# INTERNATIONAL FLAME-RADIATION TRIALS IN HOLLAND.

SUBSTANTIAL savings in fuel and improvements in performance of cement kilns, furnaces for making steel, non-ferrous metals and ceramics, boiler furnaces and many other types of furnace would result from a better understanding of the processes of flame radiation. At present, the radiating properties of non-luminous gases, such as $CO_2$ plus $H_2O$, are sufficiently well-known to enable the thermal radiation of non-luminous flames to be calculated fairly accurately, provided that their temperature, their geometric dimension and composition are known. The case is different, however, with luminous flames, which are diffusion flames containing carbon particles. Very little is understood about the formation of these particles, due to a combustion and thermal cracking and to incomplete combustion; nor is the evolution of these particles during the progressive penetration of outside air to the flame interior understood. It is not possible at present to calculate the effect on the flame of heavy hydrocarbons capable of generating carbon particles, and the influence of the furnace wall temperature on the cracking process is equally unknown. A vigorous international effort to close this important gap in engineering knowledge has been in progress for the past two years on a specially built experimental furnace at the works of the Royal Netherlands Steel Company at Ijmuiden, Holland, where scientists from France, Holland, Great Britain and Sweden have been at work on a joint project. Two views of the furnace, showing the special testing equipment, are reproduced in Figs. 1 and 2, and Figs. 3, 4 and 5, on page 706, show the general arrangement. The results of the first year's work have now become available and are appearing in full detail in the pages of the *Journal* of the Institute of Fuel.

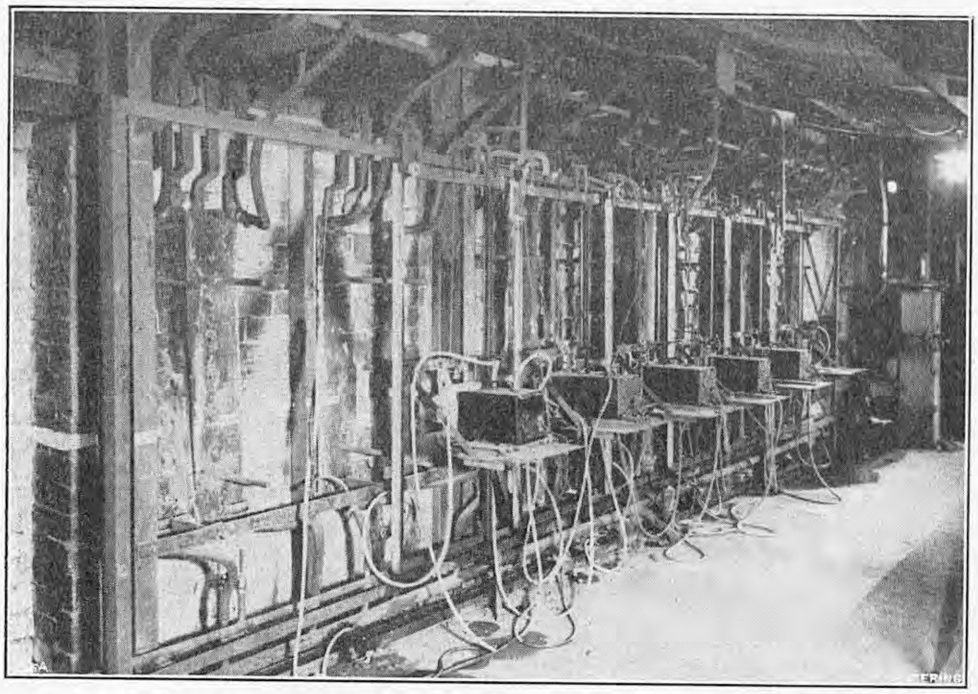


FIG. 1. NORTH WALL OF FURNACE, SHOWING RADIATION PYROMETERS.

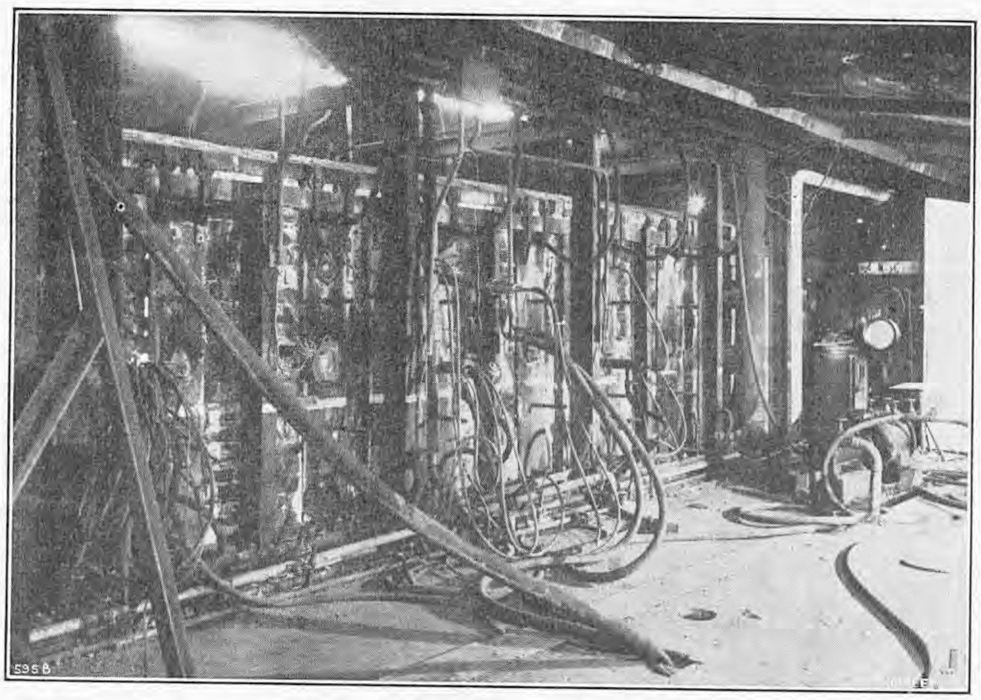


FIG. 2. SOUTH WALL, FITTED WITH PROBES.

As the experimental flame must not be scaled down by more than two or three to one (linear dimension) and must be subject to the same relation between mixing processes and heat transfer as it would be in an ordinary industrial furnace if conclusions from the work are to be usefully applied to industrial problems, the minimum size of the experimental furnace is still fairly large. The largest industrial flames in boilers, open-hearth furnaces, glass tanks or metal reheating furnaces rarely exceed 9 ft. in diameter and 45 ft. in length, and an experimental flame 3 ft. in diameter and 15 ft. in length is used in the investigations. The furnace consists of a tunnel 7·5 m. long by 2 m. wide and 2 m. high, built in 25-cm. fireclay brick; the roof has a lift of 20 cm. at the centre. The brickwork at the burner end is designed to give a more or less evenly distributed air flow at the beginning of the flame. A refractory baffle at the farther end of the furnace forces the waste gases through a narrow opening, to give a horizontal flame and reduce the effect of the external wind conditions; it also limits the dimensions of that part of the furnace which has to be brought to the "steady-state" condition for measurements. Various vertical slots and holes are distributed over the furnace to allow for the insertion of probes and the sighting of instruments.

Two types of experiments were decided upon, namely, performance trials, which provide information on the relation between the flame and its surroundings at points along the flame, by measurement made outside the flame; and combustion-mechanism trials, which show what is actually happening as the fuel burns, by measurements showing the extent of combustion. The first year's experiments culminated in intensive performance trials from which certain interim conclusions can be drawn. In such performance trials, relatively few measurements are made on a large number of flames, corresponding to a variety of fuels and of other variables which govern the performance of industrial flames. As there are so many variables, and as the furnace itself has some uncontrollable variability, a careful statistical plan had to be followed. In these investigations, therefore, five variables were examined, each on two levels, by a factorial method. These variables are the quantity and type of fuel, the quantity and type of atomising agents, and the quantity of combustion air. In all, 48 trials were carried out.

The measurements taken during these trials consisted of a vertical traverse with mirror-type radiation pyrometers at various points along the flame; readings with probe and wall heat-flow meters; a suction-pyrometer traverse and a gas sampling traverse at the baffle; measurements of the flame contour at all possible points along the flame; and optical-pyrometer readings of the flame at all possible points. The intention of the trials was not only to reveal the effect of changes in these variables, but also to give information on the development of suitable instruments for use in this and industrial furnaces, and to assess their effectiveness in precision measurement and control of the furnace.

Taking the last two points first, it can be said that the experience of the trials was satisfactory. In all cases, the accuracy of control on the input variables and on the furnace was as good as the accuracy of the instruments. In other words, the effects found were genuinely due to changes in the variables and not to systematic inaccuracies in the instruments (many of which had to be specially developed) or to trends not under the control of the experiment. The statistical analysis of factorial experiments of this sort is a highly complex matter. In the present case, the work has been carried out in three countries, the greater part of it in the United Kingdom.

While allowances must be made for the simplifying assumptions that it was necessary to make if conclusions useful to designers could be drawn from these investigations, it may be said that the following indications are observed.

The time or distance of travel of the flame from the burner has a primary influence on the emissivity of an oil flame. This influence is greater than that of any of the main variables. Very broadly, it can be said that the flame emissivity is unity up to two metres from the burner and then falls steadily to a value of about 0·5 at four metres and probably reaches calculable non-luminous emissivity in another one or two metres. It is probable that combustion is proceeding more or less uniformly with distance over the range where the emissivity is falling steadily, and that the region of constant high emissivity is the region where fuel is evaporating and cracking under the influence of heat with a deficiency of air.

The only significant effect on emissivity of the variables in investigation on the early part of the flame is that due to variation in fuels. Oil and pitch creosote were compared, and pitch creosote gave the higher emissivity. Temperature, on the other hand, may be affected significantly in the early part of the flame by fuel quantity, air atomisation (instead of steam), and a high quantity of atomising agent. All these increase the temperature. Reduction of the quantity of combustion air has its largest effect at an intermediate position, probably because insufficient air for combustion has been drawn into the jet at an earlier stage in the flame, while, later in the flame, the "false" air is in excess of the "intentional" combustion air.

A decrease in the quantity of atomising agent gives a strong increase in relative emissivity, and so does an increase in the quantity of fuel. The type of fuel also appears to have an effect, but this is not certain. Since the relative emissivity is always falling in the tail of the flame, a higher value simply means a slower fall; that is, a longer flame. The only important effect on the temperature at the tail of the flame is that caused by variation in fuel quantity; as might be expected, a higher fuel quantity gives a higher temperature.

Certain practical consequences follow, even from the detailed observations on which these interim conclusions are based. For example, it is obvious that, since the flame radiation varies greatly with distance along the flame in spite of the flattening effects of longitudinal radiation from the hot walls, it is necessary to take account of this in calculating radiant-heat transfer in boilers or furnaces. The assumption that radiation is uniform along the flame length is not accurate enough. Further, it is possible to construct curves, on the basis of the calculations made in these experiments, to show flame emissivities for various distances along the flame. Based on the grand mean for all the trials, and allowing the spread indicated by the maximum effect expected from altering one of the five variables over the range considered in the trials, a sufficiently accurate result may be achieved. Another practical conclusion from these trials concerns heat radiation from the early part of the flame. The use of air instead of steam as an atomising agent gave an increase of 13 per cent. Similarly, the use of creosote pitch instead of oil gave an increase of 20 per cent. Observation of the tail radiation showed that an increase of 39 per cent. in the fuel input gave an increase of 49 per cent. in the radiation at 3 m. distance from the burner; a reduction of 25 per cent. of the excess air gave an increase of 17 per cent., and a decrease of 45 per cent. in the quantity of the atomising agent gave an increase of 13 per cent. in the radiation at this point. These results have an obvious bearing on the design and operation of many types of furnace.

Another practical result from the trials has been the design of a total-radiation meter which is very sensitive, can be calibrated on the absolute scale, and requires a very small radiation angle. It can be used on any practical furnace where a cold heat sink on the other side of the flame is practicable, and it enables changes in total radiation to be subdivided into the relative effects of changes of mean radiant temperature and mean emissivity. Further work is required, however, before a method is available for the reliable determination of absolute emissivity.

The combustion mechanism trials which have now been started at Ijmuiden cover the next stage in these investigations. While maintaining a constant fuel-quantity rate and air rate, detailed measurements are being made in all parts of the flame to determine such things as the flame composition, the carbon particle size, local emissivity, flame temperature, degree of mixing, etc. In such experiments as this there is a need for more measurements and more accurate measurements than in the performance trials. For example, in the performance trials, $CO_2$ is measured at the exit point only. It is necessary in the combustion mechanism trials to make such measurements along the length of the flame.

The first series of combustion mechanism trials has been completed recently and the next series will be carried out in the spring of 1952, on a new furnace which is shortly to be built in the same works through the generosity of the Royal Netherlands Steel Works themselves. The new furnace, which it is hoped to bring into operation about March, 1952, will be about the same size as the present one, but will have a fundamental alteration in that it will be possible to vary the load of the new furnace by means of water-cooled pipes at various levels and points. This will present another point of similarity between experimental conditions and an industrial furnace.

Behind all this work on flame radiation, which is directed towards a theory of heat transmission and the establishment of laws of luminous flame radiation, stand three classes of work, namely, the full-scale work in progress at Ijmuiden, model work, and laboratory work.

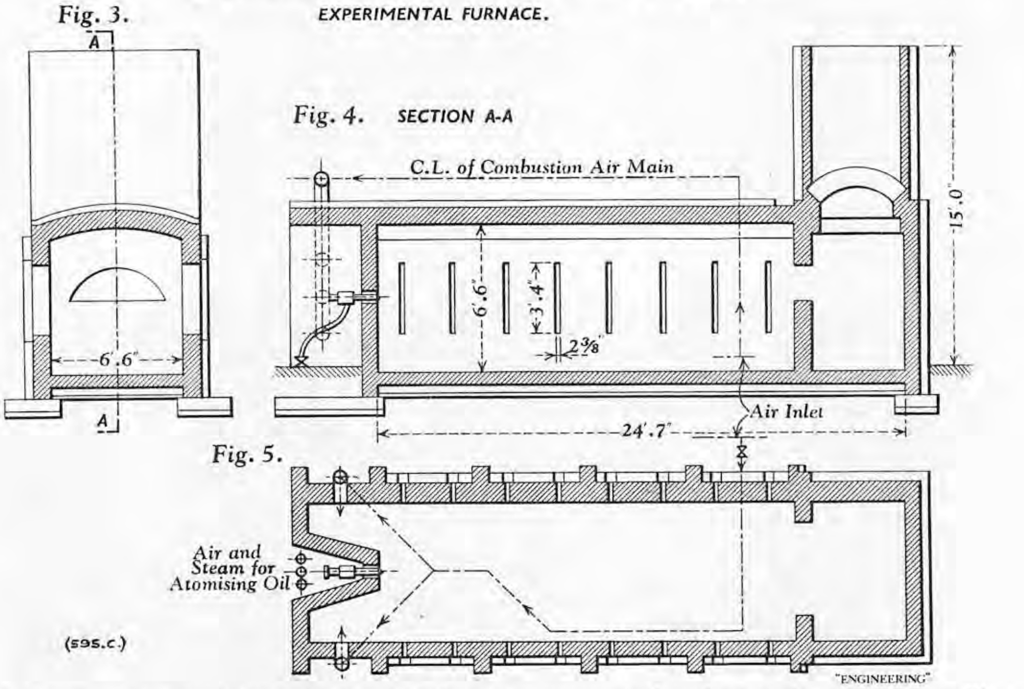
The full-scale work at Ijmuiden will shortly be supplemented by Swedish experiments on the furnace now being reconstructed at Stockholm. This furnace was used by Professor Lindmark many years ago in establishing the body of work for which he is well known. It has water-cooled walls, as compared with the refractory wall at Ijmuiden, and it will be of particular interest to observe the parallel experiments which will be carried out between the two furnaces. Various industrial applications of the water-cooled furnaces are likely to be held particularly in mind, such as glass-making furnaces and water-cooled boilers. Professor O. G. Hammar is directing the Swedish work, which is to be carried out in close conjunction with the Joint Committee which directs the work at Ijmuiden; and the Shell Petroleum Company have made available a supply of the same "reference" fuel as is used at Ijmuiden.

Work on model furnaces, such as that carried out by the United Steel Companies Limited, and by the Aerodynamics Section and the Steelmaking Division of B.I.S.R.A., will be supplemented shortly by a replica of the Ijmuiden furnace, 6 ft. long, constructed by the Shell Petroleum Company at Delft. There it is proposed to investigate similarity problems, with a view to the possibility of getting valuable results at a reduced expense. The wall temperatures of this furnace can be varied from the well-insulated condition of the Ijmuiden furnace to the water-cooled condition of the Stockholm furnace.

Constant laboratory work is necessary to provide the information required to make the flame radiation trials a success. Much of this is carried out at the Physics Laboratories of the British Iron and Steel Research Association in London, where such matters as droplet formation, and the physical and chemical details of the mechanism of combustion, have been and are being investigated. The whole project is supervised by a Joint Committee of scientists from France, Great Britain, Holland and Sweden with Professor G. M. Ribaud as chairman and two representatives from each national committee. The chairman of the British Committee is Professor O. A. Saunders, of the Imperial College of Science and Technology, London. In general charge of the studies included in the research programme is Mr. M. W. Thring, head of the Physics Department of B.I.S.R.A., while Mr. J. E. de Graaf, head of the Research Laboratories of the Royal Netherlands Steelworks, is in charge of the Ijmuiden experiments. The address of the Secretary-General of the British Committee, who, we understand, would be pleased to hear from anybody interested in this work, is at the B.I.S.R.A. Physics Laboratory, 140, Battersea Park-road, London, S.W.11.

## FLAME RADIATION TRIALS.

EXPERIMENTAL FURNACE.




## LITERATURE.

*Laboratory Design.*

Edited by H. S. COLMAN. Reinhold Publishing Corporation, 320, West 42nd-street, New York, U.S.A. [Price 12 dols.]; and Chapman and Hall, Limited, 37, Essex-street, London, W.C.2. [Price 96s. net.]

*Mechanical Engineering Laboratory.*

By C. W. MESSERSMITH and C. F. WARNER. John Wiley and Sons, Incorporated, 440, Fourth-avenue, New York 16. [Price 3·50 dols.]; and Chapman and Hall, Limited, 37, Essex-street, London, W.C.2. [Price 28s.]

AMERICAN books on the design and equipment of scientific laboratories are apt to engender in British technological breasts mixed feeling of envy and nostalgia for the days before present post-war circumstances compelled the practice of a rigorous austerity in existing British laboratories, and almost suppressed all hope for the new scientific buildings that are so sorely needed. Even in the United States, however, laboratory construction was practically at a standstill throughout the second World War. Since then, of course, American scientific activities have been expanding at a phenomenal rate; and from a shrewd community which, notwithstanding its wealth, is rightly anxious to secure the best value for expenditure on the facilities for research that it regards as second only to abilities, appeals for assistance in the planning and furnishing of science buildings soon began to reach the National Research Council in even greater numbers than before the war. A pre-war advisory body was accordingly re-activated in 1947 as a Committee on Design, Construction and Equipment of Laboratories, whose members, representative of science teaching as well as of industrial and institutional research, were charged to prepare a new and fully modern report on laboratory construction to replace a similar report which their predecessors had published in 1930.

Edited by Mr. H. S. Coleman, Assistant Director of the Mellon Institute and chairman of the committee, the report takes the form of a large and handsomely-bound book, printed on expensive paper that does full justice to the reproductions of photographs and architectural drawings with which it is profusely illustrated. The text consists of 42 articles by a corresponding number of contributors, each of whom has expert knowledge of one or more aspects of laboratory construction or utilisation. The arrangement of these chapters falls conveniently and logically into four main parts, the first of which treats, along general lines, of structural materials, permanent furniture and service supplies. Among the latter, provision for domestic ventilation figures more prominently than is warranted by the more equable climate of this country, but the American precautions against noxious chemical fumes and other hazards to the safety and well-being of scientific workers are none the less attractive, comparing favourably with the conditions under which a deal of first-class research is somehow accomplished in extemporised British laboratories.

The ten articles by university professors, which comprise a main section devoted to teaching laboratories, discuss in detail almost every conceivable aspect of that subject, from the selection of the site to the disposition of minor items of apparatus. The emphasis throughout is on the equipment for practical science students at university level; so pre-occupied, it would seem, with chemistry that all but marginal subjects like biochemistry or metallography are crowded out of the scientific curriculum. In the third main part, where attention is directed to the general requirements of industrial laboratories, the scope is extended to include the fields of the metallurgist and the biologist, and there are articles of special interest on the design of laboratories for high-pressure research, pilot-plant operation, and the safe handling of radio-isotopes. To exemplify how far the ideal laboratory can be realised in practice, the last quarter of the report consists of descriptions of a dozen or so actual laboratories, many bearing names that are deservedly famous throughout the world of science. The outstanding impressions gained from a study of these excellently written and illustrated articles are, first, the immense amount of forethought that has led to such rewarding results; and, secondly, the admirable way in which the severely functional demands of the scientific user can be blended and merged with the æsthetic feeling of the architect into a whole that is usually dignified, often unexpectedly beautiful, and always a most satisfying and stimulating scene for the pursuit of scientific knowledge.

The regrettable dearth of attention paid, in *Laboratory Design*, to buildings used specifically for engineering research is not made good by *Mechanical Engineering Laboratory*, which is concerned primarily with the practical course work of the undergraduate student, only incidentally with the layout of testing equipment, and not at all with the architectural or structural features of a mechanical-engineering research building. Both of the authors profess mechanical engineering at Purdue University, and out of the wealth of their teaching experiences they have compiled and published what is essentially an illustrated notebook which deals, in sequence, with instruments and methods of using them, procedures for conducting trials of mechanical engineering plants, the observation and recording of data, and the computation and presentation of performance results. The subject matter covers heat engines comprehensively enough to include stationary boilers and refrigeration plants, and the more mechanical aspects of hydraulic meters, pumps and fans, but it excludes all mention of materials testing and of much electronic apparatus that is nowadays considered essential to the equipment of a mechanical engineering laboratory. If these restrictions of scope are regarded as defects, it is fair to say that the authors' insistence on the importance of good reporting, and their recommendations for the conduct of experimental trials along the lines of recognised power-test codes, are compensating features of indisputable merit. In these general respects, no less than in numerous points of detail where experience of difficulties encountered and surmounted can make all the difference, the book offers valuable guidance to teachers and sound instruction to students.

USE OF CAP BARS IN CONTINUOUS STRUCTURES.

Fig. 12.

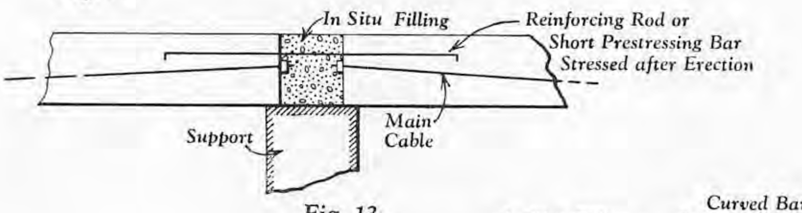
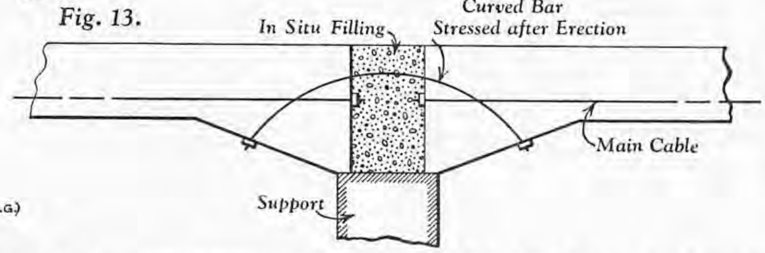



Fig. 13.




(583.G.)

# PRESTRESSED-CONCRETE STATICALLY-INDETERMINATE STRUCTURES.

(*Concluded from page* 679.)

DESIGN FEATURES AND CONSTRUCTION.

THREE of the papers gave space to descriptions of design features and successful completed structures. Messrs. Kee and Jampel described the advantages of rod reinforcement in prestressed-concrete construction, and went on to show its application to continuous beams and to portal frames. Mr. Harris and Professor Magnel devoted the larger part of their papers to descriptions of completed structures. The advantage of rod reinforcement in prestressed concrete, over the more common form of cable, arises from the greater ease of placing and stressing the stiffer rods, and from the more positive anchorage that is obtained by special nuts and washers acting against steel end plates. The rod is manufactured in diameters of $\frac{1}{2}$ in. to $1\frac{1}{8}$ in. and in lengths limited to 65 ft. The initial stress applied to the steel is usually 94,000 lb. per square inch, as compared with 120,000 lb. per square inch for cables, and the total loss of prestress is about 16 per cent. Creep in the steel at this stress is negligible, and the end fixing is claimed to permit no loss of prestress due to slip. For continuous structures where long lengths of rod are required, the bars can be extended by the use of couplers; these couplers impose some limitations, but also prompt development on the following lines. Provision of a cavity must, of course, be made to house the coupling, but the couplings can be useful when it is necessary to prestress a continuous structure by parts, in order to avoid excessive longitudinal movements at certain points along the structure.

The use of such bar reinforcement as "continuity" bars or "cap" bars is shown in Figs. 12 and 13. As has been pointed out already, short cables (or bars) cannot be accurately prestressed, and the curved form shown in Fig. 10, page 678, *ante*, to be criticised for this reason. Nevertheless, the use of such continuity bars does assist in the assembly of individual prestressed precast members. The arrangement to be adopted when constructing a prestressed portal frame from pre-cast members and utilising bar reinforcements is shown in Fig. 14, on page 708. The process can be extended more or less indefinitely to multi-storey and multi-framed buildings.

As may be seen from the foregoing, bars can, in general, be used as an alternative to wire cables, but the maximum scope is obtained when they are used to prestress individual members, the length of which is of the order of 20 ft. Their use in continuous structures is best when the structure itself is an assembly of a number of individually prestressed units, the joints being strengthened where necessary by continuity bars.

The method of avoiding the problem by prestressing the individual members of a structure and finally rendering the whole into a single continuous structure has been instanced; Professor Magnel described large multi-storey buildings erected by this technique. Mr. Harris described two bridges, one at the Festival of Britain site, and the other a multi-span bridge in Brazil, where virtual hinges were left in the structure until prestressing was completed, when the hinges were finally packed solid. In the second method of treatment, suitable for flat two-hinged arches, jacks are built into the abutments and their load regulated at intervals until the value of the thrust has become sensibly constant; by which time, it may be assumed, the deferred strains in the bridge have ceased. Examples are to be found in the bridges over the Marne, where not only was it difficult to determine the state of stress brought about by any arrangement of the cables, but where any deferred strain in the arch changed its geometry sufficiently to cause serious modification in the stresses in the arch. This treatment of regulating the reactions, which affects only the permanent loads, that is, the dead load and the prestressing force, can only be used when these loads are large compared to the live load.

The third technique—the use of an undulating cable, or the use of a straight cable with an undulating neutral axis—offers a method whereby a structure consisting of a succession of continuous beams may be prestressed without modifying the redundant reactions. The immediate limitation on an undulating cable is the number of waves that the cable can be made to assume and still be prestressed: in practice, the limit is certainly no higher than three, and even then accurate prestressing will not be possible. Alternatively, the neutral axis may be made to pass below the cable at the supports, and to rise above the cable at mid-span. In practice, this can be done by haunching the beams or by varying the thickness or breadth of the flanges. With such a treatment full economy of steel and concrete is not possible, some sections being considerably stronger than is necessary, but, on the other hand, the stressing operation is simple, direct and accurate.

Examples of such a method are to be found in a grillage of haunched beams to some reservoirs at Orleans, and in a continuous-slab road-bridge deck over a covered railway at Rouen. Professor Magnel also described the Sclayn bridge, in Belgium, where this method was employed, and which, he said, was the most important example of continuity. The Sclayn bridge, shown in Figs. 15, 16 and 17, on page 708, in a continuous-girder road bridge of two spans over the River Meuse. The two main spans are each 205 ft. 9 in. long. The roadway is about 23 ft. wide, and on each side there are cantilevered footpaths, each about 5 ft. wide. The cross-section is cellular and comprises four longitudinal walls with a transverse wall at each of the third points of each span; rectangular openings in these transverse walls allow the passage of the cables and permit inspection of the bridge. The continuous beam is supported at the middle pier by a hinge, and at the end supports each span rests on precast-concrete rockers. The main beams are prestressed by 36 cables, each of 48 wires, with a total length, including anchorage, of about 416 ft. The cables are straight in each span, with a slight change of direction above the central support; straining was done simultaneously from both ends. A compressive stress of 2,160 lb. per square inch and a tensile stress of 110 lb. per square inch were allowed for in the concrete.

# PRESTRESSED-CONCRETE STATICALLY-INDETERMINATE STRUCTURES.

Fig. 14. TYPICAL PORTAL FRAME BUILT-UP FROM PRE-CAST MEMBERS.

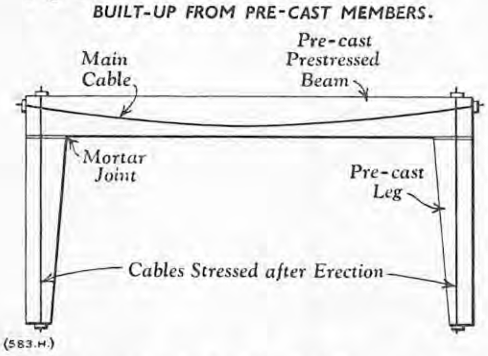



Fig. 15. SCLAYN BRIDGE, BELGIUM. LONGITUDINAL SECTION.

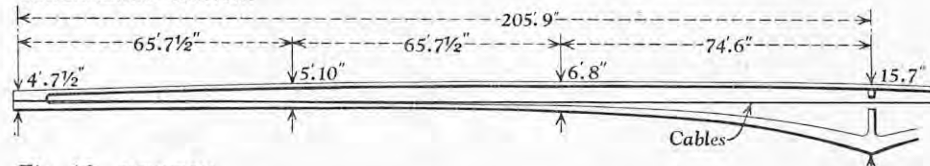



Fig. 16. ELEVATION.

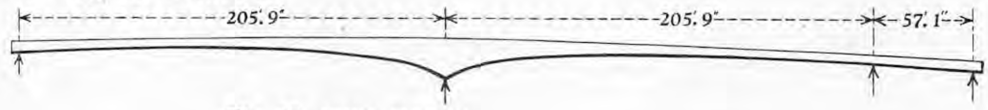



Fig. 17. CROSS-SECTION.

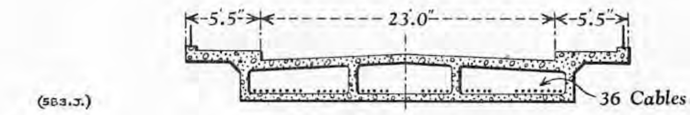
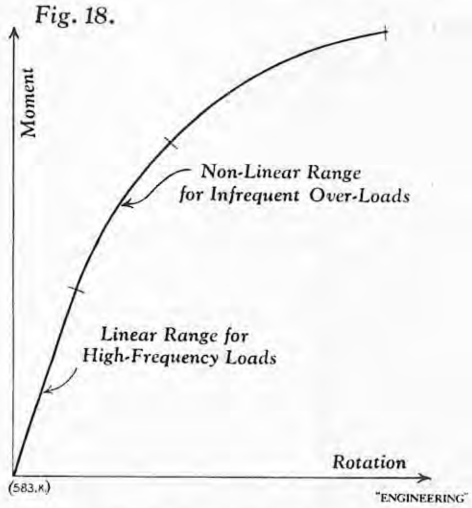



Fig. 18.




As examples of work where the structure was analysed as a prestressed continuous structure, with full allowances for the redundancies, Mr. Harris gave brief descriptions of the University Footpaths bridge at Oxford and the foundation beams to the Malago Factory at Bristol. Here the problem becomes the practical issue of controlling and placing the cables in strain.

EXPERIMENT AND RESEARCH.

Only one of the papers, that by Mr. Morice, was entirely concerned with experiment and research, although two others, those by Professor Magnel and by Messrs. Kee and Jampel, noted experimental work. In the last-mentioned paper, indications were given that experiments are in hand to determine the minimum curvature that can be employed when high-alloy steel bars are used for prestressing, and that further experiments are being conducted into the frictional losses likely with such bars. The authors indicated, as a preliminary measure, that curvature should be limited to 25 ft. for bars up to ⅞-in. diameter, and to 35 ft. for bars up to 1⅛-in. diameter. No figures were given for the loss of prestressing force due to friction with bars. Professor Magnel, however, presented two items of investigation. The first concerned tests to measure frictional losses during the prestressing of wires which pass round a single peg. His results may be summarised as follows: the loss is directly proportional both to the angle of deviation at the peg and to the applied degree of prestress. The second investigation related to the opportunity taken by Belgian engineers to measure the loss of prestress in the course of time in two cables placed for that purpose in the Sclayn Bridge. After two years from the date of initial stressing, measurements showed that "the loss of prestress is rather less than is generally accepted by designers." Such comment goes far to create confidence in the data and methods of calculation in current use.

In the single paper devoted to research, Mr. Morice touched upon two topics. First, he considered the problems involved in the use of prestressed concrete in the elastic, but non-linear, range, with particular reference to highway bridges. Briefly, the object is to tap the great reserves of strength available in this range by relating normal working stresses to the loads on a structure that are of relatively high frequency, and reckoning on using the non-linear range for those high loads that occur only occasionally (see Fig. 18). Such a design procedure, if accepted by the appropriate authorities, would lead to considerable economies in material. The paper then went on to describe some experiments in progress at the Cement and Concrete Association's laboratory at Wrexham Springs into the behaviour of prestressed frames just prior to failure. The frames consist of four main beams of 20-ft. span, inter-connected by three transverse beams spaced equally along the principal members; two such frames have so far been built. The frames were cast monolithically, the main beams being prestressed by the Magnel-Blaton system, and the transverse beams by arrangements that permit the degree of prestress to be varied. Loading of the frame is made at diverse points and the measured deflections used to check the assessment of moment redistribution that is occurring under load. Such tests should lead to the determination of the maximum permissible overloads for structures with an economical degree of transverse stiffness and prestress for normal working loads. One of the frames has already been tested to ultimate failure, under loading designed to bring about rupture at a predetermined point in the frame; failure occurred initially by local crushing of the concrete, followed by the formation of a shear crack at the cable line. Large deflections developed in the failing beam, while simultaneously the remainder of the frame relaxed to its unloaded deflection, but with the collapse of the failing beam the load was immediately redistributed and further points of failure developed throughout the frame. Failure of the beam was sudden and complete, not as is commonly found in tests on normal reinforced concrete, where first the concrete fails and then spalls off as the steel reinforcement distorts.

On the last evening of the symposium, Dr. F. G. Thomas, M.I.C.E., summed-up the papers and discussions, emphasising the difficulties and differences of opinions that are as yet unsolved. He appealed in particular for the publication of data from all sources of information, so that the loading of structures might be more accurately assessed and the most economic designs prepared to meet these requirements to the general benefit and satisfaction of all concerned.

THE LATE MR. W. A. DUTTON.—We regret to learn of the death on November 22 of Mr. William Allwood Dutton, A.M.I.E.E., for many years chief engineer of the turbine division of the Brush Electrical Engineering Co., Ltd., Loughborough. Mr. Dutton, who was born at Spurstow, Cheshire, in 1879, was educated at Arnold House School, Chester, and at Owens College, Manchester, and served an apprenticeship to engineering with P. R. Jackson and Company, Manchester. He joined the Brush Company in 1901 as assistant to the works electrical engineer and, after a period on electric-motor design, was transferred to the turbine division, in which he was closely concerned with the development of the Brush-Ljungstrom turbine. He retired in May, 1945, though he retained his connection with the firm in a consulting capacity.

# THE IRON AND STEEL INSTITUTE.

(Continued from page 695.)

METALLOGRAPHY AND PROPERTIES OF TRANSFORMER SHEET.

THE remainder of Wednesday morning, November 21, was devoted to the joint discussion of two papers, namely, "Metallography of Carbon in Silicon-Iron Alloys Containing 4 per cent. Silicon," by Mr. E. D. Harry, of the Steel Company of Wales (Lysaght Works), Limited, Newport, and "The Variation in Electrical Properties of Silicon-Iron Transformer Sheet," by Mr. S. Rushton and Mr. D. R. G. Davies, the second paper describing work undertaken at the Imperial College of Science and Technology, London.

When presenting his paper, Mr. Harry opened with an account of the mode of occurrence of carbon in 4 per cent. silicon-iron alloys used for the manufacture of transformer sheets. He stated that sheet bar might contain 0·050 to 0·10 per cent. of carbon, whereas finished sheet, which might have been annealed at temperatures ranging from 750 deg. to 1,150 deg. C., could have a carbon content varying from below 0·005 per cent. to 0·030 per cent. The carbide phase in these silicon irons was duplex in structure and consisted of the ordinary iron carbide, $Fe_3C$, and what was believed to be an iron-silicon-carbon compound, the two carbides appearing to form a eutectoid.

In the second paper, which was presented by Mr. D. R. G. Davies, the authors stated that the properties which silicon-iron transformer sheets should possess had been reviewed in detail by Mr. F. Brailsford in 1943. They comprised, firstly, high permeability; secondly, low iron-loss at a frequency of 50 cycles per second and flux densities of 10,000-15,000 gauss; and thirdly, high space factor. The present paper gave an account of a study of the variations in iron-loss values of sheets produced from a single cast of silicon-iron transformer sheet, and was based on 264 values from the 11 ingots of the cast, and on the iron-loss values of all the 160 sheets produced from one particular ingot. The statistical technique of analysis of variance had been employed to show the contributions to the total variation among these values due to difference between ingots, variation due to different positions in an ingot, and variation due to differences in the position of the sheet in the pack at the sheet-rolling stage. For the 264 sheets from the 11 ingots of the cast, the mean iron-loss, after the first annealing, had been 1·17 watts per kilogramme, at 50 cycles per second, and 10,000 gauss; the range was 0·89 to 1·48. In order of importance, the significant factors contributing to variation were: differences between ingots, differences between positions in the sheet-rolling pack, and differences between positions in ingots. Although the effect of a second annealing was to bring about an overall improvement in quality, the improvement was in the worst material, the best material being made worse by this second anneal. As a result, the range had been reduced to 1·01 to 1·44 watts per kilogramme. The study had revealed the complexity of the transformer-sheet problem and indicated that it could not be solved completely until systematically planned experiments, designed to isolate the causes of variation at each stage of processing, had been undertaken.

Dr. R. V. Riley, in opening the discussion, stated that Mr. Harry had commented on the apparently large amount of carbide phase in the microstructure of a 4 per cent. silicon, 0·01 per cent. carbon steel, and had said that the amount of carbide phase produced seemed to be rather more than would be expected if a plain-carbon steel containing a similar amount of carbon were taken as a basis of comparison. This was entirely in agreement with his (Dr. Riley's) own observations on iron-carbon-silicon alloys of much higher silicon content and higher carbon content. These observations might be taken as evidence that the carbide did not contain a percentage of carbon sufficient to give cementite, $Fe_3C$. Some measurements which he had carried out indicated that the average carbon content of the silico-carbide phase was between 2 per cent. and 3·5 per cent., and not the 6·6 per cent. which would be necessary if the phase had the composition of cementite. The author had expressed the opinion that the two carbide phases were completely insoluble, or showed only limited mutual solubility at room temperature. While this might be true, it must not be interpreted as indicating that the silico-carbide phase had a fixed composition in respect of silicon content, at any rate not in the higher silicon range of iron-silicon-carbon alloys. Dr. J. Hurst and he (Dr. Riley) had shown that this phase existed in commercial 10 per cent. to 15 per cent. silicon irons, and in these alloys there was very little doubt that the silicon content of the carbide phase varied with, and bore some relation to, the silicon content of the alloy as a whole.

Turning to the second paper, by Messrs. Rushton and Davies, the treatment which these authors had given to a works problem was worthy of note, and there were many other operations in works which would repay study in this fashion. The variations reported in the ingot were interesting. It always seemed that steelmakers had considerable difficulty in casting ingots, and, in this instance, he suggested that a possible way of removing the non-metallic impurities which appeared to be so troublesome in this industry would be to cast the steel centrifugally, into fairly large cylinders, which were then split longitudinally, opened out under a press, squeezed down, and both sides of the sheet machined. The part which had been on the inside of the cylinder would then contain the non-metallic particles which were not desired, and these were removed in the machining operation. The material could then be reheated and rolled into sheets. This was simply a development of the blowing of ordinary window glass. The glass blower blew a cylinder, opened it out and pressed it flat.

Mr. A. D. Grace asked whether Messrs. Rushton and Davies, in taking the test of watts loss, had made any allowance on account of variation in the gauge of individual sheets. It had been found that, with the ordinary No.-14 gauge hot-rolled sheet, there could be variations which would cause a difference in the watts loss of something like $\pm 0{\cdot}02$ watt per pound (not kg.). That, of course, was purely due to the eddy-current component, which was more or less proportional to the square of the thickness. If that had not been taken into consideration, it might account for some of the extreme variance found between sheets in a pack, but it did not account for anything like the whole variation, so that it would not alter the authors' conclusions.

Mr. H. H. Stanley stated that this was probably the first occasion on which papers dealing with 4 per cent. silicon transformer steel had been put before the Institute for discussion. The paper by Messrs. Rushton and Davies showed that, with the process which they described, very wide variations in the product resulted, and this suggested that the process was very difficult to control, so that manufacturers who had found a way of getting what they thought was rather better control were very reluctant to publish information regarding the operation of their process. Consequently, Mr. Davies's firm, Messrs. Richard Thomas and Baldwins, were to be commended on the fact that they had given permission to publish work of this type, because it involved the cutting up of a very large number of expensive sheets, and the planning and carrying out of the experiments and testing must have added considerably to the cost. It was all the more unfortunate, therefore, that the work should have been confined entirely, at least as published in the paper, to a statistical study. Having used such large amounts of precious material, it was a pity that some metallurgical tests had not been carried out, or, if they had been carried out, published, so that the relationship between the theories and hypotheses on decarburisation and other factors and the actual results found in the sheet could be judged.

Dr. M. L. Becker, in commenting on Mr. Harry's paper, stated that the structures of commercial silicon sheets might seem to be fairly close to those of pure iron-silicon alloys, but in actual fact they were very far from being pure iron-silicon alloys. A very small amount of carbon added to an iron-silicon alloy would considerably alter the shape of the equilibrium diagram. Not only was carbon present, but so also was nitrogen, which he did not think had been recorded in the paper, but which was certainly present; moreover, manganese was there, and both these elements would assist the carbon in encouraging the existence of the austenitic phase over a wide field. To come to the point, he felt that there were two phases present at the annealing temperatures used by Mr. Harry. If that were the case, it must be considered that those two phases would have different compositions. If there were one phase which was ferrite, no doubt containing a high percentage of silicon and, it might be expected, a low percentage of carbon, the other was austenite, containing a relatively large percentage of carbon and probably less silicon. On that point, he would like to ask the author whether he had any evidence that the silicon content of some areas in his specimens was less than in the others. If such an alloy were then cooled, even quite slowly, it was not to be expected that this two-phase condition would disappear during cooling. The structures were therefore to be interpreted from the point of view that there were two separate zones present in the same alloy, and, accordingly, the structure of the two separate zones would be different.

Mr. H. Morrogh, in commenting on the paper by Mr. Harry, said that, with regard to the low-temperature annealed sheet, he was puzzled by the statement that when the carbon content was more than 0·012 per cent., graphite was invariably present, and also by the statement that when the carbon content was less than 0·006 per cent. no free carbide could be detected. He presumed that, at this temperature, ferrite, saturated with carbon, was present and, in some cases, free carbide existed, which was relatively unstable. In the presence of so much silicon it was to be expected that carbide would decompose fairly readily, so that in all samples containing more than a certain percentage of carbon, graphite would be found and, in samples containing less than that percentage of carbon, no visible graphite and no visible iron carbide would be seen. He knew nothing of the manufacture of this type of alloy, but he wondered whether the author had experienced any grain growth during his low-temperature annealing and whether, if he had obtained such grain growth, he had observed whether it was affected by the presence of graphite. In a completely different industry, in the production of malleable cast iron, it was found that grain growth of ferrite was almost completely inhibited if graphite were present, but if that graphite were removed, for instance by decarburisation, ferrite grain growth occurred automatically. With regard to the migration of carbon to the surface of the sheet, the author had mentioned that the silicon near the surface of the sheet might have been oxidised, presumably giving a film low in silicon. He was surprised that the author had not attempted to confirm whether that was so or not; it should be fairly easy to do so by spectrographic means.

Mr. R. Rawlings said that he was connected with the people who used these sheets, though he did not actually use them himself. As the author suggested, during vacuum annealing silicon was oxidised, and probably vaporised as well, at the surface, thus decreasing the silicon content and allowing austenite to be formed. They had found a definite decrease in silicon, and had detected silicon in other parts of the furnace. After some time, the removal of carbon would be blocked by the formation of a continuous silica film. After a time there would be some sort of equilibrium set up, but it would not be a true equilibrium, because of the silicon concentration gradient. The final ratio of carbon concentration in the austenite to that in the ferrite might be expected to be in proportion to the solubilities in the two phases. It was interesting to speculate on what would happen if annealing were continued at 1,100 deg. C., but in dry hydrogen, so as to prevent further oxidation of silicon. The silicon concentration gradient would then level out. The high-carbon concentration near the surface, however, would now itself be the reason for the continued existence of austenite and thus for its own continued concentration near the surface. We should thus have an alloy being annealed at 1,100 deg. C., not in equilibrium and apparently not tending to equilibrium.

On the question of the existence of the silico-carbide, in view of the controversy concerning this compound, it was a pity that an attempt had not been made to extract it and analyse the residue. The author had stated that the eutectoid change took place at 400 deg. C., but there was no evidence in the paper to indicate this. On what evidence did he base this statement? Dr. Riley had mentioned the use of centrifugal casting. This had already been seriously considered, but not for long. Very little was known concerning the effect of inclusions, but what was known theoretically was that there was a certain optimum size of inclusion which had the greatest effect, and this size was, in fact, very low. That had been proved with iron carbide, using iron carbide as an inclusion; it had been precipitated at low temperatures in different sizes of spheres, and there had been shown to be an optimum size. Centrifugal casting would probably not remove the inclusions of that size.

Mr. H. Brooke Freeman, who confined his remarks to the rolling of the sheets, stated that the first operation was to take a 15-lb. bar and break it down with three passes in the mill, and then to match those breakdowns and give them another two or three passes, and then double. He would like to ask whether in this case the doubler separated them and put them top to bottom instead of simply rolling them out and doubling them over; did he change them so as to bring two outsides inside? The next thing was the running over, the operation following the reheating of the doubled pack. When doubled, the sheets were dealt with so that the two outside surfaces came together. The pack was pushed into the annealing furnace with the doubled end first, and the furnaceman turned it up along the side so that it lay along the side wall. He would like to ask the authors how many packs they ran over at a time, because it would be found that the number of packs made a considerable difference in the heating or the soaking operation. Sixteen was quite a usual number to roll in sheet works, but it had been found that it was far better to roll eight; in other words, the number of running-over furnaces was doubled and eight packs were put in a furnace and no more. The packs were turned up alongside a wall as they were put in, and they were gradually turned down, one after the other, in an endeavour on the part of the furnaceman to get them evenly heated. It would be found that there was a large difference in the watts-loss according to whether eight packs, or 12, or 16, were rolled, and the secret seemed to be to keep the temperature up all the time.

The President, in closing the discussion, stated that the last and unexpected contribution to the discussion had been well worth the few minutes which Mr. Brooke Freeman had taken in giving the meeting an insight into some of the operating details. He would ask the authors to reply in writing. Three or four years ago, he had been concerned with the shortage in the supply of these high-silicon sheets, and he remembered the difficulties which had existed in getting not merely

# ARC FORM AND MOVEMENT IN AIR-BLAST CIRCUIT-BREAKER.

(*For Description, see Opposite Page.*)

Fig. 1.

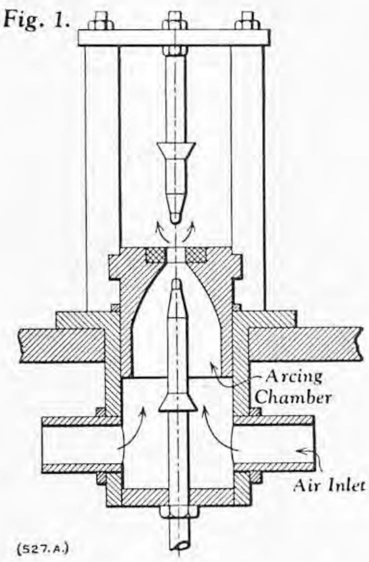
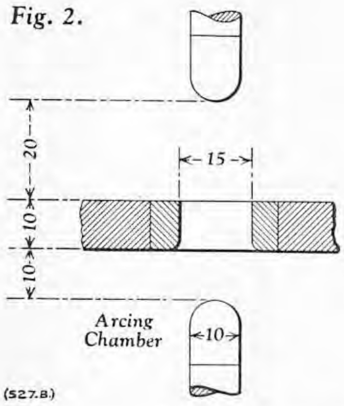



Fig. 2.



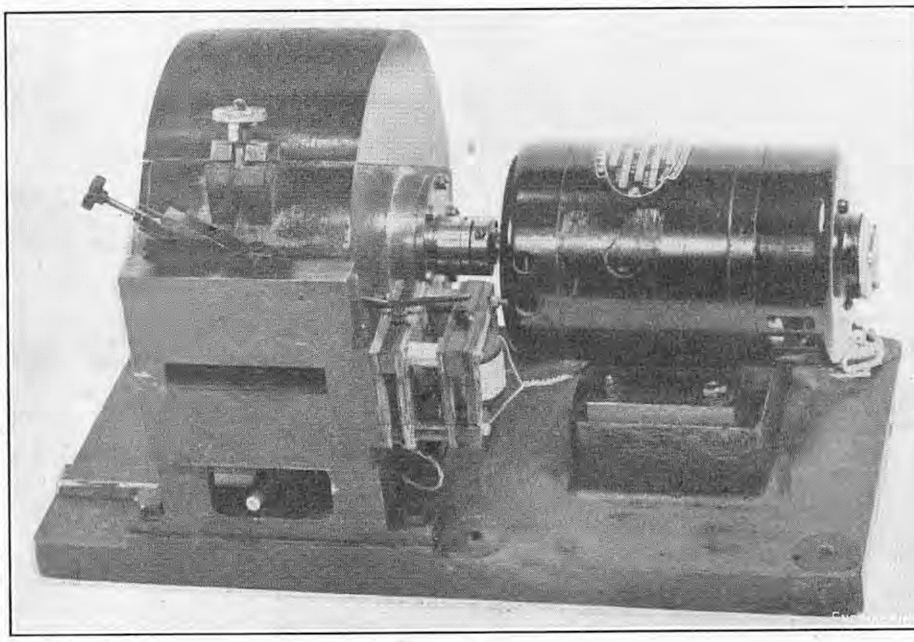



FIG. 3. CAMERA AND MOUNTING ASSEMBLED.

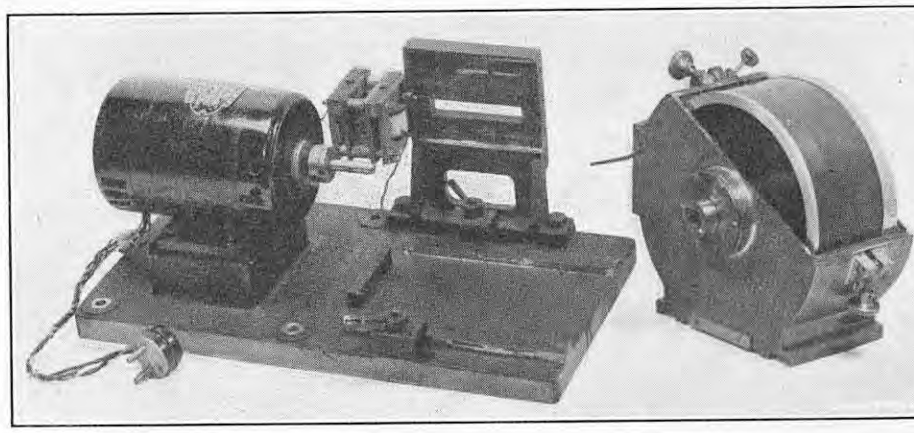


FIG. 4. CAMERA AND MOUNTING SEPARATED.

quantity but quality. In that direction there had been, no doubt, substantial improvements since then, but at that time there had been considerable difficulties in getting anything like collaboration between the relatively few companies that were producing the sheets. He had been glad to hear Mr. Stanley draw attention to the improvement in that position represented by these papers. He hoped that they marked the beginning of some publicity on the technical problems involved in producing transformer sheets.

The President then adjourned the meeting until the afternoon.

### STRESSES IN INGOT MOULDS.

The whole of the afternoon of the first day of the autumn general meeting of the Iron and Steel Institute, namely, Wednesday, November 21, was devoted to a discussion of a "Symposium on Stresses in Ingot Moulds," comprising five papers. In addition to these, two further papers, one concerned with ingot-heat conservation, by Dr. R. T. Fowler and Mr. J. Stringer, and the other dealing with ten-ton ingot moulds, by Mr. A. Jackson, were included in the joint discussion.

The various papers comprising the symposium were presented, in turn, by Mr. J. Woolman, Mr. J. W. Grant, Mr. W. C. Heselwood and Mr. W. H. Glaisher. Mr. Woolman, of the Brown-Firth Research Laboratories, who is chairman of the Stresses in Moulds Group of the Ingot-Moulds Sub-committee, Steelmaking Division, British Iron and Steel Research Association, also gave a general introduction to the symposium. He stated that one of the chief reasons for the rejection of ingot moulds was cracking, and it was primarily to investigate the basic causes of cracking that the Stresses in Moulds Panel had been set up in 1939. The Panel was now called the Stresses in Moulds Group and the other members, besides himself, were Mr. N. H. Bacon, of Steel, Peech and Tozer; Mr. G. T. Harris, of W. Jessop and Sons, Limited; Mr. A. G. Hock, of the Workington Iron and Steel Company; Mr. J. W. Grant, of the British Cast Iron Research Association; and Mr. J. E. Russell, of the English Steel Corporation, Limited.

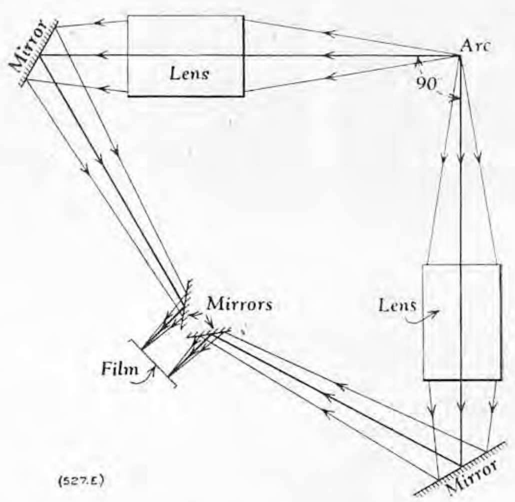
"Mechanical Properties of Ingot-Mould Irons" was the title of the first paper in the symposium. It was by Mr. J. W. Grant, who stated that the practical difficulties of making strain measurements in the complete period of the heating of an ingot mould during teeming and cooling after stripping, had prevented a complete analysis of the behaviour of the mould to be made. The tensile stress on the outer surface reached a maximum after about 4 minutes and was maintained at least until the temperature reached 400 deg. C. Creep could take place at all temperatures but the rate increased with temperature, particularly above 400 deg. C. During teeming, it was supposed that, at the same time as the outer surface developed a tensile stress, the inner surface was put into compression. As both these surfaces, and the wall between them, eventually reached temperatures of 600 to 700 deg. C., all parts of the mould would be subjected to direct tension or compression and a corresponding tensile or compressive creep. On cooling, the stresses might be in tension or compression, depending upon the temperature gradient throughout the wall, and these would cause further creep. The factors that needed to be taken into account in considering the failure of a mould by cracking included the effect of creep on the properties of the iron; the possible existence of residual tension or compression in the mould; stress-relieving at the higher temperatures; the apparent recovery of the stress/strain properties and lowering of ductility caused by stress-relieving after straining; change in structure; and growth and oxidation of iron. The second paper of the symposium was entitled "Poisson's Ratio for Cast Iron Used for Ingot Moulds," and was by Mr. J. Woolman. He stated that little reliable data existed for Poisson's ratio for cast iron at room temperature, and no reference had been found to any determination at elevated temperatures. Values between 0·23 and 0·31, however, had been quoted. A lateral extensometer suitable for attaching to a test piece in a cylindrical electrical furnace had been designed and constructed. With this, in conjunction with a conventional type Lamb roller extensometer, Poisson's ratio determinations had been made on a number of ingot-mould irons, both at room and at elevated temperatures. The value of the Poisson's ratio had been found to vary with the stress, the temperature and with repeated applications of the load, although, with the latter, the ratio tended to a constant value. Values obtained on various irons at room temperature had ranged from 0·10 to 0·21; at 450 deg. C. from 0·05 to 0·14; and, at 650 deg. C., from 0·08 to 0·25. On account of these variations it was difficult to suggest an appropriate value for use in calculations, unless some knowledge of the tensile properties of the irons were available.

(*To be continued.*)

POWER STATION EXTENSIONS.—The British Electricity Authority have received the consent of the Ministry of Fuel and Power to extend the Deptford East power station by one 52·5-MW turbo-alternator and two 250,000-lb. boilers; and the Littlebrook "C" power station by one 60-MW turbo-alternator and two 360,000-lb. boilers.

# ARC FORM AND MOVEMENT IN AIR-BLAST CIRCUIT-BREAKER.

Fig. 5.



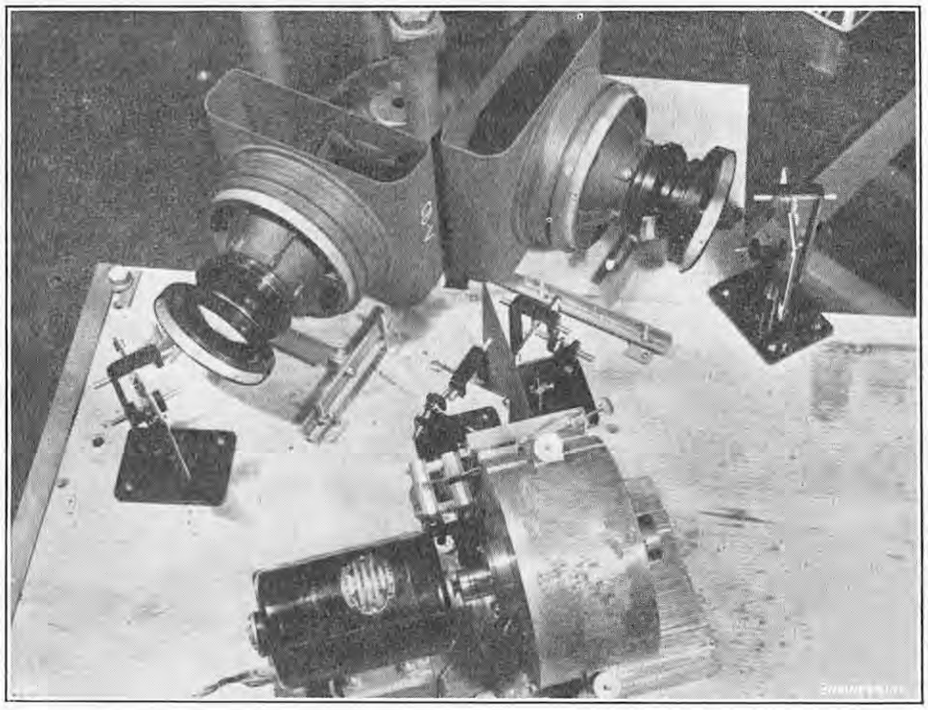



FIG. 6. ARRANGEMENT USED TO RECORD ARC MOVEMENT IN TWO DIRECTIONS.

## ARC FORM AND MOVEMENT IN AN EXPERIMENTAL AXIAL AIR-BLAST CIRCUIT-BREAKER.*

By F. O. MASON, B.Sc. (Eng.), A.M.I.E.E.

THE present article deals with the initial stages of a study which is being made of the physical nature of the arcing phenomena involved in air-blast circuit-breakers. So far, and primarily with the object of obtaining a general picture of the form and movement of the arc, the study has been confined to the top (or downstream) gap of an experimental gas-blast switch. This section of the arc column was chosen as being the most convenient to study for the preliminary survey, and also as offering the easiest section to photograph while the apparatus and technique were being developed. The method adopted for this initial study uses a rotating-drum camera photographing a cross-section of the arc, through a thin slit in a manner similar to that used by Kirchstein and Koppelmann.†

The study was made of arcs drawn in the experimental switch shown schematically in Fig. 1, opposite, and operating in an inductive circuit with an approximately symmetrical current of 1,100 amperes r.m.s. obtained from a generator excited to 6,600 volts r.m.s. The electrode dimensions, in millimetres, and dispositions are given in Fig. 2, the top gap of 20 mm. containing that section of the arc under observation. The only variable in the test conditions was the initial reservoir gas pressure (air), although most of the tests were made with an initial pressure of 65 lb. per square inch. The latter value was chosen as being fairly representative of the pressures normally associated with the present test conditions, while affording additional information for other purposes. However, for comparison purposes, some tests were made at pressures both above and below this value.

*Photographic Apparatus.*—Essentially the apparatus consists of a drum camera and optical system. The drum camera was driven by a $\frac{1}{16}$-h.p. induction motor at 2,900 r.p.m. and rotated within a casing fitted with a horizontal slit aperture and shutter mechanism capable of operating in synchronism with the test sequence. Photographs of the camera and associated equipment are reproduced in Figs. 3 and 4, opposite. The drum has a diameter of 16 cm. and takes a 6-cm. wide film about 50 cm. in length. This gives a film speed of approximately 2,500 cm. per second past the 0·25-mm. slit (which extends across the full width of the film) thus giving a 1-mm. length on the film equal to about 40 microseconds.

The shutter mechanism is housed in the body of the camera and covers a fixed slit 1 mm. wide in the camera body itself. The shutter housing slides accurately into a framework cast integrally with the base-plate, forming a focusing mount in which a screen for focusing purposes can also be fitted. Located over the 1-mm. wide slit is the actual slit aperture formed by two adjustable plates. Operating immediately in front of the latter slit is a timing shutter which consists of a spring-operated rectangular flat steel plate with a central rectangular hole arranged so that the slit is covered by the top strip of the rectangle in the initial closed position and by the bottom strip in the final closed position. The intermediate or open position occurs during the time that the rectangular hole coincides with the slit aperture.

The shutter is operated by two solenoids which act in sequence to trip a lever into two different positions. The first solenoid operates to trip the lever, allowing the shutter to reach the open position, while the second solenoid to operate gives further movement to the lever and the shutter moves to the final closed position. By synchronising solenoid operation with the test sequence, the timing shutter was opened just before a test and closed just over 0·02 second after the start of the short-circuit (a time a little shorter than that of one revolution of the drum). This avoided double exposure in those tests where the arc persisted for more than two half cycles of current. By suitably mounting the camera base-plate on a pivoted baseboard the camera could be raised to a vertical position, thus enabling photographs to be obtained with the slit aperture vertical.

*Optical System.*—The optical system for making two simultaneous observations at right angles to one another is shown schematically in Fig. 5 and practically in Fig. 6. The arrangement shown in Fig. 5 was used to project side by side on the camera film two slit photographs of the arc from positions at right angles to one another but in the same horizontal plane. Each optical system consisted of a lens, and two surface-silvered mirrors to turn the light beam into the symmetrically placed camera. The lenses, which were identical, had a focal length of 7 in., with aperture variable from $f/2 \cdot 5$ to $f/16$, the comparatively long focal length enabling the lens to be used at a safe distance from the arc while allowing sufficient distance between lens and camera for system flexibility. As an additional precaution against lens damage, a sheet of optical glass was mounted between the arc and lens. The optical system was adjusted by focusing on to the plane of the film the image of a fine fuse wire threaded through the centre of the top and bottom electrodes. Focusing was facilitated by an accurately placed ground-glass screen located in the focusing mount referred to above. The two systems, however, were only used to check that arc movement was not confined to a single vertical plane, and also to obtain a more complete picture of the movement in space of the arc; generally, therefore, one lens system only was used, in which case, of course, the arc was projected directly through one lens on to the camera without the use of mirrors.

In the initial stages of the experimental work it was thought desirable to have some form of varying light filter, since the light intensity of the arc was varying greatly throughout a half-cycle. To this end, a graduated neutral-density filter was made in the form of a celluloid disc mounted on the shaft of a small motor running in synchronism with the generator supplying the test current and placed in front of the camera. The required gradations of density were obtained approximately from preliminary records taken without a filter but with varying lens aperture, the graduated filter being made from a disc of photographic film exposed in segments to give densities appropriate to those obtained from the preliminary tests. Perhaps a better method of obtaining a graduated filter, should it be required in the future, would be to rotate a disc of photographic film synchronously with the power frequency and expose it to the arc through a slit and lens system for a period of one half-cycle. The negative so produced could then serve as the graduated filter.

Actually, as experiments proceeded, it was found that the use of the filter was a hardly justifiable complication, and its use was discontinued for the following reasons. (i) The varying effective exposure times produced by the filter during the half-cycle made it difficult to assess the true relative intensities of the arc during the half-cycle, and tended to give a misleading impression of the arcing phenomena. (ii) The degree of variation in intensity throughout the half-cycle varied for different positions along the arc column and required different filters for different positions. (iii) The arc form as photographed was in general repeatable from test to test and thus, with experience, the degree of exposure could be adjusted beforehand to suit the particular time during arcing in which phenomena were to be examined. (iv) A good degree of control over the exposure could be obtained during photographic reproducing processes.

* Based on Report, Ref. G/XT 131, of the British Electrical and Allied Industries Research Association.

† Kirchstein and Koppelmann, "The Electric Arc in Rapidly-Flowing Gas," *Wis. Ver a.d. Siemenswerke* vol. 16 (1939).

# ARC FORM AND MOVEMENT IN AIR-BLAST CIRCUIT-BREAKER.

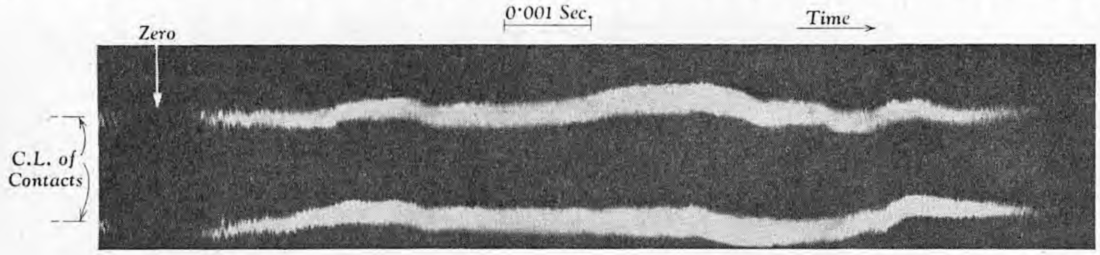



Fig. 7(*a*). Arc Movement from Two Directions at Right Angles. 65 lb. per Sq. In., 1 mm. Above Throat.

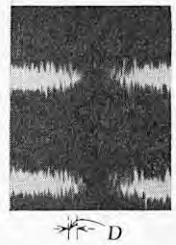



Fig. 7(*b*).

*Test Results: Observations in a Horizontal Plane.*—After the first few records had been obtained with the slit aperture horizontal it became obvious that the arc had a vigorous lateral movement. To check that this movement was not confined to one vertical plane, two simultaneous exposures on the same film were made of the arc from two positions at right angles as previously described. A record obtained from simultaneous exposures in two directions taken at 65 lb. per square inch gauge in the air reservoir (i.e., approximately 50 lb. per square inch gauge in the arcing chamber) and 1 mm. above the throat is shown in Figs. 7 (*a*) and (*b*), and indicates without doubt that the arc

Fig. 8.

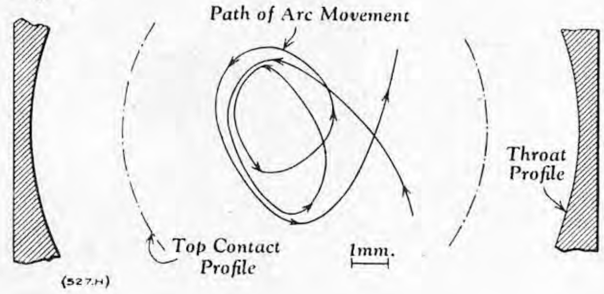
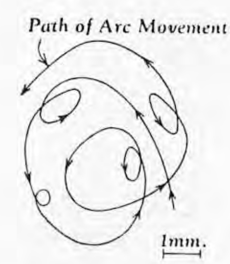
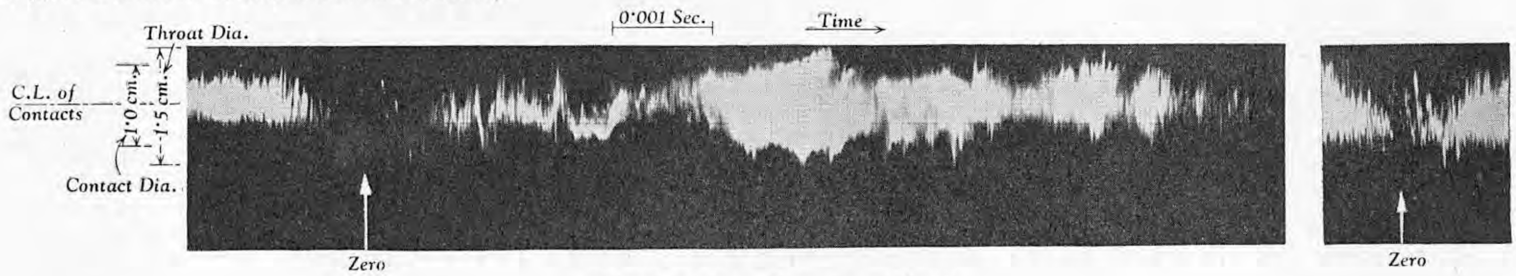
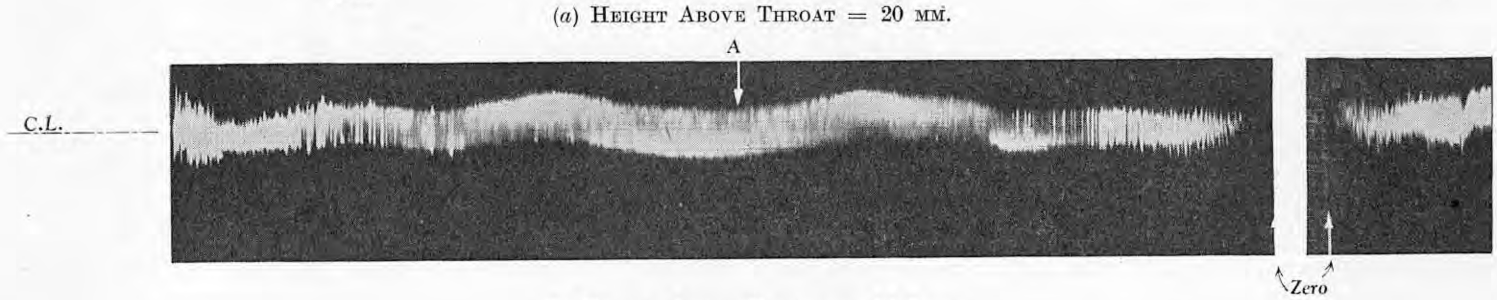



Fig. 9.

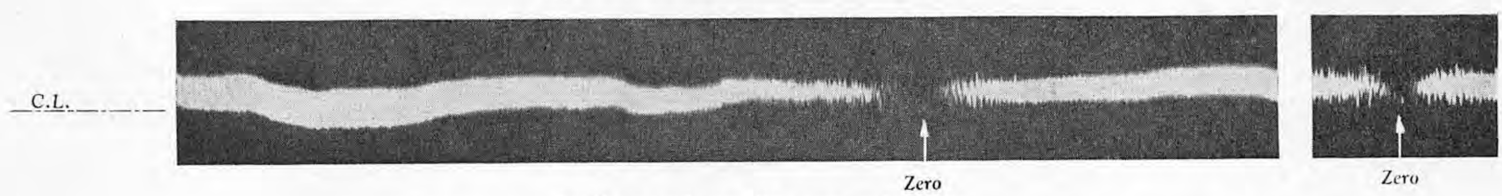



(*a*) Height Above Throat = 20 mm.




(*b*) Height Above Throat = 12·5 mm.




(*c*) Height Above Throat = 1·0 mm.

Fig. 10. Slit Aperture Horizontal for Different Positions Above Throat. Initial Reservoir Pressure = 65 lb. per Square Inch.

can move in all directions in a horizontal plane. Fig. 7 (*b*) is a section of Fig. 7 (*a*) during the current-zero period, which has been reproduced photographically to show more clearly the arc movement close to zero. It will be noticed, however, that very close to zero the trace vanishes and in fact does not appear on the original negative. The centre lines of the electrodes are shown by the short lines on the left of Fig. 7 (*a*). It may be as well at this stage to point out that records obtained in this way are photographs of a thin cross section of the arc as seen by the slit over a period of time and thus arc movement is shown in a direction at right angles to the centre line of the record and time from left to right.

By co-ordinating the position of the arc from the two traces the actual movement of the arc in the plane can be obtained; this has been done over the period D indicated in Fig. 7 (*b*) and the result shown in Fig. 8. From this it will be seen that arc movement is generally of a circulatory nature and in an anti-clockwise direction looking from above the throat. Similar records showed that this direction was independent of the sense of the current. Actually, close inspection of the original records shows that arc movement is more generally of the form shown in Fig. 9, wherein there are smaller convolutions on the main ones. The mean peripheral velocity of the main circulatory motion of the arc is roughly 500 m. per second, which is approximately twice the velocity of sound in air at N.T.P. Records of arc voltage taken at the same time showed that arc volts, as measured across the gap between the top and bottom electrodes, remained remarkably constant during the main current period and showed no corresponding variation with the rapid arc movement. This, however, was not unexpected since, as will be appreciated, the arc length is changing little despite its movement.

Fig. 10 (*a*), (*b*) and (*c*) opposite, show three representative exposures at different positions along the arc gap above the throat, all made at 65 lb. per square inch reservoir gauge pressure using a fixed lens aperture of $f/8$ and without a light filter. To one side of Fig. 10 (*a*) are the dimensions and position of the top contact and throat applying to the arc-movement photographs reproduced in Fig. 10, while at the right-hand side of each record a section of the arc photograph around current zero is reproduced in a manner similar to that of Fig. 7 (*b*). The faint horizontal lines just distinguishable on the record are merely due to small particles of dust and the like across the slit which, owing to its narrowness, was very difficult to keep entirely clear of small obstructions. When studying these records it should be borne in mind that the light intensities of the different photographs are not necessarily comparable, as they were either exposed or reproduced differently to give the best overall results in each case. A comparison of intensities over the length of the arc gap can best be obtained from photographs as shown and described later.

Incidentally, it should be noted that the arc as described and discussed herein is considered as constituting the light-emitting source and, in general, no attempt is made to distinguish, say, between the actual current-carrying path and the surrounding luminous gases. Since the light intensity of the luminous gases will vary with their distance from the arc "core," dimensions of the arc—if defined by the degree of luminosity—will obviously depend on the initial exposure time and subsequent photographic reproduction processes. This fact is rather important and is discussed later in more detail.

From the records in Fig. 10 (*a*) it will be seen that the arc form is not entirely the same at the different positions along the arc gap, and, although some marked differences between the positions will be observed during the main current flow, the distinct filamentary form of the arc arouna current zero is virtually the same in the three cases. The record taken with the slit aperture level with the bottom of the top electrode tip (Fig. 10 (*a*)) is of particular interest as arc movement appears to have its maximum displacement at this point, and moreover indicates that the arc root itself is rotating round the top electrode tip. Actually one record obtained at this position showed an occasional shadow of the top electrode tip as the arc had moved behind the contact away from the camera. A further point of interest is the bright luminous spot in the dark current-zero area more clearly seen in Fig. 10(c). This coincided with the voltage breakdown of the gap and offers confirmation of a current pulse which has been observed during re-ignition. Photographs showing this high-intensity light pulse have also been obtained in Japan* using a Boys-type camera.

(*To be continued.*)

FRENCH AERONAUTICAL TERMS.—The Technical Section of the Society of British Aircraft Constructors, Limited, Summit House, 1-2, Langham-place, London, W.1, has issued a useful and compact vocabulary, entitled "English-French Translations of Aeronautical Terms and Units," which provides conversions for commonly-understood words and phrases used by aeronautical technicians. It includes also arithmetical conversion factors from English to metric units, and vice versa. The eight-page pamphlet deals with areas, atmospheric standards, linear dimensions, engines and engine powers, loadings, performance, pressures and stresses, speeds and velocities, volumes, weights and densities, and terms used in economic studies. Copies of the booklet may be obtained *gratis* from the Technical Secretary at the above address.

* S. Fukuda, *Study of Extinction and Re-Ignition of Air-Blast Arcs by a Simplified Boys Camera, E.T.J.*, page 260, November, 1939.

# EXHIBITS AT THE SMITHFIELD SHOW.

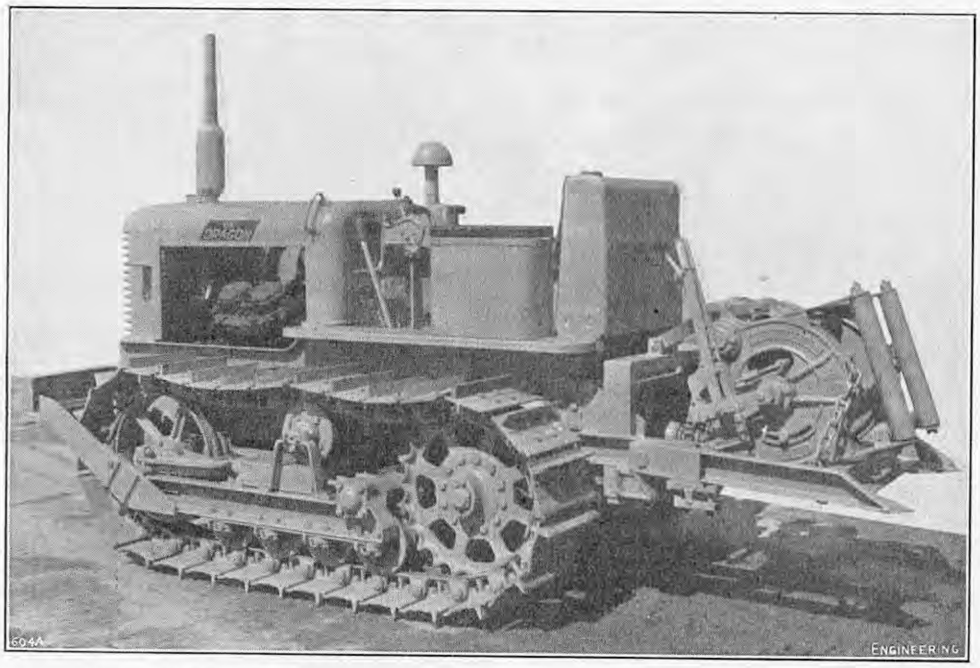



FIG. 1. "DRAGON" TRACTOR FITTED WITH REAR WINCH; VIVIAN LOYD AND COMPANY, LIMITED.

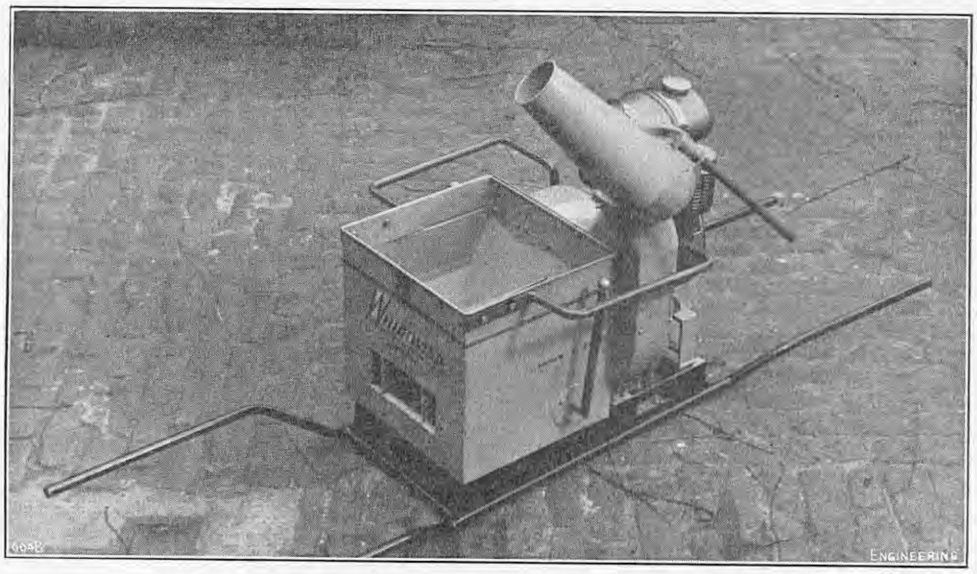



FIG. 2. "WHIRLWIND" JUNIOR DUSTER; UNIVERSAL CROP PROTECTION, LIMITED.

# THE SMITHFIELD SHOW AND AGRICULTURAL MACHINERY EXHIBITION.

THE Smithfield Show and Agricultural Machinery Exhibition continues to gain in importance and it has been estimated that this year's show, which closes to-day at Earl's Court, having been open since Monday, December 3, is probably the largest of its kind to be held. This, possibly, is true so far as the machinery section is concerned, but, unfortunately, it does not apply to livestock, the recent outbreak of foot-and-mouth disease having severely curtailed entries, which is not surprising in view of the edict that all livestock shown must be slaughtered. This is the third post-war show and, like its predecessors, has been organised by the Smithfield Show Joint Committee. The manufacturers' section of the show consists of the tractor and machinery section on both the ground and first floors and the trades section, comprising supplies and services, also located on the first floor. The exhibits in these sections cover the whole gamut of agricultural and horticultural equipment and are fully representative of those products which have made this country's agriculture the most highly mechanised in the world.

In view of the large number of new machines introduced since the end of the war, the manufacturers would have been well within their rights had they concentrated on production of existing designs. This, however, has not proved to be the case, as several of the leading manufacturers have evolved new machines, even since the last Royal Show. The Ford Motor Company, Limited, for example, recently introduced an entirely re-designed Fordson Major tractor, and Messrs. John Fowler and Company (Leeds), Limited, a new 50-horse-power crawler tractor, both of which are being shown to the public for the first time at the Smithfield Show. These two machines, however, have already been described in ENGINEERING, the former in our issue for November 23 and the latter in our issue for November 30. There are also a number of machines which, although not on view for the first time, incorporate several improvements and for which special equipment has been designed, a good example being furnished by the Dragon crawler tractor manufactured by Messrs. Vivian Loyd and Company, Limited, Camberley, Surrey, and first introduced at the 1950 Smithfield Show. Apart from a few minor changes, the general design remains much as before, but in the interests of standardisation the makers are now fitting one type of engine only, namely, the Dorman 4DS Diesel engine developing 30 horse-power at 1,600 r.p.m.

A general description of the Dragon tractor was published in ENGINEERING, vol. 170, page 540 (1950), in connection with our report on the last Smithfield Show, so it will only be necessary to give brief details here. Outstanding features of the design are clutch-and-brake steering mechanisms, unusually robust tracks, the incorporation of a rocking-type balance beam in the front-suspension system and the provision of a four-speed gearbox. Several tractors are on view which, as previously indicated, are fitted with different ancillary equipments designed to increase its usefulness, the equipments including a bulldozing blade, a power-control unit and a rear-mounted winch. Actually, two types of winch are available, namely, the Boughton and the Hesford, and a tractor equipped with the latter type is illustrated in Fig. 1, on this page, where it is shown with the sprags in the raised position. The winch is made by C. M. Hesford and Company, Limited, Ormskirk, Lancashire, and is tested for a maximum pull of 14,000 lb. It is of straightforward but robust design, the rope drum, which turns on self-oiling bearings, being engaged by a large cone clutch. A hand-brake is provided, and when both clutch and brake are released the drum is free to rotate for drawing out the rope. The rope capacity depends on the size of rope used, the drum being capable of winding 500 ft. of $\frac{9}{16}$-in. diameter rope, 375 ft. of $\frac{5}{8}$-in. diameter rope, and 300 ft. of $\frac{3}{4}$-in. diameter rope. The average rope speed is 65 ft. per minute, and the sprag, or anchor, is designed so that, when the pull is taken, excessive loads are not imposed on the tractor. The sprag folds away when not in use and there is ample ground clearance in the folded, or travelling, position.

Although Universal Crop Protection, Limited, Baltic House, Leadenhall-street, London, E.C.3, are newcomers to the Smithfield Show, their equipment has been in use in many parts of the world for a number of years. They are showing a selection from their range of spraying and dusting machines, the latter including the small portable machine illustrated in Fig. 2, on page 713. Known as the Whirlwind Junior Duster, it has been developed for use in areas not normally accessible to wheeled vehicles, the weight being as low as 85 lb.; it can easily be transported, therefore, by hand. The dust is distributed by a centrifugal fan driven by a J.A.P. four-stroke petrol engine developing 1·2 horse-power. The hopper capacity is from 30 to 40 lb., depending on the density of the powder, and the rate of distribution can be varied from nothing to 20 lb. a minute. This is achieved by closing the supply of air to the hopper and at the same time opening a by-pass duct to the fan so that, for minimum delivery, the by-pass is nearly fully opened; conversely, for maximum delivery the by-pass is closed and all the air passes through the base of the hopper. The width over which the dust can be distributed depends, of course, on the type of powder in use and the strength of prevailing winds, but with a wind speed of 5 miles an hour it is claimed that a swathe of between 450 ft. and 600 ft. can be covered. Excluding the carrying handles, the length of the unit is 2 ft. 1 in., the breadth 1 ft. 7 in., and the height 2 ft. 8 in.

The exhibits on the stand of Messrs. E. Allman and Company, Limited, Birdham-road, Chichester, Sussex, include their Model 120 crop sprayer, designed for mounting on a tractor. This unit is illustrated in Fig. 3, on Plate XLVII, from which it will be seen that there are three tanks for holding the liquid in bulk, one at the rear and one at each side of the tractor. The rear tank is supported by the hydraulic lift and the complete assembly is attached by linch pins so that it can easily be fitted to, or removed from, the tractor. The pump is of the manufacturers' gear type with bronze gears working in a phosphor-bronze casing, the free output of the pump being 687 gallons per hour and, when working against a pressure of 200 lb. per square inch, 423 gallons an hour. The booms give an effective spraying width of 18 ft. 2 in., and are designed so that they swing back if they hit an obstruction and automatically return to the working position when clear. They are moved independently by separate levers when folded to the transport position, both levers being within easy reach of the tractor driver. To give a long working life, the jets are fitted with ceramic tips, and a wide range of different sizes is available for varying the distribution. The manufacturers Genimec control system is fitted as standard equipment. This is provided with a built-in pressure gauge and pre-setting device, which ensures that the pressure regulator returns to the selected value each time the control is operated.

Good progress continues to be made with the design of sugar-beet harvesters and more attention has lately been paid to the evolution of machines suitable for use on small farms. A good example of such a machine is the single-row tractor-mounted sugar-beet harvester illustrated in Fig. 4, on Plate XLVII, which is being shown by the manufacturers, Messrs. Johnson's (Engineering), Limited, Elliott-road, March, Cambridgeshire. It is fitted to the hydraulic linkage of the tractor and is designed so that it can be lifted on the headlands in the normal way. There are two disc coulters for clearing the sides, and the beet are lifted on to the shaker-elevator by the maker's standard form of share, the beet being assisted on to the shaker-elevator by a bar-type chain assembly arranged immediately above, which also helps in cleaning. The beet are discharged from the rear of the shaker-elevator into a further elevator set at right-angles to the shaker-elevator and designed to deliver to one side of the machine. The unit is driven from the tractor rear power take-off; this drives a sprocket wheel connected by a chain to a further sprocket wheel fitted to the forward end of a shaft arranged along the side of the shaker-elevator. The rear of this shaft drives the shaker-elevator through a bevel gearbox, and a further bevel gearbox, situated at the opposite side of the shaker-elevator, transmits the drive to the elevator. A beet topper is not fitted as the unit has been designed to operate in conjunction with the manufacturer's tractor-mounted topping mechanism. This consists essentially of two horizontal discs arranged below the frame of the tractor and driven by a chain from the rear wheels, the discs operating in conjunction with a vertically-disposed spiked feeler wheel for holding the beet.

One of the outstanding advances made during recent years is the development of mechanical-handling plant suitable for use on farms. The introduction of straw and hay baling machines and the wider use of combine harvesters have, in all probability, led to this development, as the bales of hay and sacks of grain are definitely bulky for manhandling, particularly when they have to be stacked. There was a wide variety of such equipment at Earl's Court ranging from tractor-operated hoists to portable elevators, a good example of the latter being furnished by the adjustable elevator illustrated in Fig. 5, on Plate XLVII. This machine, which is being shown by the manufacturers, the Wolseley Sheep Shearing Machine Company, Limited, Electric Avenue, Witton, Birmingham, is particularly useful for stacking bales as the height of delivery can be adjusted from a minimum of 6 ft. to a maximum of 18 ft. The bed is 24 ft. long and the elevating gear consists of two endless chains arranged side by side and joined together by slats made from angle iron. The two chains are driven by a Villiers $1\frac{1}{2}$-h.p. air-cooled four-stroke petrol engine arranged on a sub-frame below the bed, the transmission assembly comprising a flat-belt drive to a primary countershaft, a chain drive to a secondary countershaft and then a further chain drive to the driving sprockets fitted at the base of the conveyor bed. The height of the delivery-end of the conveyor is adjusted by a hand-operated four-part tackle, one end of which is anchored to the bed and the other to the top of the forward support member. This is designed so that it pivots at its base and makes contact with the underside of the bed through two rollers, or wheels, one at each side. The operating mechanism is designed so that the bed is held automatically at any selected height and the equipment provided includes a telescopic support for use when the height of delivery is low and the forward supports therefore at an acute angle. The underframe is of welded-tubular construction and the complete unit is easily transported, being provided with pneumatic wheels.

The exhibits on the stand of Messrs. Whitlock Brothers, Limited, Great Yeldham, Essex, include a farm trailer fitted with tracks instead of the more usual road wheels. This unit, which is illustrated in Fig. 6, on Plate XLVII, should prove particularly useful for the collection of root crops, such as sugar beet, and for employment overseas in such places as sugar plantations, where the terrain is often soft and uneven. The tracks are made by the Avon India Rubber Company, Limited, under licence from Messrs. James A. Cuthbertson, Limited, and are being marketed by Messrs. J. W. and T. Connolly, Limited. The design is based on the tracks fitted to the Buffalo, an amphibious tractor shown by Messrs. James A. Cuthbertson at the Royal Show in 1949 and described in ENGINEERING, vol. 168, page 79 (1949). The outstanding feature of the design is the complete elimination of all pins, links and bushes, maintenance, as a consequence, being reduced to a minimum. The tracks are very flexible and are built up from vulcanised-rubber blocks reinforced by wire ropes looped round a series of externally-grooved ferrules. The blocks are joined together by plates secured to the blocks by bolts which pass through the ferrules, so that all the load is taken by the wire ropes moulded into the blocks. These tracks are, of course, not limited to use on trailers and Messrs. J. W. and T. Connolly, Limited, were showing half-track equipment designed to take the place of the rear wheels on such tractors as the Fordson Major and the David-Brown Cropmaster.

*(To be continued.)*

## THE MOTOR INDUSTRY RESEARCH ASSOCIATION.

THE sixth annual report of the Motor Industry Research Association, covering the period from July 1, 1950, to June 30, 1951, which was issued on Wednesday, November 21, calls attention to the difficulties being experienced in maintaining the level of research activity. Although the rearmament programme has contributed to this, the primary cause is shortage of staff brought about by the projected move of the laboratories to Lindley Airfield, the Association's proving ground near Nuneaton, many of the junior staff, whose homes are in London, having resisted the move and found other work nearer home. Staff problems are expected to become increasingly acute during the coming year as the time for removal approaches, and the report warns the members of the Association that they must be prepared for an appreciable contraction in the research work pending occupation of the new laboratories.

Despite this difficulty, two major development projects of the Association, namely, their new laboratories at Nuneaton and the high-speed test track, have received much attention during the past year and both projects are now going ahead. Plans for the new laboratories have been completed and building work is in progress. When finished, the laboratories and allied facilities such as libraries, offices, etc., will cover approximately twice the floor area of the existing premises at Brentford. The project includes canteens, dormitories and garage facilities which will also be available for use by staffs of member firms using the proving ground. Progress with the high-speed tracks has not been so satisfactory, mainly due to the slowness of the negotiations with the various Government departments concerned. Plans, however, have been completed, the track having been designed for sustained speeds of 100 miles an hour. It will be triangular in form, using two sides of the existing perimeter track but owing to a bend in the existing third side of this track, one leg of the course will be entirely new. The corners will, of course, be banked and in each case the surface will be supported by embankments compacted from locally-excavated materials.

Considerable progress has been made with the many other branches of the Association's work. That on the effect on engines of petrols containing a high content of tetra-ethyl lead was virtually completed last year, apart from a number of tests on the effects of valve rotation. A few runs were made on a 500-c.c. overhead-valve single-cylinder water-cooled engine operating at 4,000 r.p.m. and using a positive-type valve rotator, and these tests indicated that the use of such a device can be very effective in maintaining valve faces and seats in good condition and thus delaying failure due to "guttering." There were also indications that its use counteracted the formation of deposits on the valve stem. This work, however, was not extensive, since it was considered that the tests could not give results of general application in view of the wide variations in the design of automotive engines.

Researches into the effect of piston assembly on oil consumption and blow-by have been seriously hampered by lack of reproducibility, oil consumptions varying by as much as 5 to 1 having commonly been experienced with identical piston and ring assemblies. Originally, it was thought that this phenomenon was due to differences in ring movement, but while investigating this possibility it was found that normal square-faced gas rings were, in fact, tapered by various amounts and that by reversing the rings, oil consumptions differed by a factor of approximately 5; tests with square rings in grooves canted slightly upwards or downwards gave similar results. Even so, repeat tests on the same piston assembly on different days still gave variations in oil consumption. Blow-by, on the other hand, was nearly always consistent and reproducible. When this work was started it was decided that, in view of the large number of variations that can be made in a piston and ring assembly, it should be carried out on a single-cylinder engine using a method of determining oil consumption that would give a result in a few hours. In view, however, of the lack of reproducibility, it has become clear that this method must be abandoned in favour of a statistical approach. Accordingly, tests are now being carried out using a multi-cylinder engine and measuring the oil consumption on a daily basis. If these tests do not prove to be sufficiently reproducible, it is feared that this work will have to be abandoned as results could only be obtained on a true statistical basis by running many engines for a long period.

One aspect of the work being carried out on the fatigue strength of crankshafts, namely, the influence of special design features on the strength of cast shafts, has been completed and a report issued. This describes the effect of special features, such as web depressions, eccentric journal bores, chamfered webs, etc., and shows that none of these appreciably affects the fatigue strength, the largest change being in the neigh-

(To face page 714.)



# EXHIBITS AT THE SMITHFIELD SHOW AND AGRICULTURAL MACHINERY EXHIBITION.

(*For Description, see Page* 713).

FIG. 3. TRACTOR-MOUNTED CROP SPRAYER; E. ALLMAN AND COMPANY, LIMITED.


FIG. 4. TRACTOR-MOUNTED SUGAR-BEET HARVESTER; JOHNSON'S (ENGINEERING), LIMITED.

FIG. 5. VARIABLE-HEIGHT ELEVATOR; WOLSELEY SHEEP SHEARING MACHINE COMPANY, LIMITED.

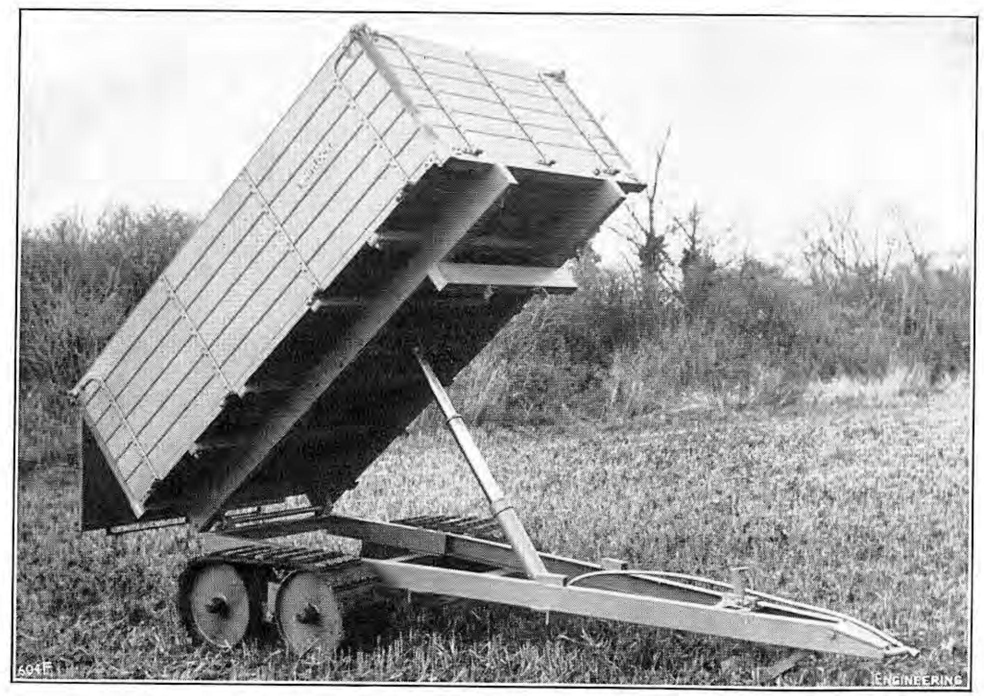


FIG. 6. TRACKED TRAILER; WHITLOCK BROTHERS, LIMITED.

# MOTOR INDUSTRY RESEARCH ASSOCIATION.

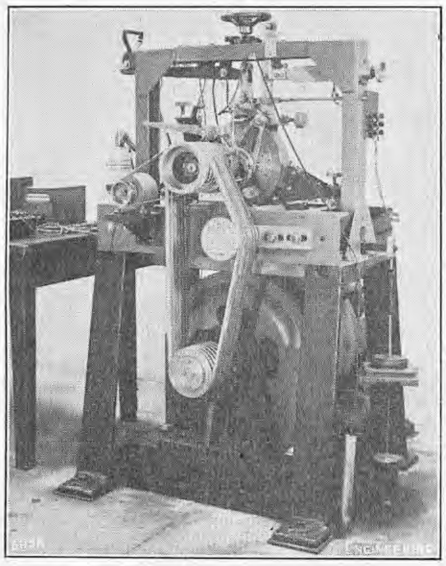


FIG. 1. RIG FOR INVESTIGATING BRAKE FADE.

FIG. 2. STRAIN-GAUGE EQUIPMENT ON MOTOR-CAR FOR MEASURING DYNAMIC STRESSES.

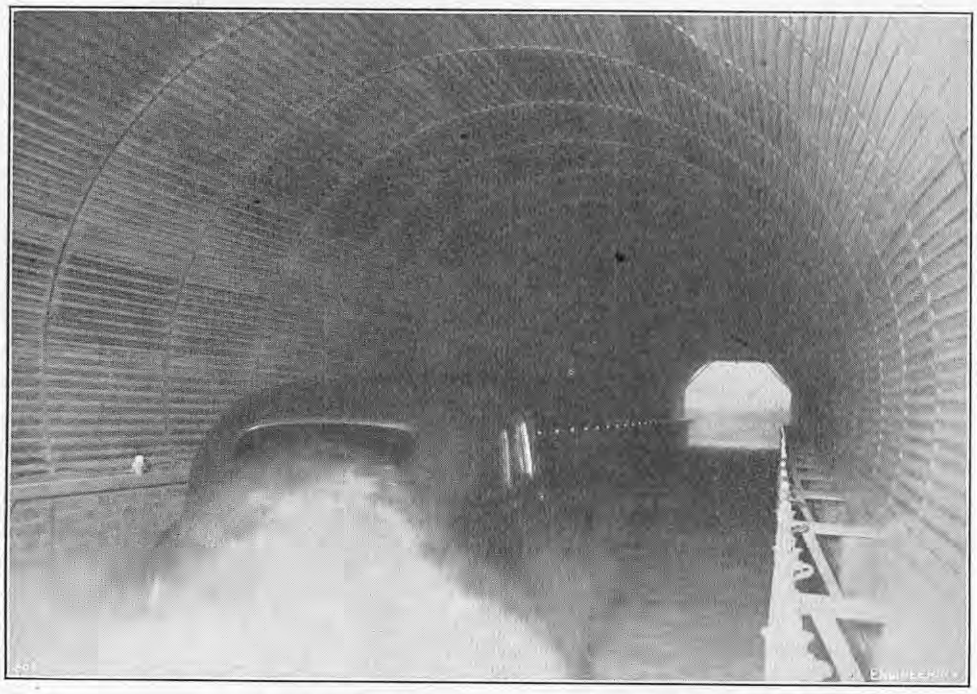


FIG. 3. DUST TUNNEL AT PROVING GROUND.

bourhood of 10 per cent. However, some designs had a noticeable effect on bending flexibility; web depressions, for example, increased flexibility by as much as 50 per cent. The work on the bending-fatigue strength of cast-steel crankshafts also has been completed and a separate report is in course of preparation. Put briefly, the bending-fatigue strengths of several varieties of cast-steel crankshafts were found to be about 40 per cent. greater than those for crankshafts of various high-duty cast irons. They were, however, surprisingly low in relation to the tensile strengths of the materials, the ratio of crankshaft strength to tensile strength, for example, being only approximately half that obtained with cast irons and forged steels. Owing to the difficulties experienced in obtaining sound castings, the work on crankshafts of nodular iron has progressed but slowly. Fatigue strengths determined so far have given a ratio of crankshaft strength to tensile strength for cerium-treated iron about the same as that for the high-duty cast irons, namely, 0·15, but for magnesium-treated irons a value of only 0·10 was obtained. Although, therefore, the tensile strengths of the cerium and magnesium-treated irons were approximately 28 tons and 50 tons per square inch, respectively, crankshafts of magnesium-treated iron were less than 20 per cent. stronger than those of cerium-treated iron.

Work on the effect of surface treatments on the fatigue strength of cast crankshafts is not yet completed. Preliminary investigations on "stepped" bars have shown an increase of approximately 35 per cent. in strength in non-reversed bending for bars which had been shot-peened and also for bars which had been cold rolled, and 45 per cent. to 50 per cent. for bars which were lapped after shot-peening, the latter result having been verified on crankshaft specimens.

The constant-stress torsional-fatigue machine developed by the Association has now been in use for over 18 months, modifications found desirable in the light of experience having been made from time to time during this period. Tests on the Association's standard design of crankshaft in low-alloy inoculated iron with $\frac{1}{4}$ in. fillets gave a nominal limiting crankpin stress of 5·4 tons per square inch, and reducing the fillet to $\frac{1}{16}$ in. lowered the limiting stress to 4·5 tons per square inch, a reduction in strength of 17 per cent. Crankshafts in a chrome-molybdenum alloy iron gave a nominal limiting crankpin stress of 4·3 tons per square inch. Tests to determine the weakening effect of oil holes have been carried out on straight bars and the presence of such a hole has reduced the nominal limiting stress from 5·6 tons per square inch to 3·7 tons per square inch. Attempts to reduce this weakening by such devices as rounding and polishing the edge of the hole and by stressing the edge by pressing into it a steel ball have proved unsuccessful.

Laboratory work on lubricating oils for high-speed compression-ignition engines was virtually completed before the issue of the Association's fifth report. During the past year, therefore, attention has been concentrated more on the results of service tests carried out by two large fleet operators on behalf of the Association. In the laboratory test, a six-cylinder engine was used for judging the performance of lubricating oils, the period of test being limited to 50 hours running, the criterion being the extent of piston-ring sticking. This was determined not only by inspection at the end of the test, but also by observing the change in the rate of blow-by during the test. Two plain and the same two oils blended with three detergent additives were tested using fuels having sulphur contents of 0·2 per cent. and 1·0 per cent., respectively. With the low-sulphur fuel, the two plain oils failed, but all six additive oils passed the test, and with the high-sulphur fuel both plain oils and one of the additive oils failed and the other five additive oils passed the test. This same distinction between plain and additive oils was shown by independent laboratory tests carried out under the auspices of the Institute of Petroleum.

The service tests, which were carried out by two large short-stage 'bus operators, showed no improvement with the additive in one case and, on a statistical analysis of the results, an 8 per cent. increase of engine life in the other case. There was an outstanding difference in condition of pistons and rings between the laboratory tests and the road trials. At the completion of a laboratory test in which the oil had failed, most or all of the compression rings were stuck in their grooves, whereas the scraper rings invariably were clean and free. On the other hand, pistons from engines which had failed in service sometimes had compression rings stuck, but in nearly every case scraper rings were completely packed with hard deposits which restricted the flow of oil through the drain holes. No reason for this difference is given in the report, but it is understood that the matter is being investigated further.

The work on the surface fatigue strength of gear teeth, that is, pitting, was concerned mainly with tests on gears in three through-hardening steels, namely, En. 24, En. 24 leaded, and En. 30A; the three case-hardening steels, En. 39A, En. 39A leaded and En. 36; and one nitriding steel, namely, En. 40C. These seven steels were chosen as a report on their bending-fatigue strength had been issued previously. The results have confirmed that pitting is a form of surface-fatigue failure, the life varying in an inverse manner with the stress applied, but the range of life covered, namely, $10^5$ to $10^7$ cycles, gave no indication of a limit below which failure would not occur. Resistance to pitting appeared to depend on the surface hardness of the materials and the use of lead in En. 24 to improve machinability, gave no reduction in the tendency to pitting; its use in En. 39A case-hardened steel, however, caused a reduction of approximately 10 per cent. in the load-carrying capacity.

Due to the serious shortage of alloying elements, the programme envisaged in the previous annual report had to be modified considerably. Attention was concentrated, therefore, on the low-alloy American steels S.A.E. 4620, 4028 and 8620 and on the British economy steel En. 320 at the expense of the work on the effect of manufacturing methods on fatigue strength. Preliminary results on these steels in terms of limiting strength and based on an assumption that the tooth fatigue strength of gears in En. 36 is 100 per cent. show that the strengths with four different heat treatments of En. 320 are 117 per cent., 85 per cent., 100 per cent. and 100 per cent., respectively, and for S.A.E.

4620, 4028 and 8620, 105 per cent., 90 per cent. and 85 per cent., respectively. Tests were also made on gears in En. 35, as this steel has much the same composition as S.A.E. 4620, and a figure of 85 per cent. of the strength of En. 36 was obtained. The report adds that work on the surface-fatigue strength of gears made from S.A.E. steels will be commenced shortly.

Tests to ascertain the effects of manufacturing methods on tooth fatigue strength have been confined to one gear each, made by finish hobbing, rough-protuberance hobbing finished by shaving, finish shaping and rough shaping followed by formed-wheel grinding. From the few results obtained, the biggest difference appears to occur between the rough-hobbed and shaved gears and the finish-hobbed gears, the latter being about 20 per cent. stronger in terms of applied bending moment. On a stress basis, however, the difference is only about 10 per cent. The reason given for this in the report is that the rough-hobbed and shaved gears have more material removed from the tooth roots than in the finished-hobbed process. In view of the considerable amount of work planned on gear-tooth fatigue strength, the Association has constructed a second hydraulic bending-fatigue machine. This machine is similar to that already installed but is improved in detail so that it can accommodate gears having a wide range of diameters and face widths and, if required, gears integral with their shafts.

The investigations into brake fade and delayed brake fade have made good progress. Brake fade may be defined as the loss of braking efficiency when operating at high temperatures and delayed brake fade as the much greater loss of efficiency after resting brakes for a period following operation at high temperatures. This work is being carried out on the machine illustrated in Fig. 1, on page 715, which has been constructed by the Association and designed so that the friction between a small piece of lining and a rotating drum can be determined over a wide range of temperatures, speeds and loads with, as far as possible, independent control of these three variables. It has been found that very useful information on fade can be obtained by subjecting the specimen to a temperature cycle in which the drum temperature is raised uniformly to about 350 deg. C. at constant speed and load and then decreased steadily. In road tests, which are carried out to correlate laboratory results, the linings are subjected to a similar, but obviously more erratic, cycle by repeated braking. Correlation has proved reasonably good, the degree of delayed fade being very marked in both cases during the temperature-decreasing part of the cycle, retardations of one-tenth normal being observed on the road. The report states that it is believed that this is the first time that attention has been drawn to this catastrophic fall in coefficient of friction on cooling after heating. It adds that there is good circumstantial evidence for believing that ordinary fade and delayed fade are caused by constituents of the lining liquefying on heating to form a film of lubricant between the lining and the drum. To verify this, linings have been "baked" before use, being held at a temperature of 300 deg. C. for some 30 minutes when there is a loss in weight of from 4 per cent. to 8 per cent.; such linings showed no fade up to 350 deg. C. either in the laboratory or on the road.

Investigations into the stress analysis of vehicle structures is concerned at present with the measurement of the working stresses in the structure of a small saloon car of "chassisless" construction, the work on a double-deck 'bus having been completed and a report issued. As in earlier work of this nature, wire-resistance strain gauges are being used, a large number of the gauges being attached to such members as the longitudinal under-frame box members, body pillars, door jambs, sills, etc., to give comprehensive plots of stress variation. The complexity of this installation will be apparent from Fig. 2, on page 715, which shows the car ready for testing. Measurement of the "static" stresses in this vehicle has been completed and a report is now in course of preparation. The tests were directed towards finding the stresses imposed by such static loads as the body structure, the engine and gearbox unit, passengers, luggage, etc. A torsional load of 2,300 lb. ft. was also applied and the results indicated that the stresses due to this torsional load were generally considerably greater than those due to the direct loads and that the most highly stressed part of the structure was the lower ends of the wind-screen pillars. Observed maximum stresses were 3,400 lb. per square inch tensile and 4,600 lb. per square inch compressive due to direct load and 8,000 lb. per square inch tensile and 12,000 lb. per square inch compressive due to torsional loading. Road work to determine the dynamic stresses in this vehicle is well advanced, the Association's own design of dynamic strain-recording equipment being used for this purpose.

The Association have continued their work on the determination of stresses in public-service vehicle type wheels, the activities during the period under review having been mainly concerned with the stresses set up due to dynamic loading in service. Wire-resistance strain gauges are being used in conjunction with a slip-ring assembly and the four-channel dynamic strain-recording equipment. A double-deck 'bus was used for the tests and, with the test procedures employed, cornering stresses appeared to be more serious than those due to either bumping or braking.

Other work in progress and referred to in the report includes the measurement of noise in vehicles. The construction of a magnetic-tape recorder is now completed and should facilitate work on this subject. Extra-mural work is in progress on piston-ring movement, fuel sprays for internal-combustion engines, ventilation of public-service vehicles, the deep-drawing of sheet metals and metal finishing. Laboratory work on piston-ring movement had been completed before the last report was issued, but road tests using L-shaped pressure-backed rings were still in progress. These also have now been completed and have shown that pressure-backed rings give less engine friction than normal rings, allow less blow-by and are sufficiently robust to permit normal handling; there was also evidence of a reduction in cylinder wear. A further report on the subject of fuel sprays entitled "Some Experiments on Spray Atomisation with Swirl Atomisers," has been circulated to members; this describes work which was largely an extension of that described in a previous report, "Some Observations on Flow in Spray Nozzles." The work on the ventilation of public-service vehicles was concluded early this year and a report issued. In this, experiments are described which were carried out to improve, by simple means, the heating and ventilation of double-deck vehicles. Briefly, the system uses the forward motion of the vehicle to promote circulation and waste engine heat to warm the air; experience gained shows an improvement in passenger comfort.

The annual report also refers to various additions which have been made from time to time at the proving ground. Facilities already there included a stretch of Belgian pavé road, a noise-producing surface, a corrugated track to excite the unsprung mass-systems of a vehicle and a dust tunnel. All these have proved most popular, particularly the Belgian pavé, which will shortly be extended. The dust tunnel, which is illustrated in Fig. 3, on page 715, has also proved most useful. The additions referred to in the report include a section of corrugated track, known as the long-wave pitching track, and a deep-water splash. The long-wave track, which is illustrated in Fig. 4, herewith, has been designed to excite the sprung mass of a vehicle and as will be seen from the illustration, comprises a number of sinusoidal waves; these are 40 ft. in pitch and measure 5 in. from trough to crest. So far, a trial stretch 100 yards in length has been laid down and although the report does not say so, it is assumed that, if successful, the track will be lengthened. The deep-water splash is illustrated in Fig. 5, herewith. It has a maximum depth of approximately 5 ft. over a length of 40 ft., a width of 12 ft. and approach roads set at an inclination of 1 in 8.

# MOTOR INDUSTRY RESEARCH ASSOCIATION.


FIG. 4. LONG-WAVE PITCHING TRACK AT PROVING GROUND.


FIG. 5. DEEP-WATER SPLASH AT PROVING GROUND.

# MANUFACTURE OF SHIP PROPELLERS.

BULL'S METAL AND MELLOID COMPANY, LIMITED, YOKER.

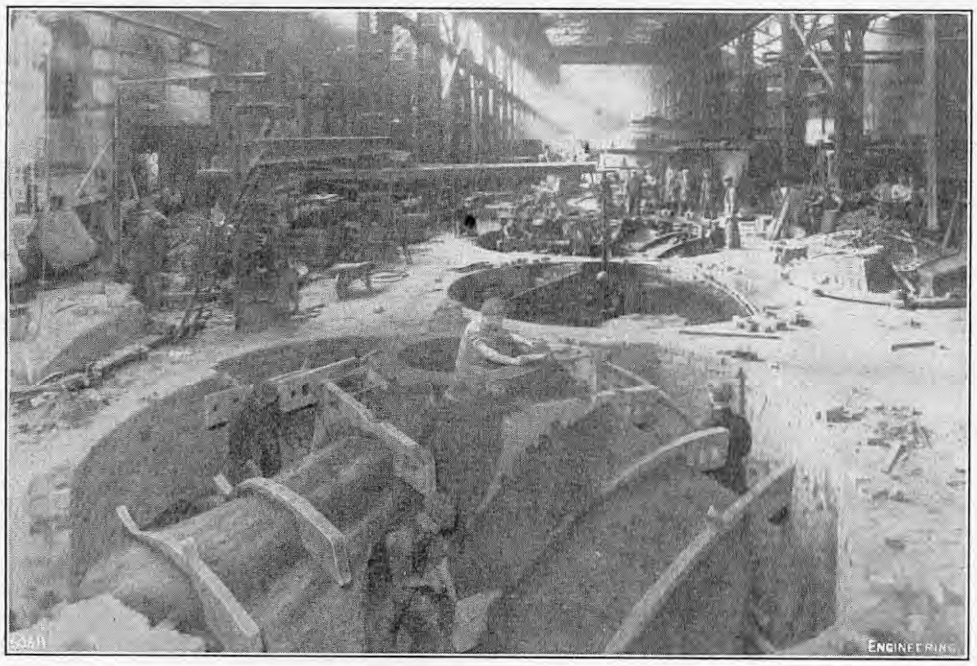


FIG. 1. PROPELLER FOUNDRY.

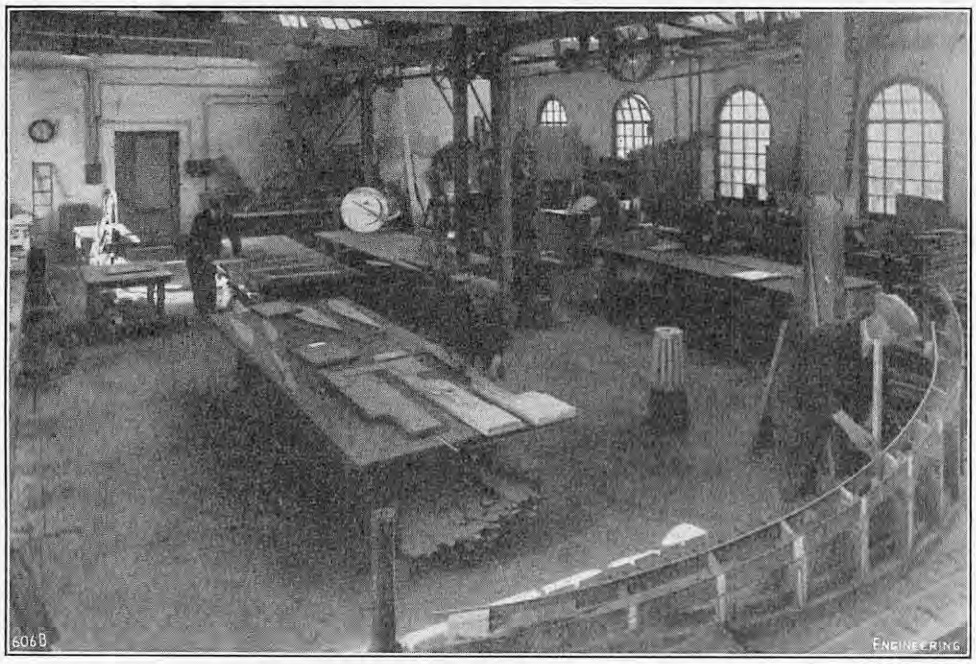


FIG. 2. PATTERN SHOP.

## THE YOKER WORKS OF MESSRS. BULL'S METAL AND MELLOID COMPANY, LIMITED.

IT was in the closing years of the Nineteenth Century that a young Norwegian, John Bull by name, employed by the Phosphor Bronze Company, Limited, set up in business on his own as a bronze-founder in London. At the time, the manufacture of bronze propellers, which had grown in favour compared with the earlier cast-iron and cast-steel propellers, was centered on the Thames and was, therefore, remote from the principal shipbuilding areas. Bull's propellers soon established a reputation, particularly on Clydeside, and his success induced him to remove his business to the north. A site was secured at Yoker, on the Clyde, beside the Renfrew Ferry, and Bull's Metal and Melloid Company, Limited, was established there in 1901. It occupies the same site to-day. The original works consisted of a shop 90 ft. long and 35 ft. wide, having two side bays; here, the entire founding and finishing of the propellers was done. This shop, which is illustrated in Fig. 1, on this page, is now the foundry, and the pattern-making, machining, chipping and finishing are done elsewhere. The larger propellers are cast in pits of which there are six in the foundry.

Some details of the casting process may be of interest. The first operation is to set up a heavy iron spindle in the centre of the pit, and to make around it three, four or five beds, depending on the number of blades required. In the case of a propeller of uniform pitch, the top surface of the loam is formed by swinging a heavy striking board round the centre spindle while raising it uniformly by causing its outer end to slide up an inclined rail. One of these rails is visible in the foreground of the photograph reproduced as Fig. 2, on this page, which illustrates the pattern shop. In this way the striking-board sweeps out portions of a helicoid. If a non-uniform pitch is required, an articulated striking board is employed. Subsequently, thin wooden sections having the shape of the blades at various radial distances from the propeller axis are placed on the bed at their correct radial positions, and are bent circumferentially into their appropriate shapes. After they have been fixed in position, the intervening spaces are filled with soft sand until a replica of the blade is formed. Construction of the reinforced cope, or cover, follows. When the latter is lifted subsequently, the soft sand and wooden sections are removed, the cope is lowered again on to the bed and the two are fastened rigidly together.

The metal ingots required for casting are melted in adjoining furnaces and raised to the correct temperature. After the furnaces have been tapped, the molten metal, conveyed to the pit in ladles, is poured into the runner-box which controls the flow of metal into the bottom of the mould. When the metal has solidified and cooled, the casting is removed. In its rough state, it is 50 per cent. to 70 per cent. in excess of its finished weight. This condition is shown in Fig. 3, on page 720, which illustrates a manganese-bronze propeller which we recently saw being cast at Yoker for Messrs. Alexander Stephen and Sons, Limited, Linthouse, Govan, Glasgow. The propeller has a diameter of 19 ft., and will have a finished weight of 17 tons. It will be fitted to the motor vessel Middlesex, owned by the New Zealand Shipping Company, Limited.

After casting, a propeller is removed to the machine shop, illustrated in Fig. 4, on page 720. There the header is removed on a horizontal boring machine and the fore and aft faces of the boss are finished to their required dimensions. The tapered bore for the tail shaft is then completed and the keyway cut. Still with its blades in the rough condition, the propeller is passed on to the finishing shop, illustrated in Fig. 5, on the same page. The usual method of finishing involves chipping away most of the unwanted metal from the blades by means of pneumatic tools and, when the dimensions are nearly those required, grinding and polishing the blades to their final shape. Static balancing is then all that is normally necessary.

It need hardly be mentioned that during all the stages of manufacture the metal is subject to careful metallurgical examination, and that the whole process of manufacture is strictly controlled. Although the metal used for propellers is termed bronze, it is, in fact, normally a form of brass containing 57 per cent. copper, 40 per cent. zinc, with the remaining 3 per cent. composed of tin, iron, aluminium, manganese and other metals. Each manufacturer, however, has his own specification and method of ingotting. "Bull's metal" has long been known to the trade.

The original capacity of the works at Yoker was between 200 and 300 tons of finished propellers annually but, in 1938, arrangements were made to increase this to approximately 400 tons per annum. During the recent war, the company manufactured nearly 2,000 tons of propellers for the Royal Navy and Merchant Navy, and for the navies of other countries, including Russia. During the same period, the company's rolling-mill had an output of nearly 4,000 tons of bronze rods of many sizes. Since the war, development of the company's resources has continued and, between 1945 and 1950, over 5,000 tons of propellers up to a maximum weight of 18 tons have been supplied. In addition, over 3,000 tons of other bronze forgings and castings have been manufactured during the past six years. The total value of all the work passed through the shops at Yoker exceeds 7,000,000*l*.

The company recently concluded an agreement with Messrs. J. Stone and Company, Limited, Deptford, London, S.E.14, whereby they will manufacture under licence the latter company's Heliston design of propeller. This design was developed in 1935 and within three years had been fitted to propelling machinery developing over 1,250,000 h.p. By 1940, the four largest vessels in the British registry were all fitted with Heliston propellers and, up to the present, propellers for over 9,000,000 h.p. have been supplied.

It has already been mentioned that, in addition to making propellers, Messrs. Bull's Metal and Melloid Company, Limited, manufacture a variety of non-ferrous castings and forgings. A more recent departure, which is also the result of an arrangement with Messrs. J. Stone and Company, Limited, is the manufacture at Yoker of ships' windows and sidelights to Messrs. Stone's designs. Collaboration between the companies in this field began shortly after the war when the demand for rolled non-ferrous bar declined markedly in favour of extruded sections. Messrs. Bull's rolling mill was affected by the slackening of demand and the directors of the company were therefore led to seek an alternative use for this part of the factory. Messrs. J. Stone and Company were then contemplating a reorganisation of their work involving the transfer of certain sections of it to other locations. One such section was the ship's window and sidelight department, situated at Oldham. The transfer of this department to Yoker took place in February, 1950.

The photograph reproduced as Fig. 6, on page 720, shows the interior of the window machine-shop at Yoker. During the past 50 years glass has been used in ever increasing quantities in ships, and there has been a steady demand for larger windows and lighter frames. The requirements of strength to withstand wind and sea, and effective sealing against the weather, have been met by the use of toughened glass, improved frames and better sealing devices. A wide range of types of brass-framed window is being manufactured at Yoker and the company has recently established a showroom where the various designs can be seen to advantage and compared. Development work is always in progress on new types of window.

# NOTES FROM THE INDUSTRIAL CENTRES.

## SCOTLAND.

PROPOSAL FOR A NATIONAL FUEL TRUST.—A National Fuel Trust, an integrated organisation to be responsible for co-ordinating all fuel resources in this country, should be set up without delay, suggested Sir Patrick Dollan, chairman of the Scottish Fuel Efficiency Committee, at the annual dinner of the Glasgow area branch of the Institute of Incorporated Plant Engineers on November 24. He appealed to the Institute to follow up the suggestion for a national fuel policy, made by Mr. Northcroft, O.B.E., in an address on "Coal and Europe," delivered at the Dunblane conference of the Institute.

SCOTTISH INDUSTRIAL SAFETY CONFERENCE.—Comparing transatlantic and British methods of accident prevention, Mr. D. H. Gordon, director of the North British Rubber Co., Ltd., said in Glasgow on November 29 that, in Britain, there were better regulations for the safety of employees and better-designed machinery guards, but the American operative had more enthusiasm for safety propaganda. The problem was fundamentally one of salesmanship. He was speaking at a Scottish industrial safety conference organised by the Royal Society for the Prevention of Accidents on behalf of the Scottish Industrial Group's Advisory Council.

LIGHT INDUSTRIES FOR LOCHABER.—Wool processing, peat utilisation, and the manufacture of aluminium household goods were among light industries recommended by Lochaber District Council on November 27 to the Scottish Council (Development and Industry) for establishment in the district. It was claimed that no other area in the North-West of Scotland offered greater possibilities of development; it had ample hydro-electric power, adequate sea and road transport, and a sufficiency of suitable labour.

OFFERS OF JAPANESE STEEL.—Offers of 14,000 tons of Japanese steel, at the present time, and of 100,000 tons next year, were mentioned by Dr. Denis Rebbeck, a director of Harland and Wolff, Ltd., on November 29, when he presided at the ceremony after the launch of the Royal Mail cargo-passenger motorship Ebro from the Govan shipyard. He described as a Gilbertian situation the fact that this steel could be offered at 60*l*. a ton, compared with, say, 25*l*. for the home article. Referring to shortages of important items in the shipbuilding industry, he expressed the hope that, with the allocation scheme in February, they would get a greater proportion of their steel needs and so build their ships in a shorter time.

## CLEVELAND AND THE NORTHERN COUNTIES.

THE POSITION IN THE IRON AND STEEL INDUSTRY.—Transactions in North-East Coast iron and steel products are becoming almost impossible. Makers and merchants have embarrassingly large arrears of delivery and little or no saleable tonnage. Raw materials are wanted in considerably larger quantities than are available. Foreign-ore users are fairly well placed as regards supplies, but imports are shrinking as ore ships are transferred to handling the transport of other commodities. The intake of scrap from abroad is still decreasing, and deliveries from home sources fall very greatly short of meeting the heavy needs of consumers. Dearth of iron and steel scrap is the chief cause of the drop in the steel production. Distributable tonnages of pig iron, though better than for some time past, are still much below current needs.

AIR SERVICES IN THE NORTH EAST.—A suggestion made to the North-East Airport Joint Committee, the secretary of which is the town clerk of Sunderland, that the Joint Committee might consider the use of helicopters for short-range flights in place of the establishment of air services for the North-East Coast area, has revived the whole question of providing or selecting an airport, or airports, in the district. The suggestion, which has been made by the British European Airways Corporation, has aroused little enthusiasm. The Tees-side Industrial Development Board, who attach great importance to the question, decided at a meeting in Middlesbrough on November 26, to request the Ministry of Civil Aviation to treat the decision regarding an airport as a matter of primary importance. Mr. J. C. H. Booth, vice-president of the Tees-side and S.W. Durham Chamber of Commerce and chairman of a special airport sub-committee of the Tees-side Industrial Development Board, said that Tees-side had been promised an airport and every effort should be made to see that it obtained one. Unfortunately, there was a vicious circle in existence: British European Airways had said that it would be useless to supply aircraft if there were no airport, while the Ministry of Civil Aviation saw no point in building an airport if British European Airways could not supply the aircraft.

## LANCASHIRE AND SOUTH YORKSHIRE.

ONE-PIECE FORGINGS FOR ROLLS.—An engineering achievement which is saving thousands of dollars has emanated from the shops of Thos. Firth & John Brown, Ltd., Sheffield. It is in connection with the production of large back-up rolls for rolling mills. A new technique has been developed for making the rolls from one-piece forgings. Before and during the war it was the practice to import the castings from U.S.A. and usually the rolls were made in two parts. To make the rolls as one-piece forgings, ingots up to 100 tons of high-grade steel have to be produced, the forging has to be carried out under one of the largest forging presses in the country, and heat-treatment carefully planned in order to eliminate the possibility of defects. Three rolls from the Sheffield works are to be used in four-high mills. Two of the rolls dispatched on November 30 are 53 in. diameter, have a barrel length of 47 in., and weigh 20 tons. They will be used in the new mills at Margam, South Wales, of the Steel Company of Wales. The third roll, which is 44 in. in diameter by 54 in. in barrel length, weighs 18 tons and is for the mills of John Summers & Sons, Ltd., Shotton.

TRANSPORT CHANGEOVER.—A further step has been taken in the proposed substitution of omnibuses for tramway cars in Sheffield. This is the receipt of sanction from the Ministry of Transport for the running of omnibuses on the Malin Bridge and Fulwood routes. There is a good deal of popular opposition to the general changeover in Sheffield, a contention being that the omnibuses will not handle efficiently the big movement of employees to and from the East End works. Moreover, three leading firms in Sheffield have always been the chief suppliers of points and crossings for British and other tramways and the loss of this trade would be a serious matter.

SAMUEL OSBORN & CO., LTD.—In 1952, Samuel Osborn & Co., Ltd., Clyde Steel Works, Sheffield, 3, attain their centenary. The business was started on a modest scale by Samuel Osborn, J.P. (1826-1891) in April, 1852. He rented a small factory now known as Brookhill Works, on the outskirts of Sheffield, and there made files from steel which he purchased. The grinding was done by water-power in nearby valleys and the cutting in the homes of his workpeople, of whom he employed 30. In 1857, Samuel Osborn began to melt his own steel and in 1871, in association with Robert Forester Mushet (1811-1891) he developed "R. Mushet's Special Steel," the first self-hardening steel and the first tungsten high-speed tool steel produced. In the closing years of the Nineteenth Century, it was estimated that they had 50 per cent. of the world's self-hardening tool-steel trade. In 1905, the firm was converted into a private limited company, and, in 1920, it became a public company. It is stated in their annual report for the year ended July, 1951, that the relationships between management, staff and workpeople are of the happiest and that the relations with trade unions are also most satisfactory, joint consultation being practised regularly in all the company's works.

## THE MIDLANDS.

ACCIDENT PREVENTION COURSE.—A special course for press-tool setters will be held at Birmingham University from December 17, 1951, to January 4, 1952. The course, which is planned to instruct toolsetters in accident prevention, will be attended by about 120 employees of small or medium-sized Birmingham firms. It has been arranged by the Superintending Inspector of Factories for the South Midland Division, Mr. R. Bramley-Harker, in conjunction with the Birmingham Safety Group and the Midland Advisory Council on Industrial Accidents and Ill-health. Power-press manufacturers have lent six different kinds of presses, with guards and tools, and these are being installed in one of the laboratories at the University.

CHELTENHAM INDUSTRIES.—Cheltenham Chamber of Commerce has issued a brochure entitled *Cheltenham and Its Industries*, which lists over 40 industries at present operating in the town, and gives details of facilities which are available for new factories. Attention is drawn to the fact that Cheltenham has developed its industries without adversely affecting the amenities of the town.

NON-FERROUS METALS IN THE LOCK TRADE.—About 90 per cent. of the British lock trade is concentrated in the adjoining Black Country towns of Willenhall, Wednesfield and Wolverhampton, and some alarm was felt recently over the possible effect on the trade of further restrictions on the use of non-ferrous metals. As a result of representations in Parliament, copper and zinc (mainly in the form of brass), used in integral parts of locks and latches, are to be exempted from the ban, and fears of heavy unemployment have been allayed.

WELFARE FACILITIES AT ROUND OAK STEELWORKS.—A new welfare block, part of an extensive modernisation scheme at the Round Oak Steelworks, Brierley Hill, Staffordshire, was opened on November 27, by Lord Ednam, son of the Earl of Dudley, who is the chairman of Round Oak Steelworks, Ltd. The facilities provided include showers, lockers and other equipment of the pit-head bath type. Lord Ednam said during the opening ceremony that the reconstruction of the works would soon be completed.

OCKER HILL POWER STATION.—The Midlands Electricity Division propose to extend the existing generating station at Ocker Hill, Tipton, Staffordshire, by providing a further 40,000 kW of generating capacity and building a new cooling tower. Some local opposition has been aroused, many of the inhabitants of the neighbourhood, which is thickly populated, fearing that the new cooling tower will bring a repetition of the condensation troubles experienced with the first two towers. The Borough of Tipton, in whose area the station stands, intends to lodge a protest against the proposed extension, but will withdraw it if a satisfactory assurance is given that plant will be installed to prevent the emission of moisture and grit.

EXCHANGE PLAN FOR METALS.—The Midland Branch of the National Union of Manufacturers is to issue a fortnightly bulletin, to be known as *The Capacity Gazette and Metal Exchange*, which will be circulated to members who wish to take part in an arrangement for notifying surplus manufacturing capacity and materials. As all transactions will be at controlled prices, it is hoped that other manufacturers will be helped, and that the private sale of scarce metal at high prices will be made very difficult, if not impossible.

## SOUTH-WEST ENGLAND AND SOUTH WALES.

POWER AND GAS SUPPLY IN SOUTH WALES.—The British Electricity Authority have spent 48,000,000*l*. in South Wales during the past three years, the Welsh Board for Industry was told at a meeting last week. The Board heard from Mr. H. J. Bennett, the new Divisional Controller, and Mr. T. H. Wood, the Chief Constructional Engineer for the Authority, a report on the progress of new power stations in the Principality. Many millions of pounds have yet to be spent before the programme is completed. Completion of the big power stations at Uskmouth and Carmarthen Bay has been delayed to some extent by the shortage of steel. The Board was also told that the supply of gas from the new coke ovens at Nantgarw was more than 5,000,000 cubic feet a day. This was more than had been anticipated at such an early date. At present, much of the gas had to be burnt, as it was made, because, owing to the lack of a gasholder, it was not possible to utilise all the gas produced.

UNEMPLOYMENT AND VACANCIES.—Although there were 24,743 unemployed in Wales, Sir Percy Thomas, chairman of the Welsh Board for Industry, pointed out that there were vacancies in specialised trades for 7,000. There was a small but significant shortage in the ship-repairing industry in the area, which, contrary to expectations a few years ago, was tending to increase. So far, less than 100 Italian operatives had entered the South Wales mining industry.

WATER-POWER SCHEMES IN NORTH WALES.—The Bill for the first of the North Wales hydro-electric schemes for which the British Electricity Authority is seeking Parliamentary sanction, has been deposited for examination by objectors. It provides for the building of three power stations, the creation of a mile-long lake, and the extension of existing catchment areas by aqueducts and leats at Dolgarrog and at Maentwrog.

STOPPAGE AT NANTGARW COLLIERY AVERTED.—Men employed at the new Nantgarw Colliery, who had tendered 14 days' notice to terminate contracts over a dispute concerning Saturday working, have agreed to defer tendering the notices. The decision followed a request by the area president of the National Union of Mineworkers, who asked for an opportunity to open discussions with the Coal Board on a Divisional level.

PRACTICE AIR-BOMBING RANGE IN GLAMORGANSHIRE.—The Ministry of Housing and Local Government states that the Government have approved the Air Ministry proposal to establish ranges for practice bombing, rocket-projectile firing and air-to-ground gunnery, some three or four miles north-west of Porthcawl in Glamorganshire. A proposal for an air-to-air gunnery range has been withdrawn after a public inquiry.

## 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.—*Western Centre:* Monday, December 10, 6 p.m., South Wales Institute of Engineers, Park-place, Cardiff. "Life and Work of Oliver Heaviside," by Professor G. H. Rawcliffe. *North-Eastern Centre:* Monday, December 10, 6.15 p.m., Neville Hall, Westgate-road, Newcastle-upon-Tyne. "Variable-Voltage Generation Applied to Alternating-Current Power Systems," by Mr. R. L. Chantrill. *District Meeting:* Monday, December 10, 7 p.m., George Hotel, King-street, Reading. "The Heat Pump and Its Importance to the Electrical Industry," by Mr. M. V. Griffith. *London Students' Section:* Monday, December 10, 7 p.m., Victoria-embankment, W.C.2. "The Van de Graaff Generator as a Million-Volt Direct-Current Source," by Mr. D. H. Homis and Mr. R. J. Ryan. *Measurements Section:* Tuesday, December 11, 5.30 p.m., Victoria-embankment, W.C.2. "A Graphical Analysis for Non-Linear Systems," by Dr. Pei-Su Hsia (read by Professor M. G. Say); and "A System Utilising Coarse and Fine Position-Measuring Elements Simultaneously in Servo-Mechanisms," by Mr. J. C. West. *North-Midland Centre:* Tuesday, December 11, 6.30 p.m., Leeds University, Leeds. "Load Shedding," by Mr. H. C. Ogden and Mr. H. Lloyd. *Scottish Centre:* Tuesday, December 11, 7 p.m., 39, Elmbank-crescent, Glasgow, C.2. "Nuclear Particle and Radiation Detectors," by Dr. D. Taylor and Mr. J. Sharpe. *Education Discussion Circle:* Wednesday, December 12, 6 p.m., Victoria-embankment, W.C.2. Discussion on "Activity Methods in Technical Education," opened by Mr. R. D. Watts. *Utilization Section:* Thursday, December 13, 5.30 p.m., Victoria-embankment, W.C.2. "The Characteristics and Control of Rectifier-Motor Variable-Speed Drives," by Mr. P. Bingley.

INSTITUTION OF PRODUCTION ENGINEERS.—*Sheffield Section:* Monday, December 10, 6.30 p.m., Royal Victoria Station Hotel, Sheffield. "Oil-Injection Method for Uniting and Separating Pressure Joints," by Mr. C. S. Clarke. *Yorkshire Section:* Monday, December 10, 7 p.m., Hotel Metropole, Leeds. "Payment by Results," by Mr. A. J. Charnock. *Dundee Section:* Tuesday, December 11, 7.45 p.m., Mathers Hotel, Whitehall-crescent, Dundee. "Generation of Fine Finishes by Machining Techniques," by Mr. P. Spear. *Birmingham Section:* Wednesday, December 12, 7 p.m., Grand Hotel, Birmingham. "Automatic Production Methods with Special Reference to the Automotive Industry," by Professor T. U. Matthew. *London Graduate Section:* Wednesday, December 12, 7.15 p.m., 36, Portman-square, W.1. "Zinc-Alloy Die Casting," by Mr. A. K. Parker. *Leicester Section:* Thursday, December 13, 7 p.m., College of Art and Technology, Leicester. Brains Trust Meeting.

INSTITUTE OF PACKAGING.—*Northern Area:* Monday, December 10, 6.30 p.m., Grand Hotel, Manchester. Film on "The Port of Manchester."

INSTITUTION OF THE RUBBER INDUSTRY.—*Midland* Section: Monday, December 10, 6.45 p.m., James Watt Memorial Institute, Birmingham. Three short papers on "Tyres and the M.I.R.A. Proving Ground."

ASSOCIATION OF SUPERVISING ELECTRICAL ENGINEERS.—*Central London Branch:* Monday, December 10, 7 p.m., St. Ermin's Hotel, Caxton-street, S.W.1. "Air Conditioning," by Mr. H. G. Y. Green. *Coventry Branch:* Wednesday, December 12, 7.15 p.m., Technical College, Coventry. "Earthing," by Mr. P. W. Cave.

ILLUMINATING ENGINEERING SOCIETY.—*Leeds Centre:* Monday, December 10, 7 p.m., 24, Aire-street, Leeds, 1. Discussion on "Architecture and Lighting." *London:* Tuesday, December 11, 6 p.m., Lighting Service Bureau, 2, Savoy-hill, W.C.2. "Dark Adaptation," by Mr. W. J. W. Ferguson. *Manchester Centre:* Thursday, December 13, 6 p.m., Town Hall Extension, Manchester. "Brightness Engineering," by Mr. W. Robinson. *Leicester Centre:* Thursday, December 13, 6.30 p.m., Offices of East Midlands Electricity Board, Charles-street, Leicester. "Lessons from the Festival About Lighting," by Mr. T. O. Freeth.

INSTITUTION OF WORKS MANAGERS.—*Northampton Branch:* Monday, December 10, 7.30 p.m., Franklins Gardens Hotel, Northampton. "Motion Study," by Miss A. G. Shaw. *Merseyside Branch:* Tuesday, December 11, 6.30 p.m., Adelphi Hotel, Liverpool. "The Profession of Management," by Mr. A. M. Hudson Davies. *Birmingham Branch:* Tuesday, December 11, 7 p.m., Grand Hotel, Birmingham. "A Works Engineer's Attitude to Works Responsibility," by Mr. L. R. Perkins.

INCORPORATED PLANT ENGINEERS.—*Dundee Branch:* Monday, December 10, 7.30 p.m., Mathers Hotel, Dundee. Address by Mr. H. E. Partridge. *Edinburgh Branch:* Tuesday, December 11, 7 p.m., 25, Charlotte-square, Edinburgh. "Fifty Years' Apprenticeship," by Mr. D. Frew. *East Midlands Branch:* Wednesday, December 12, 7 p.m., Welbeck Hotel, Nottingham. "Rocket Development," by Mr. J. Humphries.

INSTITUTE OF MARINE ENGINEERS.—Tuesday, December 11, 5.30 p.m., 85, The Minories, E.C.3. "Ductile Cast Iron," by Mr. M. M. Hallett. Thursday, December 13, 7.15 p.m., Technical College, Poplar High-street, E.14. "Welding in Ship-Repair Work," by Mr. J. W. Coulthard.

CHEMICAL ENGINEERING GROUP.—Tuesday, December 11, 5.30 p.m., Geological Society, Burlington House, Piccadilly, W.1. "Planning of Maintenance in Chemical Works," by Mr. H. Birchall.

INSTITUTION OF SANITARY ENGINEERS.—Tuesday, December 11, 5.30 p.m., Caxton Hall, Victoria-street, S.W.1. "One-Pipe Plumbing: Some Experimental Hydraulics at the Building Research Station," by Mr. A. F. E. Wise. (Adjourned from November 22.)

INSTITUTION OF MECHANICAL ENGINEERS.—*South Wales Branch:* Tuesday, December 11, 6 p.m., Mackworth Hotel, Swansea; and Wednesday, December 12, 6 p.m., King's Head Hotel, Newport, Mon. "Continuous Gauge Control in Sheet- and Strip-Rolling," by Mr. W. C. F. Hessenberg and Mr. R. B. Sims. *Southern Branch:* Wednesday, December 12, 7 p.m., University College, Southampton. "Thirty Years' Development of Opposed-Piston Propelling Machinery," by Mr. W. H. Purdie. *Yorkshire Branch:* Thursday, December 13, 7 p.m., The University, Leeds. "Theory and Practice in Bearing Design," by Professor D. G. Christopherson. *Institution (Hydraulics Group):* Friday, December 14, 5.30 p.m., Storey's-gate, St. James's Park, S.W.1. "Problems of Fluids for Hydraulic-Power Transmission," by Mr. A. E. Bingham; and "Low-Pressure Reciprocating Seals for Hydraulic Control Valves," by Mr. B. Cooke. AUTOMOBILE DIVISION.—*Luton Centre:* Monday, December 10, 7.15 p.m., Town Hall, Luton. "Life Assessment Methods for Trucks, Vans and 'Buses," by Mr. J. H. Alden. *Institution:* Tuesday, December 11, 5.30 p.m., Storey's-gate, S.W.1. "Trailers and Semi-Trailers," by Mr. A. Marenbon.

INSTITUTE OF FUEL.—*North-Western Section:* Wednesday, December 12, 2 p.m., Engineers' Club, Manchester. "Domestic Heating Research," by Dr. A. C. Monkhouse (Luncheon, 1 p.m.) *Scottish Section:* Friday, December 14, 7 p.m., Royal Technical College, Glasgow, "Fuels Derived from Coal Tar," by Dr. D. McNeil.

INSTITUTE OF PETROLEUM.—Wednesday, December 12, 5.30 p.m., 26, Portland-place, W.1. "Pre-Flame Reactions in Diesel Engines," by Professor F. H. Garner and others.

LIVERPOOL ENGINEERING SOCIETY.—Wednesday, December 12, 6 p.m., 9, The Temple, 24, Dale-street, Liverpool. "Liverpool Overhead Railway," by Mr. H. M. Rostron.

SOCIETY OF CHEMICAL INDUSTRY.—*Road and Building Materials Group:* Wednesday, December 12, 6 p.m., 11, Upper Belgrave-street, S.W.1. "Thermo-Plastic Floor Tiles," by Mr. L. H. Griffiths and Mr. W. Saul.

INSTITUTION OF STRUCTURAL ENGINEERS.—*Yorkshire Branch:* Wednesday, December 12, 6.30 p.m., Great Northern Hotel, Leeds. "New House of Commons: Foundations and Structure," by Mr. S. Vaughan. *Institution:* Thursday, December 13, 6 p.m., 11, Upper Belgrave-street, S.W.1. Joint Meeting with the SOCIÉTÉ DES INGÉNIEURS CIVILS DE FRANCE (BRITISH SECTION). "Temple Barrage on the River Lot," by Mr. L. P. Brice.

INSTITUTE OF BRITISH FOUNDRYMEN.—*Lancashire Branch:* Wednesday, December 12, 7 p.m., Engineers' Club, Manchester. "Castings for the Smithy and Forge Industry," by Mr. W. S. Spenceley. *London Branch:* Wednesday, December 12, 7 p.m., Waldorf Hotel, Aldwych, W.C.2. "Aluminium-Alloy Castings," by Mr. A. P. Fenn. *Bristol Branch:* Saturday, December 15, 3 p.m., Grand Hotel, Bristol. "Runner Practice in a Jobbing Foundry," by Mr. H. B. Farmer.

INSTITUTION OF HEATING AND VENTILATING ENGINEERS.—*Yorkshire Branch:* Wednesday, December 12, 7.30 p.m., Hotel Metropole, Leeds. Discussion on "Steam Utilisation in the Textile Industry."

DIESEL ENGINE USERS ASSOCIATION.—Thursday, December 13, 2.30 p.m., Caxton Hall, Victoria-street, S.W.1. "Report on Heavy-Oil Engine Working Costs, 1949-50."

INSTITUTION OF CIVIL ENGINEERS.—*Midlands Association:* Thursday, December 13, 6 p.m., James Watt Memorial Institute, Birmingham. "Electro-Chemical Hardening of Clays to Increase Bearing Capacity of Piles," by Dr. J. Kolbuszewski. *Yorkshire Association:* Friday, December 14, 7 p.m., Royal Victoria Station Hotel, Sheffield. "The Rapid Calculation of the Plastic Collapse Load for a Framed Structure," by Dr. B. G. Neal.

JUNIOR INSTITUTION OF ENGINEERS.—Friday, December 14, 7.30 p.m., Royal Society of Arts, John Adam-street, W.C.2. Presidential Address on "Enterprise in Engineering," by Air Commodore F. R. Banks.

## PERSONAL.

ON his appointment as Lord-in-Waiting, LORD LLOYD has resigned from the board of Horseley Bridge and Thomas Piggott, Ltd., Tipton, Staffordshire.

EARL DE LA WARR has resigned his directorship of the main board of the Brush Electrical Engineering Co., Ltd., on his appointment as Postmaster-General. MR. I. T. MORROW has been appointed to the board of the Brush Co. and will act as financial controller of the Brush-Aboe Group.

SIR DAVID BRUNT, M.A., Sc.D., F.R.S., Professor of Meteorology in the University of London, has been appointed to the board of directors of the Fulmer Research Institute, Stoke Poges, Buckinghamshire.

MR. E. C. COOKSON, A.C.G.I., B.Sc. (Eng.) (Lond.), M.I.C.E., M.I.T., has been appointed assistant civil engineer, British Railways, Western Region. Since 1945 he has been assistant engineer, permanent way.

MR. M. H. L. LEWIS, M.A. (Oxon.), has been co-opted to the board of executive directors of Crompton Parkinson Ltd., Crompton House, Aldwych, London, W.C.2, for a period of six months. Since April, 1950, Mr. Lewis has been assistant to the works director (south).

MR. JOHN LONG, formerly assistant manager of the London office of Head, Wrightson & Co., Ltd., has been appointed London manager in succession to MR. SELBY ROBSON. Mr. Robson remains a director of the firm and of Head Wrightson Processes, Ltd.

MR. JAMES GRANT has been appointed manager of the Shell Haven refinery, Essex, of the Shell Petroleum Co., Ltd., St. Helen's-court, Great St. Helen's, London, E.C.3. For the past year he has been assistant manager of the firm's refinery at Stanlow, Cheshire. MR. R. W. J. SMITH, whom Mr. Grant succeeds, has returned to a head office appointment in London. Mr. J. L. FLANAGAN, manager of the fuel-oil general department of the Shell Petroleum Co., Ltd., is retiring under the age limit on December 31. He will be succeeded by his deputy, MR. D. B. VALE, O.B.E.

MR. PHILIP SHEPHARD has been elected vice-chairman of the Automobile Association, Fanum House, New Coventry-street, London, W.1, in succession to the late SIR PEIRSON FRANK, and MR. HUGH FRASER, J.P., honorary treasurer, to fill the vacancy caused by the death of MR. GEORGE MONRO.

MR. C. F. MONTGOMERY has been appointed general works manager of the Weybridge factory of Remington Rand Ltd., Commonwealth House, 1-19, New Oxford-street, London, W.C.1.

MR. W. S. BATES, secretary of Philip & Son, Ltd., shipbuilders, Sandquay and Noss Engineering Works, Dartmouth, has been elected a director. Mr. Bates has been with the company for nearly 26 years.

MR. A. HATTERSLEY, who founded the steel firm of Hattersley and Ridge, Ltd., Sheffield, now merged with the Neepsend Steel and Tool Corporation, Ltd., has relinquished his seat on the board of the latter company to undertake consultative duties for a steel firm in Johannesburg, South Africa.

MR. J. C. CAMPBELL, chief London representative of Keith Blackman Ltd., Mill Mead-road, Tottenham, London, N.17, has retired after 50 years of service. His successor is MR. D. J. AULD.

MR. F. BURGGRAF, formerly associate director of the Highway Research Board, Washington, District of Columbia, U.S.A., has been appointed director in succession to the late MR. R. W. CRUM.

STEEL NUT AND JOSEPH HAMPTON, LTD., Woden Works, All Saints-road, King's Hill, Wednesbury, have acquired the plane and spokeshave business of the W. S. MANUFACTURING CO., LTD., Sheepcote-street, Birmingham, 15.

GLOVER AND MAIN LTD., have announced the formation of a new subsidiary company, MAIN REFRIGERATION LTD. The first directors are MR. P. D. M. AIRD, MR. F. DUNN and MR. C. MARLEY.

THE FAIREY AVIATION CO., LTD., Hayes, Middlesex, announce that the name of their Australian subsidiary concern has been changed to FAIREY AVIATION CO. OF AUSTRALASIA PTY., LTD. The postal address, namely, Box 41, P.O. Bankstown, New South Wales, is unchanged. An office at: 4th Floor, Royal Insurance Building, 414-418, Collins-street, Melbourne, Victoria, has been established with Mr. E. C. Turner as company liaison representative.

FINA PETROLEUM PRODUCTS LTD., have now removed from their Mayfair address to 25, Victoria-street (South Block), London, S.W.1. (Telephone: ABBey 7822.)

ALFRED HERBERT LTD., Coventry, have acquired a controlling interest in the Sigma Instrument Co., Ltd., Letchworth, for which they are the sole selling agents in this country. The Sigma Instrument Co. are specialists in the manufacture of gauging instruments.

# THE YOKER WORKS OF BULL'S METAL AND MELLOID COMPANY, LIMITED.

(*For Description, see Page* 717.)

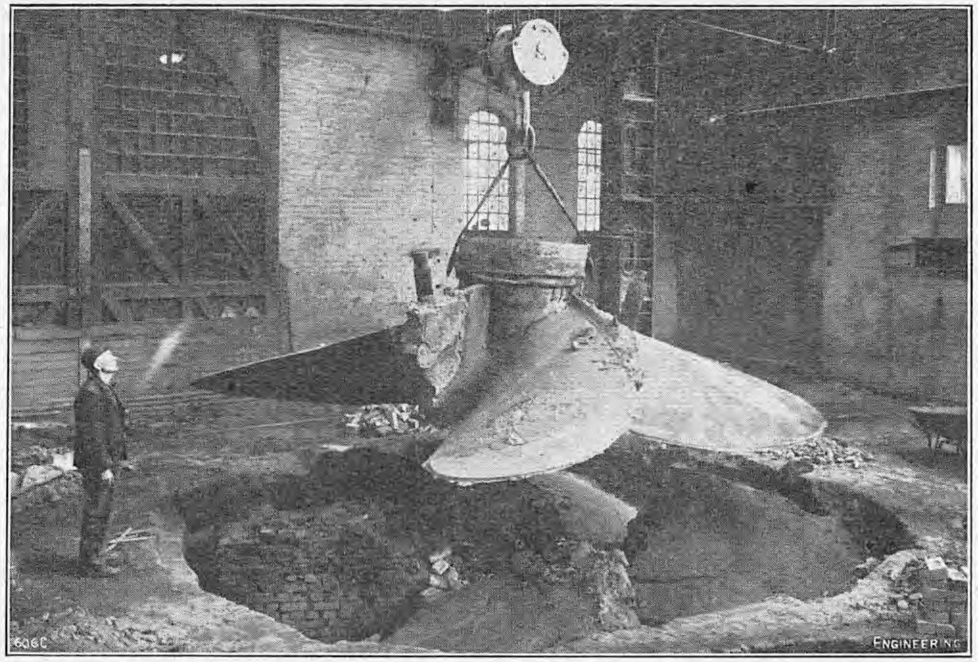



Fig. 3. Newly-Cast Propeller for M.V. "Middlese."

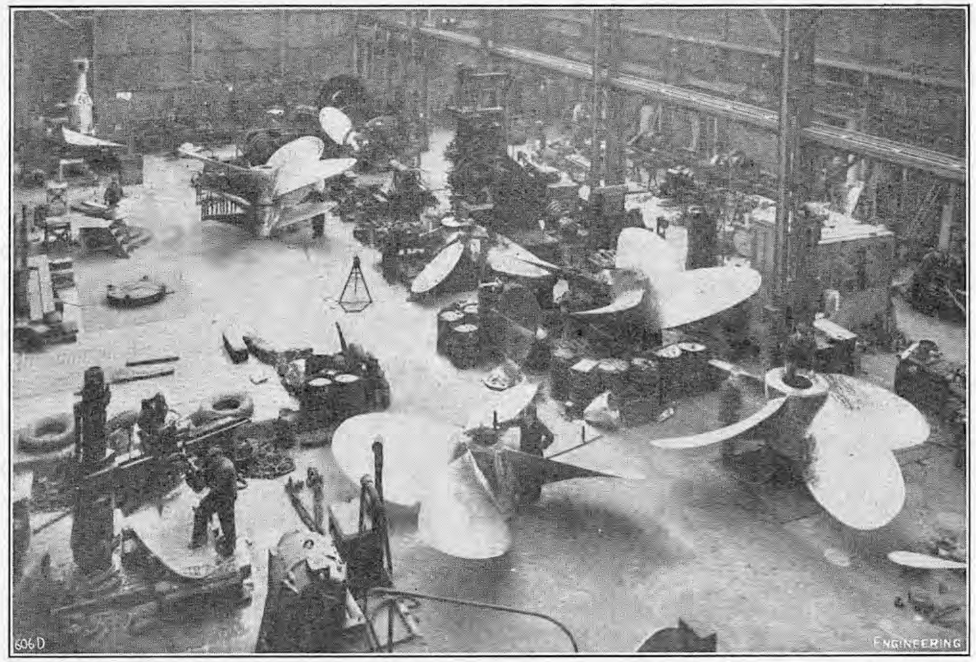



Fig. 4. Machine Shop for Propellers.

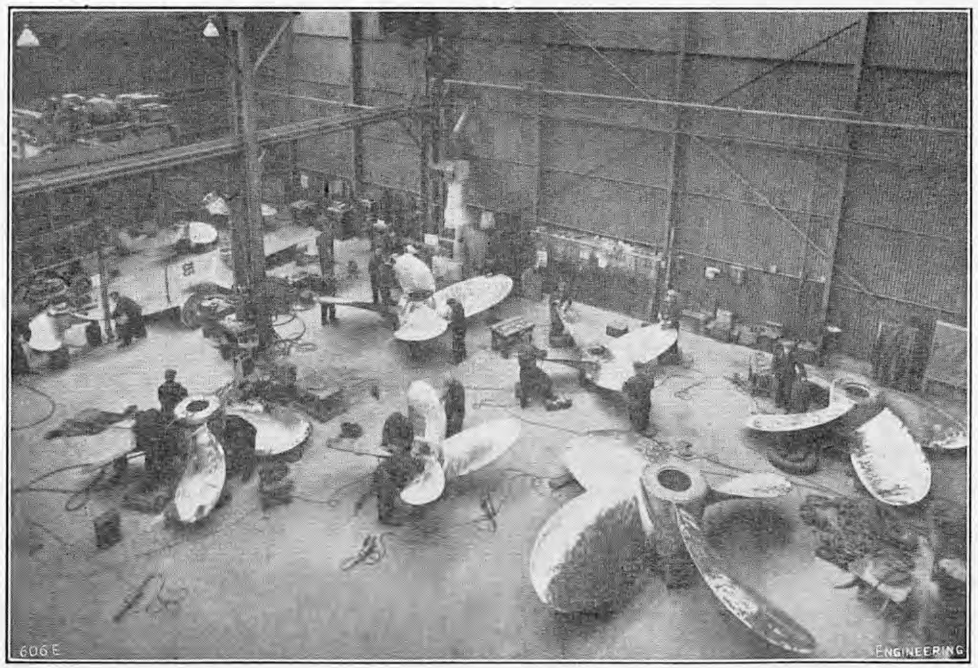



Fig. 5. Propeller-Finishing Shop.

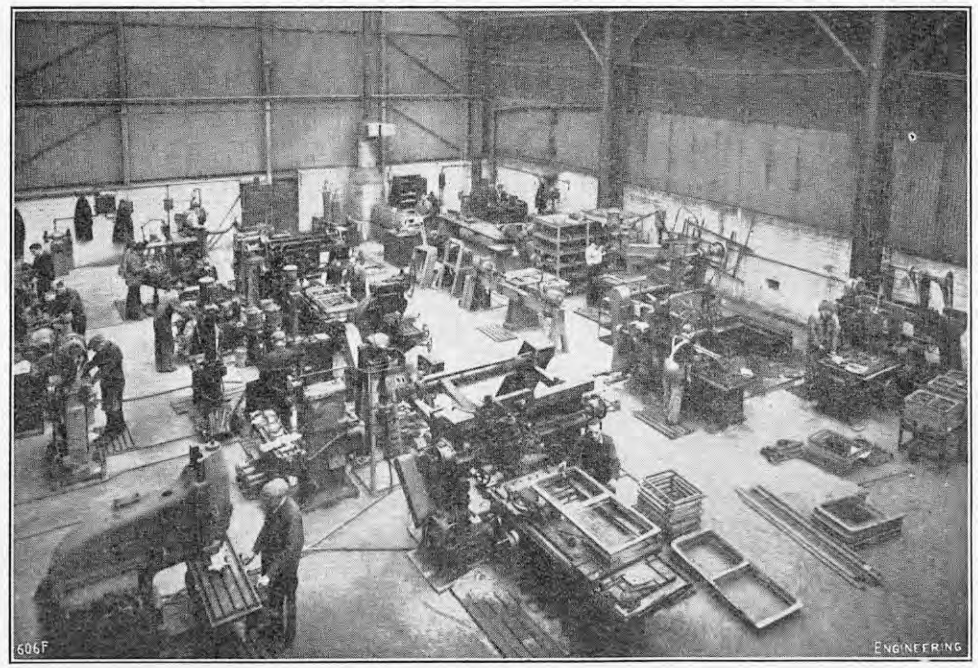



Fig. 6. Machine Shop for Ship Windows.

# ENGINEERING,

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# ENGINEERING

*FRIDAY, DECEMBER* 7, 1951.

VOL. 172. No. 4480.


## WORK CONSCIOUSNESS.

THERE is no obvious direct connection between the two books of which particulars are given at the foot of this column*; the indirect connection, however, is of some importance. It is remarked at the beginning of Chapter I of the first of these publications that the majority of the people in Great Britain "enjoy good food, are well clothed, and live in comfortable houses or flats. They have come to regard these benefits as theirs by right . . . and few of them see anything remarkable in the standard of living they enjoy." This is unfortunately true, but how long the people of this country will be able to enjoy their present standard of living if they adhere to their present standard of application is another matter. A standard largely based on the charity of the people of North America, together with a process of running into debt, is not likely to endure indefinitely.

These remarks may, perhaps, give an incorrect idea of the nature of the book. It is not concerned with an examination of the financial state of the country; its purpose is to give some account of the complex industrial activity on which that state is based. In view, however, of its opening remarks, it is apparently hoped that a fuller knowledge of the material facts of the situation by the "majority" may do something towards encouraging a better realisation of the part which, individually and in the mass, that majority must play if its present standard is to be preserved; because, as the same opening paragraph continues, the present standard "really is remarkable, for it means that they are getting at least three times as much wealth from the country as Nature could normally provide, and the increase is due entirely to human ingenuity."

Much has been written and said about the lessons contained in the various reports of the Anglo-American productivity teams. It is probably not specifically stated in any of them, but a general impression given is that one reason why American workpeople take so keen an interest in the fortunes of the firm for which they work is that they have a general understanding of the part which its activities play not only in their own well-being, but in that of the country as a whole. It has been said that American workmen apply the whole of their interest and ability to forwarding the manufacturing efficiency of their firm because each man hopes that some day he will be the manager. This is, no doubt, an exaggeration, but the active and practical interest which a very large proportion take in industrial efficiency, and in the problems of manufacture, is shown by the considerable numbers who, frequently at considerable personal sacrifice, manage to get a college education. Many who set out with the object of obtaining a degree or diploma fall by the way, but large numbers succeed. The standard attained is in the majority of cases not high, possibly not equal to the standard of the Higher National Certificate, but the academic level reached is sufficiently high to impart an understanding of manufacturing and industrial problems very different from that possessed by the average workman in this country.

It will be understood that these remarks about college education have no reference to the great United States universities of international reputation. In addition to these, however, there are in that vast country hundreds of colleges, technical and otherwise, of varied status and it is in these that the enlightened workpeople here referred to are educated. If in some way the workpeople of Great Britain could be given a more instructed appreciation of the real problems of industry, they might be more willing to co-operate in endeavours to solve them. *The Wonderful Story of British Industry* is a contribution towards the engendering of such an understanding. It recounts the origin of the great manufacturing industries, explains their geographical distribution and gives some account of their operation and techniques. The descriptions are clear and straightforward, with none of the rather wearisome facetiousness which so frequently appears to be considered necessary in the popular treatment of serious subjects.

Although perusal of this book might give almost any working man a better understanding of the operations of the firm by whom he is employed, and possibly a better appreciation of their aims and difficulties, it would be wild optimism to suppose that it will be read by any considerable fraction of the workpeople of this country. It is possible, however, that if it were made available in school and technical-college libraries, it might usefully influence some members of the younger generation, in whose hands the future of industry and of the country lies. These remarks may appear to credit this book with a higher importance than, perhaps, its authors would claim. It is far from being the only example of its class, but it is a good example. The point that it is being used to illustrate is that any method which can be used to give workpeople a more intelligent interest in their own work should do something towards increasing their willingness to employ any methods by which the efficiency of performance of that work may be improved.

It is in connection with the remark that the book would be a useful addition to the shelves of school and technical-college libraries that the second book which has been mentioned has a bearing on this

* *The Wonderful Story of British Industry: A Record of the Enterprise, Skill and Invention of the British People.* Ward, Lock and Company, Limited, 6, Chancery-lane, London, W.C.2. [Price 15*s*. net.] *The Young Wage-earner: A Study of Glasgow Boys.* By Professor T. Ferguson and J. Cunnison. Published for the Nuffield Foundation by Geoffrey Cumberlege, Oxford University Press, Amen Corner, London, E.C.4. [Price 8*s*. 6*d*. net.]

matter. *The Young Wage-Earner* is a report upon a study of the careers, over three years, of 1,349 Glasgow working-class boys who left school at the age of 14 in January, 1947. The report enters into considerable detail, has much to say about the influence of housing conditions, size of families, loss of one or more parents and other matters, on the performance of the boys in industrial life. Particulars are given about leisure-time activities, church-going, sickness, delinquency and other determining factors. All these matters are of social importance and the report upon them deserves careful study, but they are not germane to the subject of this article nor, indeed, to the professional interests of this journal.

There are, however, other aspects of the report which do bear on the present subject. Naturally, contact was lost with some of the 1,349 boys who originally formed the basis of the investigation, but of 1,127 cases of which full particulars were gathered, although only 283 were the sons of skilled tradesmen, no fewer than 541 were engaged in skilled trades or training for them. Of the boys whose fathers were in skilled trades, 51·6 per cent. were themselves employed in skilled trades; of those with fathers in semi-skilled trades, 49·4 per cent.; and of those with fathers in unskilled trades, 44·7 per cent. The report makes some reservations about the meaning of the expression "skilled trade" as it is used here. It does not necessarily mean that a boy was serving an apprenticeship, as some boys described themselves as apprentices when actually they were not so. Further, the term "skilled tradesman" as used in the report must not, in all cases, be understood to mean a craftsman. Precisely what definition of a skilled tradesman is adopted is not clear, but, whatever it is, it applies equally to fathers and sons.

It is satisfactory to learn that in this fairly large sample, taken in an industrial city, a considerably larger number of boys than of their fathers were engaged in skilled trades, especially in view of the statement that the main consideration dictating the choice of a skilled trade "was the interest of the work; even the level of wages was for most a subordinate consideration." Boys who entered unskilled or dead-end jobs usually obtained higher wages in the early years. In view of the shortage of skilled workers in the country, it is gratifying to find that so large a proportion of the boys chose to enter skilled trades because of interest in the work, and it is clear that the boys should receive every encouragement and assistance that is possible.

There is, however, another side to the picture, indicating a direction in which there is considerable room for improvement. Only 12·6 per cent. of all the boys attended evening classes during the whole of the period studied, 5 per cent. attended at first but gave up before the end, and 10 per cent. started late. No list of occupations is given in the report, but as the investigation took place in Glasgow, it may be assumed that a fair proportion of the boys were engaged in some branch of engineering. Many engineering firms arrange for their trade apprentices to attend technical classes during the day time and such attendance would, presumably, not be entered as evening-class work, so that the proportion receiving technical education may have been higher than 12·6 per cent. The encouragement boys receive to improve their knowledge of the industry in which they are employed must mainly come from those who employ them. Boys who have the type of ambition which seems to be common among American workmen will probably look after themselves, but for many some assistance in school days by direction to suitable reading and possibly some guidance from Juvenile Employment Committees might do something towards building up a shop staff possessing a truer appreciation of the effect of its own activities on the fortunes of the nation. The report indicates that the raw material for such a staff is not lacking.

# ACCIDENTS ON RAILWAYS.

THOUGH the accident rate on British Railways is low—the chance of fatality is equivalent to 0·7 person per million train miles—the drain on the national effort due to accidents, at a time when every possible man-hour of work must be utilised, has led Colonel G. R. S. Wilson to suggest that the Railway Executive might have to consider setting up a special safety organisation such as the American railways have found advantageous. Not that the Executive, or, indeed, the National Union of Railwaymen, have been idle in the matter, but "the static character of the [accident] figures seems to suggest that a fresh line of approach may be required to achieve the considerable reduction which is so desirable from all points of view." In workshops generally, as on the railways, men often break rules that have been framed solely for their safety. It is difficult to eradicate the attitude to safety regulations which seems to be the cause of this unthinking disregard—an attitude that is probably based on the idea that a man is more of a man who shows a certain readiness to take risks. If that idea is a by-product of the primitive—and therefore dominant—instinct to physical bravery, any special safety organisation must pierce this psychological barrier.

In his annual report* for the year 1950, Colonel Wilson stresses the point that the number of accidents to railwaymen is still too high, "when it is considered that most of the accidents are avoidable if only the men themselves could be prevailed upon to exercise more care and to observe rules which are designed solely for their own safety." Nevertheless, for the first time since 1947 there was a decline in the proportion of train accidents which were attributable primarily to the failure of the human element; 44·8 per cent. of train accidents were in this category in 1950, compared with 50·5 per cent. in 1949.

Improvements in rolling-stock design and construction have helped to reduce accidents. The number of tyre failures was down from 56 in 1949 to 23 in 1950; the number of failures of coupling apparatus from 3,462 to 3,026; and the total failures of rolling stock and permanent way from 4,062 to 3,609—mainly due to the reduction in coupling failures as old and obsolete wagons are withdrawn, mostly from the private owners' fleet. The number of axle failures, however, rose from 39 to 51. Most of these were wagon axles; for carriages, a supersonic method of testing for wheel-seat flaws was brought into general use during 1947 and 1948, and the success achieved is shown by the figures for broken carriage axles: five in 1946, eight in 1947, two in 1948, one in 1949, and two in 1950. The repair position in respect of locomotives and carriages was generally good, since there was a margin in the stock of locomotives and more carriages were available for traffic than in the previous year. New wagon construction, however, was unable to keep pace with the expanding volume of freight traffic, and though there was a marked improvement in the repair position the scrapping programme had to be drastically curtailed during the later part of the year. Two serious fires in passenger trains have led to a full inquiry and remedial action is being taken.

The British Transport Commission have accepted the wider extension of automatic train control as an ideal to aim at, and a large-scale experiment with an improved non-contact apparatus is being continued on the East Coast main line between Barnet and Huntingdon. The new equipment is intended to combine the advantages of the former Great Western Railway's footplate indications with those of the more modern magnetic link between the track and the engine which was developed by the London Midland and Scottish Railway.

The shortage of labour for track maintenance is causing concern, and though every effort is being made to overcome the difficulty by extending the use of mechanical equipment and by maintenance contracts with outside firms, it is becoming increasingly difficult to keep the track everywhere in fit condition for ordinary fast running, let alone restore it to the very high pre-war standards of line, level and stability. Safety has therefore to be maintained by local speed restrictions, the number of which, on main lines, rose from 24 at the beginning of 1950 to 60 at the end of the year. Even so, derailments attributable to track defects increased from 34 in 1949 to 44 in 1950. In an accident at Tollerton, where the engine and four coaches of an express passenger train were derailed, the ganger had failed to take all the necessary hot-weather precautions, and this factor, combined with a shortage of ballast, caused distortion of the track. Research is being undertaken into the holding power of various types of ballast, and special attention is being given to the several factors which affect the free expansion of rails in fishplates.

Two matters on the civil-engineering side which raise wide issues are the unsatisfactory nature of "occupation" level-crossings and the inadequacy, for modern road traffic, of many railway over-bridges. According to Colonel Wilson, the whole conception of occupation crossings has been reviewed by the British Transport Commission at the request of the Minister of Transport and their report is now under consideration. "Consultation with many other authorities will be required," he states, "but the problem is urgent and, in the interest of safety of road and rail users alike, its solution should not be delayed." On the question of weak over-bridges, Colonel Wilson says there are still many such bridges which require costly reconstruction or strengthening to carry modern road traffic, and he draws attention to the accidents that can occur if road hauliers fail to observe the provisions of the Motor Vehicles (Authorisations of Special Types) Order, 1941.

Apart from the technical features which have been mentioned, however, the principal obstacle to improved safety, which is reiterated several times in the report, is the shortage of labour. At the end of the year, there were nearly 7,000 vacancies in the relaying and length-maintenance gangs, or approximately 13 per cent. of their total establishment, and many length gangs were at less than half strength. It is also becoming more difficult to obtain recruits for service as signalmen. Colonel Wilson states that the pride of profession which plays a large part in the traditional outlook of signalmen is still much in evidence, but that, at the same time, as much as possible should be done to lighten their task and improve safety by modernising equipment. Unfortunately, the earlier plans of the Railway Executive to accelerate the provision of track circuiting and block controls have been retarded by financial stringency, but the question is again being examined, following a serious accident at Penmaenmawr.

Though Colonel Wilson would no doubt be the last to mention it, the vigilance of the inspecting officers of railways has long been one of the most potent factors in preventing and reducing accidents. The co-operation of expert but independent inspectors is valued by the railways, and their recommendations are carefully examined. The total number of persons killed in the working of railways in 1950 was 316, and the total injured was 27,016. These figures were lower than the averages for 1946-50, but they are still far too high; in the national interest it would be worth quite a considerable expenditure on a "special safety organisation" to reduce them.

* *Report to the Minister of Transport upon the Accidents which occurred on the Railways of Great Britain during the year* 1950. H.M. Stationery Office. [Price 2s. net.]

# NOTES.

### FIFTY YEARS OF RADIO COMMUNICATION.

THE 50th anniversary of Marconi's first transmission of radio signals across the Atlantic occurs on Wednesday, December 12. The story of this successful attempt to pass intelligence electromagnetically over so great a distance, after it had been predicted mathematically that the limit was 165 miles, has often been told. It may be recalled, however, that the transmitter was erected at Poldhu in Cornwall, where current from a 25-kW 50-cycle alternator was supplied at 2,000 volts to two transformers with a ratio of 1 to 10, which were connected in parallel. The output of these transformers was passed through high-frequency chokes to a closed oscillatory circuit, in which a condenser discharged across a spark gap through the primary of a high-frequency transformer. The secondary of this transformer was in turn connected across a second spark gap and condenser to the primary of a second high-frequency transformer. The secondary winding of the latter transformer was in series with the aerial, which consisted of a fan-shaped array suspended between two 150-ft. masts at 1-m. intervals. It is estimated that the fundamental wavelength of the signal emitted from this station, the design of which was due to J. A. Fleming, was between 1,000 and 2,000 m. An associated receiving station was established at Signal Hill, St. John's, Newfoundland; and it was here that the pre-arranged signal, which Poldhu had been instructed to transmit, was received by a self-restoring coherer which was connected in series with a telephone ear-piece and an aerial consisting of a 400-ft. wire suspended from a kite. As the rise and fall of the kite in the wind varied the capacity of the aerial the use of any of the types of syntonic receiving apparatus then available was precluded. Experiments were continued for the next twelve months, using a more powerful station at Glace Bay in Canada for transmitting and Poldhu for reception. Both these stations were afterwards used for transmitting telegraph news to ships, while in 1920 Poldhu was, for the first time, employed for telephonic transmission. The station was finally closed down for public purposes two years later, although it was later notable as the place where Franklin carried out his researches on directional short-wave transmission. Poldhu was finally dismantled in 1938. Its site is now marked by a granite column commemorating the two important events with which it has been associated; and the surrounding land with the cliffs and foreshore was presented to the National Trust in 1937 by Marconi's Wireless Telegraph Company.

### THE INSTITUTION OF MECHANICAL ENGINEERS.

"Cup-Drawing from a Flat Blank" was the subject of a paper by Dr. S. Y. Chung, B.Sc. (Eng.), A.M.I.Mech.E., and Professor H. W. Swift, M.A., D.Sc. (Eng.), M.I.Mech.E., which was presented by Professor Swift at a meeting of the Institution of Mechanical Engineers on Friday, November 30. At the University of Sheffield, the authors took experimental measurements covering a wide range of conditions—between 500 and 900 measurements were made on each cup drawn—using a 50-ton single-action crank-press of the double-sided type, and a 4-in. cup-drawing apparatus based on an industrial single-action tool. Seven punch heads were used, with a profile radius varying from $\frac{1}{8}$ in. to 2 in.; also seven die rings with profile radii from $\frac{1}{16}$ in. to $\frac{5}{8}$ in. Both pressure blank-holding and clearance blank-holding were used, in conjunction with circular flat blanks, which were drawn into cylindrical cups. The blanks were nominally 0·039 in. thick and frequently, but not always, 8 in. in diameter. The first part of the paper, on the experimental investigation, dealt with the influence of various factors on the forces and strains involved in drawing. With pressure blank-holding, it was found that wrinkling was severe for blank-holding forces below 5,000 lb., but absent above 10,000 lb. Below 8,000 lb. the maximum punch load increased rapidly, but above this value it remained almost unchanged and the quality of the cup was visually perfect. It was concluded that forces from 10,500 lb. for 7-in. blanks to 15,500 lb. for 8-in. blanks were suitable; with clearance blank-holding a positive clearance of 0·002 in. was suitable. On investigating the effect of drawing ratio, it was found that the radial strain during drawing might exceed 70 per cent., while the material might thicken at the rim by over 30 per cent. and thin near the base by nearly 25 per cent. At high drawing ratios the necking at a zone around the profile radius of the punch developed rapidly, and, since fracture commonly occurred at this neck, it delimited quite sharply the range of successful drawing. The die profile radius had a greater effect on the punch load with smaller drawing ratios, but its effect on the process work was greater with large ratios. Die profile affected the practical problem of success or failure in drawing; for a given blank diameter there was a specific radius below which failure was inevitable. The designer was justified in his common assumption that the surface area of the drawn cup was effectively the same as that of the initial blank. With a large punch profile radius the necking at the zone between the cylindrical wall and the radius to the base was less marked; also, there was little thinning due to bending, but a more general thinning over the base. Failure at the base due to biaxial stress was of primary importance and was under investigation. With regard to the effect of radial clearance between the punch and die throat, the maximum punch load and the process work both fell somewhat as the clearance was increased; a net clearance of about 30 per cent. was suitable for general purposes with free drawing and a reduction of, say, 50 per cent. The authors, at the end of the first part, gave a simple empirical punch-load formula. In the second part of the paper, they treated the problem analytically, considering first the instantaneous distribution of stress at a representative stage in drawing, and then the development of strain in a particular element of metal during its passage through the die. There was good agreement between the analytical and experimental treatments. The computation involved in applying the theory was complicated and not recommended for general use, but it might be possible to develop a fairly simple set of tables and formulæ for press and tool designers.

### SYMPOSIUM ON NOTCH-BAR TESTING.

On page 670 *ante*, we gave a programme of a symposium on "Recent Developments in the Notch-Bar Testing of Materials and their Relation to Welded Construction," arranged by the Joint Committee on Materials and their Testing of Technical Institutions and Societies in Great Britain, and the Institute of Welding. The meeting was held at the Institution of Civil Engineers, London, and Mr. Howard J. Thompson, President of the Institute of Welding, should have occupied the chair. In his unavoidable absence, however, it was taken by Dr. E. C. Rollason, who has been Professor of Metallurgy at the University of Liverpool for some two months, having taken over the post as from October 1 this year. In the course of his opening remarks, Professor Rollason stated that the Joint Committee was made up of representatives from 26 institutions and learned societies in Great Britain and that meetings such as that taking place were organised at intervals. The last of these meetings had been held in 1950, when the subject for discussion had been prestressed concrete. Notch-bar testing had last been discussed at a meeting of the Joint Committee held in Manchester in 1937. Since that time much research on the subject of impact testing had been carried out and it was to review this work that the present meeting was being held. It is of interest to note that the Manchester meeting of October 29, 1937, which was fully reported in our columns at the time, was the first meeting to be held under the auspices of the then newly-formed Joint Committee. At the recent London meeting, papers by Mr. W. Barr and Mr. I. M. Mackenzie, on "Notch-Bar Testing and the Selection of Steel for Welded Construction"; by Mr. G. M. Boyd, on "The Assessment of Notch Ductility by a Variety of Notch Tests"; and by Professor W. Soete, of the University of Ghent, on "The State of Stress and Brittle Fracture," were discussed at the morning session, and two papers, namely, "Notch-Bar Tests in Relation to Service Performance," by Mrs. C. F. Tipper, Sc.D., and "Developments of a Testing Method on Brittle Fracture of Mild-Steel Plates," by Dr. J. H. van der Veen, of Ijmuiden, Holland, were discussed at the afternoon session. All the papers were presented by Dr. N. P. Allen as *rapporteur*.

### THE POWER STATION PROGRAMME.

In reply to a question by Mr. G. D. N. Nabarro in the House of Commons on Monday, December 3, the Minister of Fuel and Power (Mr. Geoffrey Lloyd) said that the British Electricity Authority planned to commission 1,100 MW of generating plant this year and 1,250 MW in 1952. When allowance had been made for plant going out of service, this should give a net addition this year of over 1,000 MW and of about 1,100 MW in 1952. Shortages of raw materials and the needs of defence might prevent these totals being reached, but he hoped that at least 1,000 MW of new plant would be commissioned this year. During 1950, British Electricity power stations had consumed $31\frac{1}{2}$ million tons of coal and might consume 35 million tons in 1951 and 38 million tons in 1952, owing to the general increase in demand. This increase in consumption would, however, be less in proportion than the increase in electricity generated, owing to it being possible to use the more efficient plant for longer periods. For instance, a full year's working of 1,000 MW of new plant would give a net saving of about 300,000 tons of coal, while a full year's working of the 1,250 MW of plant planned for next year, together with 100 MW left over from last year, should give an additional net saving of about 500,000 tons. As, however, demand was increasing the only alternative to more and more load shedding was to continue to use the old power stations at peak periods. Thus, so long as the demand for electricity increased at its present rate, savings in coal produced by the introduction of new efficient stations, though great, were not sufficient to outweigh the increase in consumption to meet the extra demand.

### BRITISH RAILWAYS AND WINTER WEATHER.

British Railways have made extensive arrangements to deal with interruptions to traffic due to winter weather. Since 1949, about 1,000 colour-light signals and 250 miles of track-circuiting have been brought into use, so that there are now 6,000 signals of this type, which penetrate fog more effectively, and 6,500 miles of the main-line routes fitted with track-circuiting, which reduces delays and increases safety, especially when visibility is bad. The automatic train control system is in operation throughout the Western Region and on the London, Tilbury and Southend Section. A modified form, which can also be used on electrified lines, is now undergoing tests on the main line between Barnet and Huntingdon. For dealing with snow and ice, 800 flame guns and 600 steam lances, connected to the engine steam-heater pipe, as well as stocks of de-freezing compounds, have now been stationed at strategic points throughout British Railways. Some 550 snow ploughs for patrol work or clearing drifts up to 12 ft. deep are also available. Arrangements have been made with military authorities to assist in the event of a serious snow blockage in any part of the country. Lines of communication have been strengthened by the opening of seven new telephone exchanges and by improvements in the trunk-telephone network, including the extension of carrier-wave telephony which enables several conversations to take place simultaneously over the same line. British Railways have studied practice on foreign railways for any known method of overcoming fog, and the research and technical departments examine any and every development which appears to offer any solution, in part or whole. By arrangement with the Meteorological Office, 51 railway control centres are warned in advance when fog, snow or frost (and, in coastal areas, gales) are expected, so that arrangements can be made to meet these conditions; the number of meteorological stations co-operating in this scheme has recently been raised from 11 to 14. Winter working arrangements continue to be improved, but the Railway Executive point out that progress depends on the amount of capital expenditure and the permitted availability of materials and man-power.

# INTERNATIONAL CONFERENCE ON ABRASION AND WEAR.

(*Continued from page* 694.)

In last week's issue, we summarised Dr. F. P. Bowden's paper on "The Friction and Surface Damage of Non-Metallic Solids," which was the first to be presented at the International Conference on Abrasion and Wear, held in Delft, Holland, on November 14 and 15. We continue our report below, with an abridgment of the discussion on Dr. Bowden's address.

Dr. H. C. J. de Decker, who opened the discussion, said that Dr. Bowden's paper confirmed his own belief that the work done on metals was a good starting point for the study on non-metals, such as rubber. Dr. D. J. W. Kreulen, who followed, asked why it was that static friction was greater than kinetic friction. Mr. P. Braber, referring to Dr. Bowden's experiment with copper sliding on indium, asked whether this bore any relation to the conditions in a bearing in which steel was sliding on a soft metal, either with or without lubrication; and, if it were lubricated, what was the friction of the lubricant? Dr. A. Schallamach thought that the friction of rubber differed from that of all other materials because there was little abrasion; no transfer of material took place. Also, it did not obey the classic laws and the coefficient of friction was not constant. The friction of rubber on glass was akin to the resistance to viscous flow, with a high temperature coefficient.

Mr. J. M. Buist inquired whether all the compounding ingredients in rubber were to be regarded as impurities, especially if they "bloomed" up to the surface, as occurred with waxes, softeners, sulphur and certain anti-oxidants; and he asked how they affected the friction. Did the break between the surfaces occur at, say, the wax rubber interface? In his opinion, much more attention must be given to the surface films on rubber before an accurate scientific investigation of the problem could be made. Mr. P. Otto asked whether, to increase the friction of ropes over sheaves, the experiment had been tried of coating the sheave with a plastic.

Dr. W. Späth said that hardness determinations were still being made, as they had been for the past 50 years, by applying a static load once only; but, he maintained, they should be continued over a long period to give correct results. Progress in the dynamic testing of materials seemed to indicate that the simple static penetration test should be developed into a prolonged dynamic test; if this were done, questions of abrasive wear required consideration. He then proceeded to describe two forms of testing apparatus, namely, the "Rotatester," in which a flanged pressure roller ran on a ring-shaped test-piece, the energy consumed being indicated by a balance and the abrasion phenomena being observed with the aid of a flash stroboscope and a sterio-microscope; and the "Vibro-tester," in which a slowly-rotating chisel was driven into the specimen by dynamic pulses of the frequency of sound. The latter apparatus, he explained, was designed for the investigation of abrasive discs, grinding wheels, graphite collectors, coal, minerals, etc. At numerous spots, the penetration of the chisel was measured in microns (0·001 mm.) and curves of constant penetration were drawn, like the isobars on a weather chart. By applying small but frequent periodic changes of load, it was possible with this apparatus to imitate the practical conditions during grinding to a high degree of approximation. Dr. G. J. van der Bie said that, with rubber, both the plastic and the elastic phenomena must be taken into account. In rubber tyres, a high coefficient of friction was required, with the least possible abrasion; but vulcanised rubber had no plastic flow—only elastic deformation. As Dr. Schallamach had remarked, rubber did not behave like a plastic metal.

Dr. Bowden, replying to the discussion, said that, while static friction was not always higher than kinetic friction, it was usually so, as there was more time for the formation of junctions between the mating surfaces. The time factor was important. The variation in the coefficient of friction was small at low speeds, but there was a considerable rise of surface temperature at high speeds. Sliding on ice was not due to pressure-melting, as was often supposed, but to local heating; it was difficult to ski on very cold snow. In reply to Mr. Braber, he thought that the conditions between a steel shaft and a soft-metal bearing were similar to those in the copper-indium experiment; the contaminating films on the surface prevented adhesion from occurring. A lubricant, of course, was a still more effective contaminant. Acknowledging Dr. Schallamach's contribution, Dr. Bowden inquired how the coefficient of friction of rubber varied with load; to which Dr. Schallamach replied that it decreased with increasing normal load, as would be expected if the area of contact depended only on elastic deformation, but he was unable to say, from memory, whether the relation between friction and load obeyed Hertz's law.

Continuing his reply, Dr. Bowden agreed with Mr. Buist that the presence of compounding agents complicated enormously the friction of rubber; if a surface layer of wax was present, he would expect shearing to occur in that layer. The corresponding behaviour of metals was artificially simplified by the presence of the oxide film. In reply to Mr. Otto, he thought that a plastic layer on a sheave would be quickly worn off. A plastic coating on the rope should help, but he did not think it practicable to insert plastic strands. Dr. van der Bie had raised an important point in drawing attention to the fact that, with metals, the deformation of surface irregularities was plastic, but with rubber it was elastic; it was possible, however, to have friction without plastic deformation. All that was necessary was that the two surfaces should approach within the range of molecular attraction.

A vote of thanks having been accorded to Dr. Bowden by acclamation, Dr. de Decker called upon Professor H. Blok, of Delft, to present the second paper in the programme, which was entitled "War on Wear."

### THE PREVENTION OF WEAR.

The world's wealth being essentially accumulated by producing capital goods, Professor Blok premised, the waste involved by their wear had repercussions on the standard of living. The value of the material worn off was not as disturbing as the labour wasted; in the end, the conservation of energy (not so much friction, but labour) was more important than the conservation of material, though there were some sorts of wear that were desirable, e.g., in running-in new machinery. The types of wear might be classified according to the geometry of contact, the level of the contact temperature, or the morphology and topography of the damaged spots; and there were physical analogies between the phenomena of wear and those in related fields, such as machining, fatigue, fracture, size reduction, and welding. The general principles on which to combat wear between mating surfaces were, in the first place, to inhibit contact as completely as possible, i.e., by full fluid-film lubrication aided by design; secondly, to convert destructive into permissible wear, for example, in avoiding scuffing of piston rings when running-in, by promoting abrasive wear; and, thirdly, by concentrating the wear on the more easily replaceable surface, as occurred with bearing metals. Much had been achieved by co-ordinating the knowledge so far gained about the wear of metals, minerals, organic materials, and combinations of them; but it was not enough. Knowledge of wear was much less advanced than knowledge of corrosion or of structural strength and rigidity, but its importance was becoming steadily greater. A limit could be seen to world productivity, when the amount of capital equipment became so great that the rate of necessary replacement matched the total resources available for construction; though this limit was not likely to be reached, as improved means for reducing wear would undoubtedly result from increased knowledge. Users of wearing products could not always be adequately organised to finance research for the reduction of wear, and producers' commercial interests sometimes conflicted with a decrease of wear; but Government interest might be aroused if it could be shown that a diminishing need for depreciation allowances coincided with a positive increase in revenues. Certainly, the current amount of effort devoted to the study of wear was not commensurate with the magnitude of the problem.

Dr. R. Houwink opened the discussion by drawing attention to the fact that some of the least tough materials were the most resistant to abrasion. He instanced rubber and asphalt, suggesting that the reason why asphalt was so good was that, while it abraded readily, the particles removed were re-absorbed in the mass. Mr. E. de Meeus, the next speaker, emphasised the value of "useful" wear such as that of a non-slipping tyre tread, the cost of which was repaid in valuable service; though he admitted that decreased tread wear might have to be paid for, to some extent, in increased road wear. Mr. Braber said that Professor Blok had referred to the abrasive behaviour of a fluidised solid as being intermediate between "one-sided" and "double-sided" wear; and he asked what type of wear occurred in a catalytic cracking plant for petroleum, in which a fluidised catalyst was pneumatically transported in a closed circuit. Mr. P. Grodzinski mentioned, as an example of desirable abrasion, the production of gauges, which could only be produced by controlled abrasion. He suggested the desirability of standardising the nomenclature of wear and abrasion; for instance, it would be an advantage if a distinction could be made in the English language similar to the German *Verschleiss* and *Abnutzung*. Mr. Grodzinski also described some experiments which demonstrated that the resistance of diamond to abrasion depended on the direction of the rubbing action. He suggested also that, as it was impossible to simulate, in an abrasion or wear test, the actual conditions in practice—for instance, inside the cylinder of an internal-combustion engine—marks might be made on the surface of the components to be tested, and their rate of disappearance might be observed. Such marks might be made, even in the hardest materials, by an abrading process like that used in a micro-abrasion tester.

Professor Blok, in reply to the discussion, commented first on Dr. Houwink's reference to asphalt roads; these, he observed, contained a high proportion of broken stones, the bitumen serving as a binder. It was the stone surface, and not the bitumen surface, that carried the traffic. For the purpose of his paper, the word "wear" required rather strict definition; he did not agree with its use, for example, in connection with the phenomena of the fibrilisation and fracture of fibres—these "bulk-strength" phenomena related to the fibre as a structural entity, and not specifically to its surface. It might have been wise to substitute another term for the word "wear" in his paper; preferably, some term derived from Latin or Greek, and internationally acceptable. The word "abrasion" would not serve, because it connoted only the types of wear in which the surface material was removed; but "mechanical migratory surface-deterioration" (which conformed entirely to his own definition of wear) was too long-winded, especially when it was used in conjunction with such additional adjectives as "single-sided" or "double-sided," "abrasive" or "adhesive," etc. It seemed wise not to introduce such a contradiction in terms as "useful wear," even when wear was the price more or less gladly paid for achieving some desirable effect. The running-in of two mating surfaces would seem to present a border-line case. It would add to the current confusion if the finishing of gauges by means of abrasives were to be described as wear—i.e., as "abrasive wear"; an appropriate term for that process would be "abrasive finishing," which would stress its intentional and, therefore, desirable finishing. Otherwise, the way would be open for including, under the notion of wear, all other finishing and machining operations, such as cutting in a lathe. He would welcome any suggestions on wear terminology that others might care to submit, and asked that they should be addressed to the secretary of the International Conference on Abrasion and Wear, Post-box 66, Delft, Holland.

The foregoing paper concluded the proceedings on the morning of November 14. At the afternoon session, the first paper presented was that of Professor Ir. J. J. Broeze, the Director of Research of the Royal Dutch-Shell Laboratories at Delft, who dealt with "The Chemical Causes of Wear."

### Chemical Causes of Wear.

In comparison with earlier theories of mechanical wear, Professor Broeze observed, the understanding of chemical action as a factor in the wear of machine parts was a recent study; most practical cases which drew attention to it had arisen within the past 20 years or less, in connection with engine and automobile practice, where the general question of wear first ripened into a technical problem of considerable magnitude. The influence of the atmosphere was shown in dry-rubbing experiments by the dependence of the wear rate on the oxygen content and on the presence of other gas constituents. Atmospheric oxygen played a most important part in certain cases of wear, where there was only a small relative motion of the parts; initially, attention was drawn to the deterioration of roller bearings under stationary but vibratory conditions. A second class of cases comprised those in which the presence of corrosive substances as components of the lubricant led to attack of the rubbing parts, with subsequent removal of the corrosion product by shearing forces; for example, the corrosion of certain bearing metals by lubricating oils which had been made corrosive by excessive oxidation due to a combination of causes in the development of automobile and aviation engines, eventually counteracted by inhibiting oxidation of the lubricant. An entirely different case was that resulting from the adventitious presence of corrosive matter (acids or salt water) in the oil, which had led to serious corrosion in marine engines. A third case was the acceptance, under special conditions, of corrosion with attendant wear in gear lubrication, resulting from the use of additives intended to combat the scoring of gear teeth under high loads and high rubbing speeds. This practice developed in the early 'thirties, in the endeavour to overcome serious trouble in automobile rear axles, caused by new designs of gears. Lastly, a certain combination of causes—gas constituents, probably acting through condensation in the oil film—entered into another class of phenomena, namely, the wear of the cylinders and piston rings of internal-combustion engines. In this case, knowledge of the chemical side of the problem had helped greatly in bringing about improvements by design, better metallurgy, and understanding of oil technology. Instancing the work of Siebel, Professor Broeze drew attention to the beneficial action of oxide films, and the absence of wear in an atmosphere of $CO_2$.

The discussion on Professor Broeze's paper was opened by Dr. F. P. Bowden, who considered that the author had given a scientific account of the problem which was a model. With regard to the effect of oxygen and $CO_2$ in reducing the rate of wear, he remarked that, if there were no oxygen present, and the surfaces were bare, the rate of wear would be "prodigious." The efficacy of oxide films, however, was determined largely by the support given to them by the underlying material; a point which Dr. Bowden illustrated on the blackboard by a graph comparing the behaviour under load of aluminium, a soft metal producing a hard oxide, and copper, a soft metal with a soft oxide. Dr. G. Salomon, who followed, disagreed with Professor Broeze's reference to sulphur dioxide as harmless; in some cases, he said, it might be highly corrosive. Dr. F. T. Barwell, the next speaker, said that, in fretting corrosion, the primary damage was insignificant in an engineering sense, but it produced debris which became oxidised, and it was this that did the serious damage. By restricting the supply of oxygen, the damage could be greatly reduced. He added, with reference to previous remarks on nomenclature, that he thought "fretting" was a good descriptive word to apply to that kind of corrosion. Dr. M. Brunner, commenting on the author's reference to lubricants, observed that used gear lubricants were often found to be corrosive. Mr. J. A. W. van Laar, the only other speaker, described some recent research on the chemistry of corrosion.

Professor Broeze, in reply to the discussion, said that Siebel had noted that the coefficient of friction of carbon dioxide was very low; in problems such as those, most inquirers looked to Dr. Bowden to provide the clues. The effect of moisture in the cylinder of an internal-combustion engine was a very involved matter, but sulphur dioxide was not usually harmful in an engine; it only became harmful when condensation occurred. In reply to a query by Dr. Barwell: extreme-pressure lubricants did produce a stable film, i.e., they were viscous lubricants. On the point raised by Dr. Brunner, Professor Broeze said that it was possible to devise lubricating compounds that were inactive at high temperatures and not too active at low temperatures.

At this point the conference adjourned for a brief interval, and on the resumption of the proceedings, Dr. de Decker called on Dr. G. Salomon, whom he introduced as an expert on high polymers, to present his paper on "Morphological Aspects of Abrasion and Wear."

### The Morphology of Abrasion and Wear.

The main theme of Dr. Salomon's paper was the significance of careful microscopic observations in the analysis of damage caused by abrasion and wear; as topics for discussion, he selected the wear of textiles and the surface cracking of polymers. Wear of textiles, he explained, was primarily a matter of dynamic fatigue, abrasion being only a minor source of damage. The useful life of textiles was limited by two fatigue phenomena, namely, the growth of cracks across the fibre, leading to a succession of brittle fractures and thus to a gradual reduction of the useful fibre-length; and longitudinal fibrillation. Surface cracking of fibres was one of the vital factors that determined resistance to wear; and from that common point, therefore, Dr. Salomon turned to a consideration of analogous phenomena in polymer films, taking the ozone-cracking of polymers containing olefinic bonds as an example of crack initiation due to chemical causes. New data were available, he stated, concerning the ozone-sensitivity of plastics containing such bonds, and it had been established that the dependence of ozone cracking on strain varied with the mechanical properties of the polymer film. The evidence obtained with chemically-initiated stress-cracking supported the assumption that the rate of crack growth decreased with an increasing rate of stress relaxation. In physically-initiated stress cracking of rubbers and plastics, the crack growth resembled that observed in ozone cracking. The cause of crack initiation was frequently obscure, but cracks could be initiated by a controlled chemical reaction of ozone with certain polymers. Ozone reacted with the double bonds of unsaturated polymers, surface cracking of stressed films of those polymers being induced by the first minute traces of ozone. A factor of note was the surprisingly large influence of prestressing on the rate of ozone-initiated crack growth. The conventional method of improving resistance to ozone was the addition of certain plasticisers. The result was a high rate of stress relaxation, so that cracks developed at strains much above those of the preponderantly elastic rubbers. Neoprene showed the smallest rate of crack growth. It was mechanically similar to the rubbers, but contained double bonds which were about 10,000 times less reactive. The rate of chemical attack was so much reduced in Neoprene that again stress relaxation, which occurred eventually in all elastomers, retarded the growth of cracks. Summing up, Dr. Salomon said that the cause of brittle cracking was the same in plastics and in metals—it was due to the distribution of stresses; but the mechanism of relaxation was different, for which reason there was an evident analogy between the stress cracking of polyethylene, and the stress cracking and stress corrosion of metals.

Professor A. van Rossem opened the discussion. Ozone cracking, he said, was purely chemical; was the result of dynamic fatigue testing also chemical? It was his own belief that all the phenomena of cracks—those that had been termed "mechanical deterioration" and "physical deterioration"—were fundamentally chemical; he asked Dr. Salomon's opinion of the suggestion. Dr. G. J. van Amerongen asked to what extent ozone would influence the results of laboratory flex-cracking tests; and whether ozone could affect the flex-cracking not only of olefinic but also of saturated materials. Mr. J. M. Buist, who spoke next, inquired how it was that even a small degree of strain could affect ozone cracking if ozone cracking was purely a chemical process. Unstrained rubber did not crack, but as soon as it was strained—even to so small an extent as 15 per cent.—cracking proceeded rapidly. If the chemical reaction involved was one of radical interchange, an explanation might be possible, but he thought that considerably more evidence was required. He asked if Dr. Salomon would amplify his remarks on that point.

Dr. R. Houwink observed that Dr. Salomon's illustrations showed cross-wise cracks in all the cellulose types of fibres (e.g. cotton and rayon) and lengthwise cracks (fibrillation) in wool; and he asked whether the two types of destruction were characteristic of those respective chemical groups. Did natural silk also show fibrillation? With reference to the transverse cracks in the cellulose type of fibre, attention might be drawn to earlier theory on the cause of the breaking of such fibres, namely, the assumption of minute sub-microscopical transverse cracks in the *micellæ* of the cellulose. Dr. K. W. Hillier said that both fibrillation and transverse cracking had been observed in the microscopic examination of fractured filaments of synthetic high-polymer fibres. The conditions of formation appeared to be similar and he inquired whether any explanation was available. Professor H. Blok, referring to a remark by Professor van Rossem about the increased chemical reactivity of a cracked surface compared with an undisturbed surface, observed that, with metals, it had been found that mechanical disturbance of a surface might well cause increased reactivity; that was indicated by the work of M. C. Shaw (*Jl. App. Mech.*, vol. 15, pages 37-44, 1948) on what he called the "mechanical activation of Grignard reactions." Shaw had been able to show how to accelerate and (more important in practice) how to control such reactions. Dr. S. M. Hagman described a simple form of apparatus for making fatigue tests of fabrics. The fabric was squeezed between rods, and a comparison made of the strength of the squeezed fabric and the original material. Differences between fabrics due to the use of different fibres, as well as the influence of the method of weaving, could be detected in that way.

Dr. Salomon, replying briefly to the discussion, said that the ozone reaction, about which Professor van Rossem inquired, was not strain-sensitive. Answering Dr. van Amerongen's question: ozone could influence the chemical cracking of saturated materials. A direct-current motor placed close to a wall gave off concentrated ozone and this would accelerate ozone cracking. Replying to Mr. Buist, Dr. Salomon pointed out that rubber covered with glycerine or water did not crack. He was not prepared to explain how strain affected a chemical process, but he repeated that it did do so. Dr. Houwink had asked if natura silk had a fracture like that of wool; it had not—in fact, nothing else fractured like wool. Cotton certainly developed micro-cracks, and it changed its properties completely with variation of moisture content. The peculiarity observed by Dr. Hillier in the fracture of synthetic high-polymer filaments was not, he thought, likely to affect future work. Crack initiation in organic glasses could be due to purely physical causes, or traces of solvent. In rubber, it might be due to a hard surface film, which fractured when kept under stress; crack propagation, on the other hand, depended not only on the rate of chemical attack, but also on the rate of tearing of the strained rubber due to stress concentrations at the ends of cracks.

This concluded the proceedings on November 14.

*(To be continued.)*

Film of the "Argonarc" Welding Process.—The British Oxygen Company, Limited, have prepared a film on the Argonarc welding process, the premiere of which was given at the Hammer Theatre, Wardour-street, London, W.1, on Tuesday, December 4. The film is in two reels, the first of which illustrates the equipment and application of the process in the industrial field. The second reel, in the production of which the Aluminium Development Association has co-operated, deals with the welding of aluminium and its alloys. The films are on 16-mm. Kodachrome and the running time for the two reels is 53 minutes; both, however, are self-contained and can be shown independently. Further particulars of the film can be obtained from the company's photographic department, North Circular-road, Cricklewood, N.W.2.

# FUEL AND POWER PROJECTS.

Fig. 1. VARIABLES REPRESENTED IN MINISTRY OF FUEL AND POWER COAL-BURNING GAS-TURBINE PROJECTS.

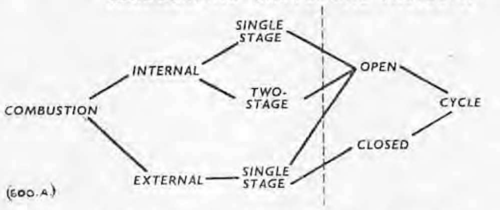



Fig. 2. COAL-BURNING COMBUSTION CHAMBER FOR PARSONS 500 H.P. EXPERIMENTAL ENGINE.

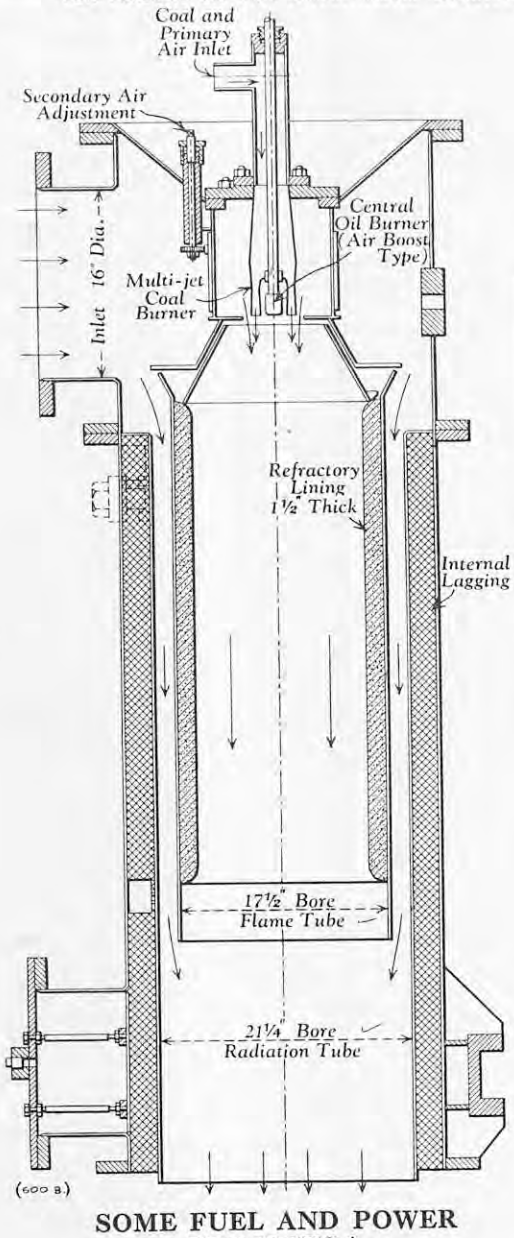
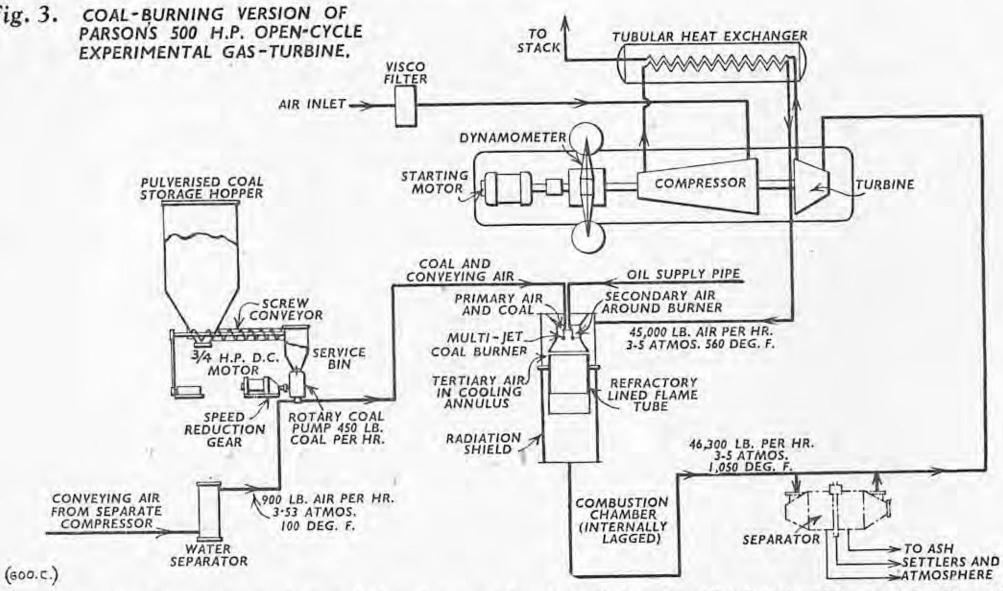



Fig. 3. COAL-BURNING VERSION OF PARSONS 500 H.P. OPEN-CYCLE EXPERIMENTAL GAS-TURBINE.




## SOME FUEL AND POWER PROJECTS.*

By H. ROXBEE COX, Ph.D., B.Sc. (Eng.)

IN the prosecution of a major plan, not only is there a demand from many who know it exists to learn how it is going on; there is the need for those in charge to sum it up and decide for themselves where, in fact, they have got to. The work in progress which I intend to describe is the research and development work of the Ministry of Fuel and Power. It is the first description of this work with any pretension to completeness.

At the beginning of the Ministry of Fuel and Power Act of 1945, the Minister is "charged with the general duty of securing the effective and co-ordinated development of coal, petroleum, and other minerals and sources of fuel and power in Great Britain, of maintaining and improving the safety, health, and welfare of persons employed in, or about, mines and quarries therein, and of promoting economy and efficiency in the supply, distribution, use, and consumption of fuel and power, whether produced in Great Britain or not." The national organisations for the control of the coal mining, electricity supply, and gas industries are primarily concerned with fuel and power supply. The nationalised fuel and power industries can be regarded as sharing with the Minister his duties concerned with the supply of fuel and power, but not, in general, his responsibility for promoting the best use of fuel and power. That responsibility lies with the Government. This broad differentiation between supply and utilisation responsibilities applies in the field of research and development, with which this lecture is particularly concerned. For the discharge of his research and development responsibilities in matters of supply, the Minister depends largely upon the National Coal Board, the British Electricity Authority, and the Gas Council. Petroleum not being a nationalised industry, the Minister's position *vis-à-vis* the oil companies is, of course, less formal. The research and development required for petroleum production are well performed by the companies themselves. The Minister's representatives are in touch with the research and development organisations of the oil industry, and this appears to be quite satisfactory. Whereas in the cases of research in the coal, gas, and electricity supply fields, most of the Minister's responsibilities are discharged through the machinery of the nationalised industries, and in the case of research in petroleum supply by informal connections with the private enterprises concerned, he discharges his responsibilities for research in fuel and power use directly. We have, then, a rough division of research responsibilities into the supply field, wherein duties are shared between Government and industry; and the utilisation field, which falls primarily to the Minister.

Of particular interest, in view of the sharing of duties between the Minister and the industries in the field of supply, is the case of research directed towards the increased safety, health, and welfare of coal miners. The National Coal Board has to secure the safety, health, and welfare of persons in their employ and to do this must engage in research and development investigations. The Minister has to secure the prosecution of research for the advancement of safety and promotion of health of miners. His chief instruments are the Mines Inspectorate and the Safety in Mines Research Establishment. To enable the Minister to discharge the variety of scientific and technical duties consequent upon his responsibilities for research and development, a scientific organisation has been created in the Ministry of Fuel and Power. There is, on the one hand, the Scientific Division under the Chief Scientist, and, on the other, advisory bodies, reporting to the Minister, which work in association with the Scientific Division.

The Scientific Division has at present four main parts. There is the Scientific Branch, the Fuel Efficiency Branch, the Safety in Mines Research Establishment, and an Administrative Branch. The Scientific Branch is concerned with the achievement of fresh knowledge for the better use of fuel and power. The Fuel Efficiency Branch exists for the application of current knowledge to the improvement of fuel and power utilisation. The Safety in Mines Research Establishment is directly concerned with the scientific problems arising from the Minister's responsibility for maintaining and improving safety and health.

To these three branches of the Scientific Division correspond three advisory bodies set up by the Minister. The Chief Scientist is a member and the executive officer of all three. The Scientific Advisory Council advises the Minister on the researches conducted on his behalf by the Chief Scientist, and is also the Minister's instrument for examining the programmes of research of the nationalised industries. The Council reviews these programmes as part of its general duty of co-ordination of research in the fuel and power field, and, when it considers them, it examines as well the programmes of the Ministry, of the Fuel Research Board, and of the Research Associations concerned with fuel and power research. The Council seeks to discover whether there are any gaps in the programmes which should be filled, or any unnecessary duplications of effort, and it advises the Minister accordingly.

The Fuel Efficiency Advisory Committee advises the Minister on the current problems of fuel and power utilisation and the work of the Fuel Efficiency Branch. The Safety in Mines Research Advisory Board performs corresponding functions in the field of safety in mines. The governmental organisation for Safety in Mines has a long history, and the present laboratories at Buxton and Sheffield date back to 1928. The Fuel Efficiency Branch was created in 1941, the Scientific Branch in 1948. The work of the older sections is well known, but, in the case of the Scientific Branch, while certain facets of its work have been described, its position, purpose, and programme have not previously been reviewed.

If the work done to promote greater safety and health is left out of account, the research and development in the fuel and power industries is mainly devoted to the more efficient and more economical production and supply of fuel and power, and the research and development in the Ministry is, as has been made clear, mainly concerned with their more efficient use, or is concerned with investigations of such character that the first steps are most appropriately taken by the Government. There is a simple test which we apply to any proposal for scientific or technical work: we ask "Is this a potentially economic proposition and will it, if successful, provide economy in the use of fuel?" If the answer is wholly affirmative, and the estimated benefits commensurate with the estimated cost of experiment, we seek to put the proposal to the test.

This test we apply to the work of the Fuel Efficiency Branch and the Scientific Branch. In the former, it has resulted in the development of a nation-wide fuel efficiency service, staffed by 150 engineers of all grades having at their disposal a small fleet of lorries and cars ("mobile test units") carrying instruments permitting the analysis of the heat creation and disposition in an industrial plant. This branch has been able to indicate how large savings of fuel can be made in industry. All the time production is increasing and, as fuel and power production is not keeping step, industry must of necessity produce more per unit of energy consumed.

Meanwhile, there is being conducted by the Scientific Branch a longer-term attack on the fuel efficiency problem—the development of means of using more economically the energy available to us. It is this longer-term work which is particularly the subject of this lecture. It includes not only the development of ways of using familiar fuels more effectively, but the investigation of hitherto neglected but possibly economic sources of power. In this work we have concentrated so far on Britain's indigenous sources of energy. These sources include, of course, water and wind, but the phrase brings first to mind the indigenous mineral sources of fuel and power, which means just coal and peat. Our investigations on the use of the

* The 38th Thomas Hawksley Lecture, delivered to the Institution of Mechanical Engineers on Friday, November 16, 1951. Abridged.

# FUEL AND POWER PROJECTS.

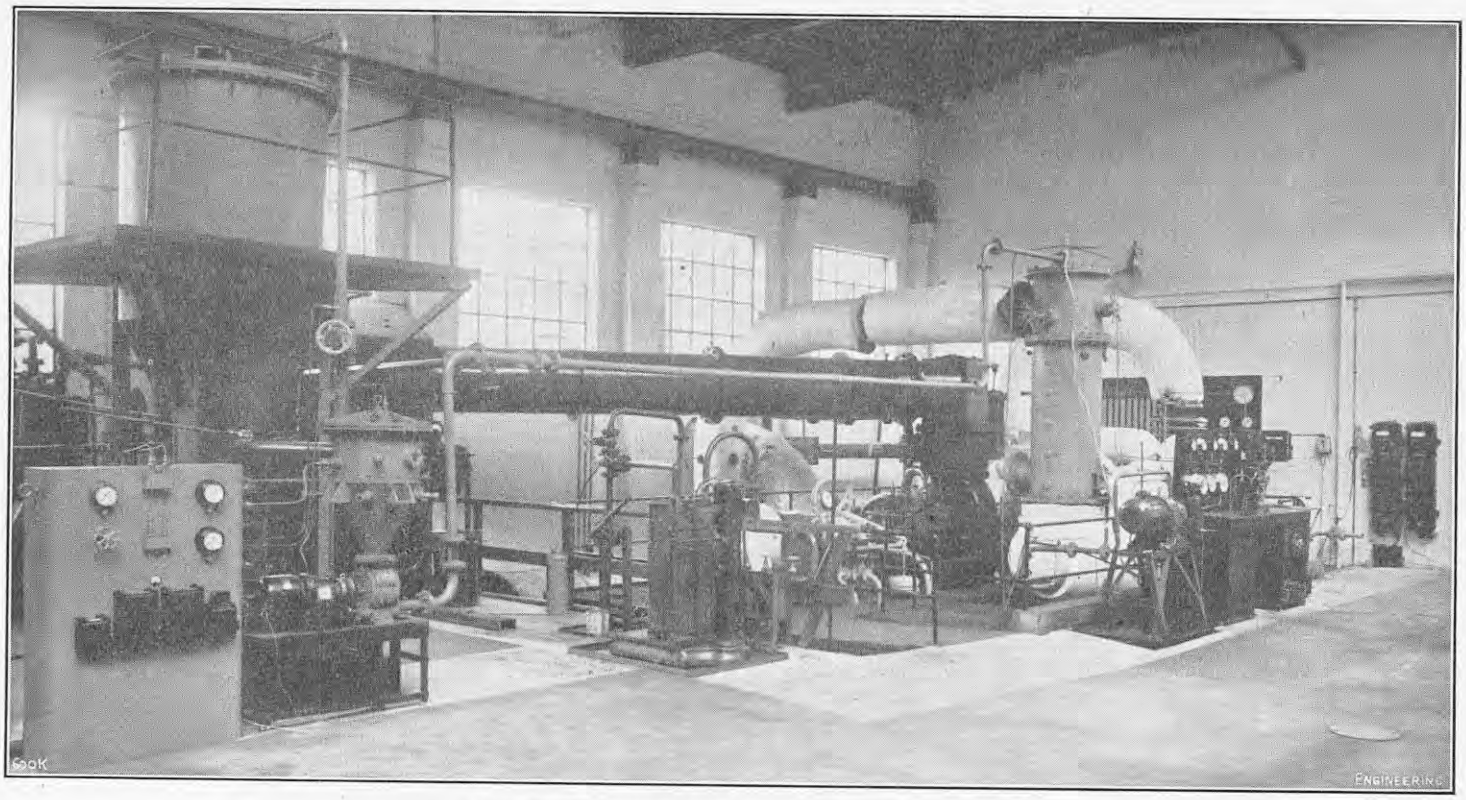
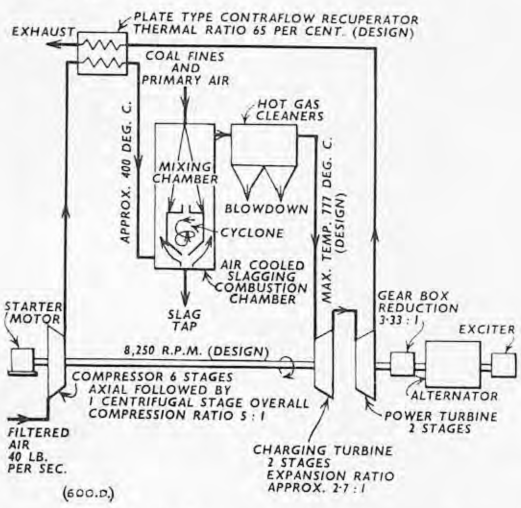


FIG. 4. PARSONS COAL-BURNING GAS TURBINE.

Fig. 5. CYCLE DIAGRAM.




2,000 KW ENGLISH ELECTRIC COAL-BURNING GAS-TURBINE SET.

Fig. 6.

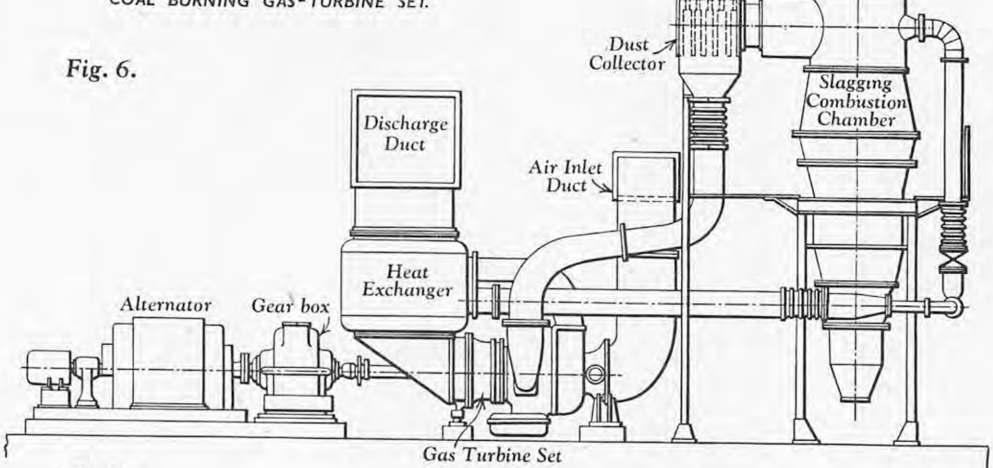
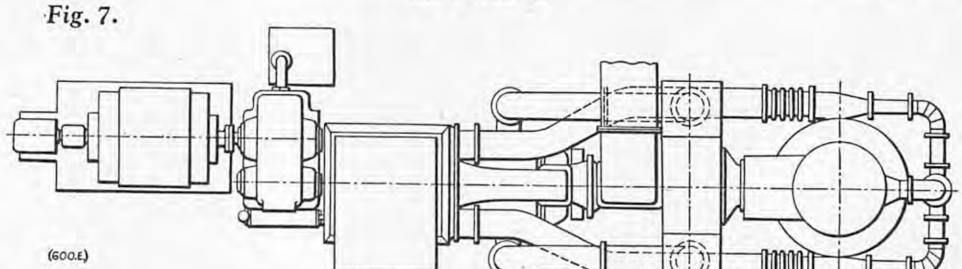



Fig. 7.




energy in coal can be put into three groups—the use as an engine fuel of coal in the solid form, the use of the gases normally available from coal, and the development of fresh means of gasifying coal.

The conventional external-combustion engines burning coal, while capable, particularly in the case of the steam turbine, of further improvement, have reached a stage of development where major advances in overall economy are no longer probable. Big changes are more likely to come from other brands of heat engine, and the development of the gas turbine in Great Britain for aircraft, and in Switzerland for industrial purposes, pointed at the end of the 1939-45 war to the need for examining the possibilities of the industrial gas turbine against the British background, and hence to the study of the industrial gas turbine with coal as the fuel.

The majority of gas-turbine plants make small, and in some cases no, demands for cooling water. There is, in consequence, little restriction on their siting. Secondly, the absence of steam boilers and hence of buildings for them—components which account for almost two-thirds of the cost of conventional steam-turbine power stations—is a powerful attraction from the capital cost point of view. This advantage must, of course, be offset to some extent by the air heaters and heat exchangers of gas-turbine plants and by the cost of certain gas-turbine components, but it is certainly not thereby counteracted. Thirdly, gas-turbine efficiencies—which, of course, vary greatly with the design—are similar to steam-turbine efficiencies, so, taking account of the very different states of development of the two species, on the thermal efficiency basis alone the gas turbine has great promise. The combination of gas and steam turbine is in some circumstances more promising still.

This is the general case for the gas turbine. In my view, a more detailed case can be made only by careful economic comparisons with other kinds of machine for particular sets of conditions, and by the collection of data through design, construction, installation, and test. The promise of the industrial gas turbine has too long been just promise, and the necessity for solid and extended test to discover if the promise can be kept is overdue. It is the policy of the Ministry of Fuel and Power to provide the means for long running, under practical conditions, of gas turbines which, though experimental, are designed for industrial duty and are of sizes sufficient to provide reliable design and cost data. The decision to work on gas turbines to use indigenous fuels filled the serious gap which was still apparent in the national research and development programme when the work on liquid-fuel gas turbines was well under way. There is, of course, provision under the Government for liquid-fuel gas-turbine research and development for marine purposes, and important work has long been in hand at the Parsons and Marine Engineering Turbine Research and Development Association (Pametrada) and at the National Gas Turbine Establishment. This work is applicable to liquid-fuel gas turbines for industrial as well as marine purposes, and is of the greatest interest in connection with the large gas-turbine plants which have been ordered by the North of Scotland Hydro-Electric Board, the British Electricity Authority, and the Ministry of Supply.

The obvious step has been taken of organising collaboration between these parties, so that problems of common interest are discussed between them, and the application of the work of one in the field of another is always possible with the minimum of difficulty. At the formal level, this collaboration is exemplified in the Industrial Gas Turbine Development Committee. In addition, the people at work on the various gas-turbine projects are in frequent contact. In particular, the Ministry of Fuel and Power's contractors have quarterly meetings with the Ministry's engineers and representatives of research organisations in the Gas Turbine Collaboration Group, which is proving to be a most valuable means of concentrating attack on the many problems of common interest.

The coal-consuming gas-turbine projects of the Ministry conform to an obvious but desirable pattern. There is possible a great variety of gas-turbine cycles and it is not feasible to try them all; but it is possible to try examples which exhibit the major variables, and we have envisaged our coal-burning turbine plan as standing on four "legs."

The major variables we have chosen are indicated diagrammatically in Fig. 1 on page 726. The four "legs" are crossed by the dotted line, defining our coal-burning gas-turbine projects as: the open-cycle single-stage internal-combustion gas turbine; the open-cycle two-stage internal-combustion gas turbine; the open-cycle single-stage external-combustion gas turbine; and the closed-cycle single-stage external-combustion gas turbine.

Towards the achievement of the open-cycle internal-combustion coal-burning gas turbine, work has proceeded along three lines which might be described as large-scale laboratory combustion experiment, the running of an adapted experimental engine, and the design and construction of an engine for development purposes. The laboratory work has been done under the auspices of the Department of Scientific and Industrial Research at the Fuel Research Station, Greenwich, and at the British Coal Utilisation Research Association, Leatherhead. At the former place, Mr. T. F. Hurley has tested two kinds of "dry" combustion chamber. One is a tubular "straight-through" chamber employing his multi-grid burner and the other is a vortex chamber. These experimental chambers successfully burn pulverised coal at 500 lb. per hour. In both of them the air flow is arranged so that combustion of the particles takes place while they are in suspension. When chambers of these kinds are used with gas turbines, the ash is separated from the products of combustion in a dry state.

At Leatherhead, Mr. W. V. Battcock has worked on a "wet" combustion chamber—that is to say, one in which the flow is arranged so that combustion largely takes place on the walls of the chamber, where the ash remains behind in a molten state and is withdrawn in a "wet" condition. This is the so-called "cyclone" chamber, also referred to as a slagging chamber.

The running of an adapted experimental engine to which I have referred has, in fact, been a far more complex operation than these words indicate. The engine in question is the 500-h.p. open-cycle gas turbine belonging to C. A. Parsons and Company, Limited. The coal-burning work in connection with it has been done by that company under direct contract to the Ministry. It was first necessary to develop a combustion chamber, and a version (Fig. 2) of the straight-through tubular type already described was chosen. It was also essential to have adequate means of cleaning the products of combustion before they passed through the turbine, and a satisfactory means of pumping the fuel into the combustion chamber. The difficulties to be overcome before these essential components could be integrated into a satisfactory whole with the engine were of the character common to all development work and call for no special comment. The satisfactory stage has been reached at which the engine, which first ran on coal, without the cleaners, on February 14, 1951, is running successfully on fuel of which 80 per cent. passes through a 200 B.S. mesh sieve. The arrangement of the cycle is shown diagrammatically in Fig. 3, and the whole plant is shown in Fig. 4. The coal storage and feeding arrangements are prominent on the left of Fig. 4, and the vertical feature on the right is the combustion chamber, standing on the "Sirocco" dust collector.

The design and construction of a gas-turbine plant planned from the outset as a coal-burning engine has been in the hands of the English Electric Company, Limited. This plant is of 2,000 kW capacity. The rotating parts are of normal design. The cycle diagram is in Fig. 5 and the corresponding parts will be identified in Figs. 6 and 7.

A compact plate-type heat exchanger, made to the English Electric Company's design by Joseph Sankey and Sons, Limited, of Bilston, has been embodied. The thermal ratio is 65 per cent. The way the plates are arranged in this heat exchanger, which measures roughly 6 ft. by 5·5 ft. by 4·5 ft., is shown in Fig. 9. Both the combustion chamber and the heat exchanger are prominent features in Figs. 5, 6 and 7. The leading particulars of the plant are shown in Fig. 5. After extended running on the test bed, due to begin in 1952, it is intended to use this engine as a piece of industrial equipment.

(*To be continued.*)

## LABOUR NOTES

EARNEST pleas for improved efficiency in the railway service are contained in the December issue of the *Transport Salaried Staff Journal*, the official magazine of the Transport Salaried Staffs' Association. Alderman Percy Morris, M.P., the President of the Association, states that the recent findings of the Railway Staff National Tribunal have added another fourteen to fifteen million pounds to the salaries and wages bill of the Railway Executive, "making approximately 35,000,000*l.* more this year." While the progress already made is to be welcomed, there are a number of objectives still to be realised and the work of the Association is not finished. At the same time, Mr. Morris contends there are duties to be performed as well as rights to be claimed. The improvements in salaries and wages were overdue and the Association makes no apology for pressing its claims. It is obvious that the money required for meeting the claims is not to be found in the industry at the present time and some of it will be obtained by increasing freight charges, provided that the Minister of Transport agrees.

Mr. Morris considers that the chairman and members of the Railway Executive have disappointed the Association in several small but important matters. It cannot be denied, however, Mr. Morris continues, that, on major issues, Mr. John Elliot and Mr. W. P. Allen have conducted negotiations on behalf of the Railway Executive with exemplary patience and goodwill. It is easy to believe that they do not resent the Tribunal's findings in favour of the Association. The executive committee of the Association were informed recently that an increase in railway effort of only 2 per cent. would make a tremendous difference, and, Mr. Morris informs his readers, the Railway Executive seeks their help in trying to secure this. He considers that the Executive is entitled to the assistance of all members of the Association and he asks them individually to make a ready response to the appeal.

Members of the Railway Executive will not benefit personally from improvements in railway efficiency, but any steps in this direction should prove to be to the mutual advantage of both the Executive and the Transport Salaried Staffs' Association. They would, in fact, give "a much-needed fillip to the transport industry." Mr. Morris emphasises that this is not a political issue but one of supreme importance and common sense. He concludes: "We demand the best, so let us give of our best. It will strengthen our claim. Keep an eye on future legislation and resolve to do everything possible not only to save our industry but to enhance its prospects. Service marked by personal integrity and efficient workmanship will lift us out of the Slough of Despond and make life more worth while."

Changes in the full-time rates of wages, which came into operation in the United Kingdom during October benefited more than 1,707,000 workpeople, and the total cost of these increases is estimated by the *Ministry of Labour Gazette* for November to amount to approximately 526,000*l.* a week net. Apart from agricultural employees in England and Wales, the increases principally affected persons engaged in the iron and steel industry and the furniture-manufacturing trades. Other persons receiving advances in their wages included workpeople employed by company-owned motor-omnibus undertakings in Great Britain and by the London Transport Executive, manual employees in the non-trading services of local authorities in Scotland, and operatives engaged in tobacco, leather, and glass-container manufacture.

Of the total increase in wages of 526,000*l.* during October, about 262,000*l.* was the result of Orders made under the Agricultural Wages Act or the Wages Councils Acts; approximately 123,000*l.* resulted from arrangements made by Joint Industrial Councils or by other joint standing bodies established by voluntary agreement; and some 52,000*l.* was brought about by arbitration awards. Direct negotiations between employers and workpeople or their representatives were responsible for increases amounting to a further 49,000*l.*, and the remaining 40,000*l.* resulted from the operation of sliding-scale arrangements based on the interim index of retail prices.

During the first ten months of the current year, some 10,126,000 workpeople received increases in their net wages, which were estimated by the Ministry of Labour to amount to some 4,537,400*l.* a week. In the transport and communications industries, 1,339,500 persons received increases amounting to 680,400*l.*; in the building and contracting industries, 1,107,000 persons received increases totalling 571,300*l.*; and, in the distributive trades, 1,263,500 persons obtained advances aggregating a further 477,600*l.* Other industries to benefit substantially during the ten months from January to October last included the textile trades, in which 737,000 employees obtained rises amounting to over 419,000*l.*; mining and quarrying, in which 423,000 workpeople benefited to the extent of over 166,000*l.*; vehicle manufacturing, in which 306,000 operatives secured advances totalling more than 133,000*l.*; and paper and printing, in which 273,500 persons received increases amounting to nearly 205,000*l.* Some 895,000 people engaged in the agriculture, forestry and fishing industries obtained advances which amounted, in the aggregate, to 312,700*l.* Increases in the engineering, shipbuilding and electrical-goods industries totalled 84,800*l.* and were shared by some 190,000 persons. During the first ten months of 1950, there were net increases amounting to 681,000*l.*

Industrial disputes in progress in the United Kingdom during October last were definitely more numerous than those which occurred during the preceding month. There were, in all, 207 stoppages in progress during October and, in them, 29,100 workpeople were involved and 111,000 working days were lost; compared with 177 disputes in September, in which 35,100 persons took part and lost 110,000 days' employment. The corresponding figures for October, 1950, were 124 strikes, with 40,400 people engaged in them, at a cost of 246,000 working days lost. Of the 207 strikes in progress during October last, no fewer than 115 occurred in the coal-mining industry and, in these, 12,900 miners took part and lost 27,000 days' work. In the shipbuilding and ship-repairing industry, 22 disputes were in progress during the same month, 4,800 operatives being involved and over 30,000 working days being lost. Eleven stoppages arose in the engineering industry, in which 1,900 workpeople took part and 18,000 working days were lost.

Figures for industrial disputes commenced during the first ten months of the present year show that the position has deteriorated somewhat, compared with that obtaining during 1950. A total of 1,511 stoppages were begun during the period between January and October last, in which some 335,400 workpeople were involved and more than 1,557,000 working days were lost. During the corresponding period of 1950, there were 1,165 strikes and, in them, 281,300 persons took part and lost 1,291,000 days. In the first ten months of this year, there was only one strike in the agricultural, forestry and fishing industries combined, in which 200 employees took part and which caused the loss of 1,000 working days. It may be mentioned, in contrast, that no fewer than 910 strikes during this period occurred in the coal-mining industry, an average of three out of every five. Some 115,000 miners were concerned in these stoppages and 311,000 days' production was lost.

The Minister of Labour, Sir Walter Monckton, announced in the House of Commons on November 30 that the dispute concerning lightermen employed at the Port of London had been reported to him by the employers' side under the terms of the Industrial Disputes Order and that he had decided to refer the matter to the Industrial Disputes Tribunal for an award. Following the ban on all overtime at the port, which was imposed by the Watermen, Lightermen, Tugmen and Bargemen's Union on November 26, Sir Walter stated, he had had discussions with the two sides of the industry and had come to the conclusion that it would be to the advantage of both the employers and the trade unions if an authoritative decision were given on the points at issue between them on the pay claim. The disadvantage of this was that it did not provide an opportunity for discussing measures for improving the efficiency and productivity of the industry, as contemplated by the Ministry of Labour committee of investigation.

The existing acute stage in the dispute has arisen owing to differences of opinion regarding the working of overtime. The lightermen's union claims that this is entirely a voluntary matter, whereas the employers contend that it has always been the practice for lightermen to work overtime when required. Port tribunals recently dismissed the appeals of some lightermen against their suspension for three days for declining to work overtime at the union's behest, in connection with an earlier stage of the dispute. Support for the lightermen's union was given at a meeting of the National Amalgamated Stevedores and Dockers on December 2, when about one thousand delegates, representing some 7,000 members of that union, decided by a large majority to ban all overtime at the port until an authoritative decision is reached regarding the suspension of lightermen and tugmen refusing to work overtime on the orders of their union.

# PHOTOGRAPHY OF PROPELLER CAVITATION.

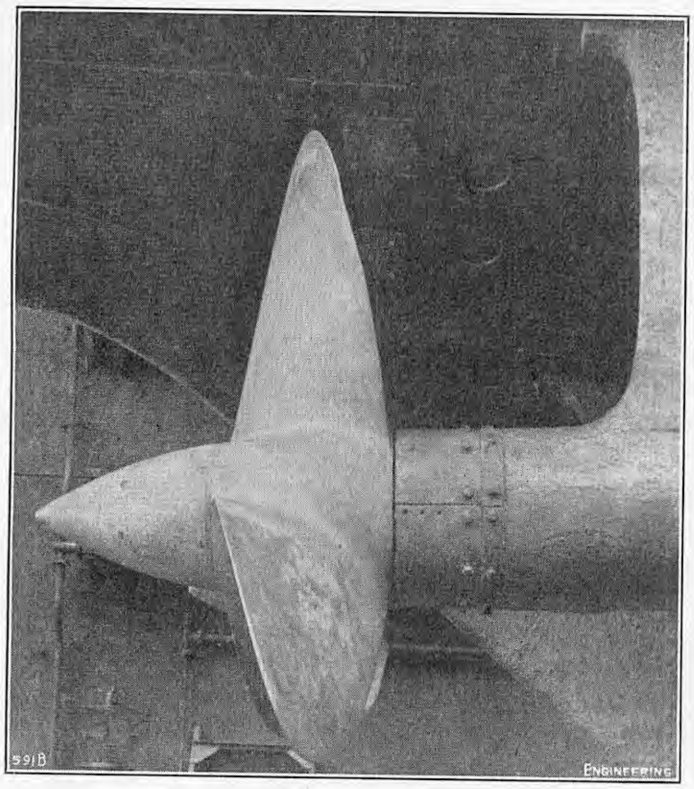


FIG. 1.

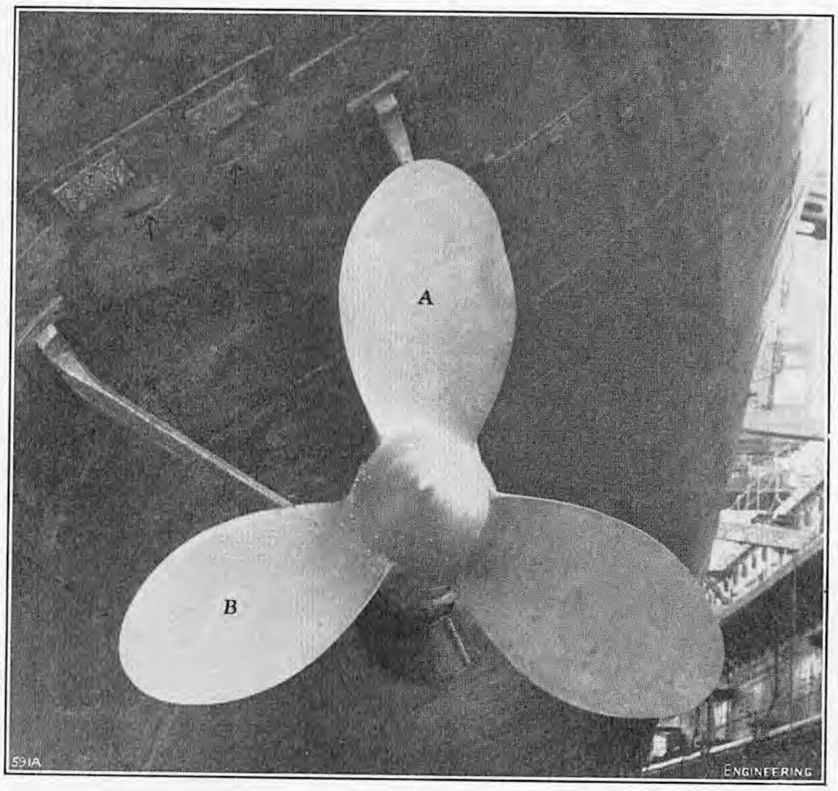


FIG. 2.

FIGS. 1 and 2. VIEWS OF PROPELLER, SHOWING POSITIONS OF PORTS IN SHIP'S HULL.

FIG. 3. DAYLIGHT EXPOSURE WITH PINHOLE CAMERA.

FIG. 4. FLASHLIGHT EXPOSURE WITH PINHOLE CAMERA.

## PHOTOGRAPHY AT SEA OF PROPELLER CAVITATION.*

By J. W. FISHER, B.Sc., Ph.D.

IN this paper, a brief account is given of what is believed to be the first successful attempt at direct-observation and short-duration flash photography of the cavitation on the blades of a ship's propeller at sea. Hitherto, the state of cavitation of ships' propellers could be inferred only from cavitation-tunnel tests of scale-model propellers. Tunnel conditions, however, do not exactly simulate the full-scale conditions at sea. The principal reasons are that the tunnel usually operates with well de-aerated fresh water, while seawater is approximately air-saturated; the flow into a model screw is free of the turbulence and wake velocity variations to which the ship screw is subjected, together with further disturbance due to pitch and roll; the Reynolds number is, as a rule, much less ($\frac{1}{10}$ to $\frac{1}{20}$) for the model than for the ship screw; and the model, unlike the real propeller, has a high degree of surface finish and is free of the wear-and-tear imperfections of the average ship propeller.

Some allowances and corrections can be made in interpreting the model data more realistically; in particular, any loss in thrust or efficiency of the model attributable to cavitation can be compared with corresponding losses determined during ship trials, thus establishing an indirect check on the correlation of model and full-scale propulsive effects. Indeed, for a long time the term "cavitation," as understood by marine engineers, appeared to be almost synonymous with a degree of blade cavitation sufficient to cause loss of thrust and efficiency, or to result in harmful erosion effects.

In this connection, therefore, it is clearly desirable to discover by direct observation the reliability or otherwise of model predictions, including those concerning the onset and development of cavitation in its incipient and early stages. The only way to do this is to provide the hull with transparent viewing ports which will permit stroboscopic observation and short-duration flash photography of the propellers while the ship is operating normally at sea. This was done in 1948 in one of the ships used for experimental work, and the observations then made by the author are described in this paper. The ship was a twin-screw vessel with three-bladed propellers, 8 ft. 3 in. in diameter.

A pair of 1-in. thick glass ports was fitted on both starboard and port sides, a short distance ahead of the plane of the propeller blades. Observations were made on the starboard propeller only and Figs. 1 and 2, herewith, taken in dry dock, show the pair of starboard ports, above the propeller. These ports opened from a small space below the steering flat and necessitated a rather cramped posture when viewing or photographing the propellers. The glass discs were 8 in. in diameter and separated by 16 in. between centres. One was covered by the flash lamp while photographs were taken through the other. Blade A, in Fig. 2, pointing vertically upwards, was photographed through the upper port while illuminated via the lower, and blade B, in a nearly horizontal position and moving upwards near the hull, was photographed through the lower port and illuminated via the upper one. These two blade positions were the only ones permitting satisfactory photographs.

Even in these positions, the restricted angle of entry of light into the water (cone of semi-angle 49·5 deg.), together with the inclination of the hull surface at the ports, seriously limits the extent of propeller-blade illumination. When not in use, the ports were covered on the inside of the hull by iron plates securely bolted around the rims. Before use, a diver was employed to remove any oily deposit or marine growth which might impair transparency.

All important is the clarity of the water. On looking through the cleaned ports in daylight in good water conditions, every detail of stationary blade surface was visible, and objects could be clearly discerned on the harbour bottom at a depth of some 30 ft. After a storm, on the other hand, or at times of heavy plankton population, conditions could be so bad that nothing but a dim shadowy outline of the blades could be made out. With artificial illumination by reflected light, lack of back-scatter from the general body of the water is all important, so that really clear water conditions are essential if worth-while photographs are to be secured.

Although direct observation by daylight in clear water does enable the onset of cavitation near the tips to be detected by the appearance of intermittent white flashes, all detailed study must be made by short-duration flash photography or visually by shaft-synchronised stroboscopic illumination. Adequate flash illumination was secured by means of an S.F.2 "Sieflash" tube, mounted in a reflector and fitting over one of the glass ports. This tube was operated by discharge of a 4-microfarad condenser (for visual observations) or of a 50-microfarad condenser (for photography) charged to 2,500 volts by means of a power pack and rectifier operating from the 220-volt

* Paper presented at a meeting of the North-East Coast Institution of Engineers and Shipbuilders, held in Newcastle-on-Tyne on October 26, 1951. Abridged.

# PHOTOGRAPHY OF PROPELLER CAVITATION.

Fig. 5. CAVITATION ZONES ON BLADE BACKS, VIEWED ALONG PROPELLER AXIS – SHIP PROPELLER.

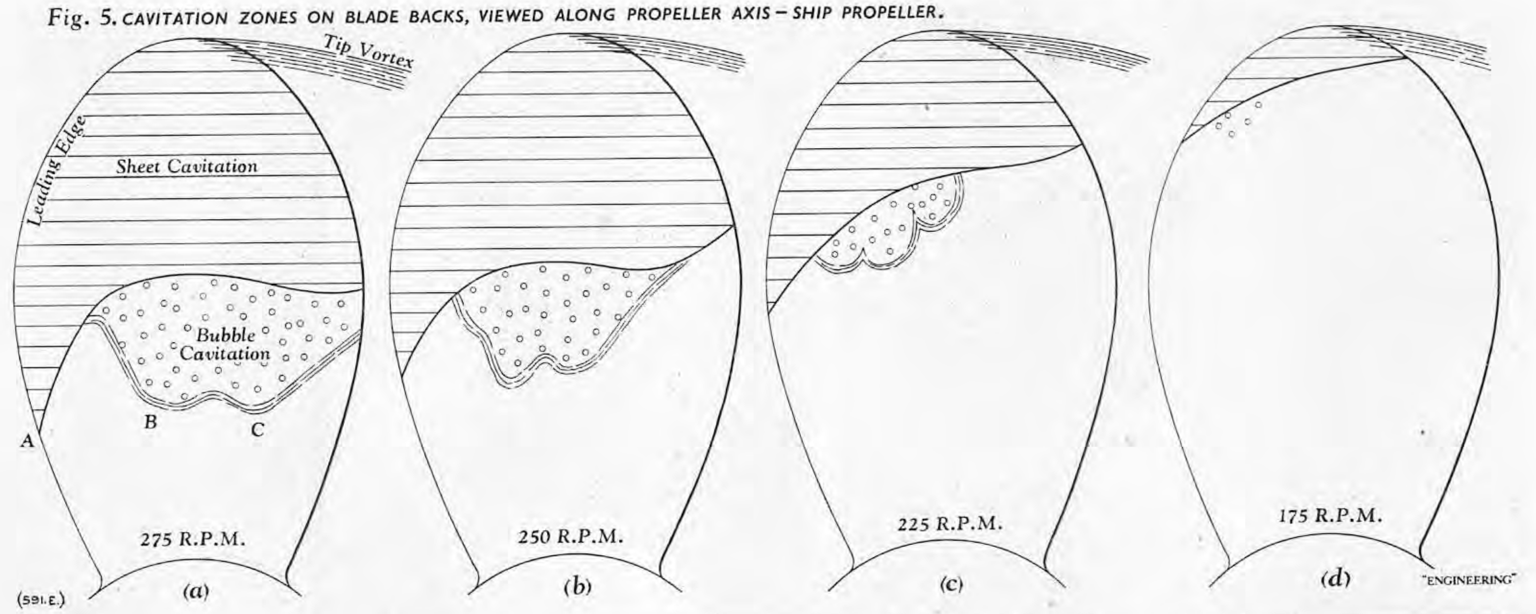



FIG. 6. 275 R.P.M.

FIG. 7. 250 R.P.M.

FIG. 8. 225 R.P.M.

FIG. 9. 180 R.P.M.

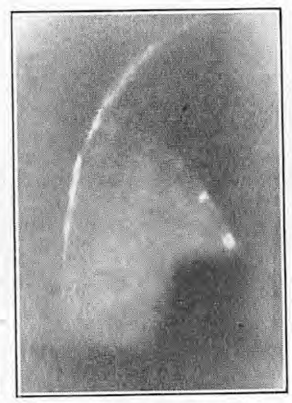


FIG. 10. 150 R.P.M.

FIG. 11. 120 R.P.M.

FIGS. 6 TO 11. CAVITATION OF BLADE IN "A" POSITION.

TABLE I.

| Propeller R.P.M. | V, ft. per sec. | S, per cent. | J. | δ. | δT. | r, ft. | β. | δ*. |
|---|---|---|---|---|---|---|---|---|
| 275 | 28·4 | 33 | 0·75 | 3·45 | 0·18 | 2·0 | 0·49 | 0·65 |
| 250 | 26·2 | 32 | 0·76 | 3·9 | 0·22 | 2·3 | 0·55 | 0·64 |
| 225 | 24·2 | 30 | 0·78 | 4·6 | 0·27 | 2·6 | 0·62 | 0·65 |
| 200 | 21·9 | 29 | 0·79 | 5·6 | 0·34 | 3·0 | 0·73 | 0·61 |
| 180 | 19·9 | 28 | 0·80 | 6·8 | 0·42 | — | — | — |
| 175 | 19·5 | 28 | 0·81 | 7·2 | 0·44 | 3·4 | 0·83 | 0·63 |
| 150 | 16·9 | 27 | 0·82 | 9·5 | 0·60 | 3·8 | 0·92 | 0·70 |
| 120 | 13·6 | 26 | 0·83 | 14·6 | 0·93 | ~4 | ~0·96 | ~1·0 |
| 100 | 11·4 | 26 | 0·83 | 21 | 1·4 | — | — | — |
| 80 | 9·2 | 25 | 0·84 | 32 | 2·1 | — | — | — |
| 65 | 7·5 | 25 | 0·84 | 48 | 3·2 | — | — | — |

alternating-current ship supply. The induction-coil triggering circuit for the tube included a bell-push type of switch, held in the operator's hand; and, in series with this, a make-and-break spring contact attached between a convenient bearing block and the propeller shaft, and so adjusted that the tube could trigger only when the blade under observation occupied a selected position in the field of view of the port.

The miniature 35-mm. type of camera was found most suitable for the job, and all the pictures were made either with a Contax or a Leica camera. In order to photograph as much of the blade surface as possible from the rather close proximity necessitated by the positioning of the ports, special wide-angle lenses were used. For the Contax, an Orthometar $f.4 \cdot 5$, 3·5-cm. lens was used in place of the standard Sonnar 5-cm. lens, and, in the case of the Leica, an Elmar $f.3 \cdot 5$, 3·5-cm. lens was employed. These wide-angle lenses increased the field of view angle from the usual 45 deg. to about 62 deg.

The procedure adopted to take a photograph was, after setting the camera focus, as follows. With the camera shutter closed and the hand trigger-circuit switch closed, several flash illuminations were observed in the direct view-finder, to select the best camera orientation. Continuing to hold the camera carefully in the selected position, the shutter was opened and a single flash allowed to occur by momentarily pressing the hand trigger switch and then quickly releasing it to prevent a second discharge. As soon as the hand switch is closed, the flash follows at the next closure of the propeller-shaft contact, thus ensuring that the blade is always illuminated when occupying the pre-selected position. The camera shutter was then closed.

Owing to the large aperture used, $f.4$, and high-speed panchromatic Super XX film, it was necessary to work at night in order to avoid fogging by diffused daylight during the period the shutter was open awaiting the exposure flash. The latter was, in fact, rather erratic at times, and a number of shaft revolutions might occur before a successful triggering took place.

The flash resulting from a 50-mf. condenser discharge was really much too vivid for visual observation; the eye was momentarily blinded, and details of the propeller-blade surface showed up against a greenish background only during the eventual recovery stage of the eye. A small capacity of 4-mf. was therefore used for visual observation and, when the propeller-shaft triggering contact behaved itself, good stroboscopic vision was provided.

To obtain a picture covering an exceptionally large angle of view, an experiment was made with a simple pinhole camera. This consisted merely of a flat box holding a quarterplate at a distance of 1 in. behind a hole of 0·028 in. diameter. This size of hole, though far too large for good definition at such a short plate distance, was in fact necessary to provide a reasonable light aperture. In spite of this, a tolerably clear picture of blade cavitation at 250 r.p.m. with the blade in position B (Fig. 4, on page 729) resulted after exposure to 100 consecutive flashes, and the angle covered was the maximum possible from water to air. Even then, the tip of the blade in the B position was outside the field of view. The laminar cavitation shows as a white area just below the leading edge; and the double pronged extension of burbling cavitation towards the axis is also clearly shown. This photograph may be compared with Fig. 5 (*b*), above. Naturally, the distortion associated with such an image is enormous, as will be seen from the corresponding daylight exposure of the stationary propeller shown in Fig. 3, in which the (distorted) outline of the blade appears in the B position, leading edge uppermost. To a lesser, but still very marked degree, this is true also of all the photographs taken with the wide-angle lenses, particularly the close-up views of the blade in the B position.

Since the most important part of the interpretation of these photographs is that of finding out just where cavitation starts on the leading edge of the blade, and over what region of the blade surface it extends, steps must be taken to measure up the inevitably

# PHOTOGRAPHY OF PROPELLER CAVITATION.

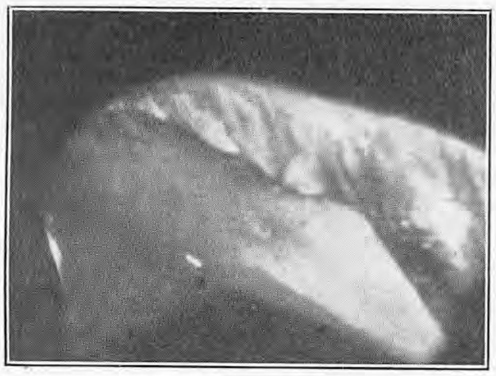



FIG. 12. 275 R.P.M.

FIG. 13. 275 R.P.M.

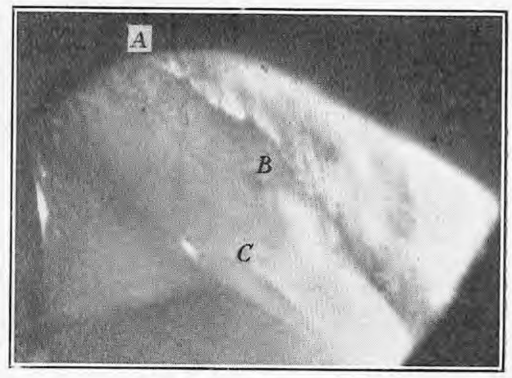


FIG. 14. 275 R.P.M.

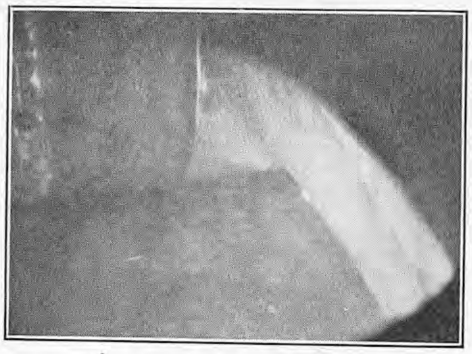


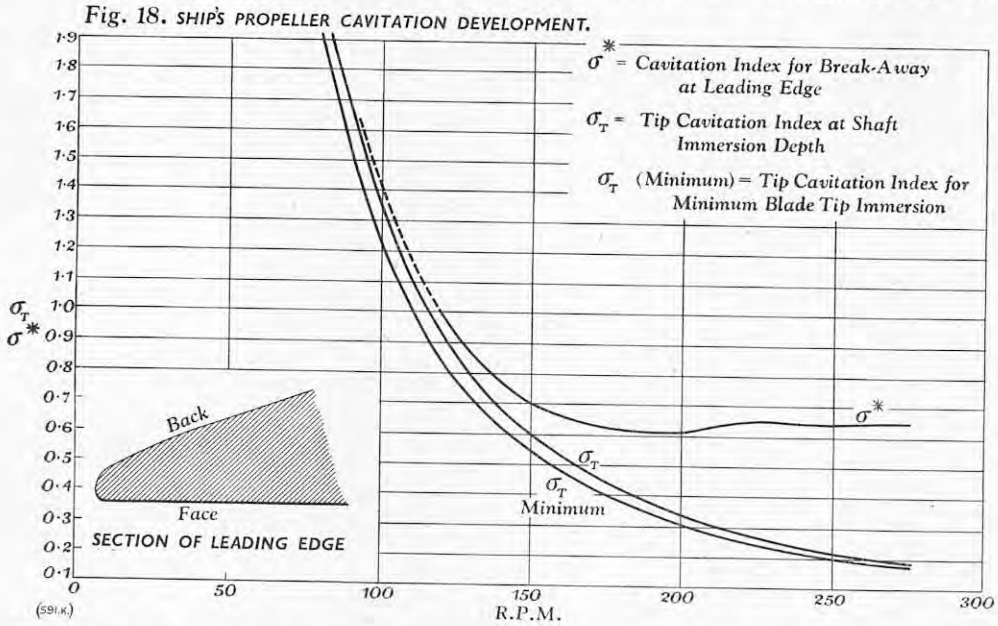
FIG. 15. 275 R.P.M.

FIG. 16. 250 R.P.M.

FIG. 17. 175 R.P.M.

FIGS. 12 TO 17. CAVITATION OF BLADE IN "B" POSITION.

Fig. 18. SHIP'S PROPELLER CAVITATION DEVELOPMENT.




distorted photographs. The ideal way of doing this would be to take pictures with a known co-ordinate grid already marked out on the blade surface. In any future work of this kind, there should be no difficulty in marking out the blades in such a way while the ship is in dock. In the present case, however, there was no opportunity to do this, so the next best procedure was adopted, namely, that of marking out the blade periphery into equal known measured intervals.

To this end, with the ship at anchor in daylight, a diver placed round the edge of the blade a chain made of metal tags painted white, and soldered at intervals of 6 in. to a long wire. By bending these tags round the blade edge, the chain could easily be fixed in position. It was then photographed when occupying the position selected for subsequent flash photography. As a further aid, and one which turned out to be most valuable, the diver was instructed to scrape the blade surface very lightly with a file at the positions covered by the metal tags. After removal of the chain, subsequent flash photographs under operating conditions always showed up these marks very plainly. They can be seen along the trailing edge in Figs. 6 to 11

The natural markings on the blade surfaces also provided intermediate reference marks which, in spite of varying degrees of distortion, could be easily recognised in the various blade photographs on account of their characteristic patterns. By linking up with the measured peripheral marks, these helped considerably in localising the cavitation boundary zones shown in the photographs. The pictures taken through the lower port, with the blade in the B position, were those which showed most clearly the positions of flow break-away on the leading edge for various speeds of rotation. Those taken in the A position provided data for localising the sheet cavitation at the trailing edge.

The diagrams of Fig. 5 were constructed in this way; the blade areas covered by cavitation were estimated by sketching outline diagrams on a scale-model blade surface, held so as to correspond as closely as could be judged to the appearance in the actual photographs. This was rather difficult to do, but it is believed that the diagrams present a fairly good approximation to the true state of affairs. As mentioned above, the provision of reflecting marks at known points of the blade surface, to supplement those at the periphery, would have greatly simplified the work and, at the same time, increased the accuracy.

A representative series of photographs of the blade in the A position is reproduced in Figs. 6 to 11 for speeds, respectively, of 275, 250, 225, 180, 150 and 120 r.p.m.; and Figs. 12 to 17 show the appearance in the B position at speeds of 275, 250, and 175 r.p.m.

The photographs show clearly the two types of cavitation. There is the "sheet" type, cross-shaded in the diagrams of Fig. 5, which at the tip merges into the tip vortex cavity; and there is the "bubble" type, indicated by small circles in Fig. 5, which first became visible at about 175 r.p.m. (Fig. 5 (*d*), Fig. 9). The double-pronged inward-extension of the bubble zone, so clearly depicted in Fig. 14, is emphasised by the greater distortion of the pin-hole camera photograph of Fig. 4, where it appears as two white blobs. The sheet cavitation shows a very turbulent break-up near the trailing edge at speeds of 225 r.p.m. and over. Tip vortex cavitation was first visible in the A position at about 80 r.p.m., but the first indication of its intermittent inception was provided by the rather characteristic accompanying noise, which first became audible at about 65 r.p.m.

Table I, on page 730, summarises the computed numerical data for the trial, using the following terminology: D = propeller diameter = 8·25 ft.; P = pitch = 9·25 ft.; V = speed of propeller advance; N = revolutions per second; S = slip = $1 - \frac{V}{NP}$; J = advance coefficient = $\frac{V}{ND}$; $r$ = radial distance from axis to a point on the leading edge; $\beta = \frac{r}{r_o}$; $r_o$ = propeller radius; $p$ = static pressure at propeller axis; $\delta$ = cavitation index at axis = $\frac{p}{\frac{1}{2}\delta V^2}$ (vapour pressure of water negligible compared to $p$); $\delta_T$ = tip cavitation index = $\frac{p}{\frac{1}{2}\delta[V^2 + N^2\pi^2 D^2]} = \frac{\delta}{1 + \frac{\pi^2}{J^2}}$; and $\delta^*$ = local cavitation index at the inner boundary of sheet cavitation on the leading edge = $\frac{\delta}{1 + \beta^2 \frac{\pi^2}{J^2}}$.

A significant relation was found, defining the radial distance along the leading edge to the point where the flow breaks away as sheet cavitation. This can be expressed by saying that, with increasing speed, $\delta^*$ tends to a constant value at this break-away position. From Table I it will be seen that this critical value is about 0·65, which, at 8 ft. immersion, corresponds to a resultant water speed of about 67 ft. per second past the blade at this point. These values were derived from photographs taken in the B position when the immersion depth was about the same as that of the propeller axis (8 ft.). In Fig. 18, the values of $\delta_T$ and $\delta^*$ are shown as functions of the propeller r.p.m. Naturally, at the lower speeds of rotation, when the sheet cavitation is confined to the peripheral part of the blade, the flow there is greatly complicated by the rounding off of the blade profile, coupled with the concentration of shed vorticity towards the tip. Measurements of the photographs at 120 r.p.m. and less do not permit more than a rough approximation to the shape of the $\delta^*$ curve in this region, which is therefore indicated by a dotted line as it merges into the $\delta_T$ curve.

At the highest speed observed, 275 r.p.m., the cavitation zone had extended inwards by about two-thirds of the radial distance along the leading edge ($= 0 \cdot 5 r_0$). A section of the leading edge at this point is shown as an insert to Fig. 18. It is not surprising that the critical cavitation index for two-dimensional flow about such a bluff shape should be as high as 0·65.

Visible tip vortex cavitation was present when $\delta_T$ was as high as 2. In Fig. 9, the cavitating tip vortices from all three blades can be seen. A cavitating trailing root vortex was visible at speeds over 150 r.p.m.; at higher speeds this trailed away many yards astern, eventually passing out of the field of vision of the ports. The exact speed at which it first appeared was not ascertained; it was never seen at night by the light of the flash, but only as a diffuse white streak during daylight observation.

An interesting feature of the night observations was the presence in the sea of large numbers of phosphorescent organisms. These acted as luminous tracers of the streamlines and showed very clearly the eddies in the wake of the "A" brackets. The general effect of these streaks and gyrations of flowing sparks provided a most fascinating spectacle.

A $\frac{1}{8}$ scale model of the ship screw was tested in a cavitation tunnel and photographs demonstrated that there was indeed a close qualitative similarity between the full-scale cavitation phenomena and those of the model, when the latter was run in aerated water. The effect of aeration is to develop the bubble type of cavitation without materially affecting the sheet variety.

To develop corresponding degrees of cavitation, it appeared that the model screw had to be run at a speed higher than the calculated equivalent speed; the discrepancy was most marked in the speeds for onset of visible tip-vortex cavitation. On the other hand, a reliable estimate of quantitative differences is unfortunately precluded in this case, because of uncertainties in the ship speeds. The hull was badly fouled after seven months out of dock and, owing to the limited time available for this work, no speed trials could be undertaken at the time. A true scale effect would, in fact, be difficult to find, because it would involve simulating as closely as possible the hull-flow conditions in a cavitation tunnel, and then comparing the results with full-scale observations of the type described here. The limited view of the propeller is a drawback, particularly as this is confined to the neighbourhood of the hull, where the blades are subject to maximum wake effects, thus making still more unfair a direct comparison with the behaviour of the model in a uniform flow.

By using the ship itself as a full-scale "cavitation tunnel" with improved or extended underwater viewing facilities, it would, in fact, seem that much information of practical value could be obtained, which could not be inferred with sufficient accuracy or detail from model trials. Such data need not be restricted to cavitation on screws or hull appendages but could include investigations of flow direction and turbulence by means of suitably attached indicator threads or vanes. The modern technique of electron flash photography has made this entirely practicable, and it is hoped that this brief account of some first attempts in this direction may point the way to its future possibilities.

STEEL RATIONING.—The control of the distribution of alloy and carbon steel—as announced by the Minister of Supply on November 12—is to begin on February 4, 1952. The new arrangements will be similar to those in operation up to May, 1950, and, with certain exemptions under a "small-quantities exemption clause," as from February 4 no person may acquire or use specified types of steel unless an authorisation has first been obtained. The authorisation will permit the consumer to acquire steel direct or to allow his sub-contractors to purchase steel. Any consumer (except a sub-contractor) requiring steel in the controlled forms who has not already stated his requirements to the appropriate department or to a regional office of the Ministry of Supply, should apply at once to the department which is normally approached on matters of production. Small consumers, namely, those whose requirements are 25 tons or less a quarter, including not more than 10 tons of sheets, should apply to their Ministry of Supply regional controller. In cases of doubt, application should be made to the Ministry of Supply, Iron and Steel Division, Shell-Mex House, Strand, W.C.2. Copies of the new Order—the Iron and Steel Distribution Order, 1951 (S.I. 1951 No. 2006)—may now be obtained from H.M. Stationery Office, price 6*d*.

## WORLD SUPPLY OF NON-FERROUS METALS.*

By R. LEWIS STUBBS.

*(Concluded from page 703.)*

IN any survey of the pattern of future consumption, allowance must be made for the important role played by scrap, the amount of which will continue to rise in increasing proportion with the rise in the consumption of virgin metal. Only when consumption rises quickly, as is now the case, does the available scrap tend to lag behind and so to aggravate the immediate shortage. In an interesting paper presented in February, 1949, to the United Nations Scientific Conference on the Conservation and Utilisation of Resources, Mr. H. J. Miller estimates the total production of lead from 1847 to 1947 at 85 million tons, of which 65 per cent. may be ultimately recovered as scrap. In the same period, 80 million tons of copper were produced, 60 per cent. of which may be ultimately recovered. This recoverable scrap constitutes a vast pool of metal which will continually be re-used and recirculated, virgin metal being constantly added to it as necessary to meet demands. Lead is the classic example of the importance of scrap which, nowadays, amounts to some 40 per cent. of the metal consumed. The great part of this is recovered by salvage, the remainder being process scrap. The lead scrap pool dates back a very long time and its growing size may, in fact account for the slight decline in the consumption of virgin metal. Until recently, the main dissipating use of lead has been the small amount which has gone into pigments, but now increasing quantities are being used in the United States to make high-octane petrol.

Copper is another almost indestructible metal, but its cycle of return to the pool is much longer. At present about 35 per cent. of the copper used comes from scrap, of which between one-half and two-thirds is the result of salvage, the remainder being process scrap. Copper has only been used on a large scale for a generation or two, and in 20 or 30 years from now the amount of scrap obtained from salvage may represent an even higher proportion of the total consumption than in the case of lead to-day. Its main dissipating use is for copper sulphate. With zinc, scrap now represents some 25 per cent. of the metal consumed, but the prospects of the pool growing are not so good, since some of the main uses involve the ultimate loss of the metal, such as in pigments and protective coatings. Tin is used mainly in an indestructible metallic form but, unlike copper, its chief use is in very thin coatings on steel, and most of this metal is not recovered. Nevertheless, because of its high price, 20 to 30 per cent. of the tin used in the United States and the United Kingdom is secondary metal from various sources. In these and other metals we cannot help feeling that the best form of conservation lies in reclaiming them rather than in restricting their use.

Before considering the resources of ores available to meet future requirements for the non-ferrous and light metals, some general observations on world resources are worth noting. Firstly, up till the present certainly not more than two-thirds of the land surface of the earth can be said to have been explored for minerals, and while it is probable that the remaining third will be found to contain less mineral wealth in proportion (since some areas are known by geologists to be necessarily sterile) there must, nevertheless, be huge unknown resources awaiting location. Most of the great discoveries in the last 20 years have been made in the so-called explored regions, and these will no doubt continue. Our knowledge of the earth's surface is really very limited and all over the world existing sites are being found to be much richer than formerly supposed, as, for example, recently in Britain. Neither must it be forgotten that the period between the first and second world wars was one of over-production when there was no urge to seek new ores. To say that the total mineral resources of the earth are diminishing each year is a mere truism, of no importance so long as fresh deposits continue to be discovered, as they always have been. Another factor which has an important bearing on the estimation of world resources is that in the last 20 years important new methods of locating ore bodies have been introduced. Although science has not yet succeeded in evolving any method of locating really deep deposits, the scientific aids available to prospectors now include the use of the air-borne magnetometer and field methods such as soil micro-analysis and the analysis of plants known to take up metals in easily detectable quantities if they are present to an abnormal degree in the soil as a result of the proximity of ore deposits. In these various ways ore bodies not revealed by outcrops are successfully located.

The present high prices have led to much more active prospecting, the results of which can be seen in the large number of new mines and workings now being opened up; and here it is to be noted that these ventures have been based on work begun when prices were much lower than they now are. Another result of the price stimulus will be the exploitation of poorer ores than those previously worked; and as extraction techniques improve, the amount of such ores increases. The mining of ores at lower levels will also prove economic. Many mining companies know quite well what additional reserves can be reckoned on as prices advance. It is often said that all the accessible deposits are now being worked, but it may be observed that few places were less accessible than Northern Rhodesia, Mount Isa and Broken Hill in Australia, and Flin Flon in Canada when the deposits were discovered.

In the following detailed examination of the supply of ores for the various metals, I propose to take them in order of the probable demand in the long-term future, say, from 25 to 50 years; I do not think that anyone seriously believes that the supply of non-ferrous metals will be exhausted before then, and forecasts which have been based on the figures published by various companies giving their total resources can hardly be taken as a basis for serious conclusions. In any estimation of future mineral supplies, it is important to distinguish between the published reserves and the unknown resources. Most mining companies are cautious in declaring their reserves, for obvious commercial reasons and also, in some cases, because they are taxed on them.

Everyone agrees that there is plenty of aluminium in the world; in fact, it is said that aluminium constitutes 8 per cent. of the earth's crust. It is mainly present in the form of clays and other silicates which though they can be used as ores, are not so used at present, only bauxite being mined on a large scale. But bauxite is found in large quantities in many parts of the world and there is no immediate prospect of other sources having to be used. The only factor likely to limit aluminium production is the availability of electrical power, the cost of which constitutes about 60 per cent. of the present cost of the metal. The future of aluminium is very closely linked with the development of hydro-electric power or other large-scale plants for producing electricity cheaply. I think we can, without being unduly optimistic, assume that we are in no danger of seeing the reserves of aluminium ores coming to an end in the foreseeable future. With regard to metal production, the total world output in 1951 is expected to be 15 per cent. higher than in 1950; and by the end of 1953, to be as much as 50 per cent. higher than it is to-day. A dozen new smelters are in course of erection in different parts of the world, the largest being in North America.

Magnesium is in a position similar to aluminium in that it is very plentiful and is believed to constitute 2 per cent. of the earth's crust. It is obtained from deposits of magnesite and dolomite and from brines and sea water, and so is virtually unlimited. Its production generally requires electric power, though thermal processes are also used. The United States consumed about 20,000 tons in 1950 and expects to be using about six times this quantity annually by 1960. Production is now being increased accordingly.

Authoritative figures for the reserves of copper are difficult to obtain. The total "officially reported" in the Year Book of the American Bureau of Metal Statistics for 1951 is approximately 60 million (metric, tons, but this does not include a number of the largest mines both in America and elsewhere. From recent company reports, it is evident that approximately 7·9 million tons should be added to the above figure; but even this fails to include many important mines for which no reserves have been published. The output from the mines in question, which are situated in America, Russia, Japan, Germany, Spain, Yugoslavia and Turkey, totals about 1,060,000 tons per annum, and conservatively assuming the average life to be 15 years this means a further reserve of 15,900,000 tons. On this basis the total reserve is nearly 84 million tons. For commercial reasons, however, it is unlikely that the figures which have been "officially reported" are in fact as large as the reserves which are known to exist, and it is judged that a reserve of at least 100 million tons of copper is already within sight, or sufficient for about 44 years at the current rate of mine production. Prospecting for fresh deposits is continually going on, and valuable "finds" are not infrequently made; it should be remembered, for instance, that the enormous underground ore-bodies of the North Rhodesian copper belt were unknown until about a quarter of a century ago, and other deposits of comparable magnitude may well be discovered in years to come. It is apparent, too, that as methods of extraction improve, grades of ore previously regarded as uneconomical will become workable; and the development and continual improvement of the froth-flotation method of concentration is a dominating factor in this direction. For these and other reasons there seems to

* Paper entitled "The World Supply of Non-Ferrous Metals, including the Light Metals," read at a meeting of the Institute of Metals, on Wednesday, October 17, at which a general discussion on "Metal Economics" was held. Abridged.

be no ground for supposing that supplies of copper will be insufficient to meet the essential requirements of an expanding economy for many years to come.

The latest and most authoritative survey of the available resources of zinc is to be found in the paper by Dr. K. C. Dunham, presented to the 18th session of the International Geological Congress, Great Britain, 1948, dealing with reserves of ores of lead and zinc. In quoting his figures, Dunham observes that a high proportion of the estimated reserves mentioned falls within the possible and speculative (inferred) categories, and only a small proportion, less than one-third, can be regarded as proved or probable (measured or indicated). Nevertheless the estimates are made by experienced mining engineers, and are not flights of fancy. Other reliable estimates of resources were made by Mr. W. R. Ingalls in 1931 and Mr. W. P. Shea in 1940 and 1947. These estimates are given in Table V. which also includes the annual rate of consumption. It will be noted that the estimated reserves have grown more rapidly than the rate of consumption. Thus from 1931 to 1940 reserves increased at an average rate of 3 million tons per annum, and from 1940 to 1947 at an average rate of 4·3 million tons. Discoveries of new zinc deposits are being made in many parts of the world and are far too numerous for any detailed mention. The most important are perhaps those in Canada and French North Africa. In Canada, the new Barvue mine alone expects to produce 4,000 tons of ore a day in 1950 and surface drilling has already outlined 17 million tons of ore. The exploitation of poorer ores, as well as of the vast heaps of slag from lead blast furnaces which lie all over the world, will be at present prices, assuming that they continue, a further source of metal. Thus at Bergamo in Italy a new smelter is being built especially to deal with the abundant local supplies of poor-grade ore.

**Fig. 5. WORLD DISTRIBUTION OF METAL PRODUCTION BEFORE AND AFTER THE WAR**

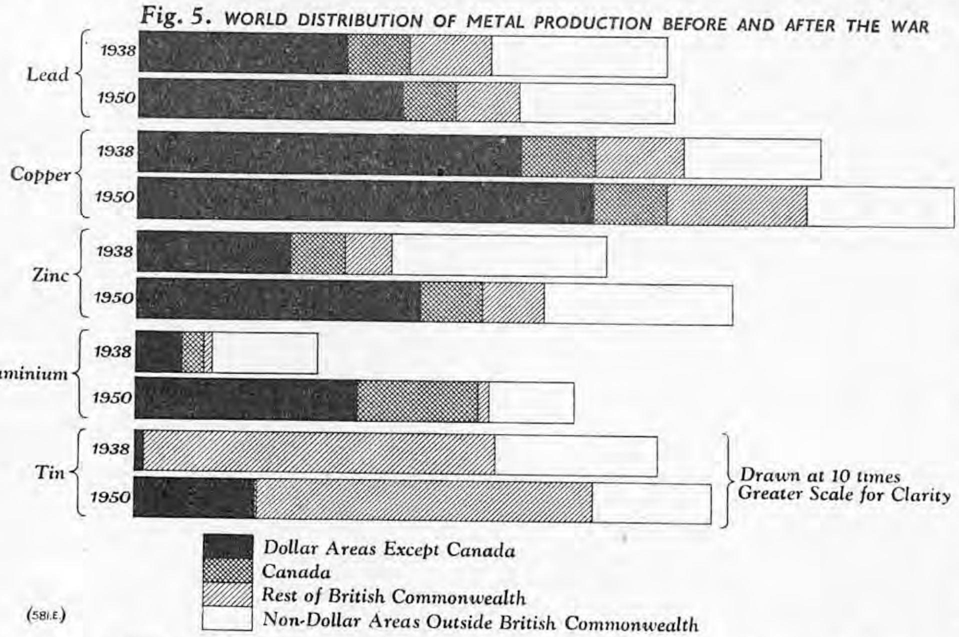



TABLE V.—*Zinc.*

| Year. | Annual Rate of Consumption. | Estimated Reserves. |
|---|---|---|
| | Millions of Metric Tons. | Millions of Metric Tons. |
| 1931 .. .. | 1·1 | 24·5 |
| 1940 .. .. | 1·8 | 39 |
| 1947 .. .. | 1·6 | 57 |
| 1950 .. .. | 1·8 | 65 |

TABLE VI.—*Lead.*

| Year. | Annual Rate of Consumption. | Estimated Reserves. |
|---|---|---|
| | Millions of Metric Tons. | Millions of Metric Tons. |
| 1947 .. .. | 1·8 | 32·5 |
| 1950 .. .. | 1·6 | 31 |

TABLE VII.—*Estimated World Reserves of Non-Ferrous Metals*, 1949.

| Metal. | World Reserves. Thousands of Metric Tons. | Years' Supply at Current Rate of Production. |
|---|---|---|
| Bauxite (crude ore) .. .. | 1,400,000 | 200 |
| Copper (recoverable content) | 100,000 | 45 |
| Zinc (gross content) .. | 70,000 | 39 |
| Tin (recoverable content) .. | 6,000 | 38 |
| Lead (gross content) .. | 40,000 | 33 |

In the case of lead there has so far been no overall world shortage, although there have been some local shortages which in future may become more serious, particularly if the shortages of zinc and copper continue. Since zinc and lead are generally found together, the new mines referred to under zinc will provide an important addition to the reserves of lead. Mr. W. P. Shea, in 1947, and Dr. K. C. Dunham, in 1948, both made estimates of the world reserves of lead as shown in Table VI. New smelters are being built in Belgium, Bolivia, Chile and Spain and extensions to existing plant are being made in Canada, French Morocco and Germany. It has also been reported that the Trepca plant in Yugoslavia is being enlarged.

Since the end of the war the production of tin has been in excess of consumption, the shortages experienced during, and immediately after, the war having allowed substitutes to become well established. It has been said that the resources in Malaya, from which about 35 per cent. of the world's tin is obtained, are rapidly being depleted, but the real trouble is that prospecting has been prevented by the local disturbances. The present rate of production may be subject to some periodical fall, but when this does occur it will serve to stimulate the finding and working of new tin-bearing ground which is known to exist in Malaya. Granted favourable conditions, production at a steady rate should be maintained for many years. Good reserves are known to exist in Indonesia, the Belgian Congo and Bolivia.

It is worth noting that, in general, the reserves of the principal non-ferrous metals seem to vary according to likely future demand, with aluminium at the top of the list and lead at the bottom. It is hard to believe that this is just a matter of chance. Since it is fashionable nowadays to quote the known reserves of metals in terms of their life at the present rate of production, the figures given in Table VII, compiled in 1949 by Mr. E. W. Pehrson of the United States Bureau of Mines, are reproduced. They take into account figures for the U.S.S.R. published before the war. Though the estimates are probably the best possible, they should not be regarded as the last word, since new discoveries have recently been made. This survey seems to show that the reserves of ore are likely to suffice for a long time to come and this view is obviously shared by the industrialists who have embarked on large-scale expenditure on smelting plant all over the world.

Having shown that the long-term supplies can cause little anxiety, we now turn to the problems of the present shortages where the position is much less clear. It is at least evident that they were brought on by stockpiling and are now aggravated by defence needs. Furthermore, as always, every shortage, however small, intensifies the demand. This situation seems likely to continue for some time and to be followed by a high demand for civilian consumption for an indefinite period. All this uncertainty of course affects the flow of investment towards the development of mining and smelting, and the time-lag between a new mine or smelter and actual production must always be allowed for. Moreover, it must be realised that this is practically the first time outside of war when metal consumption has exceeded production and producers naturally fear a sudden return to the former normal state of affairs. Nevertheless, new mines are being opened up, and the *Engineering and Mining Journal* mentions no fewer than fifty quite new copper, zinc of lead ventures in the first half of 1951. I believe that the real shortage is only a few per cent. and that these new projects are good evidence that it will not last much longer; but we are always faced with the very real difficulty that we cannot determine the extent of the demand as long as consumption is limited by the shortage of metal. Before considering United Kingdom prospects, it is interesting to see what has happened to consumption in the leading countries since the shortage began. Table VIII, relating to copper and zinc, shows that, with the exception of the United Kingdom and the United States, consumption in most countries has actually risen substantially, the countries best off being those with a large home production. In other words, the two countries with the greatest purchasing power and who are the largest regular importers now find themselves the most seriously hit by the shortages.

The causes of this situation are fairly clear. Firstly, there is the rapid growth of the fabricating industries in exporting countries such as Canada and Australia. Thus, in Australia, the home consumption of zinc has been encouraged by the fixing of an exceptionally low internal price, and more recently, Canadian metals have cost more to us than to local consumers; the same price differences are observable in other exporting countries. If there were not these differences in price, no doubt measures would be taken to see that the needs of the home consumer were adequately met. This trend, which is of course by no means new, is being given further encouragement now that exporting countries find that money is losing its value and often does not command the equipment and machinery they need. Secondly, planning and control have become features of economic policy both here and in the United States. In both countries, efforts have been directed towards keeping down the price of metals, and recently even the United States, with its colossal dollar purchasing power, has seen itself outbid for foreign ores because it could not have sold the resulting metal at the home price.

The whole-hearted determination of the United States and the United Kingdom to solve their difficulties and those of the free world by international planning and control is shown by their setting up the International Materials Conference as a means of ensuring the fair distribution of the raw material resources of the world. Here, it may be remembered that previous schemes for the international distribution of metals have seldom proved successful; it remains to be seen how far the fear of aggression may improve the chances of success now. If the International Materials Conference allocation scheme should fail, the United States may well resort to buying for its armament needs at higher prices in the open market; and this in turn might lead to a general resumption of free trading in metals and the weakening of the present arrangements by which the United States and the

TABLE VIII.—CONSUMPTION OF COPPER AND ZINC, 1938, 1949, 1950 AND 1951.

| Copper. | United Kingdom. | United States. | Belgium. | France. | Australia. | Italy. | Canada. |
|---|---|---|---|---|---|---|---|
| 1938 Quarterly average .. | 66,400 | 96,112 | 7,500 | 28,025 | 4,350 | 23,000 | 9,247 |
| 1949 Quarterly average .. | 80,975 | 234,750 | 11,750 | 30,050 | 8,325 | 15,800 | 23,000 |
| 1950 Quarterly average .. | 84,775 | 326,250 | 14,250 | 29,250 | 8,900 | 22,525 | 24,275 |
| 1951—First Quarter .. .. | 83,100 | 313,000 | 17,800 | 37,200 | 8,505 | 29,000 | 29,200 |
| Second Quarter .. | 87,700 | 316,000 | 19,200 | 31,300 | 8,900 | 29,000 | 33,800 |
| Fourth Quarter alloc. | 87,450 | 317,460 | 16,480 | 35,030 | 8,500 | 23,080 | 27,580 |
| Zinc. | | | | | | | |
| 1938 Quarterly average .. | 54,850 | 102,822 | 25,875 | 22,250 | 8,060 | 8,775 | 9,017 |
| 1949 Quarterly average .. | 50,475 | 171,500 | 15,000 | 26,750 | 11,250 | 7,025 | 10,350 |
| 1950 Quarterly average .. | 60,150 | 249,200 | 16,250 | 25,250 | 13,000 | 8,750 | 12,750 |
| 1951—First Quarter .. .. | 46,400 | 195,200 | 19,000 | 27,100 | 12,100 | 11,000 | 14,100 |
| Second Quarter .. | 46,600 | 200,000* | 29,000 | 27,900 | 13,100 | 11,000 | 15,400 |
| Fourth Quarter alloc. | 58,450 | 221,461 | 22,160 | 26,910 | 13,010 | 9,390 | 12,780 |

* Estimated.

United Kingdom are now able to get good supplies of metal more cheaply than some other countries. European countries have been less enthusiastic towards planning and control, though they may envy the United States and us our more stable prices. The influence of the Organisation for European Economic Co-operation may well be strong enough to bring them more closely together in the metals field and a beginning may already be observed in the adoption of a uniform control of end-uses of copper in member-countries.

The loss of the free market—a sensitive measure of the balance between production and consumption—means that the planners have now to decide for what purpose metals or their substitutes are to be used. As in food, for example, they have to decide what is good for us—a task really for the superman. In any case, the pattern of control and planning in an inflation-world seems likely to last and prospects of a return to free markets are perhaps more remote now than at any time since 1945. It is therefore pertinent to consider what others are doing and what we might do to ensure our supplies under these new conditions. For a start, it is interesting to examine the diagram reproduced in Fig. 5, on page 733, which shows the changes in distribution of non-ferrous metal production between Commonwealth and foreign countries since 1938. In the diagram distinction is also made between the dollar-area countries and the others. The largest increases in production have taken place outside the Commonwealth and, what is more significant for our future supplies, they are mainly in dollar areas, namely, in North and South America. Bearing in mind our need in this country to maintain dollar expenditure at a minimum, there seem to be three main ways in which we could act: firstly, by placing long-term contracts; secondly, by encouraging production in non-dollar areas where we may expect to enjoy a first call on new output, especially in the Commonwealth; and thirdly by maintaining and fostering ventures with headquarters in London. This country and the United States have already placed long-term contracts, often accompanied by loans, a condition of the loan being the repayment in metal arising from the new production. An outstanding example is our arrangement with the Canadian aluminium producers. The United States have also made similar loans abroad from Economic Co-operation Administration funds, aimed primarily at increasing production but also likely to result in an increase in supplies for America. The long-term contract method at an agreed price has always been used for aluminium and is now being extended to the older metals.

Incentives to increase production and to bring new mines into operation have been adopted in other countries, and since the development of mining in the Commonwealth is still largely based on London, we might also take steps to ensure that incentives at least as effective are available to firms with mines in Britain itself and in the Commonwealth. Thus in the United States approved new mining and smelting projects can obtain accelerated tax amortisation. The United States Department of the Interior has announced that 18 of the new projects so favoured are expected to yield the following total new production by 1955: copper, 96,000 metric tons; lead, 106,000 metric tons; and zinc, 230,000 metric tons. Aluminium production is to be increased by a total of 1,750,000 tons over the same period by similar encouragements, and magnesium by 178,000 tons. For other approved new ventures the United States authorities have undertaken, in the event of a fall in prices, to purchase metal or concentrates at an agreed floor price during a period sufficient to ensure the return of capital. Furthermore, they have made advances for approved prospecting ventures repayable in terms of ores or metal. In Canada, a new mine is allowed exemption from tax for three years and the high rate of mining development there is evidence of the effectiveness of this method of encouragement. Before applying such incentives, however, our taxation laws would appear to need overhauling since, at present, they seem to be a serious deterrent to London-based mining companies which, in fact, had tended to remove their headquarters elsewhere in recent years until this was forbidden in 1950. We cannot afford to overlook the fact that they have been our best and most certain sources of supply in the past and that we may be even more dependent on them in future. It seems unfair that these companies, whose operations are carried on oversea, should be liable to United Kingdom tax on all their profits even if they are not remitted to this country. The granting of complete relief from double taxation would also seem to be desirable; the Finance Act of 1950 only partly met this handicap.

Moreover, British-controlled mining companies do not enjoy depletion allowances comparable with those in other countries, particularly in North America, where large depletion funds can be built up out of tax-exempt current revenue, these funds being available for further exploitation when existing ore bodies have been worked out. These are but a few of the changes which our taxation laws would seem to need, if British companies are to continue to have a chance of playing a part in opening up world resources. However equitable our mining taxation may be compared to that imposed on other United Kingdom industries, it falls far short of the practice in other countries, and that is the real criterion. Not a single mining company of any size has been floated in the United Kingdom since the war, and it seems certain that none will be under present conditions.

## SOME UNKNOWNS IN GEAR DESIGN.*

By DR. H. E. MERRITT, M.B.E.

IT is not to be inferred from the title of this lecture that gear manufacturers do not know their business. On the contrary, the business is one which demands a great deal of knowledge and skill. On the purely technical side the knowledge required may be broadly classified under the headings of "geometry" and "physics," and of these it is proposed to exclude geometry, which, although having many ramifications, has the advantage of being demonstrable and exact. The field which remains uncultivated is that of the physics of gear-tooth engagement.

Gear design is probably unique in engineering in that the overall dimensions, and hence the weight and cost of a complete gear unit, are determined by the permitted stresses at one place, namely, the zone of engagement of the teeth. For a given combination of materials, the volume swept by the gears is inversely proportional to the permitted stress. Since it has been estimated that the total annual value of the gears and gear units produced in this country is 100,000,000*l*., simple arithmetic indicates that an average increase of 1 per cent. in permitted stresses would save 1,000,000*l*. a year. After making any reservations which this over-simplified calculation may suggest, it still remains obvious that more intensive study and more exact knowledge might result in large benefits to the national economy. Although a number of investigations of considerable importance and promise are now in hand, the total volume of research on gears is clearly inadequate; but such research must be of a co-operative character, with a proper co-ordination of the work carried out in different places. It is commonplace that in this country there is a serious gap between fundamental or basic research and the application of the results in industry, and it is equally true that the requirements of industry are not made sufficiently clear to those equipped to do fundamental research. The British Gear Manufacturers Association could obviously play a most important part in acting as an interpreter in this matter.

Specialist gear manufacturers will probably agree that the first "unknown" is often the power required to drive a machine for which they are asked to supply the gears. Too often the designers of the machines do not know it, and gear manufacturers have to rely upon their own judgment and experience of similar installations in order to determine gear sizes. An exchange of information, for which the B.G.M.A. appears to be the proper medium, of design data or agreed methods of estimating power requirements for defined classes of machinery could well prove of the greatest value from the national point of view. It is true that in many cases the measurement of mean or peak loads is a matter of great difficulty, and there appears to be scope for the development of new or improved techniques for the measurement of transmitted power. A number of techniques of this kind have, of course, already been developed, but there is still room for methods of instrumentation which can be quickly applied to existing installations without disturbing their operation.

The maximum intensity of loading always exceeds the mean loading, from one, more or all of the following causes: cyclic variations in the externally-applied torque; cyclic variations due to torsional vibrations; accelerating forces caused by tooth errors (usually called "dynamic increments"); and errors of tooth alignment caused by elastic deformation of the shafts, bearings and casings. Some of these items cover too wide a field for discussion here, and only two will be touched upon. The effects of mal-alignment, whether due to machining errors or distortion, can only be appreciated if they are considered in relation to the deflection of the teeth. Reference must be made to the work of Dr. H. Walker in this connection. In the case of gears made from normalised or heat-treated steel of medium tensile strength, the tooth deflection is so small that the concentration of loading resulting even from errors associated with the highest class of manufacturer appears prohibitive. On strictly theoretical grounds one would not, in fact, expect the gears to work at all, and the fact that they do so is the result of the bedding in of the surfaces during the earlier periods of running.

In certain types of high-duty drive in which the elastic deformation of the mounting is considerable (notably spiral-bevel and worm drives) modification of the tooth spirals is now general practice. This modification, however, is of arbitrary character, made possible by the flexibility in the design of the cutters or of the machine settings associated with spiral-bevel and worm-gear generation. The same technique does not, however, appear to have been developed for industrial spur and helical gears other than in very embryonic fashion. Scope would appear to exist for the development of what might be called "controlled tooth spiral modification" by supplementary machine motions. Considering the case of a somewhat wide and slender pinion, the effect of deflection due to bending and torsion on the distribution of load across the face width can be calculated. Parallel examples of calculation have been made in connection with screw threads and long splined shafts. The result of such a calculation is merely frightening, and does not lead much beyond the conclusion that slender pinions should be avoided. If, however, the order of the calculation is reversed and the final shape of the tooth spiral is determined under an assumed condition of uniform tooth loading, the result is the modification of tooth spiral which should be the objective.

The occurrence of dynamic increments of tooth load has been implicitly recognised ever since speed factors came into use in rating formulae. It has been recognised that all such speed factors are empirical, and although they may be associated with complex-looking formulae, these formulae are merely attempts to give algebraic expression to empirical result or personal guesses, and do not rest upon any rational basis. A number of methods have been proposed in order to take into account the errors and elasticity of the teeth, and the speed and moments of inertia of the gears, but the possible modes of vibration of gears, in association with the attached masses, are so complex that any formula which purports to give the dynamic value of tooth load must be regarded with suspicion. In a speed-factor curve covering a wide range of speed, it must necessarily be assumed that the accuracy of the gears is appropriate to their speed, and the relationship between speed and accuracy is a subject worthy of further investigation. With certain broad assumptions, the teeth will not momentarily separate until the semi-amplitude of the dynamic increment of tooth load exceeds the mean transmitted load; and, conversely, if separation does not occur, the maximum tooth loading will not be more than twice the mean. Attempts have been made (and it is not intended to discourage them) to measure the intensity of tooth loading by photo-elastic methods applied to running gears made of photo-elastic material, under intermittent illumination. A difficulty in designing apparatus of this kind is that the tooth profiles may not retain their accuracy, whilst the elastic properties of the gear system may be unknown. In any such apparatus these elastic properties should be adjustable, since they cannot be separated from the results. An alternative method of approach might be to use metal gear rings and to mount them on photo-elastic webs in order to measure variations of torque, rather than of tooth stress.

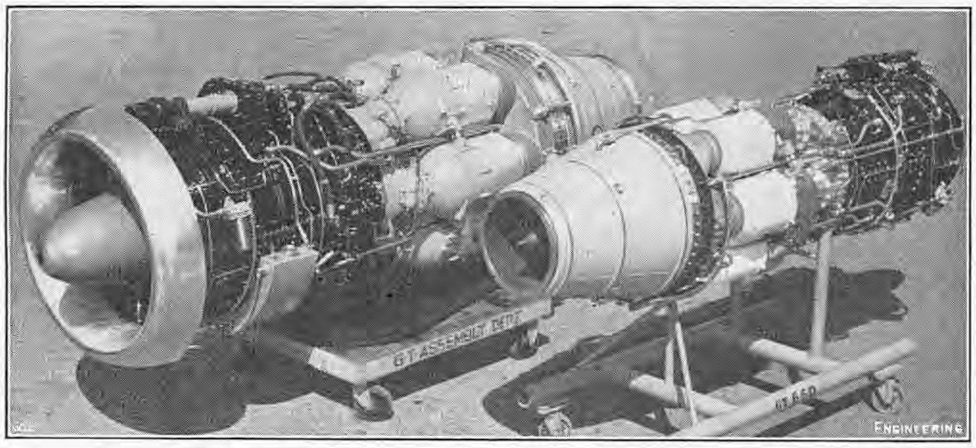
The basic problem in design is to relate permissible stress to actual stress. It is seldom that either of these is actually known. By applying elementary beam theory, the maximum stresses at the root of a tooth can be calculated, provided that certain assumptions are made. The first problem is to make the right assumptions! This matter cannot be separated from the precise shape of the tooth profile and its departure from the nominal involute. Dr. Walker has dealt with the case which may be described as "controlled profile-modification," but when tip-easing is applied by generation from a modified basic rack (as defined in the appropriate British Standard specification) the conditions of engagement are very different. The author proposes to deal with this question at greater length on another occasion, but it is, perhaps, important to emphasise that in research work the strength of gear teeth cannot be divorced from the minutiae of tooth profile.

Perhaps the most serious gap in our knowledge, as far as tooth strength is concerned, is the effect of fillet form and stress concentration on the endurance of the material. Work on this subject has of course been done, using photo-elastic technique; but although this gives a useful qualitative picture and may be valuable in comparing the strength of different tooth forms, it does not appear possible to apply the results quantitatively to actual design practice. The two principal factors requiring further investigation are the behaviour of different materials in regard to endurance under conditions of stress concentration (briefly described as "notch-sensitivity"), and the scale effect, whereby teeth of geometrically similar form, but to different

* Paper presented at an extraordinary general meeting of the British Gear Manufacturers Association, held in the Piccadilly Hotel, London, W.1, on November 6, 1951.

# "ORENDA" AXIAL-FLOW TURBO-JET ENGINE.

A. V. ROE (CANADA), LIMITED, MALTON, ONTARIO.




scales, do not behave similarly. A further aspect of the matter, which stands in urgent need of more extended investigation in this country, is the strength of case-hardened teeth. The work of Mr. J. O. Almen will be familiar to those concerned with high-duty gears for motor-vehicle transmissions, as well as the work of the Motor Industry Research Association. Nevertheless, it appears that the results of this work are not yet sufficiently well known to all designers concerned with high-duty case-hardened gears; one often sees gears specified in En.39, when material having a lower alloy content would probably be equally satisfactory. To make the best use of low-alloy case-hardening steels, which is now a national necessity, brings with it an urgent demand for more precise knowledge of the refinements of tooth design and of the specification of heat-treatment processes.

Another question on which information is lacking is that of the effect of variable-load cycles on endurance. The rating formulae contained in the B.S. gear specifications are not even empirical (meaning based on limited data), but merely represent guess-work which may, or may not, have been inspired. The author, having done the guessing in question, feels privileged to say this. Fatigue tests take a long time, and the number of fatigue-testing machines required for a comprehensive investigation is very considerable. There is a strange contrast between the large batteries of machines that one sees engaged on the properties of materials at elevated temperatures, and the one or two machines at work on gear-tooth investigations. The difference does not represent the relative importance of the problems, but only the difference of emphasis by which the research needs of the two branches of industry are made known.

The criterion "pounds per inch of face width" is not yet dead, and a last effort is needed. The Hertzian criterion of maximum compressive stress has been extensively used as a basis for comparing surface loading, but it is to be observed that the maximum permissible compressive stress at the surface, for any material, appears to bear no relation to the endurance stress of that material measured in other ways, notably in tension and in reversed tension and compression. Moreover, there appears to be no experimental evidence to show that the effects of different moduli of elasticity in different combinations of materials have any meaning in design practice. It can be concluded that, if the maximum Hertzian compressive stress is to be used as a criterion, the permissible stress to be assigned to any materials must be determined empirically. The simpler criterion represented by the load per inch of line contact per inch of relative radius of curvature is, therefore, simpler and equally satisfactory; it is used by many designers. When applied to industrial rating formulæ, of the kind now contained in the B.S. gear specifications, however, it was found that the larger sizes of gear appeared to be overloaded when the permissible stresses were determined by using a speed factor based on r.p.m. The criterion was therefore modified to the form $S_c = \frac{F_c}{R_r^{0 \cdot 8}}$, where $S_c$ is the surface-stress criterion, $F_c$ is the load per inch of line contact, and $R_r$ is the relative radius of curvature. The index 0·8 was, again, empirical. The author has now been able to show that the results of the B.S. rating formulæ are very closely consistent with the use of an unmodified criterion, $S_c = \frac{F_c}{R_r}$, in conjunction with a speed factor based on pitch-circle velocity. There is an additional allowance for gear ratio which need not be discussed here; the broad conclusion, which is sufficiently interesting, is that the unmodified criterion is, in fact, the present basis of B.S. rating formulæ. Future investigations could usefully be directed to the inquiry of whether this criterion is adequate.

(*To be continued.*)

## "ORENDA" AXIAL-FLOW TURBO-JET ENGINE.

In the last two years it has become clear that the axial-flow turbo-jet is the accepted power plant of the high-performance military aircraft of the immediate future. It may be of interest, therefore, to give an outline of the principal constructional features of the Canadian Orenda axial jet engine, which was on view at the Society of British Aircraft Constructors' exhibition at Farnborough in September, 1950, but about which, little could be said at the time. The Orenda, which is shown in the illustration behind the Chinook (an earlier and smaller engine of similar design), was designed and constructed by Messrs. A. V. Roe (Canada), Limited, Malton, Ontario, for the Royal Canadian Air Force, as a power plant for the twin-engine long-range fighter aircraft, the CF100, built by the same company. The design was started in September, 1946, and the engine ran for the first time on February 10, 1949. A year later, it had completed 2,000 hours of test-bed running, and in July, 1950, two Orenda engines made their first flight installed in the outer nacelles of a Lancaster "flying test-bed." By February 5 this year 5,000 hours' running had been completed.

In the Orenda, air enters a ten-stage axial compressor through an annular intake; on leaving the compressor, it passes through diffusing ducts to six interconnected tubular combustion chambers. The hot gases leaving the combustion chambers are ducted to a nozzle box and thence to a single-stage axial air-cooled turbine coupled to the compressor, and are ejected through a tail cone. The engine develops a static thrust of over 6,000 lb. at sea level, and has a specific fuel consumption of 1 lb. per lb.-thrust per hour. The dry weight is about 2,500 lb., the diameter is 42 in. and the overall length is about 10 ft. The annular air intake is formed between the compressor-intake casting, of magnesium alloy, and a casting housing the front rotor bearing and the auxiliary-drive gearbox, and supporting the 32-volt electric starter-motor, which is covered by a nose fairing. The front-bearing housing is supported from the intake casting by six tubular struts, enclosing the auxiliary-drive take-off shafts, electric cables, and lubricating-oil pipes. The compressor stator blades, of aluminium alloy, are dovetailed in rings which are held in place by spacer rings bolted to the stator casing, a two-piece magnesium-alloy casting.

The first nine compressor-rotor discs are of aluminium alloy, the tenth of steel; separated by spacer rings, they are mounted on a drum, the ends of which are secured to alloy-steel stub shafts. The blading of the first, second, third and tenth stages is of steel, the remaining blades being of aluminium alloy. The blades of the first three stages have "fir-tree" fixings; the last seven stages of blading are dovetailed. There is provision for bleeding air from the second, fifth and eighth stages for cooling various engine components and for aircraft services, and a small amount of air is allowed to leak past the seal between the tenth rotor disc and a gland on the cast aluminium-alloy diffuser casing, for cooling the rear face of the turbine disc.

The compressor rotor is carried in two bearings, the forward one already referred to, and the centre bearing—a self-aligning thrust bearing housed in the inner ring of the annular diffuser casing. The centre bearing, which is cooled by air drawn from the fifth stage of the compressor, consists of two ball-thrust bearings, separated by accurately-ground spacer rings. To allow for deflections of the compressor shaft during flight manœuvres, the bearing housing, which is spherically-ground on its periphery, is held by a spring against a flexible rubber thrust-ring which deforms slightly under misalignment but restrains the rotor assembly against axial movement.

Ducts in the diffuser casting convey the compressed air to the six combustion chambers, which are arranged around an aluminium-alloy "backbone" casting, joining the diffuser casting and the turbine nozzle box, and carrying the turbine bearing. Within the combustion chambers are flame tubes in a high-temperature alloy; the outer casings of the combustion chambers are of mild steel, the expansion sections being aluminium-alloy castings. Fuel is injected into the flame tubes by double-orifice atomising burners mounted on the diffuser ducts, and projecting into the noses of the flame tubes. For lighting, interconnecting tubes are provided between the combustion chambers; two of these tubes are equipped with torch igniters comprising a fuel spray and a sparking plug. An automatic timing relay is provided for starting the engine, to ensure that the starter motor, the torch-igniter fuel valves, and the torch-igniter sparking plugs are actuated in the correct sequence.

The transition ducts from the combustion chambers to the turbine-nozzle annulus form part of the nozzle box, a welded assembly of steel castings and pressings in which the turbine guide vanes and the shroud ring of the turbine rotor are mounted. The nozzle box is cooled by air drawn from the second stage of the compressor, which is also fed to the interior of the backbone casting and to the turbine stub-shaft bearing. The turbine consists of an austenitic-steel disc, in which heat-resisting nickel-chromium alloy blades are secured with fir-tree fixings. Cooling air from the fifth and tenth compressor stages is fed to the front and rear faces, respectively, of the turbine disc. The stub shaft, integral with the turbine disc, is attached to a main shaft, which in turn is splined to the compressor shaft. From the turbine, the hot gases pass out through the jet nozzle by way of a tail cone, of stainless-steel sheet with an insulating layer on the outer surface of Fibreglass and foil protected by an aluminium covering.

The fuel system was developed by Messrs. Joseph Lucas, Limited. Fuel is fed to the six burners, through a flow distributor, by two variable-stroke pumps, with overspeed governors, the delivery of which is regulated automatically by a flow-control unit connected to the pilot's throttle lever and responding to changes of altitude, so that a constant engine speed is maintained at all altitudes for any setting of the throttle lever. The high-pressure fuel shut-off cock is incorporated in the flow-control unit. For lighting up, fuel is introduced to the torch igniters through a solenoid-operated reducing valve. Lubricating oil is fed by an oil pump through a ring main at a pressure of 15 to 18 lb. per square inch to the rotor bearings, the gearboxes and the drive-shaft flexible coupling. Separate scavenge pumps are provided for the centre and rear bearings, the front oil drains and the shaft coupling, returning the oil to a 13-pint oil tank; in the case of the centre and rear bearings, it is returned by way of a heat exchanger in which fuel is used as the coolant.

Earlier this year, some of the development problems of the Orenda were described by the chief development engineer of the company.* In the earlier stages, the engine showed some instability, and a tendency to surge during rapid accelerations which was cured by redesigning the first and second stages to give a better air-velocity distribution. One of the most serious mechanical troubles encountered was the occurrence of fatigue failures in the seventh-stage compressor-rotor blades arising from resonance at certain engine speeds, which necessitated some redesign to ensure that the critical blade frequency no longer coincided with engine exciting frequencies. As already mentioned, flight trials of the Orenda were originally carried out in a Lancaster aircraft with two Orendas installed in the outboard positions, but in order to extend the range of testing to higher speeds and to altitudes above 33,000 ft., the operational ceiling of the Lancaster test-bed, an Orenda has been installed in a North American Sabre aircraft. High-altitude testing has shown that the engine possesses excellent combustion stability. The latest development on which information has been released is the fitting of after-burning equipment in the tailpipes of the Orenda engines fitted in the CF 100 all-weather fighter, to provide a considerably increased thrust for take-off and combat.

* "The Development of the Avro Orenda Jet Propulsion Engine," by D. W. Knowles. Presented at the Semi-Annual Meeting, Toronto, Canada, June 11-14, 1951, of the American Society of Mechanical Engineers.

## NOTES ON NEW BOOKS.

*Testing of Measuring Equipment. National Bureau of Standards Handbook* 45.

Superintendent of Documents, U.S. Government Printing Office, Washington 25, D.C., U.S.A. [Price 1.25 dols.]

A SERIES of four hand-books, compactly presenting a comprehensive survey of information relating to weights and measures regulations current in the United States of America, is completed by the present volume, issued by the United States Department of Commerce. This hand-book, which deals with commercial measuring equipment and practice, is a companion volume to an earlier one, No. 37, which was devoted to weighing; and the two together are intended to provide practical instructions relative to all types of devices that United States inspectors of weights and measures are normally required to examine. The subject-matter of *Handbook* 45 covers linear and volumetric measures, odometers and taximeters, bottles for milk and lubricating oil, grease-dispensing devices, meters and vehicle tanks for liquid fuels, dry measures, baskets and boxes for fruit, and meters for water, gas and electricity. Typical forms of each class of appliance are described, often with explanatory diagrams, and recommended testing apparatus and procedures are laid down in some detail. Although—indeed, more likely because—American appliances and methods of examination differ materially from the British equivalents in points of detail, besides embracing some forms of equipment not commonly used in this country, *Handbook* 45 will be of technical interest to British weights and measures inspectors. For American commercial establishments either using or making measuring appliances, it obviously has a considerable value which is shared, within limits, by similar British firms, especially if their products are for export.

*Synchronous Machines: Theory and Performance.*

By CHARLES CONCORDIA. John Wiley and Sons, Incorporated, 440, Fourth-avenue, New York 16, U.S.A. [Price 5·50 dols.]; and Chapman and Hall, Limited, 37, Essex-street, London, W.C.2. [Price 44s. net.]

THIS book is of transatlantic origin, being one of a series written by members of the staff of the American General Electric Company; and its primary object is to present a unified development of the fundamental circuit theory of the transient performance of synchronous machines. Considerable knowledge, not always elementary, is assumed on the part of the reader, although the volume is stated to be intended primarily for the practical engineer who wants to learn something about the subject without searching elsewhere. After a short account of the construction of a synchronous machine, its "mathematics" are described in general terms and its steady state, balanced operation, three-phase and single-phase short-circuit currents and short-circuit and starting torques are considered in detail. The treatment throughout is mathematical and owes a great deal to the work of Messrs. S. B. Crary and G. Kron, to whom fitting acknowledgment is made. That a large manufacturing firm should act as sponsor to a work of this kind is an indication of the advances that have been made since electrical theory and practice were regarded as antagonists.

*Typical Microstructures of Cast Iron.*

The British Cast Iron Research Association, Alvechurch, Birmingham. [Price 15s. to members of the Association; 21s. to non-members.]

THE microscope has always been a particularly valuable instrument in the study of cast irons, as the properties of these materials are largely governed by their microstructure. The general excellence of the micrographs produced by the British Cast Iron Research Association has long been recognised and it is fitting, therefore, that the Association should have produced the present work, which is intended as a practical tool for the use of foundry metallurgists, foundry engineers and other producers or users of iron castings. The main object is to provide, for reference and comparison, a series of half-tone reproductions of microphotographs of the principal types of cast irons normally encountered by the metallurgist and engineer in their daily work, at magnifications to which they are accustomed. The book is of "atlas" size, measuring $11\frac{1}{4}$ in. by $8\frac{1}{2}$ in., and in fact recalls the *Atlas Metallographicus* of Hanemann and Schreder, published in Berlin in 1929. There are 41 micrographs and in all cases explanatory text is provided on the facing page. Typical microstructures showing the various constituents of cast iron are first given, then follow, in turn, micrographs of unalloyed cast irons, special and alloy cast irons, malleable cast irons and finally some typical defects in iron castings. In a useful, well-written introduction, the dependence of the structure and properties of cast iron on cooling rate and composition are indicated and the mode of occurrence and appearance of the constituents of cast iron are considered.

## FLANGE-MOUNTED SPUR REDUCTION GEARBOX.

A RANGE of spur gearboxes, similar to the one shown in the accompanying illustration, with coaxial shafts, has been introduced recently by Messrs. Electropower Gears, Limited, Kingsbury Works, Kingsbury-road, London, N.W.9, for transmitting powers ranging from $\frac{1}{8}$ h.p. to 25 h.p. in speed-reduction ratios from 116·8 to 1, with an efficiency of approximately, 92 per cent., to 2·56 to 1, with an efficiency of about 98 per cent. Triple-reduction gearing is employed for the higher speed reductions, down to 28·2 to 1; double-reduction gearing is used for speed ratios from 25·15 to 1 to

2·56 to 1. The gearwheels are of high-tensile steel, accurately generated to give smooth, quiet and efficient running, and all components are interchangeable. The shafts and pinions are of one-piece construction and run in large ball bearings. The output shafts are designed to withstand normal overhung loads. The casing in which the gears and bearings are housed is a single casting of close-grained grey iron, accurately bored and faced. The combined oil-filter and ventilating plugs, drain plugs, and oil-level plugs are located, and oil seals are provided to prevent leakage, so that the gearbox can be flange-mounted in any position. Splash lubrication is provided. The gearbox may be belt or rope driven, or driven directly through a flexible coupling.

## BOOKS RECEIVED.

*Metropolitan Water Board. Forty-Eighth Annual Report for the Year Ended 31st March*, 1951. Staples Press, Limited, 14, Great Smith-street, London, S.W.1. [Price 5s.]

*Locomotives. A Report on the Industry.* P.E.P. Engineering Reports.—III. P.E.P. (Political and Economic Planning), 16, Queen Anne's Gate, London, S.W.1. [Price 13s., post free.]

*Ministry of Civil Aviation. Civil Aircraft Accident. Report on the Accident to D.H.89A Rapide G-ALXJ which Occurred on 10th July*, 1951, *at Skeirrip, near Laxey Head, Isle of Man.* H.M. Stationery Office, Kingsway, London, W.C.2. [Price 1s. net.]

*City and Guilds of London Institute. Department of Technology. General Regulations.* 1952. [Gratis.] *Regulations and Syllabuses for Examinations in Mechanical Engineering and Allied Subjects, for the Session* 1951-52. [Price 1s. net.] *Annual Report*, 1950. [Price 1s. net.] *Examination Results for* 1950 *(Being Part III of the Annual Report).* [Price 1s. net.] Office of the Department, 31, Brechin-place, London, S.W.7.

*The Young Wage-Earner. A Study of Glasgow Boys.* By PROFESSOR T. FERGUSON and J. CUNNISON. Published for the Nuffield Foundation by Oxford University Press, Amen House, Warwick-square, London, E.C.4. [Price 8s. 6d. net.]

*National Building Studies.* Research Paper No. 10. *An Economical Design of Rigid Steel Frames for Multi-Storey Buildings.* By DR. R. H. WOOD. H.M. Stationery Office, Kingsway, London, W.C.2. [Price 3s. 6d. net.]

*The Working of Aluminium in the Shipyard.* Information Bulletin No. 18. The Aluminium Development Association, 33, Grosvenor-street, London, W.1. [Price 2s.]

*United States National Bureau of Standards.* Circular No. 511. *Hydrogen Embrittlement of Steel. Review of the Literature.* By R. W. BUZZARD and H. E. CLEAVES. The Superintendent of Documents, U.S. Government Printing Office, Washington, 25 D.C., U.S.A. [Price 20 cents.]

## 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.

*Fireclay Refractories for Petroleum Industry.*—A new specification, B.S. No. 1758, deals with fireclay refractories in the form of bricks and shapes for use in the petroleum industry. It covers dimensional requirements and physical properties for three grades of fireclay refractories, classified according to the duty for which they are suitable. Although prepared specifically for the petroleum industry, it is expected that the provisions of the specification will be found equally useful to many other users of refractory products. [Price 2s., postage included.]

*Physical Tests of Raw Rubber.*—Part 3 of B.S. No. 1673, which replaces B.S. No. 902 and deals with methods of testing raw rubber and unvulcanised compounded rubber, has now been issued. It is concerned with methods of physical testing and while reclaimed and synthetic rubbers are not covered, this does not imply that the methods are necessarily unsuitable for these materials. Among the changes made in the new edition are the introduction of two new methods, namely, the determination of viscosity by the shearing-disc viscometer and the determination of the scorching rate of rubber compounds. On the other hand, the determination of the "mastication number" has been deleted because it is not now generally used. Moreover, as is always the case in such circumstances, the methods retained have been revised. Three new methods have been considered, but are not considered to be sufficiently developed for inclusion in the present issue. These relate to the determination of processing characteristics, the measurement of colour and the determination of ageing characteristics. [Price 2s. 6d., postage included.]

*Method for Analysis of Tin in Ferro-Tungsten and Tungsten Metal.*—A further publication in the series entitled "Methods for the Analysis of Iron and Steel" has now been issued. This, Part 22 of B.S. No. 1121, covers the method for the determination of tin in ferro-tungsten and tungsten metal. The method is based on the isolation of the tin as sulphide, using molybdenum sulphide as carrier. The tungsten is retained in solution as a complex with ammonium citrate. The tin sulphide is separated and re-dissolved, and is then reduced to the bivalent condition with metallic aluminium, in the presence of an antimony salt. The reduced tin is finally titrated with N/100 potassium iodate solution. [Price 1s., postage included.]

*Screwing Taps.*—A revision of B.S. No. 949, which has just been completed and issued, was originally proposed in order to include tables of general dimensions for taps for special fine pitch threads, threads of certain American and metric series, and other threads in common use. It was subsequently decided that some amendment to the tolerances on the threads was also desirable, and, with the publication of B.S. No. 1580, which is concerned with unified threads, it was felt that tolerances which would be applicable to unified threads as well as to those covered by the previous specification should be formulated. The present edition has been considerably enlarged and extra tables of general dimensions, and tables of limits of sizes and tolerances of taps have been included. Information is also given to enable the limits and tolerances of taps for special threads and for intermediate sizes, not included in the specification, to be readily calculated. [Price 15s., postage included.]

*Copper Coverings for Roofs.*—The Council for Codes of Practice for Buildings, Construction and Engineering Services, Lambeth Bridge-road, London, S.E.1, have now issued, in final form, Code of Practice, C.P. No. 143.104, dealing with copper coverings for roofs. It deals not only with sheet coverings for roofs, but includes also such flashings and gutters as are an integral part of roof construction. Recommendations are made for the selection of sheeting and detailed information is given regarding the technique of laying and the preparatory work entailed. Many of the details associated with the laying of the roofing are illustrated by a series of drawings. Appendices deal with gauges, thicknesses and weights of copper sheet and the physical properties of copper. [Price 4s., postage included.]

CARE OF SMALL PLANT AND HAND TOOLS.—We have received a copy of the Ministry of Works Advisory Leaflet No. 22, *Care of Small Plant and Hand Tools*, compiled for the building industry. Copies may be obtained from H.M. Stationery Office, P.O. Box No. 569, London, S.E.1, at the rate of 25 copies for 3s. 6d., 50 copies for 6s. 6d., 100 copies for 12s. 6d., or 1,000 copies for 100s., post free. The price of a single copy is 3d. net., postage $1\frac{1}{2}d$.