments, using a large vibration generator on a destroyer of the same class.

(To be continued.)

COAL LORRY WITH INTEGRAL CONVEYOR.

CHARROLD LIMITED, LONDON.

FIG. 1. LORRY PREPARED FOR ROAD.

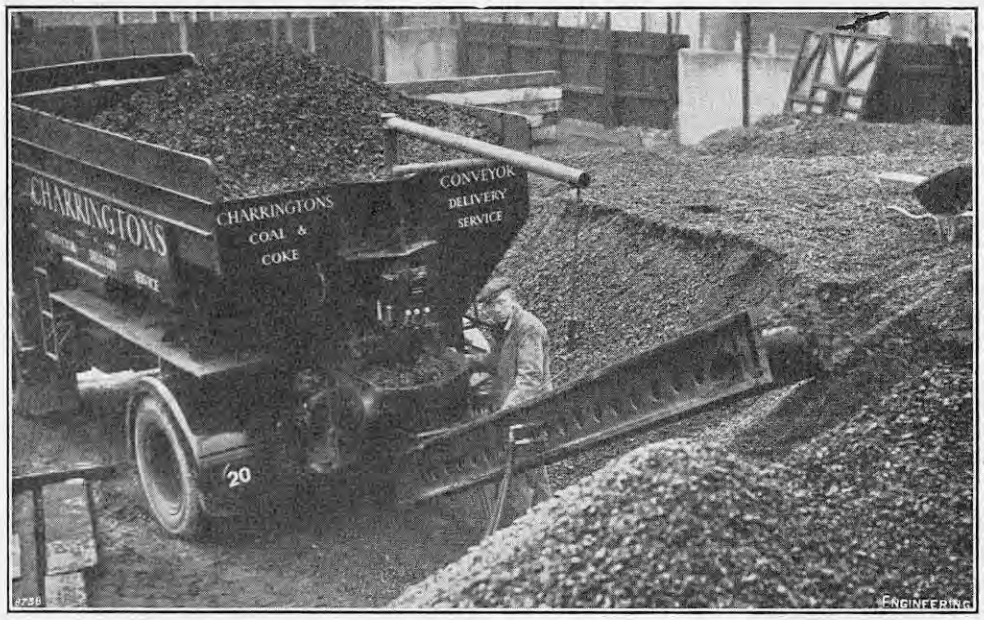


FIG. 2. CONVEYOR IN USE.

LORRY FOR BULK DELIVERY OF COAL.

THE lorry illustrated in Figs. 1 and 2, on this page, has been developed by Charrold Limited, Tower House, 40, Trinity-square, London, E.C.3, for the bulk delivery of coal, coke, etc., to those premises which do not readily permit the entry of tipping lorries. It has a metal hopper-type body, in the base of which is a scraper conveyor. A separate detachable conveyor receives the coal as it is discharged from the scraper conveyor and directs it to the point required. The detachable "toter" conveyor, as it is called by the makers, is shown at work in Fig. 2. It enables coal to be delivered in bulk over walls and through hatchways, small cellar windows and manholes, with the minimum of trouble and entirely dispenses with bagging operations.

The hopper, which is of steel construction, has a length of 12 ft., a width of 6 ft. 9 in. measured at the top, and a level capacity of 200 cub. ft. The scraper conveyor extends along the full length of the body and consists of a series of steel bars fitted to two lengths of chain arranged side by side. It is driven by the lorry engine through a power take-off on the main gearbox. This drives a shaft which is located close to the nearside chassis main-longitudinal member and extends to the rear of the vehicle. A chain drive with hand-operated clutch, then transmits the drive to a worm reduction gear which is connected to the driving head of the scraper conveyor by a further chain-and-sprocket assembly. To prevent the conveyor from being overloaded, a series of flaps is arranged along the base of the hopper. These isolate the hopper from the conveyor and are opened as required by hand levers at the rear of the vehicle.

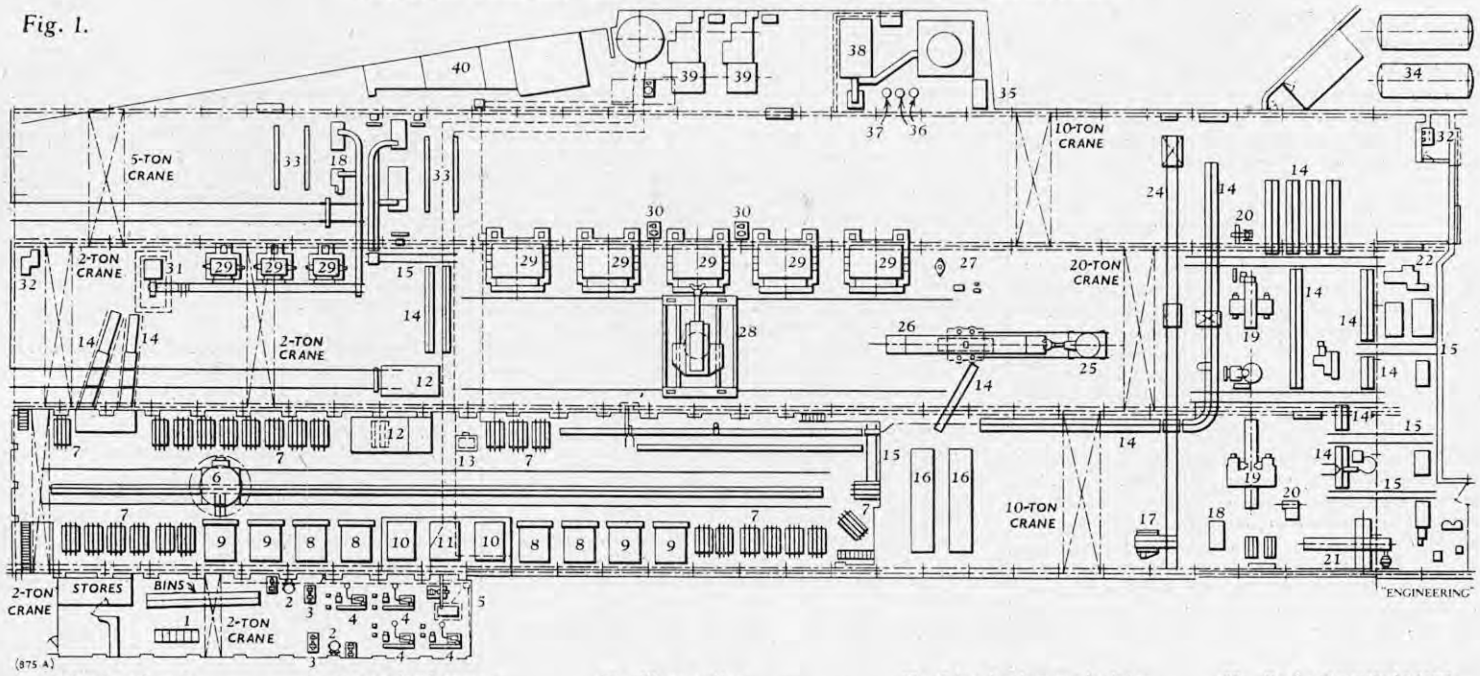
The "toter," as previously indicated, consists of a belt conveyor, the supporting framework being built up from steel pressings. It is driven by a hydraulic motor, the motive power being supplied by a small vane-type pump mounted at the rear of the vehicle chassis. The pump is driven from the same shaft as the scraper conveyor, the drive in this case being permanently engaged and the output from the pump controlled by a by-pass valve. When not in use, the toter is stored in a rack situated at the offside of the hopper, as shown in Fig. 1. To bring it into use, the unit is withdrawn by hand from its travelling position, connected to a small jib hoist installed at the back of the hopper and one end is then attached to a bracket situated immediately below the discharge from the scraper conveyor. The connection between the pump and the hydraulic motor on the toter is made by flexible pipes and these are of sufficient length to permit the toter to be placed in position and subsequently moved through its full arc of working without being disconnected. During working, the height of the toter is adjusted by means of the hand-operated hoist which is self-sustaining.

Both conveyors are controlled from the rear of the vehicle, where a separate hand throttle for regulating the engine speed is also located. The body is designed to carry $5\frac{1}{2}$ tons of coal, but extensions to the side can be fitted to increase the maximum load to $6\frac{1}{2}$ tons. Normally, however, these side extensions are only used when carrying or delivering coke. Discharge of a full load takes from 10 to 12 minutes, with a further five minutes for manipulation, the whole process being effected by a single operator.

PLANT FOR PRODUCTION OF DIE BLOCKS.

WALTER SOMERS, LIMITED, HALESOWEN, NEAR BIRMINGHAM.

Fig. 1.



1. Lubricating oil tanks.
2. Quenching oil coolers.
3. Quenching oil pumps.
4. Air compressors.
5. Quenching water pump.
6. 5-ton charging machine.
7. Loading tables.
8. Heat-treatment furnaces.
9. Tempering furnaces.
10. Oil quenching tank.
11. Water quenching tanks.
12. Shot-blasting cabinet.
13. Control pulpit.
14. Roller conveyor.
15. Roller-top bogie.
16. Cooling pits.
17. Flame cutter.
18. Cold sawing machine.
19. Milling machines.
20. Cutter-head grinder.
21. Planing machine.
22. Side planer.
23. Surface grinder.
24. Heavy bogie and track.
25. 2-ton forging manipulator.
26. Air-hydraulic forging press.
27. Intensifier, and press controls.
28. 4-ton charging machine.
29. Oil-fired forging furnaces.
30. Air compressors.
31. 30-cwt. pneumatic hammer.
32. Fuel-oil pumps.
33. Feed conveyors to saws.
34. Fuel-oil tanks.
35. Air compressor.
36. Compressed-air vessels.
37. Pressure-water storage.
38. Heating boiler.
39. Hydraulic pumps.
40. Works offices.

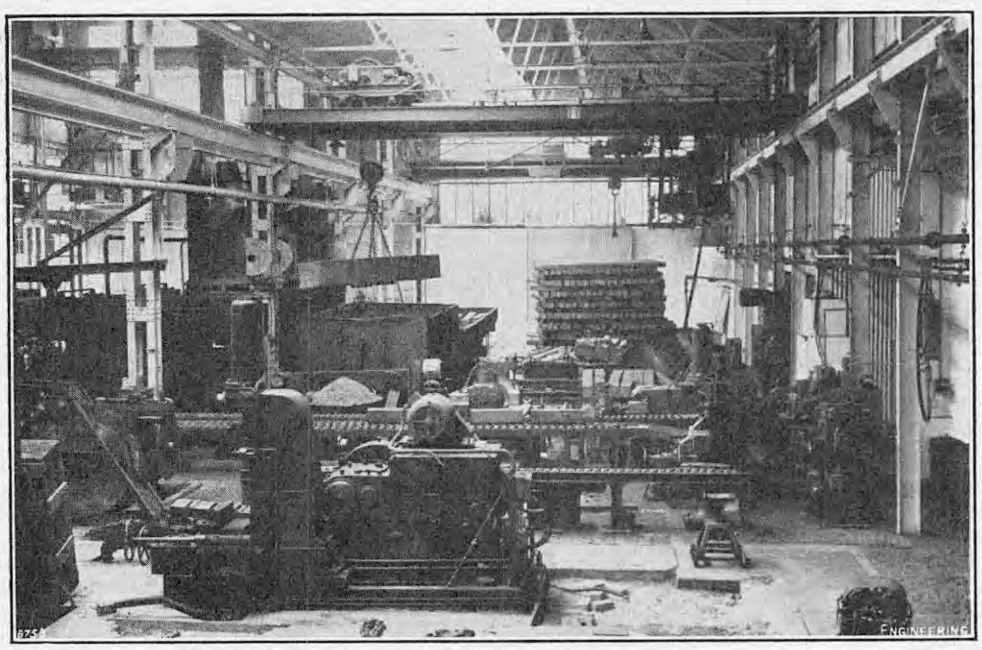


FIG. 2. STEEL STOCK, AND COLD-SAWING MACHINE.

THE DIE-BLOCK PLANT OF WALTER SOMERS, LIMITED, HALESOWEN.

THE firm of Walter Somers, Limited, was founded at Haywood Forge, Halesowen, in 1866—the year which saw also the establishment of ENGINEERING—and is remarkable in that, during the whole of that period, it has had only two chairmen, the late Mr. Walter Somers and his son, Mr. Seth Somers. Under their direction, the Haywood Forge has become one of the main centres in this country for certain specialised steel manufactures, including the making of die blocks.

Initially, the production of die blocks was relatively a minor activity of the firm, and, as recently as 1930, the output was no more than 12 tons per annum. After an intensive selling campaign, however, it rose to 100 tons in 1931 and to 750 tons in 1936. In that year, a representative of the company travelled extensively abroad to study the latest practice in the manufacture of die blocks, and, as a result, the production of die blocks rose to more than 1,000 tons in 1937.

It was decided, therefore, to build three special heat-treatment furnaces for this branch of the firm's manufactures, together with the requisite water and oil quenching tanks and a special shop to deal with the inspection, machining and hardness-testing of die blocks, to comply with a new technique acquired from the Heppenstall Company, of Pittsburgh. By these means, production was increased to 2,500 tons per annum in September, 1939. During the war, however, the plant was found to be inadequate, and all the equipment was transferred to the machine shop. Production continued to increase, reaching 3,500 tons per annum by 1942. After the war, the company, realising how important was this branch of their production, decided to allocate to the manufacture of die blocks a section of the works which had been occupied by the Ministry of Supply and to equip it for the production of these blocks on the most modern lines. It is this plant, now completely equipped, which Admiral Sir William Tennant, K.C.B., M.V.O., Lord Lieutenant of Worcestershire, formally inaugurated on Wednesday, May 14. The general arrangement of the new plant is shown in Fig. 1, herewith; and Fig. 2, on this page, and Figs. 3 to 6, on page 620, illustrate various items of the equipment. It may be remarked that some of these photographs were taken when the plant was not in full operation; for instance, those showing charges being inserted into furnaces that are obviously cold.

The process of enlarging the capacity of the plant to its present figure—4,500 tons of die blocks were produced in 1951—has been a gradual one, extending over some years, as the output steadily increased while the changes were being made; for example, the 5,000-lb. forging manipulator shown in Fig. 3, on page 620, which was designed specially for die-block manufacture and was the first of its kind to be put to work in this country, was acquired from the Alliance Company of Ohio before the war. As mentioned above, three of the heat-treatment furnaces, with their oil and water quenching tanks, were also of pre-war construction, as was the original machine shop and inspection department.

In the summer of 1948, a new 30-cwt. Massey compressed-air hammer was added, a shot-blast room constructed, and four Birlec electric heat-treatment furnaces added, with oil and water quenching tanks and the 5-ton revolving charging machine shown in Fig. 5, on page 620. By the end of that year, the inspection, testing and machining plant was at work on its present site. In 1950, a major addition was made by the installation of a 600/1,200-ton air-hydraulic Schloemann forging press and five oil-fired reheating furnaces, served by the 4-ton charging machine illustrated in Fig. 4, on page 620. This charging machine is fitted with a push-button control to raise and lower the furnace doors. The capacity of the heat-treatment plant was doubled, by the addition of four more electric furnaces, rather larger than the original five, which have an aggregate hearth area of 400 sq. ft.; and two cooling pits were provided, each capable of holding over 50 tons of die blocks.

The new shops have been laid out so that the material progresses in a uniform sequence of operations, and without retracing its path, from the store (at the top left corner of Fig. 1) to the final inspection, in the shop at the bottom right-hand corner. Roller conveyors are extensively used, supplemented by roller-top transfer bogies running on rails. The Massey hammer is used to forge blocks weighing up to 300 lb. each, and the Schloemann press for heavier forgings. The hot finished forgings pass down a gravity conveyor to the heat-treatment bay or to the cooling pits. After heat-treatment, the forgings are shot-blasted if necessary and, after a preliminary inspection, transferred by crane and conveyor to the machine shop. An important item of equipment in this shop is a duplex milling machine, supplied by Messrs. Noble and Lund, Limited, designed to mill two faces of a die block simultaneously. After machining, and final inspection the die blocks are transferred to the despatch bay, which adjoins the machine shop. We understand that, the output in the present year has reached 400 tons a month, which still leaves a considerable margin of capacity in hand.

NOTES FROM THE INDUSTRIAL CENTRES.

SCOTLAND.

APPOINTMENT OF MANUFACTURING EFFICIENCY PANEL.—A proposal by the Scottish Board for Industry to appoint an advisory panel to improve techniques and achieve greater efficiency and output was unanimously approved at a conference of about 100 industrialists and representatives of trade unions and other organisations, held in Glasgow on May 7.

CONTROL OF GASES FROM WORKS.—Aluminium works and certain other industrial plants in Scotland which are responsible for producing "noxious and offensive" gases will require to be registered with the Department of Health for Scotland under an Order which comes into force on July 1. The Order brings up to date an Act of 1906 for the control of gases from industrial works, and adds certain hitherto unlisted gases. Copies of the new Order can be obtained at H.M. Stationery Office.

TRAMWAYS IN GLASGOW.—There was much to be said for the retention of the tramway car in a densely-populated area such as Glasgow, said Mr. E. R. L. Fitzpayne, the general manager of Glasgow Corporation Transport Department, at a luncheon of the Scottish Association of Manufacturers' Agents in Glasgow on May 2. The main advantage of the tramway car over the omnibus was its capacity for coping with peak-load traffic. Glasgow, he said, was the only large city in Britain with a penny fare and a weekly omnibus ticket.

REFLOATING OF STRANDED TUG.—A coffer-dam built by Ferguson Brothers, Port Glasgow, was taken up river by floating crane on May 9 and placed in position over the flooded engine-room of the Clyde Shipping Company's tug Flying Buzzard, which was run aground on a shingle bank near Bowling on April 21 after having been in collision with an oil tanker.

THE LATE MR. J. MACKIE.—It is with regret that we note the sudden death of Mr. James Mackie, A.M.I.Mech.E., which occurred on April 28, while visiting a client of his firm, Macrome Ltd., Wolverhampton. Mr. Mackie was their Scottish technical representative.

CLEVELAND AND THE NORTHERN COUNTIES.

TEES TRADING STATISTICS.—Statistics submitted at a meeting of the Tees Conservancy Commission held at Middlesbrough on May 5 encouraged Ald. B. O. Davies, who presided over the proceedings, to remark: "It seems to me that our optimism has been justified; we are now turning the corner of what I hope will be a very successful future." He was referring to a report which showed that the revenue received from river tolls and dues in March was the highest since November, 1950, showing an increase of 4,799*l*. over the previous month and of 4,475*l*. over the figure for March last year. Imports totalling 275,263 tons showed an increase, in both coastwise and foreign trade, amounting to 35,973 tons compared with February. The rise was due principally to increased unloadings of iron ore (24,722 tons).

SHIPBUILDING AND REPAIRING DIFFICULTIES.—The current issue of the *Joint Production Committee's Journal* issued by William Gray & Co., Ltd., the West Hartlepool shipbuilders, states that shipbuilding and repairing cannot be viewed with the same enthusiasm as was the case a year ago. The order book is well-filled, but freights are showing a tendency to fall and it is difficult to forecast shipowners' reactions if freights continue to decline and building costs remain high. The steel shortage, which affects everything from plates to rivets, nuts and bolts, and electrodes, is making delivery dates difficult to keep. On the repairing side, Continental firms are reappearing as keen competitors.

LOCOMOTIVE BUILDING AT STOCKTON.—When members of Stockton-on-Tees Corporation Industrial Development Committee visited the works of Metropolitan Vickers-Beyer Peacock, Ltd., Stockton, last week, the chairman of the firm, Mr. E. W. Steele, said it was fitting that Stockton, the birthplace of the first commercial steam railway in the world, should now produce the latest type of electric and Diesel-electric locomotives. Members of the Committee inspected several 50-ton electric locomotives, costing 40,000*l*. each, on order for Brazil. The Stockton works have orders in hand sufficient to provide 3½ years of work.

BRITISH TANKERS TO BE OVERHAULED ON THE TYNE.—Ten vessels belonging to the British Tanker Co., Ltd., are due at Tyne repair yards. They are the British Enterprise and British Marquis, due at Swan, Hunter, and Wigham Richardson, Ltd.; the British Bugler at Hawthorn, Leslie & Co., Ltd.; the British Statesman and British Duchess at Palmers (Hebburn) Co., Ltd.; the British Ambassador, British Fidelity and British Prospector at the Wallsend Slipway and Engineering Co., Ltd.; the British Supremacy at the Middle Docks and Engineering Co., Ltd.; and the British Lancer at Smith's Dock Co., Ltd.

EXPORTS OF COAL, IMPORTS OF STEEL.—For the first quarter of this year, coal and coke shipments from the Hartlepools amounted to 534,468 tons, an increase of 28,142 tons on last year. A cargo of United States steel is due in the Tyne on May 17 in the United States steamer Harry Culbreath. This will be the first cargo of its kind to arrive in the Tyne under the recent agreement whereby America is supplying steel to Britain.

SWISS MERCANTILE MARINE.—At the handing over of a new ship for Swiss owners, Mr. F. C. Pyman, managing director of William Gray & Co., Ltd., West Hartlepool, said that he thought his company had built more ships for Swiss owners than any other firm. There was now keen competition for orders from this source, from Italian and Dutch firms. The ships brought goods to the Rhine, where the cargoes were discharged into barges and conveyed to Switzerland.

APPRENTICES VISIT LEONARDO DA VINCI EXHIBITION.—Messrs. Head, Wrightson & Co., Ltd., Thornaby-on-Tees, adopted a novel and instructive method of markin the completion of new premises for their apprentices' school. All the pupils, numbering about 60, travelled to London recently when they inspected the Leonardo da Vinci exhibition at the Royal Academy and visited such more usual sights as St. Paul's, the Tower of London, and the House of Commons.

LANCASHIRE AND SOUTH YORKSHIRE.

LOSS OF COAL PRODUCTION.—It is computed that, up to May 8, the North-Eastern Division of the National Coal Board lost, in potential production, 23,000 tons of coal on account of disputes at Bullcroft and Brodsworth collieries. Strikers at Brodsworth have refused to return to work, in defiance of their leaders. The strike has arisen from a dispute between a Jugoslav miner and a deputy. The 31 Italian haulage hands at Bullcroft are still suspended on full pay because the Bullcroft men refuse to work with them.

STEEL EXPORTS HAMPERED.—Among the orders for tool steels lost by Sheffield manufacturers, owing to the rigidity of Board of Trade regulations, was one of a value of 200,000*l*., which went to French steelmakers. The complaint made in Sheffield is that directions of export quotas are issued for various markets and licences for larger amounts are unobtainable. It is asserted that there is no serious shortage of Sheffield's special steels.

VISITS OF FAMILIES TO WORKS.—In what is described as "good housekeeping" week, wives and families of employees of Thos. Firth and John Brown, Ltd., Sheffield, have been conducted round the works to see the processes of steel melting, rolling, forging and machining. Managers of departments and members of the staff have acted as guides to parties of visitors, and, on some evenings, there have been more than a thousand visitors.

COLLIERY REPAIR WORKSHOPS.—The first central workshops for carrying out all major repair and reconstruction work for the North-East Divisional Coal Board, have been officially opened at Birdwell, near Barnsley. They will serve twelve collieries in the South Barnsley area and will permit the Board to do their own heavy engineering work instead of having to let much of it out to contract. When work was begun on the depot in 1950 it was estimated the cost would be 100,000*l*.

THE MIDLANDS.

TITANIUM AS A MATERIAL OF CONSTRUCTION.—Imperial Chemical Industries Ltd. have been carrying out research on titanium for some years. Some of the results of their work have now been made known, and specimens of the metal in various forms have been shown on the company's stand at the British Industries Fair at Birmingham. The metal has been prepared in the form of ingots, rods, strip, plates, sheets, tubes and wire. Casting and working of titanium is carried out at the Witton, Birmingham, works of the company's metals division, with raw materials prepared by the general chemical division at Winnington, Cheshire. Under normal atmospheric conditions, molten titanium attacks all known refractories and melting and casting have to be carried out in an atmosphere of argon.

WOLVERHAMPTON POWER STATION.—Wolverhampton power station, which ceased generating nearly two years ago as the result of a serious breakdown, is expected to be in operation again in a few weeks. During the period of idleness the steam plant has been rebuilt, and the opportunity has also been taken to overhaul the alternators. Work has likewise been done on the cooling tower, to prevent a recurrence of the troubles previously experienced with water vapour in the neighbourhood.

EXPORTS TO AUSTRALIA.—The position with regard to exports from this country to Australia has been reviewed by two prominent speakers recently. Mr. W. H. Kitson, Agent General for Western Australia, said at the official British Industries Fair luncheon, at Castle Bromwich, that within 9 to 12 months Australian economic troubles should have been overcome, and normal trade with Great Britain would then be resumed. Of motor cars, Mr. L. P. Lord, chairman and managing director of the Austin Motor Co., Ltd., said at Southampton on May 5, that his company has restarted shipments to Australia. At present they are sending 1,000 cars a month.

GOLDEN JUBILEE CELEBRATIONS AT THE B.T.H. WORKS—Fifty years of manufacturing at Rugby were celebrated by a luncheon in the works canteen of the British Thomson-Houston Co., Ltd., on Friday, May 2. Mr. H. L. Satchell, M.B.E., director and manager of the Rugby Works, presided over the assembly of 230 which included Mr. James Johnson, M.P., for Rugby, the Mayor and Town Clerk of Rugby, the secretary of the Engineering and Allied Employers' Leicester and District Association, a number of trade union officials and some 200 employees of the British Thomson-Houston Company. Some of the latter have over 50 years of service with the company, and many over 40 years.

RAILWAY ACCIDENT AT BIRMINGHAM.—The 4.45 p.m. train from Castle Bromwich to Birmingham collided with a stationary train as it entered New Street station, Birmingham, on May 5. The rear coach of the stationary train was de-railed and badly damaged, but only one passenger required hospital treatment.

AWARD FOR FACTORY DESIGN.—The bronze medal and diploma of the Royal Institute of British Architects has been awarded to the Birmingham firm of S. N. Cooke and Partners for their design for a new factory at Studley, near Redditch. The factory, which covers 2½ acres, has been built for Needle Industries Ltd., and is a single-storey building designed for flow production.

METROLOGY LABORATORY.—A new metrology laboratory has been completed at the Birmingham College of Technology. It will be operated by the College's production-engineering section, and will also undertake work of the National Physical Laboratory.

SOUTH-WEST ENGLAND AND SOUTH WALES.

SITE FOR NEW COLD-REDUCTION STEEL PLANT.—A statement of the Government's decision on the site for the new cold-reduction plant of the Steel Company of Wales is expected within the next fortnight. A site at Llangyfelach has been provisionally chosen. This was one of the sites originally selected for the second Welsh cold-reduction plant but, after a substantial sum had been spent on preparatory excavations, it was abandoned in favour of Trostre, Llanelly.

UNEMPLOYMENT IN WALES.—The Trades Union Congress South Wales Regional Advisory Committee are to visit factories to investigate reports of redundancy. Another instance of this came to light last week when 75 employees of A.B. Metal Products Ltd., Ynysboeth Trading Estate, Abercynon, were given a week's notice. The factory employs about 600 persons on the production of switches and electrical components. Though some factories have laid off operatives, there were no large-scale local increases in unemployment during April.

PORTLAND CEMENT MANUFACTURE IN WALES.—The annual report of the Aberthaw and Bristol-Channel Portland-Cement Company states that production and deliveries of cement from the works during the past year were the highest in the history of the company. Unauthorised absenteeism of all employees during 1951 amounted to only 0·06 per cent., or six hours in every 10,000 hours worked.

STRIKE AT BWLLFA COLLIERY.—An unofficial strike of South Wales miners has involved more than 4,000 men employed at pits in the Aberdare Valley during the past week. The stoppage began at the Bwllfa Colliery at Cwmdare over a dispute concerning men working in a wet district. The men concerned complained that the management had stopped a custom under which men who had finished their stint for the day in the district were allowed to leave the colliery early. The Coal Board denied that they had stopped the custom and claimed that they merely wanted to prevent the spread of leaving early.

NOTICES OF MEETINGS.

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

INSTITUTION OF ELECTRICAL ENGINEERS.—*London Students' Section:* Monday, May 19, 7 p.m., Savoy-place, Victoria-embankment, W.C.2. Annual General Meeting and Film Evening. *Education Discussion Circle:* Tuesday, May 20, 6 p.m., Savoy-place, Victoria-embankment, W.C.2. Discussion on "The Teaching of Engineering Economics," to be opened by Professor R. O. Kapp. *Supply Section:* Wednesday, May 21, 5.30 p.m., Savoy-place, Victoria-embankment, W.C.2. Discussion on "275-kV Developments on the British Grid System," to be opened by Mr. D. P. Sayers, Mr. F. J. Lane and Dr. J. S. Forrest.

INCORPORATED PLANT ENGINEERS.—*Liverpool and North Wales Branch:* Monday, May 19, 7.15 p.m., Radiant House, Bold-street, Liverpool. "Pumps and Pumping," by Mr. C. N. Hillier.

INSTITUTION OF CIVIL ENGINEERS.—Tuesday, May 20, 5.30 p.m., Great George-street, S.W.1. James Forrest Lecture, "The Progress of the Science of Soil Mechanics during the Past Decade," by Mr. H. J. B. Harding.

INSTITUTION OF ROAD TRANSPORT ENGINEERS.—*Midlands Centre:* Tuesday, May 20, 7.30 p.m., Crown Inn, Broad-street, Birmingham. Annual General Meeting.

ROYAL SOCIETY OF ARTS.—Wednesday, May 21, 2.30 p.m., John Adam-street, Adelphi, W.C.2. Shaw Lecture on "Industrial Accidents," by Mr. H. R. Payne.

ROYAL METEOROLOGICAL SOCIETY.—Wednesday, May 21, 5 p.m., 49, Cromwell-road, South Kensington, S.W.7. (i) "A Statistical Model for Water-Vapour Absorption," by Mr. R. M. Goody. (ii) "An Essay on the General Circulation of the Atmosphere Over South-East Asia and the West Pacific," by Mr. B. W. Thompson.

ROYAL STATISTICAL SOCIETY.—*Research Section:* Wednesday, May 21, 5.15 p.m., London School of Hygiene and Tropical Medicine, Keppel-street, W.C.1. "Some Statistical Aspects of Anthropometry," by Mr. M. J. R. Healy. *Society:* Wednesday, May 28, 5.15 p.m., London School of Hygiene and Tropical Medicine, Keppel-street, W.C.1. "Statistics of Tins and Cans," by Mr. J. Ryan.

INSTITUTION OF CHEMICAL ENGINEERS.—*Midland Section Graduates' and Students' Section:* Wednesday, May 21, 6.30 p.m., The University, Edmund-street, Birmingham. Symposium on "The Research Work of the University of Birmingham Chemical Engineering Department."

INSTITUTION OF PRODUCTION ENGINEERS.—*Wolverhampton Graduate Section:* Thursday, May 22, 7.30 p.m., Wolverhampton and Staffordshire Technical College, Wulfruna-street, Wolverhampton. "Principles of Drop, Press and Upset Forgings," by Mr. J. D. Gutteridge. *Shrewsbury Section:* Wednesday, May 28, 7.30 p.m., The Technical College, Shrewsbury. "Designs for Fabrication to Replace Castings," by Mr. S. M. Reisser.

ROYAL SANITARY INSTITUTE.—Friday, May 23, 10.15 a.m., Town Hall, Bangor. Various papers, including "Anglesey County Water Scheme," by Mr. W. H. Austin. Afternoon: Visit to Anglesey to inspect the Cefni water scheme and dam.

SOCIETY OF INSTRUMENT TECHNOLOGY.—Tuesday, May 27, 7 p.m., Royal Society of Tropical Medicine and Hygiene, Manson House, Portland-place, W.1. "Recent Advances in the Industrial Use of the Microscope," by Mr. E. W. Taylor.

ROYAL INSTITUTION.—Friday, May 30, 9 p.m., 21, Albemarle-street, W.1. "Sir Christopher Wren Through His Drawings," by Mr. John Summerson.

PRICE OF LEAD.—Another reduction has been made in the price of lead. The Ministry of Materials announce that from May 14 the price of imported good soft pig lead is decreased from 147*l*. to 131*l*. per ton, delivered.

THE BRITISH CONTRIBUTION TO TELEVISION: ERRATUM.—We regret that, in our account of the convention on the "British Contribution to Television" an error occurred in the third column of page 553. "A camera of the Smitson type" should read "of the Emitron type."

CAMBRIDGE UNIVERSITY EDUCATIONAL FILM COUNCIL.—The fifth report, dated February, 1952, of the Cambridge University Educational Film Council states that a film recording the construction of the new building for the Engineering Department has been made; another has been made in the Mathematical Laboratory to illustrate rapid computation with the Edsac; and in the Department of Agriculture, cinematography has been employed for research on ploughing. During the current academic year, however, the film sessions which have been part of the regular time-table of engineering students since 1944 are not being held.

THE INSTITUTE OF BRITISH FOUNDRYMEN.

THE 49th annual conference of the Institute of British Foundrymen, St. John-street Chambers, Deansgate, Manchester, 3, will be held at Buxton, Derbyshire, from June 10 to 13. On the first day, Council and committee meetings will be held at the Palace Hotel in the afternoon, and, in the evening, a reception and dance will be held at the Pavilion by invitation of the Mayor of Buxton.

On Wednesday, June 11, the annual general meeting of the Institute will be held at 9.15 a.m., at the Spa Hotel, when, after the presentation of awards, Dr. C. J. Dadswell, M.I.Mech.E., will be installed and will read his presidential address. Professor R. J. Sarjant, O.B.E., D.Sc., will then deliver the Edward Williams Lecture on "Fuel and Metal." In the afternoon, at 2.30, two papers will be presented and discussed, the first being "The Role of the Research Foundry Unit," by Mr. G. A. Lillieqvist and the second, the report of Sub-Committee T.S.35—"Flow of Metal." In the evening, the annual banquet will be held, at 7 for 7.30, at the Palace Hotel.

On Thursday, June 12, three simultaneous sessions, designated B, C and D, will be held in the morning from 9.30 until 12.30 p.m. and, in the afternoon, E, F, G, from 2.30 until 5.30. Three papers will be presented at each of the morning sessions and two at each of the afternoon sessions. The papers at session B comprise: "Strength, Structure and Composition of Unalloyed Grey Irons," by Dr. H. T. Angus; "Production of Large Ingot Moulds from the Sand-slinger in a Mechanised Foundry," by Mr. J. Raymond Jones; and "Methods Employed in the Production of Heavy Iron Castings," by Mr. J. Richardson and Mr. C. F. Lawson. The three papers at session C are to be: "Manufacture of High Quality Steel Castings at a Competitive Price," by Mr. J. J. Dewez; "Probable Trends in British Steel Foundry Practice," by Mr. F. Cousans; and "Production of Manganese-Steel Castings," by Mr. F. Cousans and Mr. W. C. Meredith. The papers at Session D will be: "Sand-Cast Beryllium Bronze," by Mr. L. Grand; "Gas Removal from Molten Aluminium Alloys," by Mr. A. W. Brace, and "Grain Refinements of Non-Ferrous Castings," by Mr. G. Swinyard.

The two papers at each of the three simultaneous afternoon sessions are as follows: Session E: "Some Effects of Magnesium on the Formation of Graphite in a Solidifying Cast Iron," by Mr. I. C. H. Hughes and Report of Sub-Committee T.S.32—"Internal Stress in Castings." Session F: "Progress by the Steel Foundry Industry on the Elimination and Control of Atmospheric Dust," by Mr. J. F. B. Jackson, and "Thermal Expansion and Contraction of Compacted Steelfounding Sands and Mould Wastes," by Dr. D. V. Atterton. Session G: "Gamma Radiography in the Foundry," by Mr. R. J. Hart, and "Recent Experience with Basic and Acid Electric Steel," by Mr. L. W. Sanders.

On Friday, June 13, visits will be paid to the works of Sheepbridge Equipment, Limited; David Brown and Sons, Limited (Penistone); Hadfields Limited; Newton, Chambers and Company, Limited; the Brightside Foundry and Engineering Company, Limited; Edgar Allen and Company, Limited; the English Steel Corporation, Limited; and Osborn Foundries, Limited. The Conference will close with a dinner-dance at 7.30 for 8 p.m. at the Palace Hotel, Buxton.

BRASS FOUNDERS' PRODUCTIVITY CONFERENCE.

THE Association of Bronze and Brass Founders and the National Brassfoundry Association are to hold a conference on productivity at Harrogate from June 23 to 26. The associations hope that all firms in, or allied to, the industry will send representatives. The purpose of the conference is to evolve methods of implementing the recommendations of the report of the brass-foundry productivity team which visited the United States. Fourteen papers are to be presented and discussed, and 13 films, some of them produced in America, are to be shown. Sir Thomas Hutton, general manager of the Anglo-American Council on Productivity, will take the chair at an inaugural dinner at the Hotel Majestic on Monday, June 23. Meetings will be held on the whole of Tuesday and Wednesday, and on the morning of Thursday, June 26. A competition, with a prize of 10*l*., for the best detailed routing sheet and cost sheet of a specified casting, is being organised. Dress will be informal throughout the conference. The fee is 2*l*. 10*s*. 6*d*. Application forms are obtainable from the conference secretaries, Messrs. Heathcote and Coleman, 25, Bennetts-hill, Birmingham, 2 (Telephone: MIDland 2901).

PERSONAL.

SIR WILFRID EADY, whose retirement from the Treasury was recently announced, has been appointed a whole-time director of Richard Thomas and Baldwins Ltd., and a director of the Steel Company of Wales Ltd.

MR. LESLIE GAMAGE, M.C., has been elected President of the Institute of Export for the tenth consecutive year. He has also accepted an invitation from the President of the Board of Trade to continue as a member of the Council of Industrial Design, on which he has already served for seven years.

MR. ALEXANDER P. TRAILL, O.B.E., director and general manager of the Manchester Dry Docks Co. Ltd., Manchester, has been elected chairman of the Dry Dock Owners and Repairers Central Council for 1952-53. MR. W. B. JOHNSTONE, O.B.E., a director of Alexander Stephen & Sons, Ltd., has been elected senior vice-chairman and MR. A. C. WADDY, O.B.E., a director of William Gray & Co., Ltd., junior vice-president.

MR. C. M. COCK, M.I.E.E., M.I.Mech.E., who, as stated on page 111, *ante*, had been nominated to succeed MR. J. S. TRITTON, M.I.C.E., M.I.Mech.E., as President of the Institution of Locomotive Engineers, 28, Victoria-street, London, S.W.1, has now been elected President.

MR. A. HASELDEN retires under the age limit from his position of director of manufacture, Ford Motor Co., Ltd., Dagenham, Essex. His services, however, will be retained in an advisory capacity. Mr. Haselden's successor is MR. C. THACKER.

British Railways, Western Region, announce that MR. S. STEVENS, M.Sc. (Eng.) (Lond.), A.M.I.C.E., M.I.Struct.E., M.Inst.W., has been appointed district engineer, London, and MR. H. G. LAKEMAN, A.C.G.I., B.Sc. (Eng.), A.M.I.C.E., district engineer, Bristol.

DR. H. HOLLINGS, O.B.E., is relinquishing his posts as director of the London Research Station of the Gas Council and as controller of research, North Thames Gas Board, on June 30. His successor is DR. R. H. GRIFFITH.

DR. P. D. MERICA, executive vice-president, has been elected President of the International Nickel Co. of Canada Ltd. DR. J. F. THOMPSON continues as chairman and chief officer of the company. MR. R. L. BEATTIE, vice-president and general manager of the company's Canadian operations, and MR. H. C. F. MOCKRIDGE, Q.C., have been elected to the executive committee of the board. MR. J. R. GORDON, assistant vice-president, has been appointed to the further post of assistant general manager. MR. W. F. KENNEDY has succeeded, as secretary, MR. H. S. WINGATE, who will devote his full time as vice-president and a director of the company.

LT.-COLONEL K. G. MAXWELL, M.C., Assoc.M.C.T., M.I.E.E., who succeeded MR. A. E. DU PASQUIER as manager of the publicity department of the Metropolitan-Vickers Electrical Company Ltd., Trafford Park, Manchester, 17, in May, 1933, retired from executive duties on April 30, after 41 years of service with the company, but will continue to be available in an advisory capacity. MR. E. E. WALKER, hitherto assistant manager, publicity department, has succeeded Colonel Maxwell.

MR. R. J. HIRD, B.Sc., for the past 3½ years chief engineer of Mavor and Coulson Ltd., Bridgeton, Glasgow, S.E., has been elected a director of the company.

MR. F. J. LARARD, M.I.E.E., M.I.E. Aust., late of the Colonial Engineering Service, Malaya, has been appointed manager of the London office of Brush Export Ltd.

MR. D. A. STEWART, A.M.I.C.E., A.M.I.E.E., is now acting as consulting civil engineer for Messrs. Sandberg, 40, Grosvenor-gardens, London, S.W.1, with particular reference to concrete design and testing.

Two new directors have been appointed to the board of Platt Bros (Sales) Ltd., Oldham, namely, MR. F. G. HAWKINGS, as home sales director, and MR. E. C. MARLAND as technical director.

MR. WALTER HART has retired from the managing directorship of Kerry's (Great Britain) Ltd., Warton-road, Stratford, London, E.15, but retains his seat on the board. Mr. Hart joined the company in 1906 and became managing director in 1934. His son, MR. W. NORMAN HART, has succeeded him as managing director.

The RT. HON. ALAN LENNOX-BOYD, M.P., Minister of Transport and of Civil Aviation, has appointed Mr. O. F. Gingell (transport) and Mr. S. M. A. Banister (civil aviation) to be his joint principal private secretaries.

MR. H. HOBDELL has been appointed advertising and sales-promotion manager of British Paints Ltd., and associated companies.

MACROME LTD., Wolverhampton, announce that, until a successor to the late MR. JAMES MACKIE, A.M.I.Mech.E., who was their Scottish technical representative, is appointed, all inquiries will be dealt with by their Scottish office, at 249, St. Vincent-street, Glasgow, C.2. (Telephone: Central 5066.)

THE COAL UTILISATION COUNCIL are opening to-day (May 16) a new showroom and information centre at 341, Bath-street, Glasgow. It is under the control of MR. A. L. DALLAS, who is responsible for the Council's work in Scotland.

PLANT FOR PRODUCTION OF DIE BLOCKS.

WALTER SOMERS, LIMITED, HALESOWEN, NEAR BIRMINGHAM.

(*For Description, see Page* 617.)

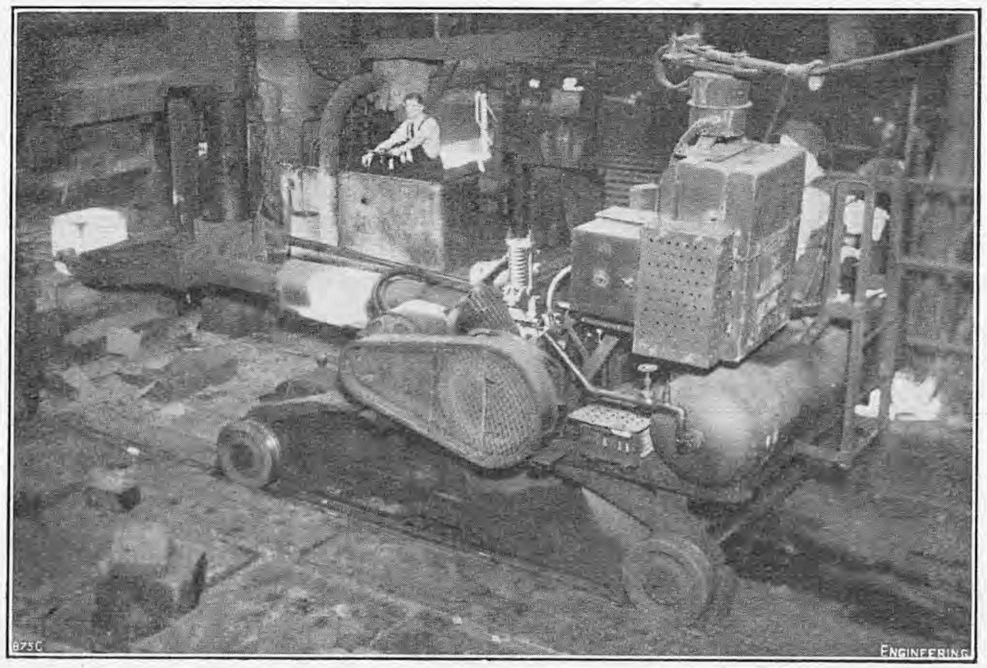


Fig. 3. Forging Manipulator.

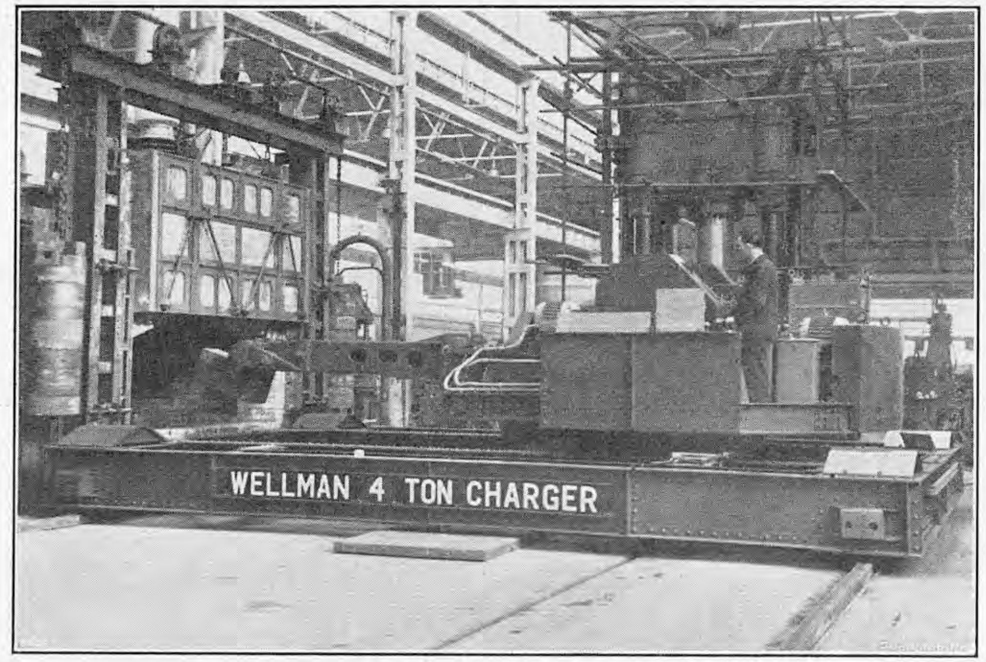


Fig. 4. Charging Machine and Reheating Furnaces.

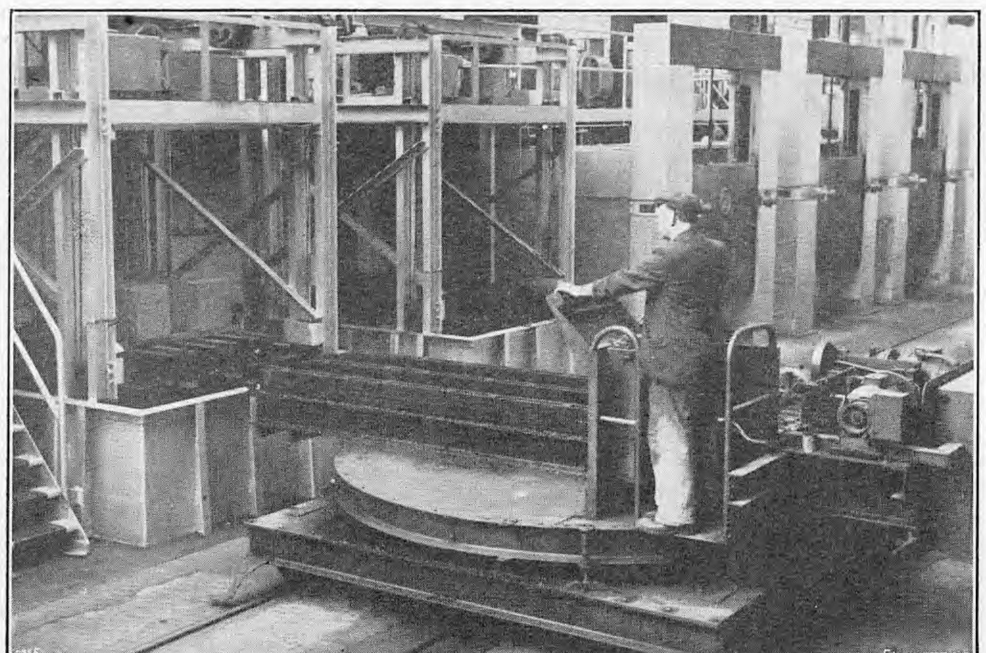


Fig. 5. Charging Machine in Heat-Treatment Shop.

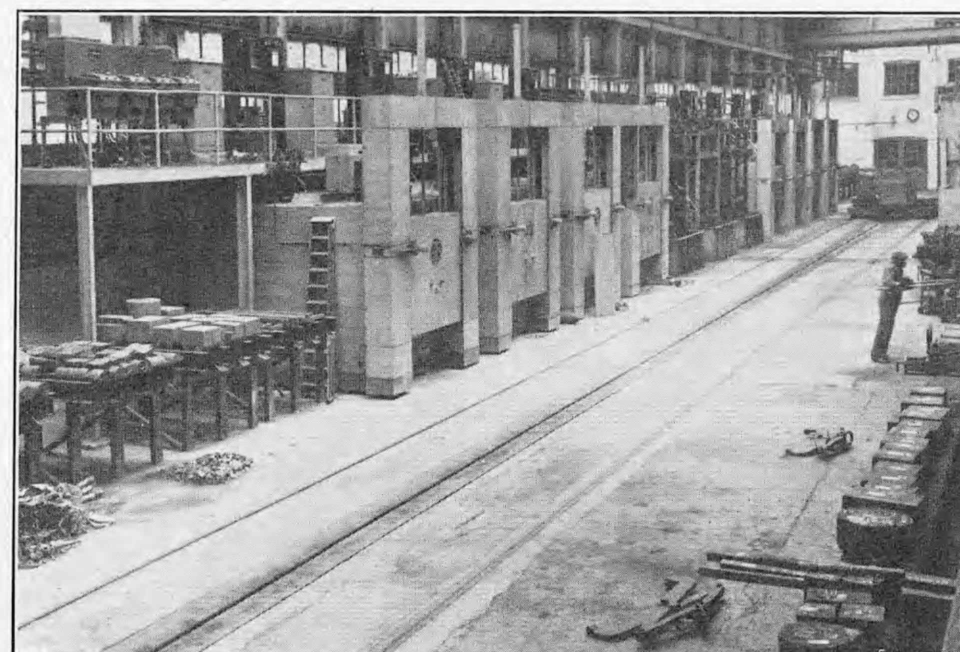


Fig. 6. Heat-Treatment Furnaces and Quenching Tanks.

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ENGINEERING

FRIDAY, MAY 16, 1952.

VOL. 173. No. 4503.

THE ECONOMICS OF FUEL AND POWER.

AN urgent problem is how British industrialists can most efficiently and economically obtain the increasing supplies of power and heat which are needed for their existence. Hardly less urgent is how householders are to be provided with the heat which is essential or at least desirable for their well-being. Demands under both these headings are increasing and, as far as can be seen, must be met from native coal resources, either in the raw state or after conversion into electricity or gas; for even a cursory examination shows that alternatives which are possible in theory can offer little relief in practice. Water power is being economically developed almost to the limit. The utilisation of tidal and wind power on any large scale is not practicable; and the gas turbine, using peat or methane as fuel, is not likely to make more than a small contribution. Even the most optimistic cannot regard the employment of atomic power as probable for many years.

This is, briefly, the situation which is being considered by the Power and Fuel Resources Committee, now sitting under the chairmanship of Lord Ridley. It must be admitted that their task is difficult. It must also be agreed that it is not being made easier by the tone of some of the evidence that is being placed before them, nor by the fact that controversy on important matters of detail, which should be considered judicially, has burst out in *The Times* and elsewhere. The results have been arguments and misrepresentations which are engendering a good deal of heat between the protagonists of the use of different forms of fuel and, in particular, have given rise to an attack on the employment of electricity for what is conveniently called space heating. This has gone so far that the prohibition of the use of electric fires, cookers and water heaters has been suggested on the score that such prohibition would be a panacea for present ills.

We feel it only right that such a desperate remedy should not be administered until all the evidence available has been most carefully sifted and weighed, or at least until the case against electricity has been examined from the economic and civic points of view. An opportunity for performing the former of these tasks is provided by a speech made by Sir John Hacking at a recent luncheon of the Institute of Fuel. Dealing with the efficiency of electrical generation, he observed that the average thermal efficiency of the national generating plant now stands at 22 per cent., a figure which it is hoped to increase to over 26 per cent. by 1960. Improvement along these lines cannot be expected, however, by the employment of back-pressure turbines in large stations, as has been advocated, since the high cost of the heat distribution systems connected with such plant would often render it uneconomic. As regards distribution, after allowing for transmission losses and for the heat consumed in the transport of coal from the pithead to the generating station, electricity is delivered to the consumer at an efficiency of about 19 per cent. As, however, the efficiency of its utilisation is 100 per cent. its overall efficiency is also 19 per cent.

The next question, which naturally arises, is how this figure compares with the efficiency of other forms of fuel. It is common ground that the method of allocating works losses is the determining factor in the assessment of the efficiency of gas production. If the Gas Council's method of allocation is adopted for this purpose, an efficiency of 47 per cent. is obtained. This figure is accepted by Sir John Hacking, with the proviso that it neglects the power used in the gasworks, but takes credit for the heat content of by-products, such as tar and some of the coke breeze, which are used for road making and the heat content of which is therefore lost. When these adjustments are made, the efficiency of gas production falls to 38 per cent. and, as the utilisation efficiency of a gas fire is, at its best, not more than 50 per cent., the overall efficiency works out at about 19 per cent., a figure equal to that of the electric fire. Discussions on efficiency are excellent occasions for the display of dialectic. We think, however, we are right in saying that members of both the electricity and gas industries who have studied the question generally agree with the foregoing as a correct statement.

The overall efficiency of the open grate, taking the figures given in the Egerton report, is also not more than 19 per cent., and only reaches that figure when used continuously. Higher efficiencies are, of course, obtainable by using the most modern types of grates and "closeable" fires; and still higher figures can be reached with large coke-fired boilers, supplying hot-water radiators. In fact, as Mr. E. R. Wilkinson points out in a recent letter to *The Times*, where more or less continuous space heating is needed, particularly when coupled with the supply of hot water the available evidence suggests that solid fuel probably shows a balance of advantage in fuel economy. On the other hand, for all other heating, cooking and water-heating purposes, solid fuel is not, in general, the most economical medium, and, as regards the alternatives, there is little to choose between electricity and gas on the score of overall fuel efficiency. It may, therefore, be argued with conviction that, on this ground alone, there is no case for banning the electric fire and that to adopt such a course would not be in the best interests of the community.

Fuel economy, however, is not the only factor in the situation. The use of raw coal in the home imposes a load on the transport system which it would be wise to do something to relieve. It results in the expenditure of unnecessary labour, as is shown by the fact that, while it requires about $7\frac{1}{2}$ man-hours to raise a ton of coal, it needs about 50 woman-hours to burn it in the home. The type of grate of which there are still too many in use burns coal under conditions which contribute to atmospheric pollution and, for its satisfactory usage, requires fuel of a quality that is often unobtainable at the present time. Although the new efficient appliance is better in these respects, its output is largely in the form of convected heat, so that, while satisfactory as a space heater, it is less effective in providing radiant heat.

For reasons of convenience as well as economy, therefore—and the two are interconnected—it seems to be generally agreed that the ideal arrangement is to use modern solid-fuel appliances for long-hour purposes. For intermittent use, that is, for periods up to about six hours, electric and gas fires are, on the other hand, more efficient; in fact, as Sir John Hacking pointed out, it is for such intermittent use that these fires are principally employed, for coal fires are still burned throughout a winter's day in a very large majority of the households. Electric and gas fires are used, not to replace this type of heater, but to provide warmth for short periods in rooms which would not otherwise be heated. This, it may be pointed out, is not the same as to argue that the "base load" of winter space heating should be provided by solid fuel and that electricity or gas should be used only for "topping up" in extremely cold weather. Such a policy is naturally opposed by the British Electricity Authority.

So far, in our argument, the protagonists have been divided into two camps, depending on whether they do or do not advocate the use of solid fuel for the domestic heating. There is, however, a further charge against those who employ electric fires, on the ground that this type of equipment harmfully increases the demand on the system and thus, by causing load shedding, interferes with the industrial production of the country. As Sir John Hacking pointed out, however, the national system load factor during the year ended March 31, 1952, was a little over 47 per cent., while that for industrial and domestic consumers, in both cases, lay between 55 and 60 per cent., and for commercial consumers between 20 and 25 per cent. When account is taken of such facts that a concern working a 40-hour week with two weeks annual holiday has a load factor of not more than 23 per cent., it is clear that the domestic load is second in merit only to the continuous process industrial load. Its effect on the system load factor is therefore beneficial rather than harmful, provided only that care is taken to avoid the prohibited hours.

While, therefore, wishing to maintain a judicial outlook in considering a problem which bristles with great difficulties, we feel it necessary to express the opinion that it would be highly undesirable to prohibit the use of any particular type of heating. The individual consumer should be left free to choose the fuel and fuel-using appliances which he finds most suited to his needs, even if he chooses neither the cheapest nor the most efficient. To advocate any other course would be autocratic, and is not necessary, even with the fuel situation in its present unsatisfactory condition. It would be better if each branch of the fuel and power industry managed its affairs on a sound commercial basis without seeking to secure a privileged position at the expense of others. Every method should be sought by all branches to increase the efficiency of production and utilisation, with a view to obtaining a true balance of economic advantage in the employment of the national resources.

STEEL PRODUCTION AND CONSUMPTION.

ARCHÆOLOGISTS date the beginnings of the Iron Age some 3,000 years ago, defining it as the period when iron was adopted as the material from which weapons and tools were made. On this definition, it is still with us, and not only weapons and tools, but most of the appliances and structures on which modern material civilisation is based are dependent on its supply and fabrication. Iron is the basic material of the engineering industries, and those industries constitute the activities on which all others depend. There is a shortage of iron, or of its alloy, steel, in this country at the present time, but according to statistics collected and analysed by the Steel Section of the Economic Commission for Europe, there was not a world shortage of steel in 1950, the latest year for which full figures are available. In that year, Europe as a whole produced 60,609 million metric tons of steel and consumed 53,207 million, and the United States produced 87,723 million and consumed 85,657 million. These figures do not necessarily indicate a piling-up of stocks, as some other parts of the world used more that they contributed; Latin America, for instance, produced 1,252 million tons and consumed 3,696 million.

These figures are quoted from a United Nations report,* the purpose of which is to indicate the position and prospects of the European iron and steel industry in world economy. The report, however, raises some broader questions which it does not discuss. The consumption of steel *per capita* in Europe in 1948 was 111 kg., in 1949 it was 124 kg., and in 1950, 128 kg. Figures for the United States do not show the same consistent rise, and consumption in 1949 was lower than in 1948, but in 1950 it was the highest on record, at 565 kg. Consumption in all parts of the world shows the same rising tendency, although the overall consumption *per capita* is much less than in the highly-developed countries; for Africa as a whole, the figures for 1950 was 15·7 kg. The steepness of the rising curve of steel consumption may be accentuated by the present armaments race, and it seems possible that it may be halted by productive capacity. There is, presumably, no shortage of raw material, as iron is considered to be the fourth most abundant element in the world and, if some geophysicists are to be believed, the centre of the earth consists of a sphere of iron some 3,000 miles in diameter.

In the long run, this question of raw material supplies is clearly a fundamental one in any consideration of the future of the iron and steel industry. As already indicated, the report does not discuss it in a broad sense, but it states that, "up to 1949 and again since the end of 1950, raw material shortages have prevented full use of existing capacity," and again that "about 5 million tons more of iron contents in ores will be required than foreseen under the production plans existing in June, 1951." The maximum annual production achieved in September-November, 1950, in the United Kingdom, was 17,460 million metric tons and it is stated that, "had raw materials shortages not impeded production, a rate of 18,000 million would probably have been attained." The general conclusion come to is that plant capacity in Europe is adequate for the outputs envisaged for 1953, but that the necessary raw material may not be forthcoming. To avoid this possibility, "co-ordination of national plans at an international level" and "provision for the availability of an adequate supply of raw materials on an overall European basis" are proposed.

Ideas of this kind may well arise in the sheltered atmosphere of Geneva, but international control of the distribution of ores and scrap does not appear to be an early practical possibility. Omitting the U.S.S.R., the main European producers of steel are, in order of output, the United Kingdom, West Germany, France and Belgium, and the extent to which the iron and steel industries of all these countries are dependent on imported material may be illustrated by some selected figures. The United Kingdom in 1950 imported 55 per cent. of the iron content of iron ore and 15 per cent. of scrap; Germany, 50 per cent. of iron content; France did not import either ore or scrap, but imported 20 per cent. of the solid fuel, such as coke, and 55 per cent. of coking coal used in the industry; Belgium imported 100 per cent. of ore, but no solid fuel, and only 5 per cent. of coking coal. The maximum post-war annual production rate of these four countries was 47,656 million metric tons.

The opinion is expressed in the report that the projected outputs can be achieved if the consumption of scrap in blast furnaces is reduced to 90 kg. per ton of pig iron, compared with the 165 kg. used in 1950. This clearly implies increased supplies of ore and the figure given is 5 million tons more of iron content. Where this is to come from, the report does not state, but it is suggested that producers of raw materials "may have been unduly cautious in extending their production facilities in the absence of firm commitments from the importing countries." In addition to ore, coke and coking coal are important raw materials of the iron and steel industry. The overall deficiency in coking capacity is estimated at 4·5 million tons and, under the present ratio of distribution, 2·7 million tons of this deficiency would fall on the steel industry. This condition might be partly rectified by utilising present idle coking capacity in Western Germany and implementing plans for increasing capacity in France. Coking coal is considered to be in sufficient supply as long as important quantities are not diverted away from the iron and steel industry.

In addition to the figures relating to the main European steel-producing countries, some of which are quoted above, the report gives statistics of world production and consumption; these include reported totals for the Russian-dominated countries. The whole of this material necessarily involves a mass of figures which cannot be summarised effectively. A matter dealt with at the end of the report, which is of direct interest to this country, may, however, be mentioned. This concerns the future of the export market. Assuming that European steel can be produced at a competitive price, it is considered that it might be able to secure an 80 per cent. share of the world market. The two principal rivals are given as the United States and Japan. The former is in process of developing its productive capacity in order to cope simultaneously with the demands of both civilian and defence requirements, and it may be assumed that, ultimately, output in excess of the needs of the home market will be available. The extent to which this can be diverted to the export market will depend on international financial conditions, the future of which can hardly be foreseen. Japan, referred to in the report as a "principal rival," has a productive capacity of about 8 million tons per year, but is greatly dependent on imports for raw materials. Before the war, Japan imported about 2 million tons of scrap per year, mainly from the United States, and has since had large tonnages of war scrap. Japan also imported about 2 million tons of pig-iron from India, Manchuria and Korea, and 80 per cent. of the iron ore consumed came from neighbouring far-eastern countries. In the disturbed condition of that part of the world, it does not appear likely that Japan will be able to build up an important export industry in any early future, in spite of being favourably situated to supply the Far East.

* *Steel Production and Consumption Trends in Europe and the World.* Steel Section, United Nations Economic Commission for Europe. Geneva, Switzerland.

NOTES.

NORTH OF SCOTLAND HYDRO-ELECTRIC BOARD.

THE annual report of the North of Scotland Hydro-Electric Board for the year ended December 31, 1951 (H.M. Stationery Office, price 1*s.* 9*d.*) records that, by the end of the period, 280 MW of new hydro-electric plant became available in the area served and was producing 576 million kilowatt-hours per annum. The total hydro-electric production, including the output of the pre-war Grampian stations at Rannoch and Tummel and four other small stations, reached the rate of nearly 900 million kilowatt-hours per annum. A further 292 MW of plant, with an estimated annual output of 809 million kilowatt-hours, is under construction, and schemes with a total capacity of 226 MW and an annual output of 800 million kilowatt-hours are in various stages of promotion. In addition, projects involving a total capacity of 212 MW and an annual output of 751 million kilowatt-hours are being surveyed. During the year, construction work on the Affric, Cowal and Gairloch schemes reached the stage at which the generating stations could be started up; progress continued on the Shira, Errochty, Lussa and Storr Lochs schemes; and a start was made on those at Gaur, Glascarnoch-Luichart-Torr Achilty, Garry and Moriston. As regards transmission, some 840 circuit miles of 132-kV lines were in operation and another 280 miles were under construction at the end of the year, and ten switching stations were also under construction. Some 263,000 consumers were being served, of whom 18,861 were connected during the year. It is estimated that another 110,000 remain to be connected. In addition to meeting the requirements of their own area, every effort was made by the Board to send as much power as possible to Central Scotland, in order to reduce the seriousness of the cuts. In December, 1951, a peak amount of 198 MW was delivered, being 13 MW in excess of the contract figure. Efforts were continually made to economise in the use of scarce materials. Steel is being saved by substituting underground pressure tunnels for pipelines in five schemes. Bricks, cement and steel are being economised by the use of local stone and cement by the adoption at favourable sites of rock-fill and moraine-fill dams. Experiments were made with grain and hay drying, as well as with wind power, peat fuel in gas turbines and electric fish screens.

THE BRITISH COAL UTILISATION RESEARCH ASSOCIATION.

The annual luncheon of the British Coal Utilisation Research Association was held at the Savoy Hotel, London, W.C.2, on Wednesday, May 7, the chair being taken by the President, Sir Charles Ellis, F.R.S. The loyal toast having been honoured, the Minister of Fuel and Power (the Rt. Hon. Geoffrey Lloyd, P.C., M.P.) proposed that of "The B.C.U.R.A." The real problem of the time, said Mr. Geoffrey Lloyd—indeed, the real danger—was that excessive specialisation would produce an ill-balanced total personality. In scientific education, he suggested, it might be a good thing—assuming that it was desirable to introduce an element of the humanities—to introduce the humanities by studying the early history of science, and especially the early foundations of science. Anyone (he continued) who had spent any time in the tiny archipelago of the Greek islands would understand the fascination, from the point of view of science and the humanities, of studying the works of those intensely human men who were then beginning knowledge in its earliest phases. Sir Charles Ellis, in his reply to the toast, supported the Minister's views. In the intellectual contents of research, he said, the attitude of mind was the most important; research would never be a matter of the slide-rule only. Ultimately, it was an expression of artistic appreciation. The presence at the luncheon of Professor E. D. Adrian, the President of the Royal Society, gave to the occasion a peculiar significance, because he was joining with them to launch a new venture—the annual Coal Science Lecture, which the Council had founded in the hope of encouraging fundamental scientific thought on the subject. It was the Council's desire to encourage eminent scientists, by those means, to spare the time to review the whole subject and to explain, from their specialised knowledge, how they saw the great achievements of the past and the great objectives of the future. Sir Charles Ellis then presented the First Coal Science Medal to Sir Alfred Egerton, F.R.S., among the acclamation of the assembled company. To the toast of "The Guests," proposed by Sir John Charrington (vice-president of the B.C.U.R.A.), the Rt. Hon. Viscount Waverley replied that the Association was a development of a scientific activity that was distinctly British. The organisation of scientific research in Britain under the ægis of the Government was of comparatively recent date—it began only in the closing months of 1899, when the National Physical Laboratory was started on the initiative of the Royal Society. In scientific discovery, Britain was pre-eminent; and, at the present time, there was to be seen in increasing degree the establishment of research organisations in connection with industry. The larger industrial units had their own research establishments, but these worked in close harmony with those of the Government and with the smaller units. In that partnership of research associations —something that was exclusively British in origin—there was an active stimulus to all engaged in industry to become research-minded.

THE WORK OF ASLIB.

An encouraging picture of Aslib's work during 1951 is presented in the annual report for the year ended December, 1951. For the first time in many years the financial report shows a substantial credit balance instead of a bank overdraft. Membership has increased from a total of 1,038 members in 1950 to 1,219 in 1951. The routine inquiry work undertaken by the information bureau and library has increased by 33 per cent., and a consulting service has been set up (as from January 1, 1952) to assist industrial firms and other organisations in establishing new information services. Among the activities of the Publications Committee may be mentioned the continued work on the forthcoming "Directory of Sources of Specialised Information," to be published in two volumes; the commencement of a revised edition of the "Select List of Standard British Scientific and Technical Books," which it is hoped to publish during 1952; and the preparation of an annual "Index to Theses Accepted for Higher Degrees in the Universities of the British Isles." Other notable developments are the formation of a Midlands branch in September, and the specialist groups which include, so far, a textiles group, an economics group, a food and agriculture group, an aeronautical group, and, in process of formation, a fuel and power group. The aeronautical group has already established valuable relations with foreign organisations. The textiles group has developed a plan for sharing the cost and labour of translating foreign articles. The Council consider that, although the record for 1951 is gratifying, further expansion is still needed, and a reserve fund is to be built up to provide for contingencies.

THE VALUE OF COLOUR.

For most people the effect of colour in their environment is significant, though they cannot analyse it. In that respect, colour is like music; but whereas music, thrusting itself on the consciousness, generally produces a definite reaction, colour is so much a part of environment that many are oblivious of its potential power over mood and morale. That it has such a power none would deny who has seen a home or a place of work where the colours have been planned with skill. It may be asked, then, whether there is any way in which a progressive industrial firm can enlist the services of this subtle influence in creating pleasant working conditions. The answer is to be found in an Exhibition of Colour and Light in Industry, which has been organised by the British Colour Council at their offices, 13, Portman-square, London, W.1. The exhibition is open until May 30 (Mondays to Fridays, 10 a.m. to 4 p.m.; and Saturdays, 9.30 a.m. to 1 p.m.). The visitor is likely to come away with two impressions: first, that no factory management can afford to ignore the value of colour in promoting production, reducing accidents and reducing absenteeism—a fact that has been appreciated in recent years by a number of large engineering firms; and, secondly, that expert advice is necessary—the average decorator is not qualified to act in this capacity. Since the war, the British Colour Council have prepared schemes for a large number of firms. The value of colour in industrial surroundings was also referred to recently by Mr. Walter R. Bennett, in a paper on "Amenities in Factory Design," which he presented to the Royal Society of Arts. Mr. Bennett had to deal with several other factors, but he stressed the point which the exhibition so fully illustrates.

ANGLO-AMERICAN COUNCIL ON PRODUCTIVITY.

The fifth and final joint session of the Anglo-American Council on Productivity (the Council was formed in July, 1948) was held in London on May 6 and 8. The Council's final report—which will be published in a month or two—was approved, and the three organisations which comprise the United Kingdom section of the Council—the Federation of British Industries, the British Employers' Confederation, and the Trades Union Congress—decided to establish a British Productivity Council which will continue their co-operative work in promoting higher productivity. It is expected that this work will be done by engaging the interest of industries and helping them in their activities to increase productivity. The new Council will carry on the educational work; the productivity-team reports will be followed up, conferences and meetings will be sponsored, literature will be published and the use of films will be encouraged. The initial activities of the British Productivity Council are expected to include a national convention on productivity, to be held in London in the autumn. The Council will consist of about 24 members, and will include representatives of many individual industries appointed by the three organisations. The existing Anglo-American Council will be wound up on June 30. The United Kingdom section will continue in existence to supervise the publishing of the remainder of the teams' reports, until such time as its work can conveniently be merged in that of the proposed British Productivity Council. Reports still to be published include those on machine tools (woodworking and metal-working), constructional steelwork, inspection methods, production control, plant maintenance, conservation of fuel, heat and energy, plastics moulding, design for production, gas, simplification in industry, materials handling in industry, metal finishing, hot-dip galvanising, welding, and saving of scarce materials.

THE AMERICAN COAL-BURNING GAS-TURBINE LOCOMOTIVE.

Since we last referred (on page 18, *ante*) to the coal-burning gas-turbine unit of the Locomotive Development Committee, in the United States, some further details of bench tests have been released in a paper presented to the American Power Conference, at Chicago on March 28, by Mr. John I. Yellott and Mr. Peter R. Broadley, the director and assistant director of research, respectively. A total of 178 hours had been run on Pittsburgh-seam high-volatile bituminous coal. Combustion efficiency, as determined by ash analysis, was consistently above 95 per cent. Trouble was encountered with damp coal, and a number of alterations had to be made to the coal system. The average temperature at the turbine inlet ranged between 1,050 and 1,100 deg. F., with loads varying from 1,500 to 2,500 h.p. A number of mechanical difficulties were encountered, including troubles with auxiliary-generator lubrication, over-speed trips, hot-air leakage at the turbine inlets, and rubs of increasing severity in the turbine and compressor. On dismantling the plant for examination it was found that the turbine-rotor blades were entirely free from deposits and erosion. A very small spot of erosion on the cylinder blading was attributed to a period when the fly-ash separator was not functioning properly. There were no ash deposits anywhere in the turbine and the labyrinth seals were all perfectly clean. The paper concluded with the statement that the plant had been reassembled and was undergoing a 750-hour high-temperature high-load test. A report on this test is expected later in the year.

LETTERS TO THE EDITOR.

HYDRAULIC LOCK.

TO THE EDITOR OF ENGINEERING.

SIR,—With reference to your recent articles on the subject of hydraulic lock, I am taking the opportunity to put on record some interesting points that I encountered about five years ago, in the development of a hydraulic valve. The valve was of the piston type, wherein a controlled rate of leakage was required past one of the lands, and the form of locking and drying up of flow described by Mr. Stringer in his article on page 509, *ante*, was very much in evidence. Attempts were made to overcome it by increasing the clearance, and it was found that, though the diameter of the valve was only 0·25 in. and the length of the land the same, complete drying up of the flow occurred after a period of approximately 7 minutes, even with a clearance of 0·005 in. With a working pressure applied to the valve of 2,500 lb. per square inch, and using a normal hydraulic oil, the initial leakage on applying the pressure was, in many cases, over 200 c.c. per minute. As has been indicated in your articles, it was also found that any movement of the valve immediately freed the lock and restored the leakage to its original level; but as soon as the valve became static, a progressive decrease in leakage commenced.

The writer was not, in this case, interested in preventing the locking so much as maintaining the leakage, and as a result of the investigation an interesting design was evolved, wherein a fairly coarse V-form right- and left-hand screw thread, having three cross-overs along the length of the land of the valve, was cut to a depth of approximately 0·025 in. The resulting leakage was found to be acceptable, i.e., in the order of 20 c.c. per minute, and it was also found that there was comparatively little increase in leakage when the pressure applied to the valve was increased. A rate of some 10 c.c. per minute passing the valve at 200 lb. per square inch increased to under 50 c.c. per minute at 3,000 lb. per square inch. The reason for this comparatively small increase of leakage with pressure was never fully investigated, but was considered to be due to the turbulence in the fluid, resulting from the impingement at cross-over. The tendency of the valve to lock was also practically eliminated.

Yours truly,
R. F. WORLIDGE, A.F.R.Ae.S.

Cornerways,
Glengariff-road,
Lower Parkstone,
Dorset.
April 29, 1952.

TO THE EDITOR OF ENGINEERING.

SIR,—The article on hydraulic lock by Mr. J. E. C. Stringer, published on page 509 in your issue of April 25, gives interesting and useful information on the effects of dirt in the oil. That the presence of dirt may give rise to jamming in a piston valve is a well-known fact. The particular interest of Mr. Stringer's research lies in his observation of the harmful effects of very fine dirt particles and his finding that oil which is nominally clean is capable of causing jamming.

Some of the points raised in the article appear to call for comment. Firstly, it is stated that lock due to dirt is much more severe than pure hydraulic lock arising from eccentric movement of the piston. This may have been so in Mr. Stringer's valve, but it may not apply in general. My own experiments showed that considerable variation in values of the locking force could occur not only between different pistons of the same nominal size, but also between different relative positions of the same pair of components. Secondly, it should be appreciated that, in Mr. Stringer's valve, while lock due to dirt occurs at the end of the land controlling the port opening, lock due to eccentric movement more probably occurs at the other land, since the latter is subject to the pressure drop across its full length. The lap employed by Mr. Stringer is too small for appreciable locking to occur on the first land. There appears, therefore, to be no basis for direct comparison of the two types of lock. It would be interesting to know whether any definite relationship was established between the locking force due to dirt and (*a*) the pressure difference across the land, (*b*) the amount of lap. Also, did the valve become free on release of pressure? Referring to test (14), the surface imperfections giving rise to lock are unlikely to be identical on the two pistons employed. The comparison of the grooved piston with the plain piston is therefore not valid.

In test (15) it is suggested that the piston must be tilted to initiate eccentric locking. A piston subject to lock would always be unstable, and no tilting would be necessary to start the movement to an eccentric position. It is further suggested that some dirt may have been present in test (14), and that eccentric locking may be attributed ultimately to the effect of dirt particles on friction. It seems the results could equally well indicate that the lock in test (14) was due to dirt and not to pure hydraulic lock. Again, it is stated that the evidence obtained points to the fact that even eccentric locking may disappear when the oil is as completely freed from dirt as possible. Test (15) cannot be accepted as proof of this; why was no attempt made to obtain confirmation by testing the plain piston again in the unguided condition?

Yours faithfully,
D. C. SWEENEY.

Buswell and Sweeney, Limited,
Metro Works,
Bolton-street, Bordesley,
Birmingham, 9.
May 9, 1952.

TO THE EDITOR OF ENGINEERING.

SIR,—Mr. F. H. Towler, in his letter published on page 559, *ante*, raises a very important point, and I must apologise that this escaped mention in the account given of the Vickers-Armstrongs experiments in ENGINEERING of April 25, on page 509, *ante*. The valve spindle came free of its own accord in experiments (13), (14), (15), (20) and (21) in every case, if the oil was sufficiently filtered so as to eliminate dirt particles, and, therefore, "muck lock." The axial force then required to move the piston was less than $\frac{1}{4}$ oz., i.e., the same as that required to move it in its free state, prior to the start of an experiment.

Turning to the question of valve radial clearance: it has been observed, in another application, that when a control valve was lapped to a size-for-size fit for its bore, "muck lock" was not encountered; the action of this valve was at all times somewhat stiff, but did not become tighter with time. Equation (9), given by Dr. Sweeney on page 581, in your issue of November 9, 1951, is relevant; if the piston fit is perfect, then the $\frac{h_2 - h_1}{h_2 + h_1}$ term in this equation becomes zero, so that the sideways thrust is nil.

We should like to repeat our experiments in the guided and unguided condition with a valve having the radial clearance of 0·00005 in., suggested by Mr. Towler, but can he say where we can get one?

Yours faithfully,
J. E. C. STRINGER.

Elswick Works,
Newcastle-upon-Tyne, 4.
May 12, 1952.

THE FLOW OF METALS.

TO THE EDITOR OF ENGINEERING.

SIR,—In the abridged report of the Hatfield Memorial Lecture which you kindly published on page 601 in your issue of May 9, occurs the sentence "The general lesson for the practical man from experiments under simple shear . . ." but your abridgment makes no mention of these experiments, to which I devoted some attention. This letter is merely to let any of your readers who may be interested know that an account of the experiments under simple shear will appear in the full report of the lecture which will be published in due course (which I think means July) in the *Journal* of the Iron and Steel Institute.

Yours faithfully,
E. N. DA C. ANDRADE.

Davy Faraday Research Laboratory,
The Royal Institution,
21, Albemarle-street,
London, W.1.
May 10, 1952.

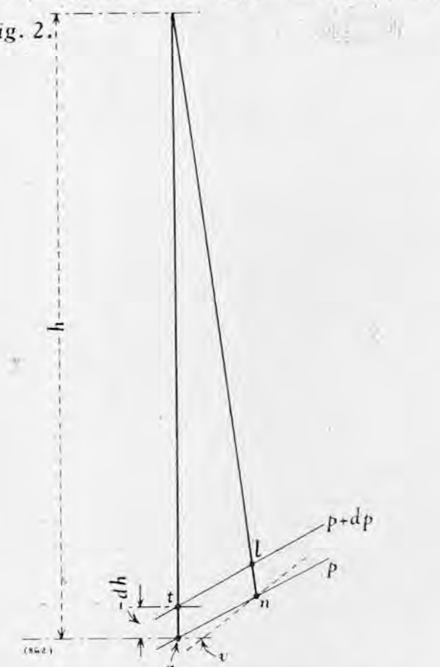
EFFECT OF CENTRIFUGAL FORCE IN AXIAL-FLOW TURBINES.

TO THE EDITOR OF ENGINEERING.

SIR,—In the article on the above subject published on page 205 of the 163rd volume of ENGINEERING, in your issue of March 21, 1947, I indicated a formula for the variation of the heat drop from root to tip of the nozzle. My attention has been drawn to the discrepancy between this formula and the formula which I used in actual practice since 1935.

On examining the article referred to, I find that I put, erroneously, $v\,dp = -\phi^2 J\,dh$; $v\,dp$ being on the actual condition line $n\,l$ (Fig. 2 in the article), the specific volume is larger than the specific volume on the corresponding portion $q\,t$ of the adiabatic line; therefore, $v\,dp = -m\,J\,dh$, where m is greater than unity. For a given working medium, m depends on the magnitude of the heat

Fig. 2.



drop h, on the nozzle coefficient, and on the ratio of $\frac{r}{r_1}$ (r being any radius, and r_1 the radius at the root).

The equation (2) in the article should have been:

$$-\frac{dh}{h} = \frac{2\,\phi^2 \cos^2 \alpha}{m}\,\frac{dr}{r},$$

and the formula (6)

$$\frac{h_2}{h_1} = \frac{1}{\left(\frac{r_2}{r_1}\right)^{\frac{2\,\phi^2 \cos^2 \alpha}{m}}}.$$

For moderate heat drops and high ϕ (usual in stages with long blades), m exceeds unity by a practically negligible amount, hence we can write:

$$\frac{h_2}{h_1} = \frac{1}{\left(\frac{r_2}{r_1}\right)^{2\,\phi^2 \cos^2 \alpha}}.$$

Yours faithfully,
B. POCHOBRADSKY.

Fraser and Chalmers Engineering Works,
Erith, Kent.
May 1, 1952.

[For convenience of reference, we reproduce herewith Fig. 2 of Mr. Pochobradsky's article of 1947.—ED., E.]

STEEL AUTHORISATIONS.

TO THE EDITOR OF ENGINEERING.

SIR,—The statement by a Ministry of Supply spokesman, which was published on page 497 in your issue of April 18, evades the issue. He stated

WEAR OF GEAR TEETH.

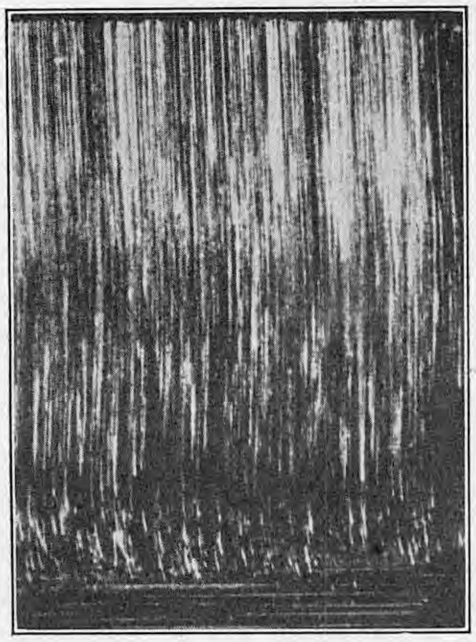


FIG. 2. MAGNIFICATION × 30.

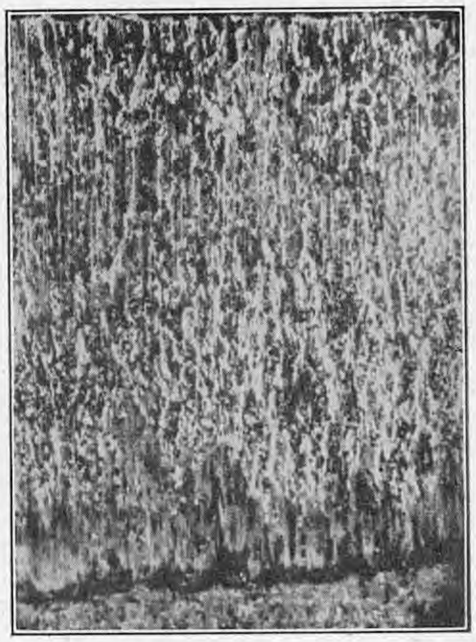


FIG. 3. MAGNIFICATION × 50.

that "It would be unwise to give forward authorisations enabling manufacturers to acquire large amounts of steel before they needed them." We agree, but our suggestion was that no harm could result from forward indents subject to confirmation by authorisation details before delivery. He gives some explanation of the difficulty of authorising far ahead, but such provisional arrangements between producer and consumer would not affect his authorisation scheme. He fears "duplicated orders," but why? Even if they were placed, only one would be authorised; and surely well-organised firms do not place them because of both storage space and finance? We still cannot understand why a fresh authorisation is necessary just because delivery is delayed. It is usual to ensure that outstanding cheques will be honoured before drawing others. The spokesman must know that if we "contact the authorising department concerned" we should get no more than a re-hash of his reply, which, in effect, boils down to "Nurse knows best"—a long-since exploded theory.

Yours faithfully,

FRUSTRATED.

May 5, 1952.

OBITUARY.

COMMANDER SIR ROBERT MICKLEM, C.B.E., R.N. (RETD.).

As we close for press, we have learned with deep regret of the death, on May 13, of Commander Sir Robert Micklem, C.B.E., R.N. (retd.), formerly joint managing director of Messrs. Vickers Limited, chairman of Messrs. Vickers-Armstrongs Limited, and a director of various other companies in the Vickers Group. Sir Robert, who was only 60 years of age, had been in poor health for some years, but continued at work until comparatively recently, when his illness became acute. We published only last week, on page 587, *ante*, a notice of his resignation from all his offices and directorships. A memoir will appear in our next issue.

MODERN BUILDING PLANT EXHIBITION.—The Ministry of Works, with the co-operation of manufacturers of building plant and equipment, has made arrangements to hold an exhibition of "Modern Building Plant" at the Sophia Gardens Field, Cardiff. It will be open from Thursday, September 18, to Wednesday, September 24, both dates inclusive. Further information may be obtained from the Ministry of Works, Lambeth Bridge House, London, S.E.1.

WAR ON WEAR.*

By PROFESSOR H. BLOK.

(*Concluded from page* 594.)

THE remaining types of double-sided wear are less simple, mainly because more complex types of interaction arise; of these types, only some representative examples will be discussed.

Abrasive wear is here defined as that type of double-sided wear in which the interaction between the mating surfaces is primarily caused by their geometric interference. This interference, resulting in a "ploughing" action, may be either on a macro-scale or on a micro-scale. Macro-abrasion occurs, for example, when two mating teeth bend under the load transmitted, so that, of the next pair of teeth to be mated, the tip edge of one tooth is not correctly spaced with respect to the root of the other and, consequently, acts as a cutting edge, producing in that root a groove which is directed perpendicularly to the relative motion. After the mating tooth profiles have thus adapted themselves to each other, macro-abrasion stops. Self-control, that is, the automatic balancing of attacking by resisting factors, is here brought about in a geometric manner.

Micro-abrasion is due to the interlocking of the surface irregularities which are invariably present at solid surfaces; it can be diminished by careful finishing. The interlocking introduces a cutting or shearing action and results in grooving of the surfaces in the direction of their relative motion (see Fig. 2, herewith).

The grooves occurring in the region of pure rolling of the tooth in Fig. 2 (the region indicated by arrows), have obviously been caused by the wear particles which, after abrading off in the neighbouring regions, were forced through the former region. This phenomenon leads us to a sub-type of abrasion which might be termed erosive abrasion or abrasive erosion, as it is the double-sided counterpart of the single-sided solid erosion. Erosive abrasion accompanies any type of double-sided wear in which wear particles are detached from the surfaces, and thus is of very frequent occurrence; moreover, it will also occur if hard foreign particles, such as dust, find their way between the mating surfaces.

Adhesive wear is the type of double-sided wear *par excellence*, being characterised by an intense kind of interaction between the two mating surfaces, namely, by their mutual adhesion in the contact areas; the adhesion introduces stresses in the surface material in addition to those produced by the load. Notably the work by Bowden and his co-workers has shown that, even at normal temperatures, adhesion between two contacting solids can be so strong that junctions are formed locally, i.e., dispersed throughout that portion of the rubbing surfaces where they contact each other. If sliding takes place, shearing of these junctions can contribute substantially to the friction, unless a good boundary lubricant is employed. The consequent tearing of material can take place in different forms according to the relative strengths of the junction and of the two adjoining surface materials. Under mild conditions, wear rates need not be alarming; but at high loads and sliding speeds, especially when contact is of the concentrated type as in gears, the plucking out and possible transfer of particles from one surface to the other can easily result in the loss of self-control, i.e., in a self-aggravating type of wear. The relevant scuffing or scoring, as it obtains in overloaded rapidly-running carburised gears, is illustrated by Fig. 3, herewith. The torn-up appearance, and traces of local melting or welding, are clearly visible. Comparison of Figs. 1, 2 and 3 is instructive in showing that the morphology of the mutilation of the worn surfaces may indicate the type and mechanism of wear involved.

In the foregoing, attention has been focused on types of wear representative of those where the mechanical aspects, in contradistinction to the chemical ones, play a major part. By way of example, protective measures have been mentioned at random. Let us now treat them more systematically, i.e., by classifying them under three general principles of protection.

The relevant three general principles of combating wear are, firstly, the provision of protective layers; secondly, conversion, and, thirdly, diversion of wear attack.

The Principle of the Protective Layer.—This principle is widely applied also for combating corrosion (by anti-corrosive coatings) and weathering (by paint coatings). For single-sided types of wear, the protective layer may be exemplified by the Stellite shields on turbine blades (to protect them against the impingement of the water droplets present in wet steam) and by the rubber coatings meant to combat solid and cavitation erosion. In double-sided wear, the principle of the protective layer reduces to the very versatile method of contact inhibition, which amounts to ensuring the greatest possible degree of separation between the parent solids of the two mating surfaces.

Complete contact inhibition, in some cases, can be achieved by suitable design, such as the use of labyrinth instead of contact seals. Silentbloc bearings belong also to this category, which, however, is of restricted applicability. For instance, Silentbloc bearings, in view of the tolerable strain of the rubber layer interposed between the two mating surfaces, can be applied only if the stroke of the oscillating or reciprocating motion is relatively small. In other cases, it is the realisation of full fluid-film, or, say, hydrodynamic lubrication that achieves complete contact-inhibition; the applicability of this expedient is limited, too.*

Whenever some degree of contact cannot be avoided, partial contact-inhibition has to be resorted to. In characteristic cases, one then has to rely on protective surface layers in a solid or plastic state that are formed on either of the two mating surfaces prior to, or during, service. Even when the material of a surface layer is rather plastic, the layer may yet show a remarkable resistance to squeezing and wiping off under compressive, or tangential, forces, provided that it is thin enough; this is owing to the reinforcement through backing-up, by a comparatively strong substratum, of the parent material underneath the surface layer. Thus one can segregate the wear-resistant function of the surface from the bulk-structural function (bulk strength and rigidity) of the body underneath the surface.

With the base reactive metals commonly used in engineering, oxidation by the atmosphere produces natural oxide layers prior to service and these may increase wear resistance quite remarkably as compared with the naked parent metals. The formation of such layers, under suitable conditions, is accelerated by the rubbing action that takes place during service; it is then termed "frictional oxidation" (cf. the paper by Professor J. J. Broeze).†

Protective layers can also be formed by an interaction between lubricant and rubbing surface; such layers are commonly termed "boundary layers." An early-recognised kind of interaction is physical adsorption. This results in the formation of boundary layers consisting of polar molecules adsorbed from the lubricant; the thickness of such layers appears to be of molecular dimensions. These layers offer a very limited protection, and even then only for as long as they remain solid (cf. the book by Bowden and Tabor, previously cited); in fact, they break down already at moderate temperatures.* According to the extensive and revealing work by Bowden and his co-workers, the breakdown coincides with the melting point of the adsorbed substance.

Bowden and his co-workers have also shown that, if metal surfaces are sufficiently chemically reactive, metal-soap layers are produced when fatty acids are present in the lubricant. The melting or softening point of the soap concerned being higher than that of the fatty acid, the protection against the adhesive

* Paper read at the International Symposium on Abrasion and Wear, held at the Rubber Stichting, Delft, Holland, on November 14 and 15, 1951.

* G. D. Boerlage and H. Blok, ENGINEERING, vol. 144, page 1 (1937).

† This paper will be printed shortly in ENGINEERING.—ED., E.

wear to be combated extends towards higher temperatures, which, however, will not ordinarily exceed something like 150 deg. or 200 deg. C. Still higher temperatures are encountered in heavily-loaded rapidly-running gears; then the extreme-pressure lubricants have to be resorted to.

It seems that all of the above-discussed boundary layers have this in common, that they lose their protective action through melting or softening at some characteristic breakdown temperature. Further, a low yield strength of the layers in their solid state appears to be conducive to low friction between the rubbing surfaces. Especially when surface temperatures are substantially influenced by the frictional heat (in contradistinction to heat produced externally), a moderate breakdown temperature can be compensated somewhat by low friction. This conception has been applied by the author to the rating of extreme-pressure (E.P.) lubricants, or, say, of extreme-pressure layers, as to the protection they afford against scuffing; recently, Williams* has systematically applied it to the classification and rating of boundary layers in general.

Finally, protective layers can be artificially applied prior to service. These layers, termed "coatings," are much thicker than boundary layers and their thickness is at least of the order of magnitude of one micron. Nowadays, they are available in a wide variety, especially in so far as they are formed by plating or by chemical means, i.e., by letting the rubbing surface in its initial unworn state react chemically with some suitable agent. Such surface treatments are very common in internal-combustion engines; carburising and nitriding are applied in gears, too.

The extensive class of chemical coatings may be exemplified by the coating produced by anodically oxidising aluminium-alloy pistons; this coating is intended to reduce the scuffing risks during running-in, and, like many other coatings, has a limited life which need not exceed the running-in period. Prolonged life is obtainable with very thick coatings, such as are produced by the hard-facing (Stellite) of valve seats.

The Principle of Conversion.—Conversion of wear attack is the conversion of a destructive into a permissible type of wear. In judging the possibilities of a contemplated conversion, "limit analysis" can be very enlightening; limit analysis refers to the assessment of the limits, of the region of service conditions, that delimit each of the wear types concerned.

There are many examples where the principle of conversion combines with the principle of the protective layer. For instance, the chemical reactivity of extreme-pressure oils converts scuffing of gears or cutting tools into a mild and self-controlled kind of corrosive wear. The protective extreme-pressure boundary layer is continually being rubbed off, but simultaneously repaired, by the chemical reaction between the parent metal and the extreme-pressure additive in the oil; the continual reaction causes a gradual depletion of the additive, so that, in the end, the extreme-pressure oil becomes perceptibly less powerful.

An example where conversion of wear attack is effective by itself is provided by the choice of a cast iron which, in being rather vulnerable to abrasive wear, allows piston rings to wear-in rapidly. Indeed, on the whole, such scuffing risks can be diminished appreciably, despite the rapid wearing-in.

Another possibility for applying the principle of conversion lies in the redesign of machine parts. This may be exemplified by the substitution of sliding by rolling bearings; then, if service lasts longer than pitting-fatigue life, pitting is substituted for ploughing and adhesive wear. An example of how wear can be converted into no wear at all is provided by the replacement of contact seals by labyrinth seals.

The Principle of Diversion.—Diversion is defined as diverting the wear attack from the surface that is economically more vulnerable to the other mating surface that can be replaced at less cost. This principle may be illustrated by the use of relatively soft and low-melting bearing materials in journal bearings; thus, in case of emergency, the punishment may be diverted from the journal to the bearing to a worth-while extent. By its very nature, diversion can only be employed in cases of double-sided wear.

In retrospect, it is worthy of note that the basic reason for applying the above three principles lies in the problem of securing control of the type of wear obtaining or aimed at. In other words, these principles are useful in eliminating self-aggravation, the element of unwelcome surprise that characterises the abnormality of critical types of wear; especially with such wear types, there is much need for supplementing their failing self-control.

It is thought that the three principles enunciated in the foregoing can guide the choice of materials for wearing parts (especially for their surfaces), the planning of maintenance, and, in cases of double-sided wear, also the choice of lubricants and lubricating methods (including the use of self-lubricating materials and of sealed rolling bearings, lubricated for life).

Apart from these general principles, there is a variety of empirical notions, rules, or formulæ that mainly aim at condensing practical experience, but mostly have a limited applicability if they are not sheer illusion. One can, for instance, point to the limited applicability of the still widespread notion that a bearing metal should have a heterogeneous, e.g., a duplex, structure in that hard crystals, which are supposed to carry the load, are embedded in a soft matrix. The general truth of this rule is easily disproved by the example of the successful copper-lead bearing metals, in which it is reasonably certain that it is the soft lead inclusions that carry the load;* further, certain homogeneous cadmium alloys perform quite well as bearing metals.

In the introductory section, it has already been concluded that increased effort needs to be devoted to waging war on wear. Workable knowledge about wear, despite the overwhelming amount of thought and energy bestowed on it, is still far from being as advanced as that about the neighbouring fields of structural strength and corrosion. This state of affairs is evidenced by the fact that there is as yet no single comprehensive book dealing with wear. In view of the steadily increasing economic importance of wear, this is disappointing, although it seems that the extension of knowledge at least keeps pace with the steady trend toward higher stresses and speeds of rubbing bodies and the consequent more intense frictional heating of their rubbing surfaces. Much could be achieved by disseminating, in unified form, the vast amount of practical and theoretical knowledge already gained in the diverse fields of wear; a logical subdivision of the matter, more or less along the lines indicated, would certainly lighten the task considerably.

Another indispensable means of mobilising resources in the war on wear consists in marshalling research at an intensified rate; thanks to the available refined observational, measuring, and interpretative (e.g., statistical) techniques, the outlook for bridging the many gaps in our knowledge is much brighter than, say, one or two decades ago. The research should extend from one extreme, the highly fundamental laboratory research, where the number of uncontrolled variables is kept to a minimum, to the other extreme, the statistical analysis of service performance with its many uncontrolled variables. The contradictions which too often exist, or appear to exist, between the results of the two extremes should be elucidated by intermediate stages of research, such as simulative bench-testing of isolated machine parts or of complete machinery.

Qualitative analysis of wear, comprising morphology and phenomenology, is well advanced nowadays. The same is not true of quantitative analysis, which aims at predicting wear rates under specified conditions of service. The latter analysis should be directed, more than has been done hitherto, toward investigating the interplay between the wear-resisting and the attacking factors; thus, badly needed insight could be gained into the important question of the extent of self-control of the different types of wear under different conditions. Last, but not least, "limit analysis," which represents a connecting link between qualitative and quantitative analysis, would yield the semi-quantitative information that is needed first of all in designing for wear, especially in so-called limit design.

* C. G. Williams, paper on "The Mechanism of Action of Extreme-Pressure Lubrication," in the Discussion on Friction arranged by the Royal Society, London, in April, 1951.

* "Running Properties of Bearing Metals," by S. Kyropoulos; *Refiner and Nat. Gas Manuf.*, vol. 19, page 67 (1940).

BRITISH OVERSEAS AIRWAYS CORPORATION.

DURING the financial year ended March 31, 1952, British Overseas Airways Corporation made a clear "overall surplus" of £268,000, compared with a deficit of £4,565,000 in the year 1950 to 1951, and a deficit of £7,792,000 in 1949 to 1950. This overall surplus represents the profit retained in the business after deducting from the net profit on the year's operations the interest paid on issued capital. These figures were given by the chairman of the Corporation in a quarterly financial review issued to the staff.

It is notable that, compared with the previous year, the output (in capacity-ton-miles) per employee per year has increased by 20·3 per cent., and the operating revenue per employee per year by 38·1 per cent. The capacity-ton-miles flown and offered for sale has increased by 19·2 per cent.; the revenue hours flown by 11·1 per cent.; the average capacity of the aircraft by 4·8 per cent.; and the average block-to-block speed by 1·8 per cent. The total operating costs per aircraft rose by 4·8 per cent. The number of passengers carried increased by 27·7 per cent.; freight carried by 14·9 per cent.; and mail carried by 26·6 per cent. The total operating revenue increased by 36·8 per cent., and the operating revenue per capacity-ton-mile by 15·6 per cent. The percentage of seats which must be filled to make the service pay has been reduced from 75 per cent. in 1950-51 to 65 per cent. in 1951-52.

CHEMICAL ENGINEERING AT THE CROSS-ROADS.*

By SIR HAROLD HARTLEY, K.C.V.O., F.R.S.

WHEN you did me the honour of making me your President, I told you of my conviction of the increasing part chemical engineering is bound to take in the industrial life of Britain. That conviction has only been strengthened and confirmed by all I have seen and heard. I have frequently had to explain to people what I understood by chemical engineering and why I was so insistent on its importance. I found that the simplest explanation was the historical sequence of events in the field of engineering. The civil engineer skilled in the technique of building structures, roads and bridges was first in the field, with an Institution founded in 1818. Next with the evolution of the steam engine, followed by power-driven machines, came the mechanical engineer; his Institution dates from 1847. Then, with the advent of the dynamo and motor came the electrical engineer, whose contributions in the distribution of power and in the field of communication by cable and wireless have changed so profoundly our way of life. His Institution goes back to 1871. In each case a specialised technology gradually developed, embodying both the results of experience and the application of science to the problems involved. A further 50 odd years saw the birth of our own Institution in 1922.

Until the Nineteenth Century, man was dependent on very few chemical reactions, except for combustion, metallurgy and fermentation. Then came the heavy chemical industry with acids, bases and fertilisers, and it was only in the second half of the Nineteenth Century that the beginnings of synthetic organic industry widened the scope of chemical industry with the production of dyes and pharmaceuticals. The Twentieth Century has seen a vast expansion of the chemical industry, with the rise of scientific methods of oil refining and of a great industry based on refinery gases and natural gas together with the production of synthetic fibres and plastics; but of equal significance has been the invasion of chemical techniques into the processing of many natural products—food, wood, rubber and leather—and into the fermentation industries. The extractive industries have become chemical industries. Many of these developments have been on a huge engineering scale, continuous processes replacing the older batch methods.

As a result there has developed "a distinct body of science which is fundamental and peculiar to chemical engineering. This involves principles, theories, procedures, methods and techniques fundamental to the majority of chemical engineering operations. While in some cases this body of science involves and utilises subject matter and principles common to other sciences, it modifies, extends, orients and combines these principles in a unique manner." (J. G. Elgin.)

At the approach to cross-roads one expects to find signs and warnings and there is no lack of them here—the Hankey Report on the supply and demand for chemical engineers in Britain, the Dunsheath Report of the Productivity Team that investigated the relations between universities and industry in the United States, the Cremer Report of the Committee on Chemical Engineering Research, and the recent discussion in the American Institute of Chemical Engineers, on "Whither Chemical Engineering Science?" The Dunsheath Committee were "impressed by the extent courses in chemical engineering have been developed in America and by the extent to which these courses are regarded as meeting a widespread demand from various branches of American industry." The number of courses in chemical engineering is exceeded only by those in civil, electrical and mechanical engineering and in 1949-50 the number of first degrees granted in chemical engineering was 4,529. "Many Americans believe that these large numbers have had an important bearing on the rapid progress on industry in the United States."

Alongside this sober statement or understatement of the facts, let me quote the words of Dr. J. B. Conant, the President of Harvard, in his address at the Diamond Jubilee Meeting of the American Chemical Society last September. "In 1902," he said, "chemical engineering had not developed as a profession. To-day there is a great shortage of chemical engineers in spite of the fact that more than 15,000 have been trained in the last five years. In short, the growth of the chemical profession within the lifetime of many of us here has been one of the amazing social phenomena of

* Presidential address to the Institution of Chemical Engineers, delivered in London on Friday, April 25, 1952. Abridged.

our times. It takes no crystal ball to show that this chemical revolution will affect the balance of the century. Whether the curve will continue to mount at the same rate of annual change is an open question; but that there will be vastly more members of this nation who were trained as chemists and chemical engineers in 2001 than there are now in 1951 seems to be one of the few certainties of the future. Notice I define the members of our profession in terms of their specialised education, not their employment; for one of the highly significant aspects of the development of chemistry in the last 100 years in all countries, but particularly here in the United States, is the way chemists have infiltrated into all sorts of positions in scientific and industrial life. This process will continue and one is safe in predicting that the work of the chemist in the United States has only just begun. The breadth of his scientific training and the strategic position of his science will make him one of the key figures in an urbanised, mechanised society dependent for its very life on the careful control of a multitude of chemical reactions."

The Hankey and Cremer Reports.

Now let us turn to the Hankey Report to see what is the position here. From that report we learn that the annual output of chemical engineers from all sources in this country between 1950 and 1954 is estimated at 200. The comparison between this figure and the output in the United States speaks for itself. There is no need to emphasise the urgent need for a rapid increase in the number of chemical engineering courses at our universities and technical colleges, and an expansion in the size of existing courses where possible. The gap is far too large to be dealt with by any new technological university, and wherever engineering courses are now given it seems only reasonable that undergraduates should have an opportunity to study chemical engineering if they so desire. In spite of the present disparity in numbers, I am optimistic for the future if the need to multiply and expand the courses in chemical engineering is recognised as most urgent both by the universities and by the University Grants Committee.

Seventy-five years have passed since the first course in chemical engineering was given by George Davis in the Manchester School of Technology. Gradually the concept of unit operations from which manufacturing processes could be built up emerged as the best scheme of training for a chemical engineer, based on a knowledge of mathematics, chemistry and physics. With the ever-widening field for the chemical engineer, his education is tending to take new shape. Its form was the subject of our American colleagues' symposium last December on "Whither Chemical Engineering Science?" The general outcome of the discussion was to emphasise the need for the chemical engineer to be trained in the basic sciences and in the fundamental laws that are common to so many unit operations, rather than in the details of the unit operations themselves. His training must aim at flexibility and adaptability of outlook and at a scientific rather than an empirical approach to new problems.

The Cremer Report contrasts the two approaches to plant design: the analytical approach, dependent on the functional analysis of the performance of existing plants, and the synthetic approach, based on experimental investigations of the mechanism of each process and the laws governing it. With the many variables that enter into plant design, the training of a chemical engineer must teach him to make a judicious compromise between these two methods of approach and to select the fields where investigation would be of value. He must grow up in the challenging atmosphere of problems, with the opportunity to see the creative power of research in progress. The Cremer Committee were appointed to report on the position of chemical engineering research in this country. After reviewing the existing facilities and taking evidence from over a hundred firms and research associations, they reached the conclusion that "existing facilities are inadequate for the purposes of the chemical and allied industries as a whole."

Those research facilities fall into three groups: first, the laboratories of the great firms like Imperial Chemical Industries, Courtauld's, the Distillers' Company, and Glaxo, and of national establishments like Harwell, all of which, together, are vastly greater in resources than those of the other two groups; next, the laboratories of the chemical engineering schools of the universities and technical colleges; and, lastly, the laboratories of the plant designers and manufacturers, which, with a few exceptions, are small and devoted to the companies' specialist fields. The need for more research of the synthetic fundamental type may be met by increasing research facilities at universities and by the growing numbers of chemical engineering schools. The Cremer Committee decided, however, that the analytical approach requires a central organisation specially adapted to this purpose, where, under some co-operative scheme with industry, the data from large-scale operations could be collected, analysed and quickly made available as a basis for plant design.

My own conviction is that the conclusions of the Cremer Committee do not go far enough in one respect. I am certain that the analysis of the results of plant operation will show up gaps in our knowledge which can only be filled by experimental investigations on large-scale pilot plant, for which a laboratory will be needed. I will go farther and say that, until we recover the initiative in chemical plant design and construction, we shall be forced to buy the "know-how" at a high cost from abroad, and it will not be the latest. We can only regain that initiative by analytical and synthetic research, for the co-ordination and application of which the organisation recommended by the Cremer Committee is essential.

The only move towards implementing the recommendations of the Cremer Report so far is the decision of the Department of Scientific and Industrial Research to publish a series of critical bibliographies on particular aspects of chemical engineering techniques. The first will deal with methods of industrial drying, and the second with grinding methods and the dispersion of solid particles. This will be a most useful contribution, but there remains the urgent need for the organisation envisaged in the report to collect, co-ordinate and publish the results of plant operations, together with a pilot-plant laboratory.

The Future of Chemical Engineering.

What is the future of chemical engineering? What part is it destined to play in meeting the ever-growing needs of mankind, with the increasing population of the world and the call for higher standards? Twenty years ago, we were destroying surplus crops; to-day we are living in an age of shortages. The primary needs of the world are energy, food, metals and other raw materials. How can they be met? What will be the contribution of chemical engineering? Let us start with energy—power and heat—for that is the key to the type of civilisation we have evolved, on which its continuance depends. I showed in a paper on "Limiting Factors to World Production," that, before 1939, there was a close correlation between the energy consumption per head and the average real income in many countries. With the inevitable gradual exhaustion of fossil fuels, great hopes are based on the use of nuclear energy in the future. Whether these hopes are likely to be fulfilled I will not venture to predict, but one thing is certain; their fulfilment will depend largely on chemical engineering.

The advent of atomic energy has introduced new features to the industrial scene. The production of materials for the construction of reactors, the production of fissile "fuel," the reprocessing of the spent "fuel" and the safe disposal of fission products all involve the development of fresh chemical engineering processes and the design and operation of new forms of plant. The design of some of this plant is based on previous experience, but much is quite new and is giving plenty of scope for ingenuity and initiative. Atomic energy has, for example, given a fresh meaning to remote control. War-time achievements were made without counting the cost, but the improvement of the economies of the processes, to the point where atomic energy can compete on level terms with conventional sources, provides a real challenge to the chemical engineer.

Solar radiation is an even more potent and ever-present source of energy. With the depletion of fossil fuels, it is inevitable that the day will come when man must harness the sun's rays. Whether it will come through controlled photo-synthesis, through photo-electricity or through fuel cells free from the limitations of the thermodynamics of the heat cycle, or other means, no one can say, but when it does I venture to predict that the techniques of chemical engineering will play their part.

Turning now to the more conventional methods of utilising energy, I take first steam power stations. There is no need to emphasise what chemical engineering has already done to raise the efficiency of use of the fossil fuels, coal, oil and natural gas. Indeed, the great developments of oil refining have gone hand in hand with the science of the chemical engineer to whom it owes the new technique of fluidisation, the influence of which is now being felt in many other industries. There is, too, the huge new chemical industry, based on refinery gases and natural gas. Much the same is true of the processing and carbonisation of coal. Indeed, apart from the need for smokeless fuels and oven coke, its future may lie in total gasification, carried out in part underground, together with the possibilities of synthesising liquid fuels where conditions are favourable. Thus, in the field of energy the chemical engineer will be an indispensable partner.

Leaving food aside for a moment and turning to metals, two facts emerged very clearly at the United Nations Conference on Resources at Lake Success in 1949; first, the growing consumption of metals with the spread of industrialisation and, second, our increasing dependence on lower-grade ores. Known reserves of non-ferrous metals will provide for, say, half a century at the present rate of consumption, pointing in the long run to a steel and light-alloy economy, with non-ferrous metals reserved for essential purposes. Chemical engineering has already contributed much to the dressing of low-grade ores, and to the extraction of metal from them. Take, for example, the extraction of gold from ores containing not more than 1 dwt. per ton, or the extraction of magnesium from sea water containing about one part per thousand of the metal. Another example is the production of extremely pure zinc by fractional distillation as a result of the application of chemical engineering principles in a field previously covered by crude empiricism.

I come now to the products for which we have to rely mainly on living organisms. To get the problem into its proper perspective, some years ago I made a study which showed that, on a value basis, 87 per cent. of farm and forest products were used as food and 13 per cent. in industry. This represents about one-third of industry's raw materials, the remaining two-thirds coming from non-living sources. Zimmermann arrived independently at much the same figures, from which it follows that the feeding of men and animals consumes about 70 per cent. of all raw materials on a value basis, and industry consumes the rest.

The Twentieth Century has seen great changes in the nature and the use of raw materials in industry, in which chemical engineering has played its part. One major trend has been the processing of natural materials like rubber and leather as their chemical and physical nature has been better understood. Another striking development in this field has been the recovery of valuable by-products during the preparation of natural materials and the processing of the waste products of agriculture and forestry. The steep liquor in which maize has been soaked prior to wet milling is an excellent nutrient together with lactose for the production of penicillin, and the yields increased rapidly when this was discovered. A valuable wax can be obtained as a by-product in sugar refining. Furfural, made on an engineering scale from maize cobs and oat husks, is used for many purposes, most recently as the starting material for making nylon.

Development of Synthetic Materials.

Another major trend has been the rapid development of synthetic materials, in some cases in competition with natural materials, in others in partnership with them. These synthetics are all carbon compounds manufactured from coal, oil or natural gas, or from natural materials such as cellulose or proteins. Fibres and plastics are two of the main developments. The field for plastics is widening daily. One of the new-comers, polystyrene, has already reached a production of over a quarter of a million tons a year. Incorporated with synthetic rubber, it replaced leather in 1950 in roughly half 500 million pairs of shoes in the United States alone. Catalysis plays such a vital part in so many of these plants that one asks the question, "Are there limits to the use of man-made catalysts?"

Some 20 years ago, I was talking to Carl Bosch, the chairman of the I.G. Farbenindustrie, about the future of tropical agriculture. He told me something that Steinmetz, the genius of Schenectady, had said to him which has a bearing on this question. Steinmetz had said: "Bosch, I know you can make indigo cheaper than God; some day you may make rubber cheaper than God; but you will never make cellulose cheaper than God."

Let us see how this remarkable prophecy stands to-day in the light of present knowledge. We can make a relatively small and simple molecule like indigo economically. As the complexity increases, as in penicillin, Nature wins; though sometimes, by taking advantage of a cheap natural product, we can compete with Nature. We can manufacture simple molecules like butadiene, and polymerise them to give synthetic rubber, or we can take mixtures of simple molecules to give copolymers; but these long chains are built up by the regular repetition of simple units. Life is dependent upon much more complex molecules, proteins and polysaccharides, the result of the long series of adjustments in the evolution of animal life. For food, we are dependent directly or indirectly on the products of photo synthesis, the basis of the living process in which solar energy is used by Nature's catalysts to convert carbon dioxide and water into carbohydrates by a complex process which we have never simulated in the laboratory. I hesitate to say that anything may prove impossible, but my conviction is that the man-made catalyst will never compete with the living cell in producing those complex molecules which its enzyme systems build so accurately and cleanly by the template methods in successive steps, which they probably employ.

In view of all this, I return to ask how chemical engineering is to play its part in future in helping to meet the world's needs for these complex molecules: clearly not by competing with Nature, but by a more intimate partnership with her. What forms will that partnership take? First, the help that agriculture will derive from improved fertilisers, from new weed-killers, fungicides and insecticides, from new antibiotics to eliminate disease in man and animals and plants, and possibly from substances which modify the soil structure to give those optimum conditions on which the crop yield so much depends. Next there is the processing of food products to up-grade and preserve them and facilitate their transport, and the processing of farm residues. Lastly, and of most significance for the future, is the partnership in bio-chemical engineering. I use the hyphen deliberately, because it is not a new form of chemical engineering, but the adaptation of its techniques to meet the conditions imposed by the living organism.

Fermentation is the oldest of chemical industries and now, with our fresh knowledge of the habits of bacteria and other unicellular organisms and plants, it is taking on a new guise as we adapt it to yield a great number of the organic substances that we need. Most striking is the use of moulds to produce on an engineering scale those powerful new antibiotics, penicillin, streptomycin and aureomycin, that have opened a new chapter in defence against disease. The phenomenal rise in production of these antibiotics, most of which were unknown ten years ago, has been made possible by most delicate feats of chemical engineering.

In a survey of this nature, whether one looks at the immediate or the more distant future, one is driven to the conclusion that the world must depend more and more on chemical techniques to meet the needs of its growing population. To do this, the chemical engineer is bound to play an increasing part in partnership with the older branches of engineering. In any project, he will be the liaison between the research laboratory and the team of engineers, the co-ordinator of their contributions. It was largely by engineering skill and invention that Britain won its place among the nations during the Industrial Revolution, and it is in these same fields, in this second Elizabethan age, that our strength still lies. Chemical engineering, the newcomer, is not competitive with the older branches of engineering, but complementary to them. It is a fourth primary technology, dependent in many ways on the other three, and destined to play an increasing part in the competitive strength of British industry.

25 YEARS OF ELECTRIC FURNACE MANUFACTURE.

THE 25th anniversary of Birlec Limited, Tyburn-road, Birmingham, 24, was celebrated at a luncheon held on Wednesday, May 7. Sketching the progress that had been made in the increasingly important field of furnace manufacture, Mr. J. H. Crossley, director, said that Birmingham Electric Furnaces, as the firm was initially named, was started in 1927 to develop new uses for nickel alloys and was associated, as it is still, with Henry Wiggin and Company, Limited, within the Mond Nickel and International Nickel organisations. The principal outlet for these alloys, which was then explored, was via the industrial electric furnace, the object being the provision of equipment which would ensure efficient and economical heat treatment. This, it may be remarked, still forms the principal basis of the firm's activities, although interesting developments have since taken place in other directions. It is also not without significance that the first furnace sold, a quarter of a century ago, is still in operation.

Mr. Crossley claimed that the firm could count many pioneering designs in this field to their credit, of which particular mention might be made of three: the rotary, drum annealing furnace, in which the vast majority of the cartridge cases produced during the war, not only in Great Britain but throughout the Empire, were treated; the duplex nitrider for aero-engine crank-shafts; and malleable annealing equipment. New heating applications, for which they also claimed to be responsible, included continuous furnace copper brazing, continuous bright annealing and gas carburising. Special attention, in addition, had been paid to the metallurgical problems involved in the application of gaseous atmospheres and the mechanical problems of designing continuous conveyor equipment. During the firm's existence, too, advances had been made in the production of gas-fired equipment and electric melting furnaces of the arc and high-frequency and low-frequency induction types, as well as heat treatment furnaces for the pottery and other trades. Finally, the manufacture of electro-dryers had been initiated, the operation of which depends on the properties of activated alumina. These dryers now find a special application in chemical and general engineering, but they were originally designed for drying the atmosphere in bright annealing furnaces.

That these claims are not unjustified was indicated to those present by an inspection of the factory, where a great deal of "tailor-made" equipment was being produced for a variety of purposes. At present, nearly 800 people are employed. There is a non-contributory pension scheme, and ample recreational facilities are provided.

LABOUR NOTES.

AT the meeting of representatives of the three principal railway unions held in London on Friday, May 9, it was decided to demand an increase of 10 per cent. in wages for all grades of railway employees. The reason given for the claim, which is being put forward jointly by the National Union of Railwaymen, the Associated Society of Locomotive Engineers and Firemen and the Transport Salaried Staffs' Association, is the rise in the cost of living and the inadequacy of the present rates of pay. Another decision arrived at at last Friday's meeting was to ask for the payment of time-and-a-half for all Saturday working between noon and midnight. Excluding men in the railway workshops, whose case for increased pay will be dealt with separately, the new claim covers some 600,000 employees and the estimated cost of the proposed increase would add upward of 17,000,000*l*. a year to the wage bill of British Railways. It will be recalled that last year, as a result of protracted negotiations, an increase of 8 per cent. was awarded to railway employees at a cost of well over 14,000,000*l*.

A resolution expressing concern at the effect which the re-armament programme is having on this country's economy and particularly on her engineering production, was passed last Friday at the annual policy conference of the national committee of the Amalgamated Engineering Union at Blackpool. Briefly, the resolution suggested that the Trades Union Congress and the Labour Party should urge the Government to obtain a peace pact between the five great Powers; to promote international discussion towards an agreement on a progressive reduction of all arms; to secure the prohibition of atomic, germ and bacteriological warfare, and to hold an inquiry into the wages of workpeople in countries which threaten Great Britain's trade. Another resolution, passed at Monday's meeting of the conference, proposed that the next Labour Government should nationalise, once again, without compensation, all the industries denationalised by the present Government.

The question of denationalisation was referred to by Alderman Percy Morris, J.P., M.P., in the course of his presidential address delivered at the annual conference of the Transport Salaried Staffs' Association, at Folkestone on May 12. He said that, if the proposals to denationalise road haulage and to introduce some vague form of decentralisation of the railways were implemented, they would "restore the worst evils of competition and bring to the transport industry the chaos that prevailed in pre-war days." The Railway Executive had effected economies amounting to 14,000,000*l*. per annum, due to standardisation, the re-routing of traffic, and other measures of co-ordination and integration. The Road Haulage Executive had performed an outstanding act of administration in acquiring and merging 3,500 separate undertakings into one great service.

The Association had frequently had to criticise the British Transport Commission and the Railway Executive, continued Mr. Morris, but these had a better conception of staff relations, consultation and management than any of the old companies, and he hoped that this policy would be maintained. The burden of re-armament was crippling the transport industry. There was a shortage of 100,000 wagons; the Railway Executive could not build a single vehicle of its programme for 1952. Its chairman had said that no fewer than "2,000 aged coaches, shabby and unfit for modern traffic," would be running this summer. No blame could be imputed to the Railway Executive. It was all due to the fear of war—the curse that blighted the life of every nation.

Speaking at the ordinary general meeting of Messrs. Newton, Chambers and Company, Limited, Thorncliffe, near Sheffield, held on May 7, at the Royal Victoria Hotel, Sheffield, Sir Harold West, managing director of the company, said that after ten years of experiment, a works college had been established. This offered business training for girls and craft training for boys, and, measured by national technical standards, their young people were giving an extremely good account of themselves. The company had good reason to be satisfied with a system of training which had attracted to Thorncliffe young people of a very good type. Many firms were now beginning to feel the combined effect of the low birth-rate of the nineteen-thirties and the raising of the school-leaving age. By 1955, industry would have only half the number of young people it had in 1945. The substantial sums spent on making both work and recreation at Thorncliffe pleasant and attractive had been amply justified.

The chairman of the company, Sir Samuel Roberts, Bt., who presided at the meeting, referred, in his statement, to the fact that the young people who passed through their works college were the future craftsmen of the firm or were destined to occupy management positions at Thorncliffe. Another matter of interest was that nearly 600 of their employees had been with the company for upwards of 20 years. In appreciation of twelve months of co-operative and efficient effort on the part of the management and workpeople, a sum of 25,445*l*. had been distributed as a profit-sharing bonus for all employees of the company. This had taken the form of an extra week's wage last Christmas.

Commenting on the present incidence of unemployment in Ulster, caused mainly by a recession in the textile, clothing and other industries, the current number of "Ulster Commentary," a monthly publication issued by the Government of Northern Ireland, points out that the decline in orders is common to the United Kingdom as a whole. The publication then quotes a recent Parliamentary statement made by the Minister of Labour and National Insurance, which is to the effect that although unemployment among women and girls has risen this spring, there has been no general worsening of the position as regards men. This has been mainly due to the road works initiated as an emergency measure by the Government in co-operation with local authorities. Some 6,112 men have been placed in work on these schemes. Pre-occupation with unemployment, the Minister continued, should not be allowed to conceal the remarkable improvement in employment which had taken place in recent years. In the spring of 1939, there were 350,000 persons on the pay rolls; at the present time, there were about 420,000. This meant that there were now six persons at work for every five 13 years ago. Between June, 1943, when unemployment was low, and July, 1951, there had been an increase in employment of 11,000 in the linen industry, 14,000 in other textiles, 10,000 in clothing manufacture, and 7,000 in food manufacture. On the other hand, the numbers employed in shipbuilding had fallen by 3,000, and those in engineering by 24,000.

In the course of a speech made during a recent two-day tour of Ulster industries, Mr. Duncan Sandys, the Minister of Supply, suggested the creation of an organisation designed to secure, for the smaller engineering firms, a substantial amount of sub-contracting work in connection with the defence programme. He had also given an instruction at the Ministry that, except in rare cases, no contracts for textiles or any other product should be placed outside the United Kingdom. Government contracts by themselves, Mr. Sandys went on to say, could not do more than touch the outer fringe of the problem, but the Government in London would do all it could to bring work to areas such as Northern Ireland, which were hard hit by unemployment.

At the annual meeting, at Middlesbrough, of the Heavy Steel Trades Section of the Iron and Steel Trades Confederation, Mr. J. Senior, the divisional officer, referred to the splendid co-operation between men and management in the steel industry, and also to developments at local works. Mr. Senior spoke of the bringing into operation of the Lackenby plant of Messrs. Dorman, Long and Company, Limited, and the reorganisation at the Skinningrove Works. Remarkable developments, he said, had also occurred at the Consett Iron Works, as a result of which the firm was now making more ingots than ever before. Mr. Senior added that he hoped that the importation of steel from the United States would help to overcome the short-time working which had been in operation at some works. Referring to working conditions, he said that, for the first time in history, men in the steel industry were to get 18 days paid holiday per annum, while men in melting and heating departments were to get a 44-hour week from June 1. There was great hope for the future.

Mr. E. G. Gooch, M.P., who was re-elected President of the National Union of Agricultural Workers at the Union's conference at Skegness on May 13, stated in his presidential address that there was an "overwhelming" case for a substantial increase in the wages of farm employees, as the rise of 8*s*. obtained last year had been swallowed up by increased prices before the men had received it. On the general question of augmenting the quantity of food grown in this country, Mr. Gooch considered that energetic steps to improve the productivity of the land should be taken without delay. He suggested that a stricter control of land use, properly planned and supervised acts of husbandry, the dispossession of hopelessly incompetent cultivators, the establishment of machinery pools, an intensification of the efforts to control pests and animal diseases and the reclamation and tilling of marginal land, were among the measures which should be immediately and vigorously pursued.

COLD-REDUCTION TIN-PLATE PLANT AT TROSTRE.

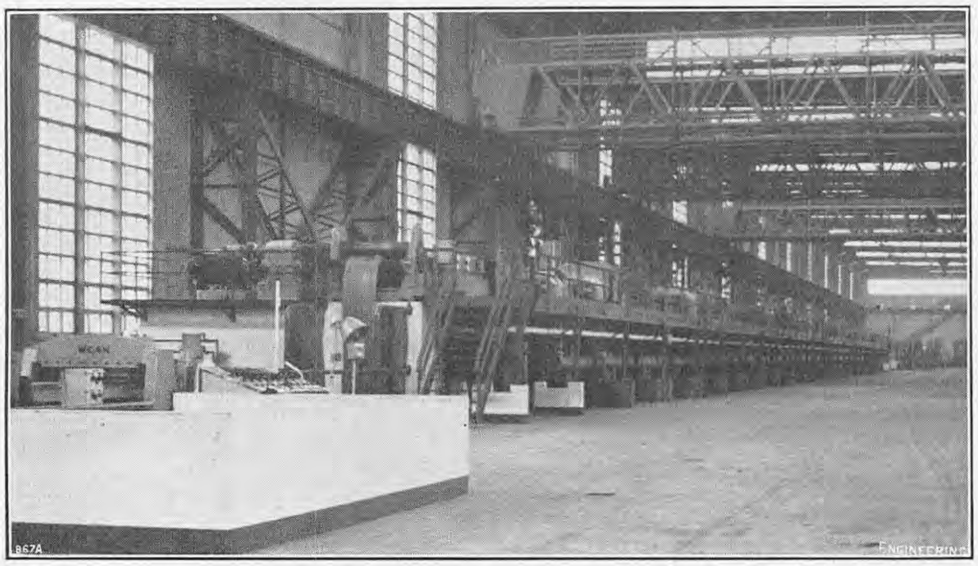


FIG. 1. CONTINUOUS PICKLING LINE NEAR EXIT END.

FIG. 2. EXIT END OF FIVE-STAND ROLLING MILL.

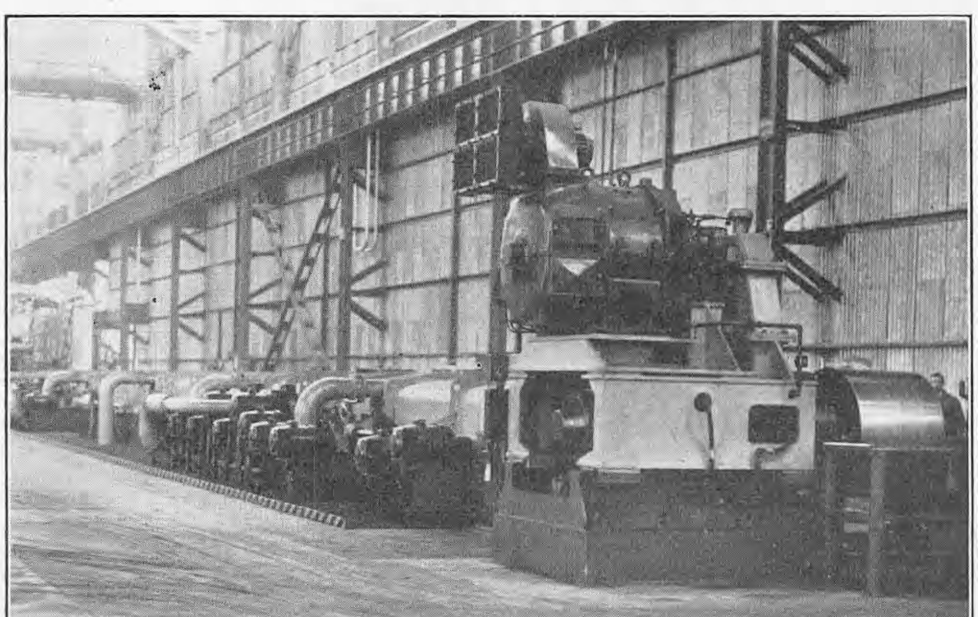


FIG. 3. ENTRY OF ELECTROLYTIC PICKLING LINE.

COLD-REDUCTION PLANT FOR PRODUCTION OF TIN-PLATE AT TROSTRE, LLANELLY.*

By H. LEIGHTON DAVIES, C.B.E.

THE outstanding development in sheet rolling in recent years has been the use of continuous mills for rolling both hot and cold steel strip sheet suitable for tin-plate gauges. This method, first established in America, was first operated in this country in 1938. The two main types of strip mill in use are tandem mills and reversing mills. Tandem mills are a series of individual stands of rolls synchronised to operate in line and used in both the hot and cold-rolling processes. These large units need a great deal of room to operate, and the capital cost is high, but they produce a large output of good-quality plate very economically and effectively. The reversing mill is a single stand of rolls, four-high, the rolling direction of which can be reversed. In some cases only the rolls are driven and in others the rolls are idle and the sheet is drawn through (as in wiredrawing), the coilers being alternatively power driven. Another variation combines both, with the rolls and coilers both under power. This type of mill is less expensive than the tandem mill; it takes up comparatively little room and is suitable for the small-output plant.

The process for producing the raw material for a strip mill is the same as for the pack mill up to the stage of the blooming mill. For strip rolling the product of this mill is in the form of slabs 3-6 in. thick and 20-40 in. wide (instead of being rolled into bars ½-¾ in. thick, 8-12 in. wide and 15-16 ft. long). These slabs are hot rolled in a continuous mill down to a thickness of between 0·074 and 0·083 in. and are finished coiled in strip form, the width of the strip being approximately the length required for the finished tin-plate.

The next operation is pickling to remove the iron-oxide scale from the strip, formed during the preceding hot-rolling process. In the latest plant now being installed in this country at Trostre, Llanelly, by the Steel Company of Wales, Limited, the pickling is carried out in a continuous pickling line, as illustrated in Fig. 1, on this page. Coils weighing 15,000 lb., 0·083 in. thick and up to 38 in. wide, are loaded on to conveyors. After uncoiling and scale breaking, the ends are trimmed in upcut shears. To enable the operation to be continuous the trailing end of one coil is attached to the leading end of the following coil by electric welding or by stitching. A looping pit acts as a reservoir to provide time for welding and stitching, and the maximum speed to this point is 1,000 ft. per minute, while the maximum speed through the acid tanks is 500 ft. per minute.

The strip then passes through five acid tanks, where the oxide scale on the strip is removed by the action of sulphuric acid. Beyond these tanks are two water-spray tanks, cold and hot, respectively, in which all adhering acid is washed off, and the strip is dried with the help of steam-heated air.

To provide time for the final operation, the strip then enters another looping pit, that shown in the foreground in Fig. 1, after which the stitch join is cut out and the edges of the coil are side-trimmed. The weld is left in, so that the strip, on re-coiling, weighs 30,000 lb. During re-coiling, the strip is coated with hot palm oil and is finally ejected over an automatic weigher on to a coil conveyor for transfer to the mill.

In the cold-reduction process, the coils are loaded from the pickling tanks on to the entry conveyor of the 5-stand cold-reduction rolling mill, which is shown in Fig. 2, herewith. This conveyor feeds a rotating rig which, in turn, guides the leading end of the coil into the guides of No. 1 stand and eventually the coil itself into the coil box, where it is paid off into the mill. The mill consists of five four-high stands and a Klein-type tension reeler, together with the necessary driving, screw-down, and control equipment. Each stand is driven by a direct-current motor through a pinion stand. The total output of the mill motors is 18,250 h.p., and the maximum speed of the fifth stand is 4,500 ft. per minute. The cast-steel housings each weigh about 100 tons and have 53-in. diameter by 47 in. long back-up rolls, also of cast steel. The forged-steel work rolls are 21 in. in diameter by 48 in. long.

During the rolling process the strip is lubricated with palm oil and passes through wood-lined air-operated wiper boxes before entering the nip of the rolls. The rolls are water-sprayed to dissipate the large amount of heat generated during cold reduction, and to control their temperature, the resulting mist being exhausted into a fog-elimination system and discharged by a chimney to the atmosphere. The palm oil and water thus applied collect in the sump at

* The second portion of the presidential address on "The Development of the Tin-Plate Trade," delivered before the Iron and Steel Institute, on Wednesday, April 30, 1952. Abridged.

the base of the mill and are run off to a palm-oil recovery system. The palm oil is separated here, and reclaimed, while the water, with a certain amount of palm oil in emulsion, is cooled and re-circulated.

Inter-stand tensiometers indicate inter-stand tension, and during acceleration and retardation the tension is automatically varied. Off-gauge material is thus reduced to a minimum. Flying micrometers, which are located between stands 1 and 2 and after stand 5, register to 0·001 in. After emerging from No. 5 stand, the leading end of the strip is automatically engaged on the reeler by a belt wrapper and is re-coiled into a 30,000-lb. coil. By this process, 10 men can produce 500 tons of strip in an 8-hour shift, or 750 tons in 12 hours, compared with the 6 tons (13,000 lb.) produced by the hand mill in the same time.

After the cold reduction, all traces of palm oil have to be removed from the strip. If this were not done, the oil would carbonise during annealing and would interfere with the subsequent tinning operation. The electrolytic cleaning lines, one of which is seen in Fig. 3, on page 629, are each capable of a maximum strip speed of 2,000 ft. per minute. The coils are loaded on to a conveyor ramp or on to the coil-charging car at the entry end of the line. They are pushed on to a mandrel-type pay-off reel from which the strip is unwound; the leading end is welded on to the trailing end of the preceding coil, so that the operation is continuous. The strip then passes through a continuous detergent cleaning unit, in which the main cleaning tank is electrolytic, with grids above and below the strip, and contains hot caustic solution. Beyond it is a second scrubber, a hot-rinse tank, a steam-heated drying unit, tension rolls, shears, and a re-coiler. The coils are wound to 54 in. diameter (about 15,000 lb.) and are conveyed by tractor to the annealing bay.

To obtain a ductile plate, it is necessary to repair the grain structure and to relieve the stresses set up in the cold-reduction process. This is achieved by heat-treatment in batch-type annealing furnaces, shown in Figs. 4 and 5, on this page. The annealing equipment consists of bases and furnaces, each base having two rows of four pedestals on which the coils are stacked four-high with the axes vertical, making a total of approximately 200 tons per charge. Over each stack is placed a special heat-resisting steel inner cover, the bottom being sealed with sand. A furnace is then placed over the complete charge.

Each furnace is directly oil-fired from 30 burners, the flame being directed down and around the inner covers, which enclose the eight stacks. The temperature of each stack and the furnace itself is continually recorded and automatically controlled. During the heating and soaking cycle inert nitrogen gas (known as N.X.) is circulated by centrifugal fans in the inner covers and around the coils to prevent oxidation. At the end of the soaking period the furnace is removed, and the inner covers are taken off when the coil temperature falls below the oxidising range. The coils are then taken off the pedestal, and when they are completely cool they are conveyed to the next department for temper rolling.

The two-stand 4-high tandem temper rolling mill is illustrated in Fig. 6, herewith. It gives all coils a skin pass, the amount of cold work given depending on the purpose for which the plate is intended. For deep-drawing material the temper rolling is sufficient to give only a closed surface for tinning. For can-body stock the first pair of rolls is sand-blasted.

The maximum speed of the mill is 4,000 ft. per minute, and each stand is powered by a 1,000-h.p. motor. The back-up rolls are 53 in. diameter by 47 in. wide and are of cast steel, while the forged-steel work rolls are 18 in. diameter by 48 in. wide. No strip cooling medium or lubricant is used. In rolling, the strip passes round a pair of 20-in. diameter top- and bottom-entry tension rolls, driven respectively by 500-h.p. and 250-h.p. motors, into No. 1 stand. From here it passes over another tension roll into No. 2 stand, which is identical with No. 1. On leaving No. 2 stand, the strip passes round a set of exit tension rolls, from where it is automatically engaged on a re-coiling mandrel. At this point the maximum weight of the coil is 15,000 lb. and it is approximately 54 in. in diameter.

When re-coiling is complete, the coil is stripped off the mandrel; and at this stage the coil is destined to be either electrolytically or hot-dip tinned. If the former, the strip is passed through a preparatory line where the edges are side trimmed and the strip is re-coiled, to ensure a good condition to maintain continuous operation in the subsequent tinning process. If the strip is to be hot-dipped, it is side trimmed and cut to plate size in the shearing line, where, instead of coiling, the off-gauge is separated into one pile and the primes into another.

The preparatory line is capable of handling and re-coiling 30,000-lb. coils, up to a maximum width of 38 in., at a maximum speed of 1,800 ft. per minute. Down-cut shears and a strip welder are incorporated so that coils can be built up to the maximum diameter desired. The speed of the strip through the line is controlled and adjusted by photo-electric cells located in the looping pits.

The coils are fed to the shearing line, illustrated in Fig. 7, opposite, through a looping pit into a side trimmer. The looping pit is equipped with photo-electric cells to ensure speed control between the pay-off reel and the rotary side trimmer. The trimmed strip then passes through a second looping pit, similarly controlled to prevent tension, and on through mechanical off-gauge and pin-hole detectors. From this stage it passes through roller levelling operations,

COLD-REDUCTION TIN-PLATE PLANT AT TROSTRE.

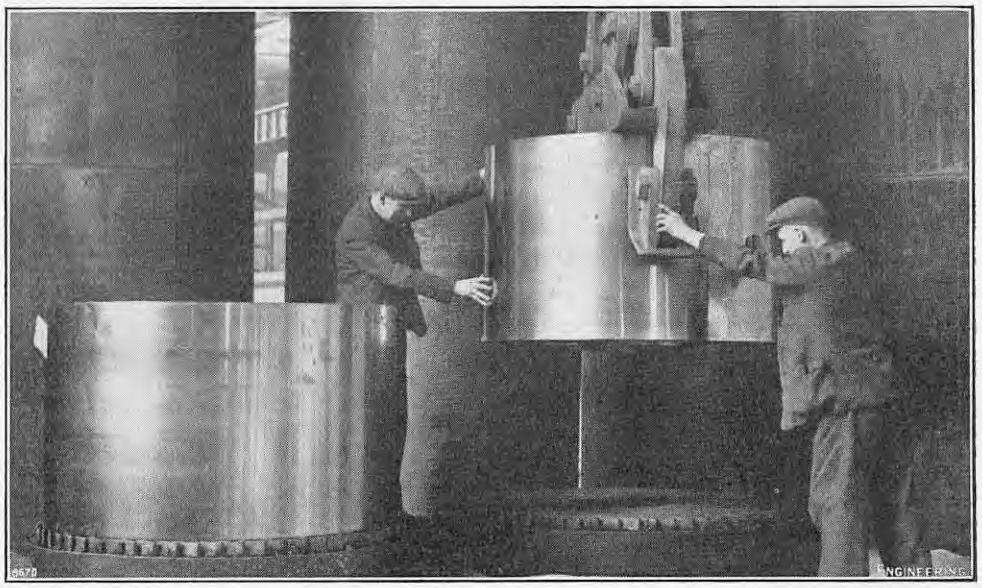


FIG. 4. STACKING COILS IN ANNEALING FURNACE.

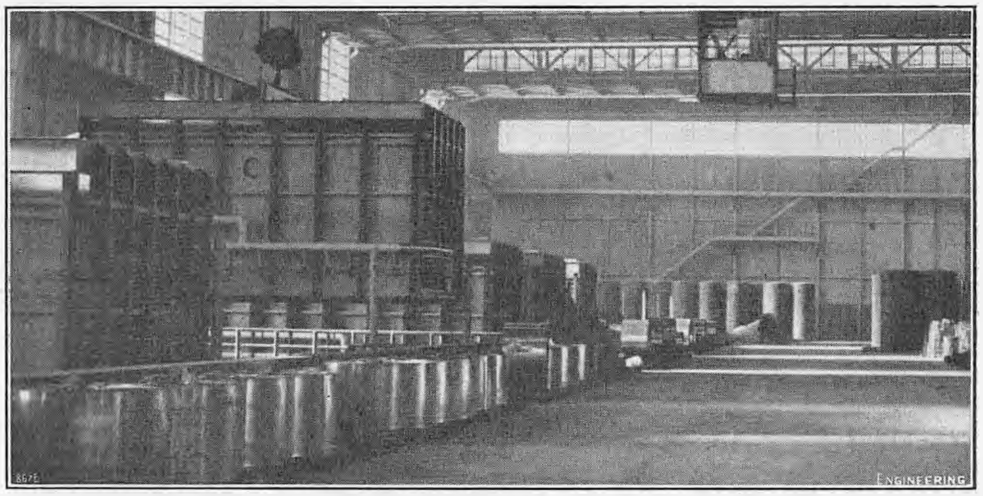


FIG. 5. LIFTING PORTABLE COVER FROM ANNEALING FURNACE.

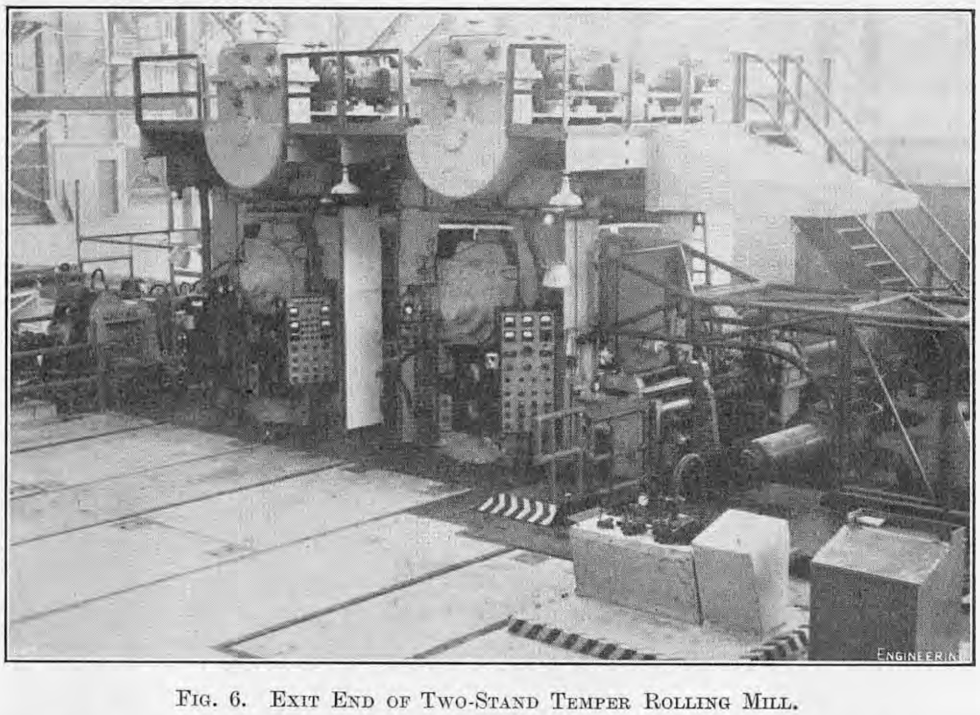


FIG. 6. EXIT END OF TWO-STAND TEMPER ROLLING MILL.

COLD-REDUCTION TIN-PLATE PLANT AT TROSTRE.

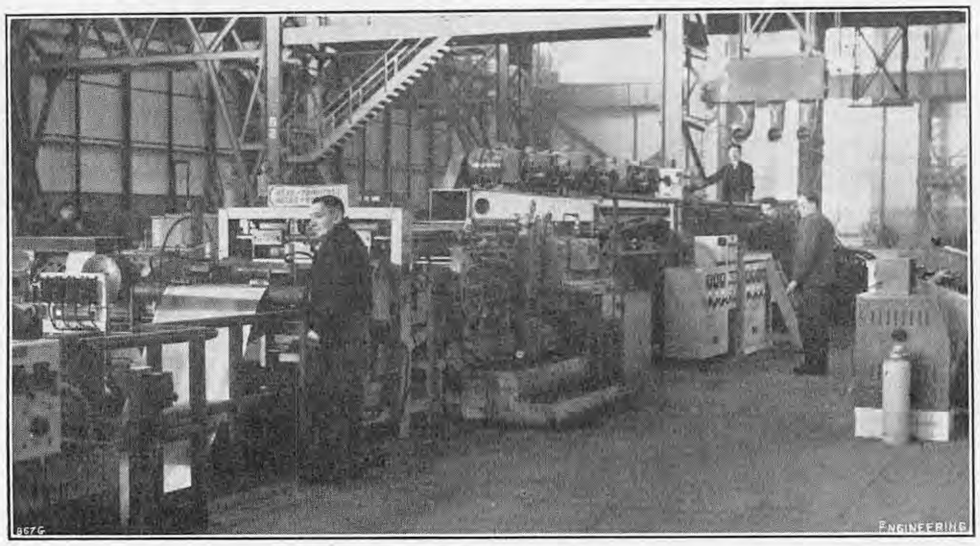


FIG. 7. TIN-PLATE SHEARING LINE.

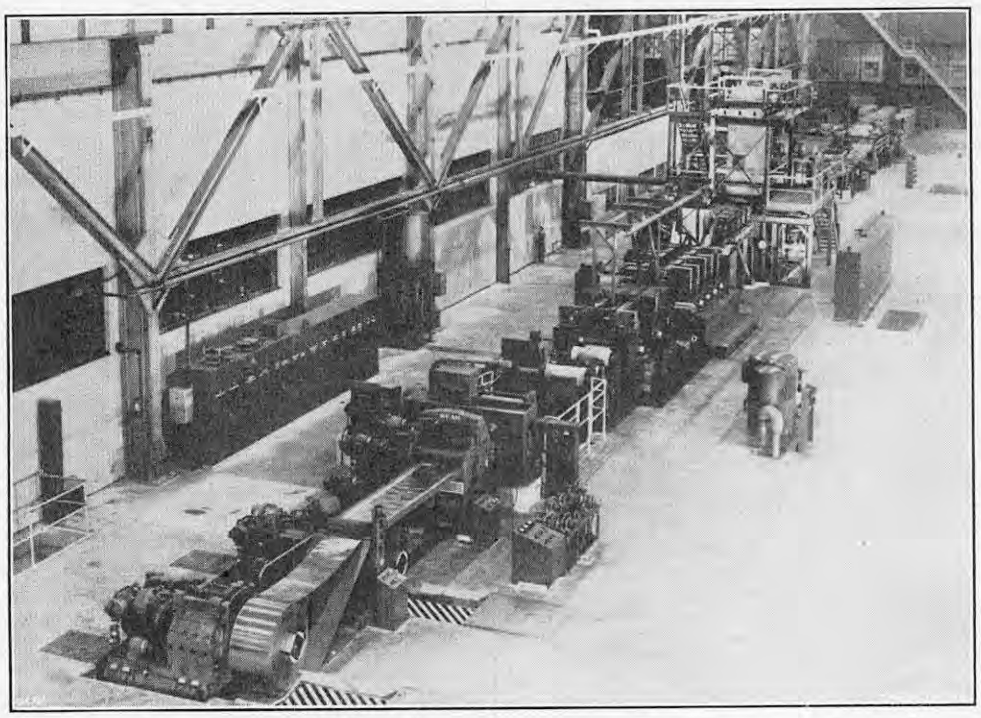


FIG. 8. ELECTROLYTIC TINNING PLANT.

before being cut up into sheets by Hallden-type rotary-driven shears. The maximum speed of the shearing line is determined by the length of the cut and varies from 650 ft. per minute at 18 in. to 1,000 ft. per minute on the 37½-in. cut. The sheared plates then travel along a conveyor to a classifier, where the off-gauge and perforated sheets are automatically stacked in one pile and the primes in another. The prime plates are then taken on stillages to the hot-dip tinning section.

Electrolytic tinning of strip can be carried out by two main methods, one acid and the other alkali. In both methods, the strip forms the cathode while slabs or strips of tin form the dissolving anode. In the acid method the electrolyte is made up of a solution of stannous sulphate, cresol-sulphonic-acid, free sulphuric acid, gelatin, and beta-naphthol. In the alkali method, the electrolyte is a solution of sodium stannate containing small quantities of free caustic soda, sodium acetate, and hydrogen peroxide. In both these methods the amount of tin deposited is controlled by one or more of the following factors: the size of the anode; the ratio of the surface areas of cathode and anode; the distance between cathode and anode; the rate of travel of the strip; the density of the bath; and the electric current.

At Trostre the electrolytic tinning is of the acid ferrostan type. The unit, shown in Fig. 8, above, is designed to work continuously and to handle coils weighing 30,000 lb. at a maximum width of 38 in. It will deposit a tin coating of ½ lb. per basis box at a speed of 800 ft. per minute, but with correspondingly decreased speed for heavier coatings. Selenium rectifiers supply the necessary direct current up to a maximum of 60,000 amperes at 16 volts. The amperage varies with the speed of the line and the weight of coating being deposited, and is automatically controlled to give a constant weight of coating at constant speed.

There are two uncoilers to aid continuous operation. The leading end of the coil is sheared and welded to the trailing end of the preceding coil, time for this operation being provided by two loops held in a 70-ft. deep pit. The length of the strip in the loop is controlled by photo-electric cells fixed near the bottom of the pit. The strip then passes through pin-hole and off-gauge detectors, for automatic rejection at the exit end of the line, followed by cleaning, which consists of electrolytic degreasing, cold-water rinsing, electrolytic pickling, and, finally, spraying with water and brushing.

The next operation is tinning, which comprises five plating tanks and one drag-out tank, where the strip is washed and the electrolyte is recovered for future use. The strip then enters the flow-melt unit, where it is electrically heated to allow the tin on the surface of the strip to flow evenly; this gives it a bright appearance and also improves the quality. It is then sprayed with chromic acid to prevent staining during storage and to enhance corrosion resistance. After drying, the strip is coated with a very thin film of cotton-seed oil, which affords the necessary lubrication for subsequent fabricating operations. It is then classified in a manner similar to that described in the shearing line, except that the classification is controlled from two visual inspection positions. The strip is sheared into plates of the required width and directed into one of three piles. Any off-gauge or perforated plate that has been detected by a flying micrometer and pin-hole detector situated further back in the line is deposited in the first pile. The second pile contains any plate of doubtful appearance, and the third contains the prime plate, which is automatically counted and recorded by means of a photo-electric counter. Stillages from the first and second piles are re-assorted for recovery or retreatment, while those from the third pile are bulk-packed for shipment.

In the hot-dip tinning process, plates from the shearing line, already cut to finished size, are hot dipped in a mechanised version of a two-path Poole Davis tinning pot, in which the tin is heated by thermostatically-controlled electric immersion heaters. In this unit the actual tinning operation is preceded by an automatic feeder and hydrochloric-acid electrolytic pickler and washer.

After cleaning in an Aetna-type cleaning machine, sheets are delivered simultaneously from each path to a cross conveyor. This conveyor transfers the sheets one behind the other to the inspection line, the travel of which is parallel to the tin-pot pass line. At this point an inspector checks every sheet for gauge and quality and classifies them into three categories. By means of push-button electrically-controlled deflector gates along the classification line, the inspector directs the prime plates into a pile at the end of the classifying table, where they are automatically counted and recorded, and stacked in piles of a known number ready for packing. The second pile consists of "menders" and the third of defective plates. The menders from both electrolytic and hot-dip tinning lines are re-tinned in the hot-dip tinning unit.

The types of "waster" that are produced by the strip method of production are far less than those obtained in the hand mill and, of course, the amount of man-handling is very small. Thus, with old-type mills, it took 7,000 men to produce 7,000 tons of plate per week; in the modern mill only 1,000 men are needed to produce 10,000 tons per week.

This progress has introduced a sociological problem, but the manufacturers have anticipated its effects by creating a fund to mitigate possible unemployment. This has been done by making a levy on the products of the mills over the past few years, which will result in a total sum of about 500,000*l*. before the plant at Trostre is in full operation.

FUTURE DEVELOPMENTS.

In very early times tin-plate was used mainly as a building material, or for open vessels and ornaments, but with the advent of canning for the preservation and storage of foodstuffs and other perishable materials, it found its real use. In many years during which tin-plates have been manufactured, only in the last 50 have there been the most radical changes in methods.

At the outbreak of war, in 1939, rolling in strip form had become almost universal in the United States, and one hot-and-cold strip mill plant was in production at Ebbw Vale, in South Wales. Various countries on the Continent were also developing along the same lines. Before that time most of the plates exported from the United Kingdom (about 400,000 tons per annum) were hot-mill rolled, but by economic arrangement with the United States, our foreign buyers, especially South America, took their supplies from America in the form of cold-rolled plates. The foreign can-makers therefore adjusted their plants to suit this type of plate and acquired a preference for its better stamping qualities. Hence, to be able to compete in export trade with America it became imperative that strip rolling should quickly supersede the old pack method in this country.

In 1947, therefore, the erection of the second cold-reduction plant was started at Trostre, in Llanelly, by the Steel Company of Wales, Ltd., the hot mill for supplying the coil being built at Port Talbot. This is likely to be followed by a third cold-reduction plant and also by the reconditioning of the original plant at Ebbw Vale to produce a greater output. It is anticipated that these three plants will produce sufficient tin-plate to cope with the total future demand, both for home consumption and for export, of between 20 and 25 million boxes per annum; that is, about one sixth of the present world production.

While these developments have been taking place, further experiments in still more modern methods of production have continued, especially in America. The following items are among those that are being, or will be, investigated: (1) Continuous casting of strip in tin-plate gauges. (2) Powder rolling of strip in tin-plate gauges. (3) Mechanical descaling instead of wet pickling. (4) Development of cluster and planetary mills. (5) Development of the five-stand cold-reduction mill as a continuous unit, with welder, looping pits, or towers at either end, and shear and re-coiler at the exit end (thus requiring lower-powered motors with lower speeds for equivalent outputs.) (6) Possibility of higher working speeds. (7) Coupling of two or more of the present continuous operations. (8) Abolition of cleaning by wet detergents and its replacement by a combination of a cleaning operation with the annealing treatment preceding continuous annealing. (9) Continuous annealing by either the horizontal or the vertical method, preceded by electrolytic cleaning to take the place of the present separate cleaning unit with batch annealing. (10) Production of strip with "universal" temper by continuous annealing. (11) Continuous hot-dip tinning of wide strip, covering coatings from ½ to 2 lb. per box. (12) Sale of tin-plate (both electrolytic and hot-dip) in coil form direct to consumers. (13) Use of very lightly coated electrolytic plate (0·2 lb.) instead of blackplate (thus eliminating finger marking and rusting, and also facilitating soldering.) (14) Production and use of differential coatings on electrolytic tinplate, whereby a heavier coating of tin is deposited on one side, or with tin coating on one side only, with a saving of tin. (15) Effect of atomic energy.

It must be remembered that, as tin has always been a most expensive commodity, it has been the aim to cover plates with as thin a coating as possible, and yet to produce a smooth and non-porous surface. To obtain this surface the tinning operation and tinning machinery have gradually been perfected, as is shown by the weight of tin coatings recorded over the past years :—

Year.	Weight per Basis Box, Lb.*	Year.	Weight per Basis Box, Lb.*
1755	14	1900	2½
1820	10	1912	1½
1857	9	1940	1
1874	4½	1952	¼ (electrolytic)

* One basis box is 112 sheets of 20 in. by 14 in. (31,360 superficial inches), weighing 108 lb.

DESIGN OF FACTORIES IN RELATION TO INDUSTRIAL TRUCKS.

MEMBERS of the Industrial Truck Manufacturers' Association who are manufacturers of power-driven platform trucks, elevating platform trucks, tractors and high-lift fork trucks, wish to bring to the notice of engineers, architects and others the difficulties they experience due to insufficient consideration having been given in the design and layout of factory buildings to the movement of industrial trucks. The use of power-driven trucks has greatly increased in recent years, and with the increasing demand for more goods from the same labour force their use will increase still further. The introduction of these trucks into buildings intended for man-handling of small unit loads has presented many problems which can be avoided in new plants if factory designers would consult truck manufacturers.

The layout of a new plant should allow fork and elevating trucks to turn and deposit their loads at right-angles to gangways, and loading bays should have sufficient width for a truck to turn and enter a railway wagon, or possibly a road lorry. Stores and buildings intended for high stacking of pallet loads should have doors which allow the appropriate height of truck to enter, and every possible overhead obstruction should be avoided if full utilisation of the cubic capacity of the buildings is to be obtained. It is appreciated that, with the older type of factory, architects can do little to assist in the improvement of layout so that power-driven trucks can be used, and that this depends on the management of the factory. However, members of the Association feel that for new factories, if more information were asked for by designers regarding the movement of goods within the factory, the layout could be designed accordingly, and would have the effect of providing an efficient means of transport immediately the factory goes into production. In the past, it has been found on numerous occasions that movement of material and goods is not considered until the layout is completed.

The successful use of trucks on ground floors has led to a demand for trucks suitable for use on upper floors. In new buildings, lifts should have capacity and length to accept both truck and load, and the upper floors must be designed to carry trucks moving with their appropriate loads. Standard power trucks will generally carry their rated load up gradients unsuitable for hand trucks, but steep gradients which may require specially-powerful driving units should be avoided if possible. The Association would be pleased to act as a focal point to facilitate an exchange of this type of information. The address of the Association is 94-98, Petty France, London, S.W.1. (Telephone: ABBey 7101.)

EXPLOSIONS IN ENGINE CRANKCASES.*

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

EXPLOSIONS in reciprocating-engine crankcases occur only occasionally, but, in view of the possible disastrous consequences, no effort should be spared to remove the cause or to obviate the effect if it is found that prevention is not possible or practicable. Steam engines are included because, while most accidents of this kind have occurred in internal-combustion engines, similar accidents with enclosed-crankcase steam engines are not unknown.

Crankcase explosions are due to lubricating oil in a readily inflammable condition being ignited in a confined space, ignition being caused by a part inside the crankcase becoming hot. Hot parts occur more often in internal-combustion engines than in steam engines. This is due to combustion products passing the pistons in the former type of engine, and to the cylinders of all such engines not being so completely separated from the crankcase. Also, for equal power output, there are usually more bearings in internal-combustion engines. As a result, the bearing oil of internal-combustion engines is more often contaminated by extraneous matter, and lubrication adversely affected. Moreover, pistons of trunk engines and piston rods of crosshead engines can be sources of overheating. Such parts of steam engines rarely overheat, so that, when an explosion occurs, it is invariably due to hot bearings, while pistons, piston rods, or bearings may be the cause in the case of internal-combustion engines.

PREVENTION OF EXPLOSIONS.

Prevention of crankcase explosions resolves itself into two problems, the first being prevention of the formation of an explosive mixture, and the second the elimination of the means of igniting the mixture. Solution of either would effectively remove the possibility of an explosion. As regards the former, if a crankcase were filled and kept charged with inert gas, an explosion could not occur. Exhaust gases of oil engines could be used for this purpose. Chemists state that, if the inert gas content could be maintained at 30 per cent. or over, a crankcase would be in a safe condition, but the author thinks that to ensure this would be difficult. While carbon dioxide would not adversely affect the condition of lubricating oil unless sea water were present, there can be no doubt about the ultimate condition of the oil if exhaust gases were led into the crankcase.

Under normal working conditions, a crankcase will first contain only air. As the lubricating oil becomes heated a portion of it is atomised by pressure and the churning action of the fast-moving parts. The small particles are thrown against the crankcase walls, where they combine and run down into the sump. Consequently, the suspended oil particles are constantly changing. These "oil droplets" give colour to the air, and the mixture is referred to as "crankcase mist," the density of which depends mainly upon the temperature of the oil. If oil coolers are adequate, the highest average temperature reached by the bearing oil of a marine engine is about 140 deg. F., which is not sufficient to vaporise the oil. The oil particles suspended in air are, therefore, in liquid form, and, while they alter the colour of the gaseous content of a crankcase, they do not alter its composition. The composition may, however, be altered by local overheating, as, for instance, when pistons of trunk engines operate at a temperature that causes the oil making contact with the underside of the piston head to vaporise. Such undesirable conditions are abnormal and avoidable.

As a rule, crankcase explosions are reported only when injury to persons or damage to property results. It is well known, however, that for every explosion that caused damage, there have been many having less serious consequences. Investigations into accidents of a serious nature have generally proved abortive because the explosions were so violent that the evidence which might have revealed the cause was destroyed. Some of the minor explosions occur after an engine has been stopped and a crankcase door has been opened for inspection purposes. In such instances, even though some part of the engine was hot enough to ignite the oil mist, it would seem that ignition was delayed until additional air entered through the door.

When a bearing becomes hot in a crankcase containing oil mist, the engine should be stopped and oil should be circulated through the bearings until the faulty bearing is at or near hand heat. Before a crankcase door is opened, the circulation should be stopped and time given for the oil to drain from the bearings, as ignition may be brought about by oil dropping on to a hot bearing, or being projected against a hot piston. The Ministry of Transport have issued a warning of the possible serious consequences of the too hasty opening of crankcase doors when some internal part is known to be overheated.

The taking of naked lights into the crankcase of a recently stopped engine is another dangerous practice. No harm will be done to the engine in the event of the oil mist being ignited, because the open crankcase door prevents a serious build-up of pressure. Instances are on record, however, where men in the vicinity of the open door have been burnt by the resulting flame. So far as the author is aware, there is no record of an explosion occurring after an engine has been stopped and before the crankcase door has been opened. This would suggest that the possibility of inflammable mist making contact with an overheated part is greater when an engine is running than when at rest. The reason for this may be that, when an engine is at rest and the gaseous contents are stagnant, oil vapour too rich to ignite surrounds the hot part and isolates it from the inflammable mist. This theory is supported by a recorded instance where, after the engine had been at rest for several minutes, a violent explosion occurred immediately it was restarted. During the time the engine was stopped, nothing was done to disturb the gaseous contents in the crankcase, and there would have been practically no change in the temperature of the bearing.

When an explosion occurs in an engine at rest and after the crankcase door is opened, the cause is probably not so much the entry of air, but the action of opening the door causing movement of the gaseous contents and varying the composition of the gases in the immediate vicinity of the hot bearing. It is not suggested that oil mist can be too rich to burn; if the size of the suspended oil particles is small enough, they will ignite and burn like a gaseous mixture. The point the author wishes to bring out is that, when heavier oil particles are converted into vapour, it is possible for the vapour to be so short of air that ignition will occur only when the rich vapour is disturbed and air is allowed to mix with it, or to be replaced by oil mist in an inflammable condition.

A fundamental necessity of power producers, or any machines required to transmit motion, is the rubbing together of metals and the production of frictional heat. The quantity of heat produced can be kept within bounds by efficient lubrication, but it is not easy to ensure this at all times and under all conditions. To ensure efficient lubrication, oil must be introduced between the rubbing surfaces by drip, splash, or forced feed. Experience has proved that overheated bearings are more likely to be avoided by the copious and continuous supply of oil to each bearing. This necessitates an enclosed crankcase.

Free oil in a crankcase is incapable of causing an explosion unless the temperature of some part is raised to the ignition temperature of the oil mist. As, however, it is impossible to ensure that such a temperature will never be reached, the only way to eliminate the possibility of an explosion would be to remove from the crankcase all oil in excess of the bare amount required to lubricate the bearings. This would mean reverting to drip lubrication, a practice that would be a step backwards.

VENTILATED v. SEALED CRANKCASES.

Opinion is divided as to whether crankcases should be vented, ventilated by a current of air, or totally sealed. The effect of venting, that is, provision of openings to the atmosphere, can be only to avoid the building up of a greater pressure than atmospheric pressure under normal working conditions, and so to prevent leakage of oil from crankcase door joints, etc. In the event of an explosion, these vents would be practically useless because of their relatively small diameter and location. It is highly improbable that the seat of an explosion would be in direct line with them. Moreover, such vents can have no material effect upon the inflammable properties of the oil mist. They might indicate the presence of smoke in a crankcase, but when smoke issues from them the condition necessary to produce an explosion will already exist. Some hold the view that crankcase vents increase the risk of an explosion, in that they provide a means by which air will enter the crankcase. The author does not accept that view, because it is questionable if free air would pass down a pipe, even one of 6 in. diameter, which is filled with oil mist at a relatively high temperature. Vents serve only to maintain the crankcase at atmospheric pressure.

The practice of ventilating crankcases by a current of air has many adherents, but the fact that explosions have occurred in engines so treated is sufficient proof that it does not ensure immunity. Constant changing of a portion of the gaseous contents in this way will reduce the density of the mist, and may reduce the violence of an explosion, but it is highly improbable that ventilation within practical limits would put every part of the crankcase in a safe condition, because of the peculiar internal construction of a crankcase. To be effective, the air would need to be admitted at so many points as to be impracticable. Moreover, the increased oil consumption is a further objection.

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

EXPLOSIONS IN CRANKCASES.

Fig. 1. CRANKSHAFT BEARING.

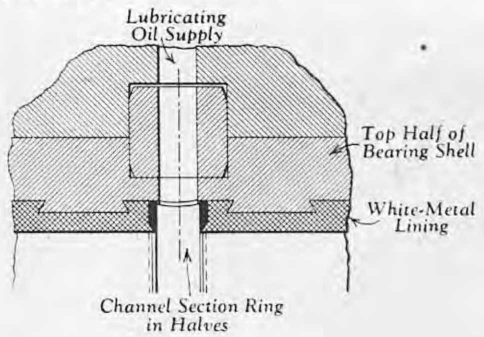


Fig. 2.

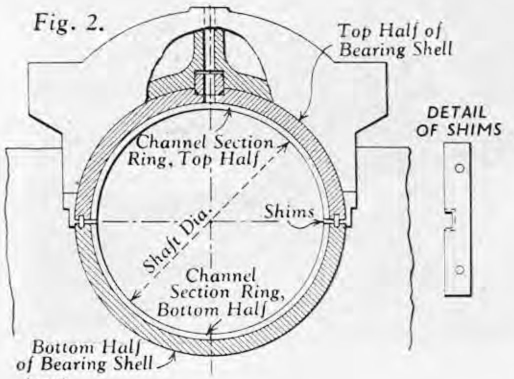


Fig. 3. METHOD OF DETECTING TEMPERATURE INCREASE IN CRANKPIN BEARINGS.

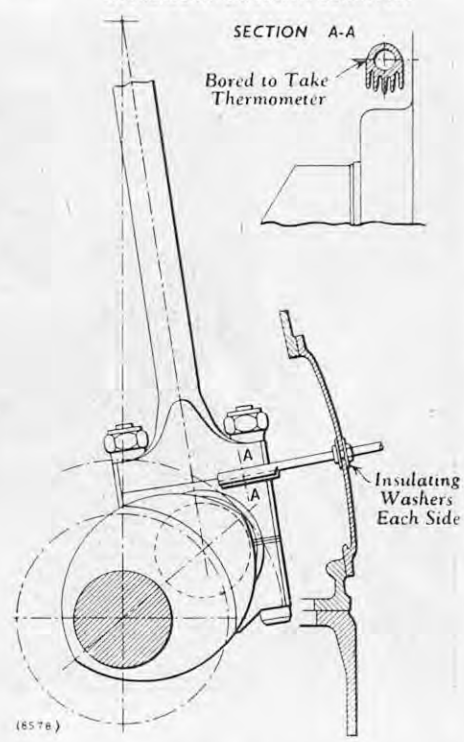


Fig. 4. DEVICE FOR INDICATING HOT CYLINDER LINERS IN TRUNK-PISTON ENGINES.

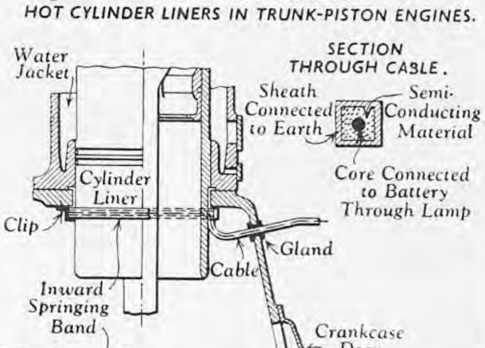
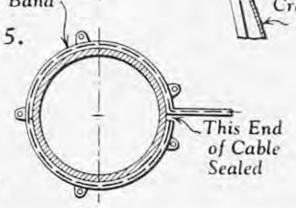


Fig. 5.



There is a possibility, remote, perhaps, but one to be borne in mind, that ventilation will have the same effect as the opening of a crankcase door when an engine is stopped because of a hot bearing. In such circumstances, therefore, it is wise to stop the ventilating fan immediately the engine stops. It is doubtful whether hermetically sealed crankcases would achieve the desired result, for the reason that a crankcase is full of air before the engine is started, and observations have shown that, even after weeks of continuous operation, air is a large part of the gaseous contents.

Another point to be considered, in regard to large marine engines, is the advantage of providing crankcases, at crosshead guide-bar level, with small doors which can be readily opened while the engine is running. The first indication of an overheated inaccessible bearing is smoke, and periodical internal inspection of the crankcase is the best means of preventing serious damage to bearings and, incidentally, a crankcase explosion. Doors are preferable to inspection windows because windows become fogged and, on occasions, in the tropics, for instance, it is not easy to differentiate between oil-mist and smoke, even when crankcases are artificially illuminated. The author considers, therefore, that it is not practicable to make enclosed crankcases safe by ventilation, and it is not possible to do so by hermetic sealing.

PREVENTION OF HOT BEARINGS.

Even if it is impracticable to prevent crankcase explosions by control of the gaseous contents, much can be done to prevent ignition of the inflammable contents. Moreover, the consequences of an explosion can be greatly minimised. As such explosions can occur only if the oil mist is ignited, and as ignition can result only from an overheated part, the obvious way to minimise the chances of an explosion and obviate serious consequences in the event of one occurring is to take all precautions to prevent a part getting hot; to provide devices which will indicate abnormal temperature rise in any part; to take steps to avoid dangerous pressure build-up in crankcases; and to prevent flame issuing from the crankcase in the event of an explosion.

It is most important to line with anti-friction metal of reasonable thickness all parts in which shafts revolve or slide. In addition to reducing the running temperature of a bearing, anti-friction metal has the advantage that it melts at a temperature below the temperature necessary for ignition of lubricating oil, and produces slackness, causing a noise which, in a four-cycle engine, can generally be heard. In two-cycle engines a hot bearing is not always indicated in this way, so that other means of detection are necessary. Other conditions which make for the elimination of hot bearings are as follows:—

Passages and pipes used to convey oil should have a bore not less than $\frac{3}{8}$ in. in diameter. Duplex strainers should be provided on both suction and delivery sides of lucricating-oil pumps, located in easily accessible positions. Pipes inside crankcases should be properly aligned to avoid strain when connected, secured in a way that will prevent vibration, free from sharp bends where dirt and other extraneous matter may collect, and annealed periodically to reduce brittleness and eventual fracture when they are of small diameter and made of copper. All metal parts not intended to make contact—for instance, a crankweb and flange of adjacent bearings—should have adequate clearance. The possibility of contact resulting from expansion when the part becomes heated to working temperature should not be overlooked. The point at which the oil leaves the crankcase should be covered by a grid of large area to prevent cotton waste, pieces of wood, etc., inadvertently left in the crankcase during overhaul, from choking the oil drain. Periodic removal of the oil to clean out sumps and oil drain tanks is recommended, the oil being purified before it is returned to the system. Lubricating-oil pumps should discharge into a gravity tank large enough to ensure a supply of oil to the bearings for a reasonable time in the event of pump failure. An alternative is the provision of an efficient alarm.

Generally, when bearings overheat, the heating process is at first gradual, and, if it is detected in time, the engine can be stopped before a bearing becomes sufficiently hot to damage the anti-friction metal. When a temperature of about 500 deg. F. is reached the anti-friction metal melts, and may run into the oil hole and stop the flow of oil. Should this occur, the temperature of the bearing will increase rapidly. If, therefore, the oil hole could be prevented from choking, the rate of temperature increase would be reduced, which would give the attendants more time to become aware of the defect. A simple method of preventing oil holes from becoming choked in this way is shown in Figs. 1 and 2, herewith. This shows the usual annular oil groove lined by a channel-shaped ring split in halves, made of a material such as copper, which has a relatively high melting point and will not damage the surface of the revolving crankpin or journal.

PREVENTION OF HOT PISTONS.

The pistons of modern crosshead engines seldom run hot and, so far as the author is aware, have never been the cause of a crankcase explosion. Trunk pistons, however, become hot as a result of either insufficient working clearance or inefficient lubrication. Piston blow-past could result in inefficient lubrication and subsequent overheating. For avoidance of overheating due to inefficient lubrication, it is important that each oil point of cylinders in trunk-piston engines should be supplied separately by a sight-feed lubricator, the drive of which should be positive. The means by which the lubricator can be seen to be working properly is not always given due attention.

Because trunk pistons become noisy as wear takes place, there is an inducement to reduce the diametrical clearance beyond safe limits. This trouble is rarely encountered in engines as delivered by the manufacturer, because the necessary working clearances have been carefully determined. These, however, are based on the assumption that all parts of the engine are in first-class order and the operating conditions strictly correct. In most instances, the operation conditions recommended by manufacturers are maintained, but this is not always so, and the working temperatures of pistons are sometimes higher than they should be, owing to unequal power distribution, improper combustion, accumulation of carbonised oil on the under side of piston heads, insufficient cooling-water or oil in cases where the pistons are cooled internally, the passing of very cold water through cylinder jackets of engines the pistons of which are uncooled, and inefficient lubrication.

A frequent cause of the running hot of trunk pistons is distortion of pistons and cylinder liners. Distortion of pistons results from injudicious driving-in of the gudgeon pin, or from running the piston at too high a temperature. Distortion of cylinder liners occurs when they are badly fitted or ineffectively cooled, or when a piston becomes hot. Whenever they are exposed, these parts should be checked for perfect roundness, to ensure that sufficient working clearance exists at all points between the piston and its cylinder liner. Particularly is this necessary after they have been operating at an abnormally high temperature due to overload or some other cause.

The author's method of checking for distortion of pistons is to provide a cast-iron ring gauge 6 in. deep and 2 in. thick, and having suitable means for handling. After being annealed, the internal diameter of the ring is machined to 0·002 in. above the drawing size of the largest part of the piston. For cylinder liners, a plug gauge 6 in. deep is provided, the external diameter being machined, after annealing, to 0·002 in. below the original cylinder bore. Checking for correct working clearance is particularly necessary when a new piston is being fitted in either a new or used cylinder liner, as spare parts are sometimes not strictly to drawing size, especially when not made by the maker of the engine.

Overheated piston rods seldom occur in single-acting internal-combustion engines, but the author has known of many double-acting engine piston rods becoming hot to the point of redness. In only one instance, however, did a crankcase explosion result. In view of the ever-increasing use of the double-acting principle, there is much to commend the practice adopted by at least one well-known marine-engine builder, of surrounding the steel piston-rod by a cast-iron sleeve and circulating water or oil through an annular space provided between these two parts. Piston rods which enter the crankcase rarely become hot owing to lack of lubricant. Generally, the trouble arises from the rod making hard contact with some part of the stuffing boxes provided at the lower end of the cylinder and top of the crankcase. In the design of such parts, therefore, it is wise to allow for liberal lateral movement of the piston rod, which occurs when the crosshead guide bars become worn or parts are not refitted in strict alignment.

(To be continued.)

ANTI-VIBRATION CLIP.—A new type of anti-vibration clip for securing pipes, cables, etc., has been developed by Messrs. Howard Clayton-Wright Ltd., Wellesbourne, Warwickshire. An oil-resisting rubber compound is extruded to cover the clip, extending to the edges, so that there is no metal-to-metal contact. Four types of clip are in production, for nominal pipe diameters ranging from $\frac{3}{16}$ in. to $2\frac{1}{2}$ in.; one is in flexible steel to specification S.84, and one in aluminium alloy to specification DTD 610; the other two types are in the same materials, but provide electrical contact through the metal tongue.

AUTOMATIC DEWPOINT HYGROMETER.

THE quantity of moisture present as vapour in the atmosphere, or in gases or mixtures of gases, is often of considerable importance, and much ingenuity has been expended on devising methods of measuring it accurately. Frequently, even a very small amount of moisture in a gas can have a deleterious effect on an industrial or chemical process, and then means must be found for detecting it and determining its amount rapidly and accurately. At other times, the presence of water vapour is essential in a reaction, but its amount must be controlled. On occasion, atmospheric moisture is believed to play an important part as a lubricant. There is, for example, some evidence that, in aircraft flying at high altitudes under conditions of low humidity, brush wear on electric motors and dynamos becomes excessive owing to the dryness of the atmosphere. Apart from its practical importance, atmospheric humidity is of interest to meteorologists, and changes in its value are a useful indication to aviators of changing weather conditions. One way in which such variations can be detected is by instruments carried in aircraft, but the speed of an aircraft is such that, if local variations and rapid changes are to be discovered by this means, instruments which are both sensitive and quick in their action are necessary.

A convenient way of finding the humidity of the atmosphere is to determine the dew point, i.e., the temperature at which moisture is deposited from the atmosphere on to a prepared surface as dew. The humidity, relative or absolute, can then be determined from tables or by calculation. When the amount of water vapour present is very small, however, so that its pressure is also small, cooling the air will not result in the deposition of dew but in the formation of frost, the liquid phase being absent. There are various forms of dew-point hygrometer but, unless somewhat elaborate, they suffer from the defect that the first occurrence of dew or frost is difficult to observe and the corresponding temperature of the prepared surface is seldom determined accurately. At the recent exhibition in London, however, organised by the Physical Society, Messrs. Elliott Brothers (London), Limited, had on view an automatic dewpoint hygrometer of improved design and high accuracy, which had been developed in their research laboratories at Boreham Wood, Hertfordshire. Although the instrument is still, technically, in the experimental stage, the problems involved in its design appear to have been overcome successfully and certain of its features are considered sufficiently novel and interesting to merit attention.

The instrument, illustrated in Fig. 1, herewith, was devised particularly for determining the humidity of very dry air, but its use is not restricted to this. It could also be employed to determine the partial pressures of gases forming a mixture. It is orthodox, in that the familiar process of cooling a polished metal surface till a film of dew or frost appears on it is employed, but unusual in the means employed to control the film. The method by which the metal surface is heated or cooled and the rapidity with which this is accomplished are a special feature, as are the automatic action, the freedom from hunting and the speed with which changes in humidity can be followed.

The basic principles of the instrument will be understood by reference to Fig. 1 and to the schematic diagram reproduced as Fig. 2, herewith. The polished metal surface on which the dew or frost is deposited is contained in the circular brass housing seen in the foreground of Fig. 1 and denoted by *a* in Fig. 2. It is a circular piece of platinum foil which is clamped around its rim between two rings of Klingerit jointing. A small area in the centre of the foil has a small copper pad or button *b*, about ⅜ in. in diameter, attached to its under-surface, and it is on this area of the foil alone that the dew or frost is deposited. It is the mirror surface of the instrument although it need not be highly finished. The air, or gas, under test is drawn through the pipe *c* into the space above the foil, which is closed by means of a glass window *d*, and is exhausted through the pipe *e* by means of a motor-driven diaphragm pump *f*. There are suitable arrangements for making the action of the pump steady and for equalising the pressures above and below the platinum foil, a necessary precaution since the diaphragm is very thin. The bellows-type pressure-equaliser is denoted by *g*, in Fig. 2. It is necessary to isolate the space underneath the diaphragm from that above it, because, otherwise, the amount of condensation or frost deposition under the diaphragm would be an unknown factor.

The air, or gas, drawn into the test chamber is made to play on the central area of the diaphragm through a nozzle on the end of pipe *c*. This area is illuminated by means of a lamp *h* contained in a box, as shown in Fig. 1. The light from the lamp is concentrated on the central reflecting area of the foil by means of condenser lenses *i*, held in an inclined frame, also visible in Fig. 1, just below the lamphouse. A small circular aperture is used to cut out

AUTOMATIC DEWPOINT HYGROMETER.

ELLIOTT BROTHERS (LONDON), LIMITED, BOREHAM WOOD, HERTFORDSHIRE.

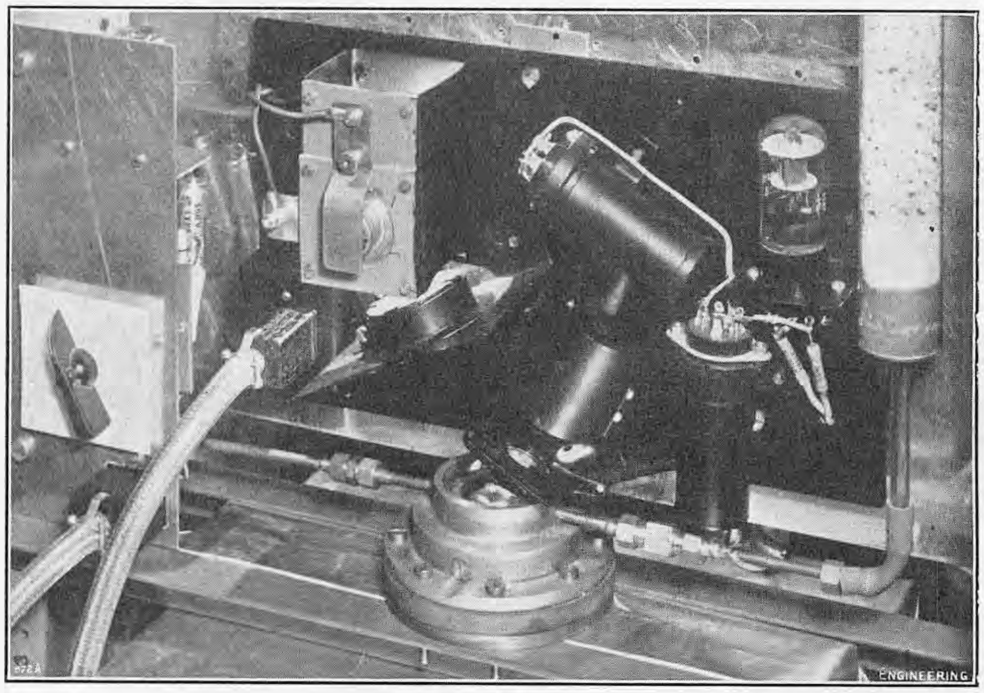
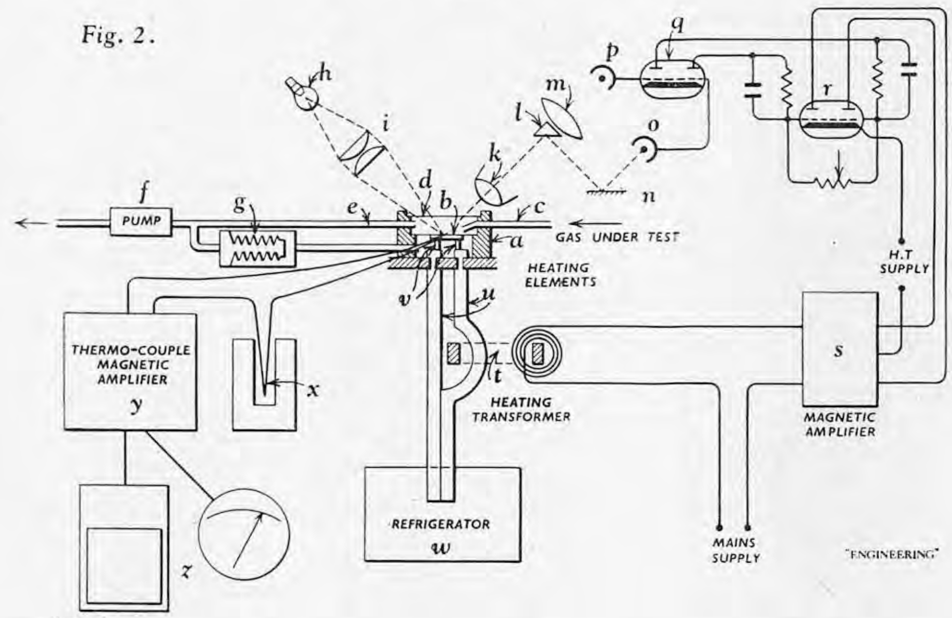


FIG. 1.

Fig. 2.



lens aberrations. The light reflected from the prepared surface of the platinum diaphragm passes upwards through an objective lens *k* and falls on a circular mask *l* mounted in front of a further lens *m*, both of which are contained in an inclined cylindrical housing. The forward surface of the mask is an inclined mirror which reflects some of the light downwards on to a small hole in an inclined tube mounted just below the cylindrical housing referred to above. The hole, surrounded by a bright patch of light on the tube, is clearly visible in the illustration. The tube contains a small mirror *n*, which reflects the light on to the sensitive element of a photocell *o* contained in a canister integral with the tube. The valve-holder into which the photocell is plugged can be seen in Fig. 1, at the top of the canister. The cylindrical housing communicates with a second canister containing another photocell *p*. The outputs from the two photocells are connected to the grids of a double-triode valve, *q*, which is visible in the upper right-hand corner of Fig. 1.

The hydrometer functions as follows. When a deposit of dew or frost is formed on the polished surface, the light directly reflected from the latter is reduced in quantity and is partially scattered. The reduction in the amount of reflected light reduces the output of the photocell *o*. At the same time, owing to the scattering, some of the light is able to pass the mask *l* and reach the lens *m*, which concentrates it on the sensitive element of the photocell *p*, the output of which is increased in consequence. A "push-pull" action, therefore, results. The optical system of photocell *p* is designed to accept the maximum quantity of light scattered by the deposit on the polished surface.

The method of heating and cooling the polished surface is interesting. So far as heating is concerned, the outputs from the photocells, after electronic amplification and passage through a stabilising circuit *r*, are used to control a magnetic amplifier *s*, the output from which determines the current supplied to the primary winding of a heating transformer *t*, of ratio 600 : 1. The secondary of this transformer consists of a single turn made up, in the first place, of two stout bars of copper *u* measuring 1¼ in. by ⅝ in. in cross-section. One of the bars is straight and the other contains a loop through which the laminations of the primary core pass. The bars are bolted together near their lower ends but their upper ends are spaced apart and furnished with copper strips *v* measuring ¼ in. by 0·015 in. in cross-section, which are joined to the button *b* and form resistive heating elements. The secondary circuit is completed through the button *b*. The power consumption of the transformer, which is fed from standard 50 cycles per second supply-mains, is about 50 watts, but the secondary current is very heavy. Cooling of the polished surface is accomplished by means of a refrigerator *w* in which the lower ends of the bars *b* are immersed. For the purposes of demonstration at the exhibition, a vacuum flask containing solid carbon dioxide was employed for the purpose.

The heating elements v also serve as a thermal restriction between the button b and the cold sink. Heat enters and leaves the platinum diaphragm, therefore, along the same path. Thus, when the system is in equilibrium, no heat is flowing to or from the diaphragm and the temperature of the latter is uniform. This arrangement allows the body, consisting of the copper button and the diaphragm, to be of small thermal capacity and its temperature changes to be extremely rapid. The heating elements v are designed to give optimum performance, and heat can be supplied or withdrawn very quickly. When the hygrometer was tested with liquid nitrogen as a cooling agent, a rate of cooling at the diaphragm of 15 deg. C. per second was obtained, and the corresponding rate of heating was 30 deg. C. per second. The delay between the generation of heat at the heating elements and a change of temperature at the polished surface is also very small. These features of the instrument are highly desirable from the point of view of rapid and precise control of temperature, particularly in an automatic system.

The temperature of the central area of the diaphragm is determined by means of a thermal junction embedded in the copper button b, just below the diaphragm. A separate hot-junction x is employed and the leads are connected to a magnetic amplifier y, the output being displayed on a panel instrument or continuous recorder z. The magnetic-amplifier associated with the thermocouple and the indicating and recording instruments employed are standard products of Messrs. Elliott Brothers.

As designed, the instrument is inherently stable. The avoidance of hunting is often difficult in a "closed loop" system but, in this case, is achieved mainly as a result of the rapidity of heating and cooling of the platinum surface. This action, and thus the thickness of the film of dew or frost, can be controlled by means of the multi-position switch seen on the left of Fig. 1. In determining the humidity of air, the equipment could be used for frost-points down to − 85 deg. C., approximately. Below this temperature, however, frost does not form in the familiar pattern of feathery crystals but as a single transparent layer, and its presence would not, therefore, be detected by the instrument.

Some light from the lamp h is reflected from the glass cover of the air chamber, but the arrangement of the optical system of the instrument is such that, after reflection from the mask l, such light does not fall on the small aperture communicating with the photocell first mentioned. It is, therefore, of no consequence. In addition, some light is scattered at all times by atmospheric dust, but it is insufficient to affect the operation of the instrument. The accuracy of the temperature reading is limited only by the accuracy of the thermocouple and the temperature drop in the frost deposit. Since the temperature to be determined is steady and the sensitivity of the instrument high, making only a thin deposit necessary, high accuracy is possible. The time of response to an appreciable change of humidity is normally only a few seconds but, owing to the time taken by a deposit to build up, it may be 10 to 20 seconds at very low frost-points, that is, when the air is very dry. In demonstrating the instrument at the exhibition, the air was partially dried by passing it through a tube containing silica gel. This tube is visible on the extreme right of Fig. 1.

MOBILE RECTIFIERS AND PLANT BREAKDOWNS.

THE replacement of direct-current rotating plant has often been an acute problem during the post-war years. Industrialists have, therefore, sometimes had to take steps to guard against failures which might interfere with production. An interesting example of what can be done in this way was provided by the breakdown of a 2,000-kW motor-converter at the Meadow Hall works of Messrs. Arthur Lee and Sons, Limited, Sheffield. This machine supplied power to the polishing stands of a hot-strip mill and, as insufficient stand-by plant was available, an appeal was made to British Railways, who, during the war years, had developed some 1,000-kW 500-volt mercury rectifier substations in conjunction with the General Electric Company, Limited.

As a result, two of these units, which were stationed at Brighton, were taken by special train to Sheffield, and installed in their final position within 20 hours of their arrival. In the meantime, arrangements had been made with the Yorkshire Electricity Board to carry out the necessary alterations to the high-tension wiring, including the disconnection and re-connection to the rectifiers of the two 1,000-h.p. mill motors. This work was also completed rapidly and, after testing and minor adjustments, the mill was again in full production just one week after the breakdown. It is interesting to note that the two units had been in store for several years and one had not been used before.

BLAST-FURNACE SLAG AS MATERIAL FOR DAMS.

To reduce costs and save cement, the North of Scotland Hydro-Electric Board have decided to use ground blast-furnace slag in the construction of the Loyne and Cluanie dams of the Glen Moriston hydro-electric scheme in Inverness-shire. The Trief process will be used. The contract for the construction of the dams has been placed with the Mitchell Engineering Company, of Peterborough, who have themselves also carried out investigations.

In 1948, the attention of the Hydro-Electric Board was drawn to the use being made of ground blast-furnace slag in the construction of a large dam by the French Electricity Board at Bort-les-Orgues, in Central France. The slag was used in part replacement of Portland cement and the reports received were so encouraging that it was decided to send to France a deputation consisting of two engineers and a chemist to get fuller details. The Trief process, which was patented by Mr. Victor Trief, a Belgian, consists of using blast-furnace slag (which is, at present, virtually a waste product) by grinding it wet on the site in a rotary grinder. The slurry so produced is passed directly into the concrete mixers to be mixed with the appropriate quantities of Portland cement, aggregate and sand, and produces a concrete which is equal in strength to a similar mixture using wholly ordinary Portland cement. The French also claim that the slag-cement concrete generates less heat when setting, and that it is more resistant to acid peaty waters than pure Portland cement concrete. The slag available from Scottish steelworks contains less lime than the slag that the French constructors used, but the Highland experiment is expected to produce results which will be of value not only to the Board and to the country's export trade in cement but as a guide in the construction of other large dams.

The Cluanie dam is to be 112 ft. high and 2,165 ft. long, and the Loyne dam 58 ft. high and 1,745 ft. long. The proportion of slag cement to Portland cement will probably be about one-third Portland and two-thirds blast-furnace slag, in which case the saving in Portland cement will amount to about 20,000 tons. In the construction of the dams, the Mitchell Engineering Company are also adopting another idea which was tried out at Bort, which is not to use shuttering but to use instead precast concrete slabs for the faces of the dams. By this means, neither steel nor timber shuttering will be needed and the demand for these two scarce materials will therefore be reduced.

PERFORMANCE OF "VAMPIRE" NIGHT-FIGHTER AIRCRAFT.

IN the April issue of the *de Havilland Gazette*, particulars of the measured performance, corrected to standard conditions, of the D.H. 113 Vampire night-fighter aircraft, known to the Royal Air Force as the Vampire N.F. 10, and recently transferred to the "open" list, are published. The Vampire N.F. 10, constructed by the de Havilland Aircraft Company, Limited, Hatfield, Hertfordshire, is powered by a de Havilland Goblin 3 jet engine delivering 3,350 lb. static thrust at sea level.

Without any external equipment, the aircraft has a fuel capacity of 330 gallons, the take-off weight is 11,350 lb., and the wing loading is 43·3 lb. per square foot. The aircraft will take off and clear a 50-ft. barrier in less than 1,000 yards. The initial rate of climb is 4,400 ft. per minute, and the climb to the operational ceiling (at which the rate of climb has fallen to 1,000 ft. per minute), 40,000 ft., takes 16·3 minutes. The maximum level speed is 467 knots (537 m.p.h.) at sea level and 452 knots (530 m.p.h.) at 40,000 ft. The limiting Mach number is 0·815. At a Mach number of 0·7 at 40,000 ft., the radius of steady turn is 1·95 nautical miles (2·24 statute miles); at the expense of some speed or height, the aircraft can be turned in a minimum radius of 0·95 nautical miles (1·09 statute miles). The still-air range, including the distance covered on climb and descent, is 345 nautical miles (397 statute miles) at sea level and 705 nautical miles (810 statute miles) at 30,000 ft. The patrol duration, assuming a mean speed of 275 knots, is 1·45 hours, allowing for the fuel consumed on the take-off, the climb, 10 minutes' combat, and the descent.

When fitted with two external drop tanks, giving an additional fuel capacity of 2 × 100 gallons, the all-up weight is increased to 13,100 lb. and the limiting Mach number is reduced to 0·755. The take-off to clear 50 ft. requires 1,300 yards. The initial rate of climb with drop tanks is 3,400 ft. per minute, and the operational ceiling, 34,000 ft., is reached in 17·5 minutes. The still-air range is 540 nautical miles (620 statute miles) at sea level and 1,060 nautical miles (1,220 statute miles) at 30,000 ft. The patrol duration is 2·7 hours.

BRITISH STANDARD SPECIFICATIONS.

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

Gears for Instruments and Clockwork Mechanisms.—When revising B.S. No. 978, covering gears for clockwork mechanisms, first published in 1941 as a war-emergency measure to assist in the reduction of the types and sizes of gears used for instruments, it was decided to produce the new edition in four parts. Part 1, dealing with involute spur, helical and crossed helical gears, was published some time ago and Parts 2 and 3 have now come to hand. Part 4 is in preparation. Part 2 is concerned with cycloidal-type spur gears, and Part 3 with bevel gears. Part 2 applies to gears for spring or weight-driven mechanisms in which the pinion is the driven member or where the pinion is required to act sometimes as the driver and sometimes as the driven member. The Swiss standard has been used as a basis on account of the prevalent use of that standard for horological work and for other applications where a cycloidal form is preferred. The specification relates entirely to the form and proportions of the teeth and sets out a range of standard modules between 0·070 and 1·000 mm. Part 3 deals with bevel gears which were not covered by the 1941 edition of the specification. It relates to machine-cut conical gears connecting intersecting shafts and having pitches from 20 to 80 DP. The teeth have a normal pressure angle of 20 deg. at the pitch cone and they may be straight or curved. The specification provides for class A gears for use where a high degree of accuracy is required and class B gears for other applications. [Price of Parts 2 and 3, 3*s.* 6*d.* each, postage included.]

Wood-Chip and Wood-Waste Boards.—In recent years, processes have been developed for the manufacture of boards, for building and other purposes, from particles of wood such as sawdust, shavings, chips and veneer trimmings or similar materials. Such boards are different from fibre boards made from wood or other vegetable fibre by a felting process and already covered by British Standard Specification No. 1142. The preparation of a quality standard for wood-chip boards is under consideration, but, meanwhile, the Institution has published B.S. No. 1811, covering methods of test for wood-chip boards, wood-waste boards and similar boards. Tests for transverse flexural strength, for deflection under sustained load, for resistance to impact and also for the determination of the effective modulus of elasticity, density, volatile content, water absorption, thermal conductivity, the surface spread of flame and dimensional changes caused by moisture are described in detail. [Price 2*s.*, postage included.]

Aircraft Steels.—Four new publications in the series of British Standard Specifications for aircraft materials have been issued. The first of these is Addendum No. 1 to B.S. No. 2S.100, covering the inspection and testing procedure for aircraft steels. The addendum concerns section 11 which covers wire for the manufacture of bolts of ½-in. shank diameter and upwards by cold forging. Clauses on a hardening test and on tolerances and various forms of mechanical testing are included. Of the other three publications, Nos. S.102 and S.103 deal, respectively, with carbon-molybdenum steel and with low nickel-chromium steel wires for the manufacture of cold-forged bolts of ½-in. shank diameter and over. The fourth publication, No. S.105, is concerned with carbon-steel wires for the manufacture of cold-forged bolts not exceeding ½-in. shank diameter. In all three cases, particulars of the chemical composition, process of manufacture, the ultimate tensile stress, the heat treatment required, and other properties and characteristics are given. [Price of each publication 1*s.*, postage included.]

Oxy-Acetylene Welding of High-Temperature and High-Pressure Steel Pipelines.—The first of a new series of specifications concerned with the welding of pipelines, B.S. No. 1821, covers steel pipelines for service conditions in which the pressure exceeds 250 lb. per square inch and/or the temperature exceeds 425 deg. F. (220 deg. C.). The conditions for the shop and the site welding of joints in such steel pipelines and fittings, up to and including 20 in. in diameter, are laid down, and the specification is divided into four parts. Part 1 defines the parent metals and specifies the types of filler rods and the welding technique. Part 2 deals with butt and other welds and specifies the method of preparation and requirements for the completed welds. Part 3 concerns branches and includes details of preparations for set-in and set-on types. Part 4 deals with sleeve welds. The specification contains many line diagrams and reproductions of photographs of satisfactory and unsatisfactory welds. [Price 6*s.*, postage included.]

ANNUALS AND REFERENCE BOOKS.

Hydrogen Embrittlement of Steel: Review of the Literature.

By R. W. BUZZARD and H. E. CLEAVES. United States National Bureau of Standards Circular 511. The Superintendent of Documents, United States Government Printing Office, Washington 25, D.C., U.S.A. [Price 20 cents.]

THAT steel absorbs hydrogen on exposure to the gas at an elevated temperature or in the environment of a chemical reaction is now accepted as a fact, though the details of the processes of embrittlement, flaking and cracking of steel in such circumstances are still subjects of discussion. Makers of high-pressure water-tube boilers, in particular, are greatly interested in the subject; but, as the authors of this brochure observe, while experiment has defined the conditions under which certain defects will occur in the laboratory, "proof that the results are generally applicable to commercial practice is lacking." The problem, therefore, is still a current one, further inquiry into which should be greatly facilitated by this selected bibliography of the literature, extending, according to the side headings, from 1800 to 1949; though the earliest reference that we have noted is to C. Despretz, in 1829. The use of the bibliography would be easier, incidentally, if the practice were adopted of setting the titles of publications in italics.

The British Journal Photographic Almanac, 1952.

Edited by ARTHUR J. DALLADAY, A. Inst.P. Henry Greenwood and Company, Limited, 24, Wellington-street, London, W.C.2. [Price 5*s.* net in Linson Board covers, or 6*s.* 6*d.* net bound in cloth.]

WITH this issue, the *British Journal Photographic Almanac* has attained its 93rd year of publication, a circumstance which clearly shows that its value is appreciated by the professional and amateur photographers for whom it is intended. All the usual features are retained. with careful revision, and some useful additions have been made to keep the contents thoroughly up to date. The original articles included in the current issue include one by the editors on Colour Photography and Science, and another by Mr. Bernard Alfieri, entitled "Finding Out with a Camera," which shows how that instrument can be employed to increase the general knowledge of the photographer and others. Other original articles deal with the photography of churches and cathedrals, narrow-gauge scientific cinematography, films for training in industry, modern methods of colour photography, and other matters of general interest to photographers. The review of new photographic materials and apparatus, notes on chemicals, formulæ, tables and other regular features included enable technical and pictorial photographers to keep abreast of modern developments and provide a mine of useful information which is always available for reference, and thus justify the subtitle of the work as the "Photographer's Daily Companion." The pictorial supplement, which consists of 32 reproductions in photogravure of work by well-known photographers, mostly shown at the exhibition of the Royal Photographic Society or at the London Salon of Photography last year, demonstrates quite clearly that photography is an art as well as a science.

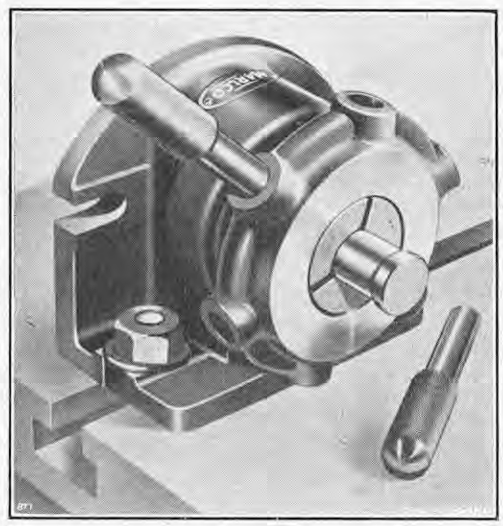
CONTRACTS.

HANDLEY PAGE LTD., Cricklewood, London, N.W.2, announce that HANDLEY PAGE (READING) LTD., are to supply four four-engined 18-22 seater Marathon aircraft to the West African Airways Corporation for service over a 6,500-mile network of tropical routes in Nigeria, the Gold Coast and French West Africa. Thirty Marathon aircraft have also been ordered for the Royal Air Force as advanced-navigation training aircraft. In them, pupils will make flights from the United Kingdom as far afield as Malta and Gibraltar. The Marathon is a high-wing monoplane with tricycle undercarriage and four de Havilland Gipsy Queen engines. It cruises at over 200 m.p.h., and has a range of 1,400 miles.

MIRRLEES, BICKERTON & DAY LTD., Hazel Grove, Stockport, Cheshire, have received an order from the Burntisland Shipbuilding Co. Ltd., for Diesel propelling machinery for a vessel to be built by them for the Currie Line, Ltd. The installation consists of two Mirrlees KVS 12 GMR engines, driving through BARCLAY-CURLE fluid couplings and thence to a common reverse-reduction gearbox of the SLM oil-operated type, manufactured by MODERN WHEEL DRIVE LTD. The final power available at the single propeller shaft is 3,565 h.p. continuously at 116 r.p.m. The engines are of the uni-directional type and each develops continuously 1,955 b.h.p. at 375 r.p.m.

ANGLE COLLET FIXTURES.

FOR use in production machining operations, two angle collet fixtures have been introduced recently by Messrs. W. H. Marley and Company, Limited, New Southgate Works, 105, High-road, London, N.11. Both tools are made of Meehanite with two accurately-machined faces at right angles, provided with locating slots for registering the fixture in the T-slots of the machine table. They are bored straight through, so that, when set up in the horizontal position—as in the accompanying illustration, which shows the larger Marley No. 2 fixture—they permit the machining of bar work. In the vertical position, a plain stop inserted between the bottom of the workpiece and the machine table allows the depth of cut to be controlled during batch production.



A tempered steel washer fitted in the cap takes the thrust of the collets and eliminates wear on the cap. A quarter-turn of the cap is sufficient to release a clamped workpiece. In the larger tool illustrated, two hardened handles are provided which can be inserted in the two most convenient of the six holes of the cap. The smaller fixture has three holes in the cap and is provided with a single handle which can be screwed into any one of them. Collets for both fixtures are interchangeable with other tools in the Marlco range. The Marlco No. 2 fixture illustrated can accommodate standard collets of $\frac{1}{4}$-in. to $\frac{3}{4}$-in. diameter, in steps of $\frac{1}{16}$ in. When set up with the collet horizontally, as shown, the collet centre is $3\frac{1}{8}$ in. above the base. In the vertical position, the height of the collet is $3\frac{3}{4}$ in. The smaller tool, the Marlco No. 1 angle collet fixture, has a capacity of $\frac{1}{16}$-in. diameter to $\frac{3}{4}$-in. diameter, in steps of $\frac{1}{32}$ in., the height of the collet centre in the horizontal plane being 2 in., and the collet height in the vertical plane $3\frac{5}{8}$ in.

THE LATE MR. J. H. MILLEN.—We regret to record the death of Mr. James Henry Millen, which occurred at Deal on Wednesday, April 30. Mr. Millen was for many years connected with the London Underground Railways, being in charge of the generating station at Lots-road, Chelsea, and afterwards becoming chief electrical engineer of the London Passenger Transport Board. On his retirement from this position he held appointments with the Ministry of Labour and the Control Commission for Germany, where he was concerned with the numerous problems connected with the re-establishment of electricity supply in that country after the war. Subsequently, he became a Regional Controller of the Ministry of Fuel and Power. He was an associate member of the Institution of Electrical Engineers.

ADHESION AGENT FOR ROAD SURFACE DRESSINGS.—The Road Research Laboratory is now recommending a dew adhesion agent, D.S. 2274, for use in road surface pressing in wet weather. It replaces cetyl pyridinium bromide, which was previously recommended but is now unobtainable. The new material is at present in adequate supply and has been shown by laboratory tests to be quite as good as the original agent recommended. D.S. 2274 is used to prevent the serious failures which may be caused by rain falling on newly-laid surface dressings. Its use means that surface dressing work need no longer be limited to periods of fine settled weather. It is applied in a solution of creosote to the interface between the binder and the stone chippings, which are scattered on the binder (tar or bitumen) immediately after it has been spread on the surface of the road. The application is made either by coating the chippings with the creosote solution in a bituminous or concrete mixer, or by sprinkling the solution on the freshly laid binder film before the chippings are spread.

LAUNCHES AND TRIAL TRIPS.

M.S. "OSWESTRY GRANGE."—Single-screw cargo vessel, with accommodation for four passengers, built and engined by R. and W. Hawthorn, Leslie & Co., Ltd., Hebburn-on-Tyne, Co. Durham, for the Houlder Line, Ltd. (Managers: Houlder Brothers & Co., Ltd.), London, E.C.3. Main dimensions: 450 ft. between perpendiculars by 61 ft. 6 in. by 40 ft. to upper deck. Hawthorn-Doxford four-cylinder opposed-piston oil engine, developing 3,780 b.h.p. at 100 r.p.m. in service. Speed, about $12\frac{3}{4}$ knots. Trial trip, April 16 and 17.

M.S. "SUHAIL."—Single-screw oil tanker, built by the Furness Shipbuilding Co., Ltd., Haverton Hill, Co. Durham, for the Afran Transport Corporation, Monrovia, Liberia, a subsidiary of the Gulf Oil Corporation, New York. Second of two sister ships. Main dimensions: 560 ft. between perpendiculars by 80 ft. by 42 ft. 3 in. to upper deck; deadweight capacity, 24,270 tons on a summer draught of 32 ft. $3\frac{1}{4}$ in.; oil-tank capacity, 23,550 tons. Hawthorn-Doxford six-cylinder two-stroke oil engine, fitted with Alfa-Laval equipment for burning heavy fuel, and developing 6,600 b.h.p. at 115 r.p.m. in service; constructed by R. and W. Hawthorn, Leslie & Co., Ltd., Newcastle-upon-Tyne. Speed, 14 knots. Trial trip, April 22.

M.S. "ILIADE."—Single-screw oil tanker, built and engined by Harland and Wolff, Ltd., Govan, Glasgow, for the joint ownership of the Société Navale Delmas-Vieljeux and the Société Anonyme Courtage et Transports, Paris. Main dimensions: 540 ft. between perpendiculars by 73 ft. by 39 ft. 3 in. to upper deck; deadweight capacity, about 19,000 tons. Harland-B. and W. six-cylinder two-stroke opposed-piston eccentric-type oil engine. Trial trip, April 22.

H.M.S. "EDDYBAY."—Single-screw vessel for carrying oil in bulk, built by the Caledon Shipbuilding and Engineering Co., Ltd., Dundee, for the Naval Stores Department, Admiralty, London, S.W.1. Second vessel of two. Main dimensions: 286 ft. overall by 44 ft. by 18 ft. 6 in.; deadweight capacity, 2,286 tons on a draught of 17 ft. 2 in.; gross tonnage, 2,156. Triple-expansion steam engine developing 1,750 i.h.p. at 227 r.p.m., constructed by Lobnitz & Co., Ltd., Renfrew; and two oil-burning cylindrical boilers constructed by the Caledon Co. Speed in service, 12 knots. Trial trip, April 23.

BOOKS RECEIVED.

The British Electrical and Allied Industries Research Association. Technical Report No. A/T 124. *An Investigation to Develop Methods of Test for Impregnating Varnish.* By H. R. HEAP. [Price 21*s.*] No. G/T 246. *Calculated Curves of Inductive Energy at the Start of Arcing in Fuses.* By H. W. BAXTER. [Price 12*s.*] No. L/T 226. *The Dielectric Properties of Certain Benzene Derivatives in the Solid State.* By A. TURNEY. [Price 4*s.* 6*d.*] No. L/T 261. *Transcription of Electrodynamic Relations into Different Systems.* By DR. H. PELZER. [Price 7*s.* 6*d.*] No. N/T 62. *X-Ray Studies of Metal Structures.* By DR. W. H. TAYLOR. [Price 6*s.*] No. Q/T 113. *The Measurement of Axial Magnetic Forces in Transformer Windings.* By M. WATERS. [Price 12*s.*] No. Q/T 115. *The Calculation of Transformer Thermal Data from Readings taken in Service.* By M. R. DICKSON. [Price 7*s.* 6*d.*] No. Q/T 116. *Generation of Gases in Transformers. Résumé of Available Information.* By M. R. DICKSON. [Price 12*s.*] Offices of the Association, Thorncroft Manor, Dorking-road, Leatherhead, Surrey.

DIN 1054. *Gründungen. Zulässige Belastung von Flächen-und Pfahlgrü ndungen.* With notes by PROFESSOR HANS LORENZ and DR.-ING. PHILIPP EBERT. Wilhelm Ernst und Sohn, Hohenzollerndamm 169, Berlin-Wilmersdorf, Germany. [Price 2·50 D.M.]; and Lange, Maxwell and Springer, Limited, 41-45, Neal-street, London, W.C.2. [Price 4*s.* 9*d.*]

Radio. By JOHN D. TUCKER and DONALD F. WILKINSON. Vol. I. English Universities Press Limited. St. Paul's House, Warwick-square, London, E.C.4. [Price 7*s.* 6*d.* net.]

Elementary Mathematics. By LEWIS W. PHILLIPS. Macdonald and Company (Publishers), Limited, 16, Maddox-street, London, W.1. [Price 12*s.* 6*d.* net.]

University of Illinois Engineering Experiment Station. Bulletin No. 393. *Investigation of the Pressure Characteristics and Air Distribution in Box-Type Plenums for Air Conditioning Duct Systems.* A report of an investigation conducted in co-operation with the American Gas Association, by PROFESSORS STANLEY F. GILMAN, ROSS J. MARTIN and SEICHI KONZO. [Price 80 cents.] No. 396. *Studies of Slab and Beam Highway Bridges: Part III. Small-Scale Tests of Shear Connectors and Composite T-Beams.* By PROFESSORS CHESTER P. SIESS, IVAN M. VIEST and NATHAN M. NEWMARK. [Price 1 dol.] No. 397. *Performance of a Gas-Fired Forced-Air Heating System in Research Residence No. 1.* By PROFESSOR SEICHI KONZO and others. [Price 60 cents.] The Engineering Experiment Station, University of Illinois, Urbana, Illinois, U.S.A.