FLOW-CONTROL WEIR AT NIAGARA FALLS.

IN view of the interest displayed in the flow-control weir at Niagara Falls, which was illustrated and described in our issue of September 24, 1943, page 241, we give below some further particulars and illustrations. In the first place it may be noted that the rise of 1 ft. in the water surface of the pool feeding the American Falls, which was expected to result from the construction of the weir, has definitely occurred, so that not only has the appearance of those Falls been greatly improved but, it is stated, an additional 30,000 horse-power is available, presumably from the hydro-electric plants on the American side. On the other side of Goat Island to the pool, that is, on the American flank of the Canadian, or Horseshoe, Falls there is also a considerably increased flow.



FIG. 1. HORSESHOE FALLS; CABLEWAY IN DISTANCE.

In our previous article the site of the weir in relation to the crest of the Horseshoe Falls was indicated by a dotted line marked on a general aerial view, but it can perhaps be more accurately located in Fig. 1, above, which has been reproduced from a photograph taken from the Canadian shore looking upstream; the two cableway towers, between which the weir is laid in the bed of the river, can be distinguished in the background. In the previous article also it was not possible to deal definitely with the relation of the ends of the weir to the Canadian shore, on which the head tower of the cableway stands, and the relation to the artificial island, which was created in approximately mid-stream to carry the tail tower, although reference to possible erosion of the Canadian bank, due to increased flow through a gap near it, indicated that the weir was not carried right up to that bank. The diagrammatic cross section of the river given in Fig. 3, page 262, will, however, clarify the matter, although, as is customary with such profiles, the vertical scale is very much greater than the horizontal scale. It will be evident from this figure that the water shoals near the artificial island, with the result that the crest of the weir simply runs into the river bed at that point. The weir has, therefore a definite length but does not end abruptly at the island side as it does near the Canadian bank. There is thus a uniform depth of water over the crest very nearly up to the island, this depth being 5 ft. at normal average flow. Further, Fig. 3 illustrates very well the difference in height above the water level of the two cableway tower tracks, that on the island being rather more than 6 ft. above the surface while that on the Canadian bank is 25 ft. As both towers are of the same height it will be obvious that the catenary of the cable is asymmetrical; not, of course, that this condition is of practical importance. The height of the top of the island was fixed to be about 1 ft. above the highest flood level yet recorded.

The cable has a sag of 130 ft. and a limiting load of 10 tons, in which connection it may be mentioned that the limiting load for a span of 1,680 ft. was 20 tons for the same pair of towers as used in the construction of a dam in Texas. The pull at the head of the towers is 300,000 lb., made up of 241,500 lb. due to the main cable, 28,000 lb. from the secondary track and 30,500 lb. from the electric cable. It will be clear from Fig. 3 that the overturning moment is balanced by the thrust on the inner track, which, it will be remembered, is inclined, and since the arm formed by the height of the towers is much greater than that formed by the distance between the tracks, viz., 76 ft. 10 in., the thrust must be greater than the pull; it is, as a matter of fact, 850,000 lb., which, translated into load per lineal foot on the ballast under the inner track, is 36,000 lb., or about twice as much as under the driving wheels of a very heavy locomotive. Although this installation is of an exceptional nature the existence of such a loading is of interest in view of the fact that it is carried on a stone-filled crib surrounded by the island structure of dumped stone. The main cable is, as previously stated, $2\frac{1}{2}$ in. in diameter and forms the track on which the stone-transporting carriage runs, the construction of which can be gathered from Fig. 2, page 262. The in-haul and out-haul endless cable for the carriage traverse is $\frac{3}{4}$ in. in diameter, as are also the hoist cable for raising and lowering the load and the cable for operating the grab release mechanism. There is also a button cable, that is, a cable fitted with spacing devices for hangers preventing sag of the carriage-operating cables. The cable carrying the inspector's car is 1 in. in diameter, the endless traversing cable being $\frac{1}{2}$ in. in diameter. The electric supplies and controls to the tail tower on the artificial island are supported by a cable 1 in. in diameter. The power cable carries a three-phase, 2,200-volt circuit; the main transformer is on the Canadian shore and there are others either near or on both towers. The control cable is made up of 10 pairs of light wires, this number being necessary to give the operator on the head tower complete control of the tail tower.

Although the laying of the weir was referred to in the previous article, the method of depositing the material was not described. It is of interest to note that the method at first attempted was to lower the stone on to the river bed, but this had to be abandoned as the load on entering the water was carried some 25 ft. to 50 ft. downstream of the site, the river current at this point being anything between 5 ft. and 8 ft. per second. The stone had therefore to be dropped from a point above the surface of the water. The lowest dropping point is indicated in Fig. 2, and the actual dropping of a heavy block from a higher point is shown in Fig. 4, on page 263. As the resulting surge and oscillations of the various cables due to the sudden release of the load were not violent, lowering the stone close to the water level before release proved unnecessary and it was eventually dumped at the transporting elevation. The photographs from which Figs. 4 and 5 are reproduced were taken looking towards the American bank, the tower in the background being that on the artificial island. It will be seen from Fig. 4 that very definite broken water exists in front of the tower, this condition indicating that in this area, at the time the photographs were taken, the weir had almost reached its full height, with its top 5 ft. below the surface of the water. In this connection, the surface shown in Fig. 4 may be compared with that in Fig. 5, the photograph

from which the latter was reproduced having been taken before any laying had been done; the inspector's car seen in it being suspended from the main cable for the purpose of making a preliminary survey.

A reference to possible erosion of the Canadian bank, by increased flow through the gap at the end of the weir, was made in the previous article, but no data were available on this point at the time of writing. It is now evident, as indicated on the right in Fig. 3, that protection has been given to the Canadian bank at this point by the deposition of stone on its face. The latest figure of about 30,000 tons of stone deposited in laying the weir and the facing, when compared with the 27,000 tons previously mentioned as having been used for the weir, seem to indicate that the facing contains about 3,000 tons of stone. It will be clear that the gap was left so that the flow of water to the power plants on the Canadian bank would not be decreased; without it, a large part of the stream would have been diverted round the artificial island to the American Falls. Further, the main flow will be more evenly distributed over the crest of the Horseshoe Falls instead of tending to concentrate at the point where recession of the crest had become very marked. This point can be seen in Fig. 1.

Some notes on the general problem of the erosion, and consequent recession, of the Horseshoe Falls may be included here. The mean rate of recession of these Falls at the central part during the period 1842 to 1906 was 3·8 ft. per annum and during the period 1906 to 1927 it was 2·3 ft. per annum. It may be inferred that the decreased rate is partly due to an increasingly large part of the flow being diverted for power purposes, but it may also arise from another cause. The bed of the river in the rapids above the Falls, and therefore the crest itself, consists of a thick stratum of hard limestone. The depth of this stratum along the present crest is of the order of 78 ft., but at the head of the rapids it is estimated to be about 130 ft. Obviously, therefore, as the crest moves upstream the resistance to erosion increases since the softer underlying strata, the erosion of which is the cause of the recession, will decrease in thickness. As these strata wear away the harder limestone is undercut and falls in large blocks. The construction of the weir, moreover, by spreading the water more uniformly over the crest will remove the eroding effect of the former somewhat concentrated flow at the centre. Apart from this the shelves at the Goat Island and Canadian flanks will, as already pointed out, receive more water.

It may be of interest to indicate how far upstream the effect of the weir will be felt. From where the river leaves Lake Erie to the beginning of the rapids is a distance of 22 miles. For the greater part of this distance the river is split into two streams by the large Grass Island. It is estimated that the rise of 1 ft. in the water level in the pool above the American Falls will be reflected in a rise of about 1¼ in. at the Lake Erie end of the river. It may be mentioned that the recession of the American Falls has been found to be negligible, though one or two falls of rock from the crest have occurred in recent years. One result of the efforts to preserve the appearance of Niagara Falls is increased efficiency of the power plants on both sides of the river. Some of the earlier plants, as might be expected from the date when they were commenced, 1890 to 1893, were not very efficient, by modern standards, but the later plants show important technical advances, and make much more effective use of the water.

We understand that the supplementary works, originally proposed, namely, some excavations in the channels leading to the flanks of the Horseshoe Falls, as well as some diverting submerged weirs in those areas, have not been abandoned, but will be proceeded with when a suitable opportunity presents itself. Some indication of the nature of these works was given in the two articles on the recession of the Falls, published in Engineering, vol. 125, page 418 (1928) and vol. 127, page 133 (1929). It does not follow, however, that the plans there outlined will not be modified, the effects of the main weir having yet to be completely analysed. The present article is based mainly on an article

FLOW-CONTROL WEIR AT NIAGARA FALLS.

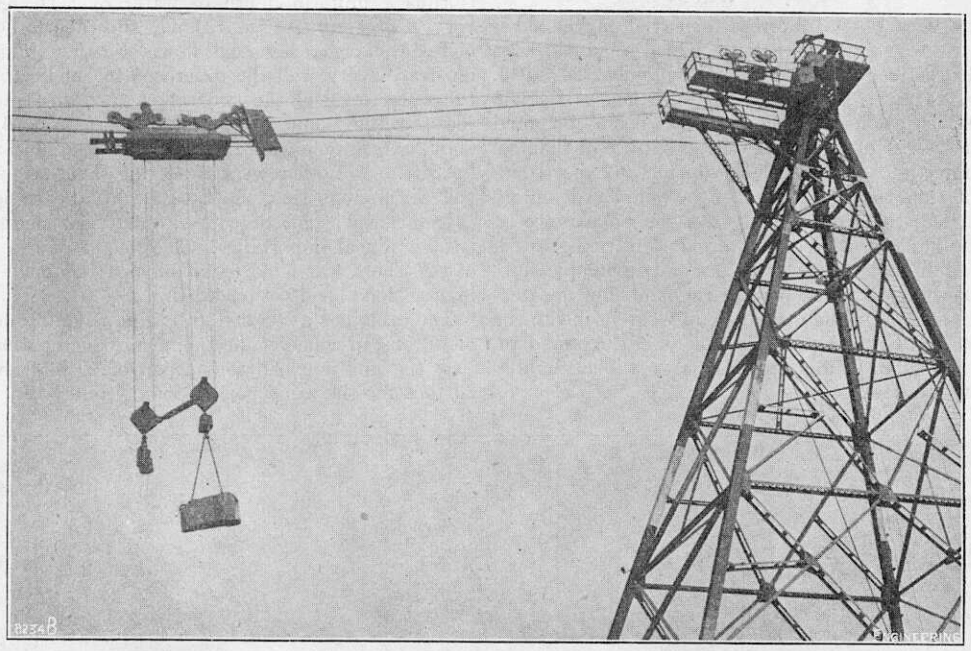
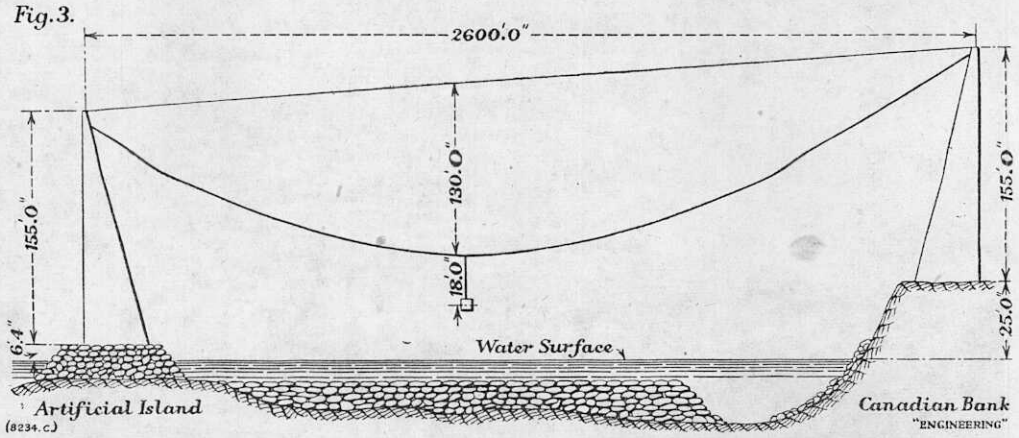


Fig. 2. Tail Tower of Cableway.

Fig. 3.



appearing in the issue for September, 1943, of *Civil Engineering*, the organ of the American Society of Civil Engineers. For the photographs, we are indebted to Mr. A. S. Robertson, District Superintendent, Ontario Power Company, and to Mr. W. E. Weare, also of that company.

LITERATURE.

The Missing Technician in Industrial Production. By John Gloag. London: George Allen and Unwin, Limited. [Price 7*s*. 6*d*. net.]

The "missing technician" whose functions are discussed in this little book is the industrial designer, and the principle that the author seeks to drive home is well expressed in an introduction by Mr. Charles Tennyson, C.M.G., the chairman of the National Register of Industrial Art Designers, as "the design of shape, structure and fabric, with a view to giving the consumer the greatest possible value in service, convenience and the delight of eye and touch." It will be seen, therefore, that the purpose of the book is basically that of the movement recently initiated by the Institution of Civil Engineers: that of producing æsthetic as well as merely technical or commercial satisfaction. Mr. Gloag concerns himself largely with "consumer goods" for domestic use, but he illustrates his points also with references to railway vehicles, tramcars, automatic ticket-issuing machines, and the superstructure of the Orient liner Orcades; though we were not aware that Mr. Brian O'Rorke, F.R.I.B.A., who was responsible for the decoration and furnishing of the passenger accommodation of this vessel, had any hand in the purely structural features—the caption to Plate I describes him as the "designer" of the superstructure. This may be a slight exaggeration or misunderstanding, but it does not materially affect the main principle that there should be the closest possible liaison between the designer for strength, the designer for production, and the designer for form and general attractiveness.

Modern Synthetic Rubbers. By Dr. Harry Barron, B.Sc., F.I.C., A.I.R.I. Second edition. London: Chapman and Hall, Limited. [Price 28*s*. net.]

The second edition of this book, it is gratifying to record, is a marked improvement on the first edition, which we felt obliged to criticise rather severely. Dr. Barron has corrected the more glaring of the earlier errors, and has added a great deal of new information, extending the book by 80 pages. Chapter 17, on ethyl cellulose, is new; and details have been included in chapter 2 regarding the plants recently set up in the United States to produce annually 860,000 short tons of butadiene and styrene, and a similar weight of the more important synthetic rubbers. Growing interest in alcohol as a source of butadiene is acknowledged by the addition of several pages to chapter 6; and the Houdry method of producing this hydrocarbon from petroleum is a feature of chapter 7, which also contains detailed estimates of the production costs of Buna-S and Butyl rubber, abstracted from a publication of the United States Committee on Patents. Formulæ for making Buna-N and Buna-S lattices are quoted in the enlarged chapter 10, which naturally includes a fuller account of the emulsion polymerisation of Chloroprene to Neoprene. Eleven pages at the end of chapter 11 testify to the amount of information which has become available during the past year regarding the applications and properties of Buna-S type rubbers. Hycar O.R., and other butadiene-acrylic nitrile copolymers, have received more detailed consideration at the end of chapter 12. Butyl rubber, in its infancy when the first edition

FLOW-CONTROL WEIR AT NIAGARA FALLS.

(*For description, see opposite page.*)

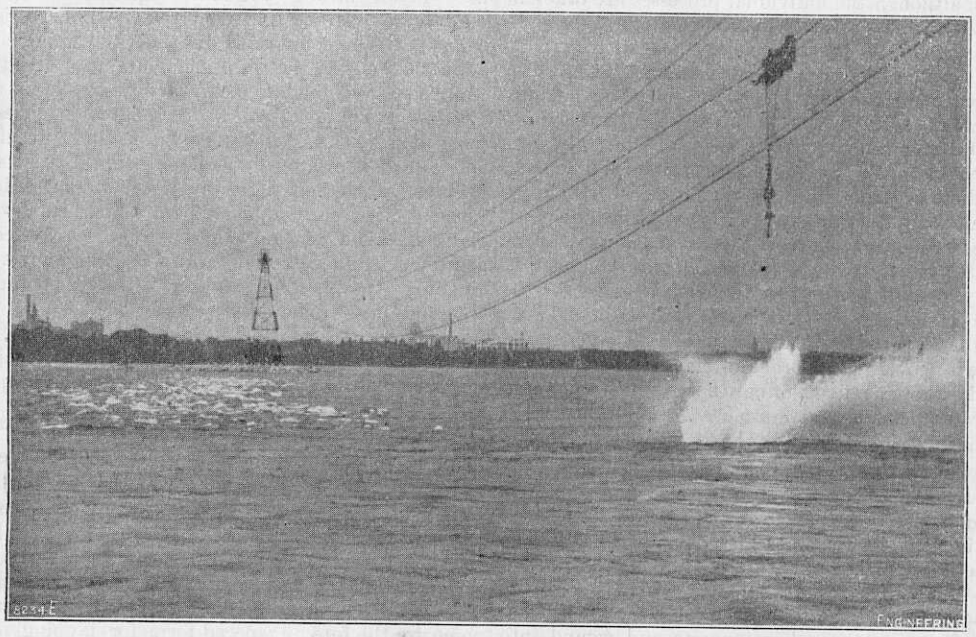


Fig. 4. Depositing Stone on Site of Weir.

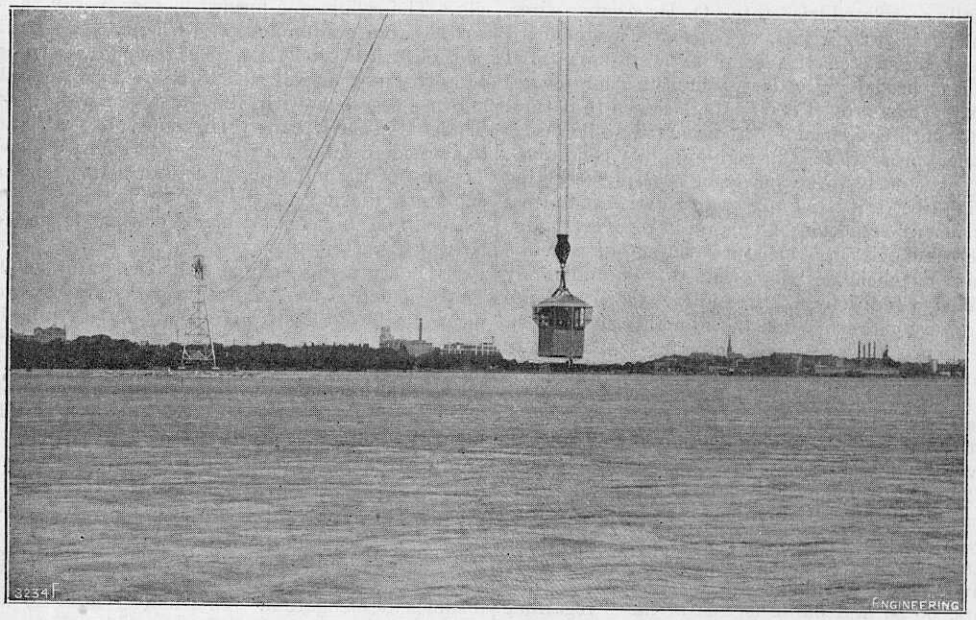


Fig. 5. Inspection Car on Main Cable.

was published, is now dealt with in some detail. The author has obviously spent much time in collecting and collating a mass of information about synthetic rubbers and rubber-like materials, and there is now a popular demand for this assistance. The new edition will prove helpful in the hands of the discriminating rubber technologist; but it still contains rather too many tables, and digests of other people's work, to allow of easy reading. Essential features of the materials now available in place of raw rubber are apt to prove elusive when the search for them involves the study of page after page of tabulated information which, in many cases, might have been more readily assimilated if presented in the form of graphs. Although the later sections of the work show greater care in preparation than was evident in the earlier volume, Dr. Barron's literary style is still open to criticism in matters of spelling, grammar, and various annoying errors which should have been detected by the proof reader. On page 13 there still appears the assertion that vulcanisation is "affected" by heating with sulphur. On page 19, the reader is assured that the Japanese control the entire rubber growing area. On page 68 appears the following statement, typical of many collections of words to be found throughout the book: "In connection with synthetic elastic materials it is of great interest, as wherever bonding to metal is required, that a solution of chlorinated rubber is frequently employed with great success, *e.g.*, for Buna-S, Perbunan, neoprene, Hycar, etc."; but on the following page it appears that "the outstanding feature about other oxidising agents in relation to rubber is the use of benzoyl peroxide." Plural nouns with singular verbs, and vice versa, abound. Fig. 10A, to which attention is drawn on page 85, is not to be found. Figs. 55 and 56, showing photographs of polyisobutylene under X-rays, were in the wrong order in the first edition; they have now been reversed, but, as the captions have also been reversed, the reader is still misled. On page 199, in two succeeding paragraphs, Dr. Barron says of Perbunan that "A suitable selection of plasticisers greatly facilitates the improvement of plasticity and also aids such other properties as tackiness, the extrusion process, etc."; and that "These plasticisers swell the Perbunan, but do not affect the processing properties to any great extent." Similar contradictions recur until, after reading through chapter 12, it is difficult to be certain about the real behaviour of Perbunan in conjunction with plasticisers. It would be helpful if Dr. Barron had drawn more upon his own experience to enlighten the reader in such instances.

SUBSTITUTES FOR SILK INSULATION OF FINE WIRES.

By A. Brookes, M.Eng., M.I.E.E.

One of the most useful insulation coverings for conductor wires as used for coil winding is natural silk, as it possesses so many general advantages over other textile coverings or enamel coatings. Such silk was principally obtained from China or Japan, together with a limited quantity of the cultivated variety from Italy. Owing to the present abnormal conditions the silk position in the wire industry has reached a serious stage. Existing stocks at wire manufacturers are being rapidly used up and, except for the special easement at present being allowed for a short period by the appropriate Ministry Control, natural silk will be restricted to vital needs.

In the telecommunication, radio and similar industries, electromagnetic coils are of especial importance and enormous quantities of relatively small coils using fine wires and large numbers of turns are manufactured. Such coils are wound on high-speed machines and, in order to get maximum production with a minimum amount of scrap, the insulation on the wire must be flexible, tough, capable of being stretched to allow 12 per cent. to 15 per cent. wire elongation, and have a high abrasion resistance. These properties are also demanded by the wire manufacturers for high-speed lapping. The insulation material, in addition, must be mechanically and chemically stable over a temperature range of — 10 deg. C. to + 50 deg. C., even when under considerable mechanical pressure due to the winding. Electrically it must have high insulation resistance, reasonable dielectric strength and low capacitance, and these properties must be retained under the extremes of atmospheric humidities and temperatures and of service conditions. Even where affected by abnormal atmospheric conditions the material must have good recovery values on restoration to normal. While having low moisture absorption the covering should not give undue difficulties with wax or varnish impregnation, either by way of chemical or physical attack or by absorption; be resistant to oils, water, petrol, dilute common acids, alkalies, waxes and varnish solvents; and have no corrosive action on copper under the above conditions. Space factor and cost are also very important points to be considered. Until recently, silk, enamel and, to a more limited extent, cotton, or combinations of these, were the usual insulation coverings on fine wire for coil winding, and established practice placed these in settled categories according to the properties demanded. Substitute materials will have to reach a very high level to equal pre-war standards for the above.

Many industries, such as those previously mentioned, demand a high copper space factor, especially for wire finer than 0·0108 in. diameter, and in many cases circuit conditions and mechanical dimensions have driven this up to a high degree, the design having been based on the pre-war existing tolerances for fine coverings. This, however, renders the question of the replacement by coarser textile coverings one of great difficulty, involving in some cases re-design of winding, modified adjustments, inferior performance, or the use of relief relays. Owing to the better space factor and lower cost, enamel covered wires have grown in popularity during the last decade, but there are cases where the necessity of impregnation, freedom from interlayer breakdown, use on coils under electrical stress or mechanical vibration, or the need for mechanical strength, demand the use of a textile covering and natural silk has proved to be the material *par excellence*. Until 1942, the quality of enamel for wire covering had improved enormously over that of say 1936, but difficulties in respect of raw materials have degraded this quality and it will steadily depreciate until new materials, such as high-viscosity synthetics of the Nylon or Formvar type in the form of enamel, and now well under way, have been commercially developed. The shortage of natural silk yarn drove wire users to enamelled covered wire where its use was possible, but this and other increased demands have greatly congested enamel covering machines and a serious bottle-neck has

been created, thus rendering further extensions to enamel inadvisable. Where space factor is of secondary importance, silk may in many cases be replaced by fine cotton, acetylated cotton (cotopa), varnish-impregnated lapped paper or pulped paper, but as this is only an extension of existing practice it will not be considered further. Glass fibre yarn is suitable for heavier gauges, usually varnish treated during covering to minimise moisture creep between the filaments, but it must be alkali-free to give the desired properties. For the small sizes under consideration, while the space factor is reasonably good, the material is somewhat deficient in elasticity.

Tropical conditions demand a high standard for fine-wire coils to prevent electrical or chemical breakdown under the varied humidity and temperature conditions existing in different localities. For instance, humidity may remain high with an average temperature little above normal; the day-to-night temperature variation may be large or it may be practically nil; there may be hot dry desert conditions or long hot dry periods followed by prolonged rain storms; or near the coast there may be high humidity with a high concentration of salt spray. The moisture content in these areas may vary between 90 per cent. and 2 per cent. or 3 per cent., with temperatures between — 10 deg. C. and + 50 deg. C. Instruments or apparatus may be installed in buildings with controlled atmospheres or under the equivalent of outside conditions, while air-borne equipment in or passing through the tropics may experience extremely varied conditions over short time intervals, and a temperature of — 40 deg. C. may be reached at high altitudes. Modern war-time conditions have driven all the Services to demand "tropical conditions," such as to specification W.T. 1,000, test condition K. 110, for a considerable proportion of the coils used in electrical equipment.

Materials usually fail electrically under conditions of high humidity coupled with high temperatures, but the frequency of cyclic changes has an enormous influence. Tests in a tropical room or chamber should be conducted with high humidities coupled with both high and normal temperatures, as in some cases more stringent conditions are given with the latter. Care must be exercised that condensation water does not drip on to or lie on the coils under test, and that the high temperatures do not dry them out and mask the effects aimed at. Suitable cyclic changes and prevention of water collection on test coils should be carefully arranged. The speed and optimum value of recovery when restored to normal atmosphere should be measured, as this is important in practice. Some materials fail miserably and others, while withstanding a single cycle, will fail under repeated cyclic changes. Faults on circuits or coils may give still higher temperatures due to watt losses and these should be taken into account. Some coils have an electric potential across them continuously and this gives an additional tendency to corrosion.

Independently of the material question, coils or any other equipment for tropical use should either be completely sealed or have good ventilation. For coils it is preferable to add some textile material over the winding and then seal with a dope varnish finish over winding and cheeks. Mildew, bacteria and insect attack are also more prevalent under tropical conditions, but impregnation and sealing, where the extra processing is warranted, gives a very definite safeguard against any of the electrical, chemical and mechanical troubles caused by tropical conditions and certainly reduces some of the difficulties from silk substitutes. It will be appreciated that the question of the use of suitable substitutes of a textile nature in place of natural silk is not one to be lightly considered, and much investigation has been conducted over the last two years by the author and his laboratory staff, in conjunction with the producers of Celanese fine filament acetate and Fortisan and with the wire coverers.

The following are the materials which have been seriously considered by the industry, as distinct from the enamels, cottons, etc., previously mentioned. The rayon grading follows the classification set out by the M.A.P., namely: Category 1, cellulose acetate, and Category 2, all other rayons. Under the modern definition of rayon as a man-made fibre, the range of materials covered by this classification, and previously termed artificial silks, makes an immediate appeal as substitutes for natural silk yarn for the covering of fine wires. The fundamental principle of manufacture is the same for all artificial silks, although the individual processes are different for the various types. A suitable material is brought into the fluid stage and is then extruded through fine nozzles, jets or spinnerets and hardened after extrusion, usually by the action of some medium which may be either air or a coagulating liquid. Rayon and natural silk threads are the only ones which are made up from long continuous filaments, as distinct from the discontinuous staple fibres which are formed into a yarn by twisting the short fibres around each other. Normally, these rayons are taken up by a process which puts a twist into the yarn, but when the yarn is to be used for the wire covering industry it is collected without twist. This lack of twist is important with all rayons used for wire coverings in order to give efficient lapping, good bedding and lack of bare spots with a minimum overall thickness and lumpiness. Careful selection of the lubricant applied to the filaments is necessary.

Cellulose acetate rayon (acetyl cellulose), ex "Celanese," is made from purified cellulose acetylated in a solution of acetic anhydride and glacial acetic acid in the presence of a catalyst. The material is precipitated with excess water, washed and dried. The resulting white powder is dissolved in acetone, and the solution filtered and then spun into filaments through spinnerets and wound into threads. The cellulose acetate of commerce is intermediate in composition between the diacetate and the fully acetylated triacetate. On large gauge wires, of the order of 25 S.W.G. and upwards, switchboard cables, cords, etc., this cellulose acetate material has been used in very large quantities for several years. It has proved itself superior even to natural silk for such coverings, owing primarily to its better electrical properties under high humidity conditions, and particularly to its power of rapidly recovering its high electrical resistance on restoration to normal atmospheric conditions. This rapid recovery is due to the fact that the moisture content of cellulose acetate is much less than that of silk under any specified conditions of humidity, the difference being most marked when the humidity is greatest. Other rayons were much inferior electrically to natural silk and in consequence were rarely used for covering electrical wires of any gauge. The cellulose acetate yarn used for the above-mentioned purpose was the standard product, as used in the knitting and weaving industry, *i.e.*, 140 denier* 26 filaments, 100/26 or 75/20 equal to a filament denier of 5 to 6, 4 and 3 to 4, respectively. For the lapping of fine wires these yarns were too thick and a special Celanese lapping yarn was developed in which the filament denier was about 1·3, *i.e.*, 33 denier 26 filaments, 50/38 and 66/52 (see later notes regarding count of yarn). This lapping yarn, while solving the lapping and overall size difficulties, was still not considered good enough for high-speed coil winding, and particularly for severe hand winding, owing to its low abrasion resistance.

Fusion after lapping, although a fairly critical process, provides a covering with very high abrasion resistance and for this reason fused cellulose acetate only is hereinafter referred to. The process consists of a light fusion of the surface of the covering, by suitable heat-treatment in wire ovens, so as to give a binding of the filaments and threads together rather than any flow of material. It is not in the nature of a conversion to an enamel equivalent, but should be carried only to a stage which still gives indications of the lapping. As the fusion process renders the covering transparent, the covered conductor differs little in appearance from uncovered copper, which may be considered a disadvantage by some, as not easily indicating bare spots. A result similar to the fusing process can be produced by the action of inert partial solvents. This process, at present, is in the experimental stage. The advantage resulting from this process is that small quantities of dyestuff can be incorporated in order to distinguish the covering from the bare copper. Bare spots, however, should never occur, unless the covering is very carelessly applied in the first place.

* This term is explained later.

Category 2 includes regenerated cellulose rayons manufactured by various processes outlined below and sold under different trade names. For the covering of fine wires, however, the only rayons of interest are those which are generally referred to as "rayon strong yarns." Cuprammonium or cuprate rayons are manufactured from mercerised cellulose. The cellulose is dissolved in ammoniacal copper oxide and the resulting solution, after filtration, is spun through fine capillary tubes so that the continuous filaments can be coagulated in an acid hardening bath. Viscose rayon is spun from a solution of xanthate of cellulose. In this case the cellulose is treated with caustic soda and subsequently with carbon disulphide, which results in the conversion of the cellulose to a very viscous solution. After filtration, and a process known as ripening, the viscous solution is forced through spinning nozzles immersed in an acid hardening bath. The liquid is thus coagulated into fine filaments which, after collection, are desulphurised, bleached and dyed. Viscose is not normally spun into such fine filaments as category 1 rayon or the cuprammonium rayons. Collodion silks, which were made by extruding solutions of nitrated cellulose in alcohol and ether mixtures followed by denitration, have fallen into disuse. Consequently, this form of regenerated cellulose is not of interest for electrical wire covering.

"Fortisan" is a regenerated cellulose material of super strength and fineness which has recently come to the fore in special form for lapping purposes. Specifically designed for these purposes, it is a most promising substitute material for natural silk. The cellulose is formed in such a way that it is free from contamination with materials having poor electrical properties. The very great strength of Fortisan—it is reported to be the strongest fibre known—together with the super fineness of the filaments in the lapping yarn, confer great resistance to abrasion combined with excellent covering power. The size of the individual Fortisan filament is only one-tenth of that of the silk filament. For this reason fine filament denier Fortisan is particularly satisfactory for use on fine gauge wires. Fortisan is made commercially in yarns of low total denier. The filaments are drawn down mechanically so as to give more or less complete longitudinal orientation of the fibrillæ and crystallites in the yarn structure and X-ray diffraction photographs show these very clearly against other rayons. Associated physically with this is the low moisture absorption of Fortisan in comparison with any of the other regenerated classes of rayon. The degree of orientation controls the extension and strength of the filaments. To the practical wire coverer and user this will indicate the necessity for proper control of angle of lay, otherwise there may be local deficiencies in the covered wire due to insufficient elongation. This matter is dealt with more fully later. Such difficulties as have been experienced have now been overcome and there is no reason why Fortisan should not form a useful substitute for silk within the limits of the lower electrical properties given by the category 2 class of rayons, and it is, therefore, to be regretted that control has limited the supply of this possible substitute. Durafil rayon is also a regenerated cellulose yarn made by another process. It is available with a filament denier of 0·3 and, therefore, gives a reasonably good space factor, but its short supply restricts its use. Lower speed lapping has proved to be necessary, although its strength is superior to that of Tenasco or of ordinary viscose rayons. Tenasco is a viscose rayon yarn of strength intermediate between that of ordinary viscose and Durafil, but it is not available in sufficiently fine filament deniers to make it suitable for the lapping of very fine wires.

(To be continued.)

The Institution of Civil Engineers.—On and after October, 1945, the present sections A, B, and C of the associate-membership examination of the Institution of Civil Engineers will be replaced by a joint section A conducted by the Institution, the Institution of Electrical Engineers, and by revised sections B and C. A copy of each of the revised syllabuses may be obtained on application to the secretary. A set of specimen question papers in the joint section A examination may also be obtained from the secretary, price 2*s*.

LIQUID FUELS AND CHEMICALS FROM COAL AND PETROLEUM.*

By HAROLD MOORE, M.Sc., F.Inst.Pet.

(*Continued from page* 205.)

Petroleum Refining.—It is apparent that in our post-war economy we shall have to give every advantage to our indigenous supplies of raw material and import a minimum of liquid fuels, but care must be taken not to exaggerate the possibilities of coal, and to think that coal products can be used as a complete substitute for petroleum. If we make this mistake we shall so handicap ourselves that we shall destroy our organic chemical industry and place our plastics industry in such a disadvantageous position that it will not be possible for it to meet world competition. Though the world production of coal (1,190 million tons in 1938) is much greater than that of petroleum (271 million tons in 1938), one must bear in mind that whereas petroleum is practically 100 per cent. hydrocarbon, coal only yields a small proportion of bodies readily suitable for further synthesis, such as the hydrocarbons and carbon-hydrogen-oxygen compounds. The mining of coal involves more effort than the winning of oil; prices are in many ways misleading, as the Government and private royalties, export taxes, concession valuations and profits are high in the oil industry. Consequently, selling price is not a reliable measure of cost of production.

In order to produce one ton of coal tar it is necessary to mine from 10 tons to 20 tons of coal, the process involving sinking shafts, strenuous underground work and expensive handling. The ten or more tons have then to be carbonised, a process involving much labour and equipment. The resulting ton of tar contains about half its weight of relatively low-value pitch. On the other hand, petroleum is produced by drilling a relatively small hole, the capital cost is low, the labour involved small, and the process of carbonisation unnecessary. The oil, though very variable, usually yields some 75 per cent. of distillate, and any residual asphalt is much more valuable than coal-tar pitch. It is obvious that the petroleum industry starts with enormous advantages, and competition from coal tar is only possible if the latter body is regarded as a by-product, the cost of its production being borne mainly by the gas and the coke.

The synthetic organic chemical industry has been built largely upon the basis of the coal-tar products, but recently, it has been found that the petroleum industry provides an excellent starting point for the preparation of many organic compounds. The petroleum gases, by-products from the refining industry, meet most of the requirements, namely, plentiful supply, low cost, great purity and the necessary chemical reactivity. It may appear surprising at first that petroleum has entered so late into the field of synthetic chemistry, for it is only during the last ten years that it has been used to any considerable extent as a basis for organic preparations. In the past, the difficulty has been to isolate pure hydrocarbons from crude petroleum, and such bodies as could be isolated in small quantities were paraffins, which did not very readily enter into chemical reaction. The dehydrogenation of paraffins to the more reactive olefines is a process only recently developed.

The growth of the petroleum chemical industry is a result of the employment of the cracking process. About the end of the Great War the increasing demand for motor spirit had resulted in a shortage in the supply directly obtainable from the lighter fractions of the crude oil, and the cracking process (known for many years before) became very largely adopted in the refineries. The cracking process, involving the application of heat and pressure to the oil, enabled the refiner to produce low-boiling spirits from the heavier and higher-boiling gas oil and fuel oil, and at the same time generated a quantity of gas, part of which was used for refinery fuel and the excess wasted. As most cracking plants operated under pressure, it was found that the motor spirit contained gas in solution which, making the lighter portion of the spirit extremely volatile, resulted in heavy evaporation losses during storage and transport. Removal of these gases, mainly propane, propylene, the butanes and the butylenes, made the spirit more stable and the distillation process used was known as "stabilising." With stabiliser equipment operating under pressure, it was not difficult to recover these distillates, and further fractionation yielded the important condensible gases—propane, propylene, iso-butane, iso-butylene, butane and butylene. It is mainly on these hydrocarbons that the new petroleum chemistry has been founded. Ethylene occurs in cracking gas in large quantities, and is now also used for synthesis, while the pentanes have been used for some time as a base for making solvents; but the greater portion of the new processes are based on the three- and four-carbon atom hydro-carbons.

Recent work has resulted in the discovery and development of commercial processes capable of polymerising, chlorinating, nitrating, dehydrogenating, hydrogenating, oxidising, alkylating and even aromatising (converting into aromatic bodies) the petroleum hydrocarbons. By the use of these and other chemical processes a large number of organic bodies are now being manufactured on a full commercial scale. Amongst these are the olefine polymers, such as polygasoline (motor spirit made by polymerising the mixed C_3 and C_4 olefines); iso-octane (by polymerisation of iso-butylene and subsequent hydrogenation); and rubber and plastic bodies, such as poly-isobutylene and polyethylene. The rubber substitute Buna-S is made from butadiene (a butane derivative) and styrene. Iso-octane can also be made by alkylation. By chlorination the chloro derivatives are made, and from these the ketones, aldehydes, esters, acids, glycerol (from propylene), ethylene glycol, etc., are obtained. Dehydrogenation enables olefines to be prepared from the paraffins, and consequently makes the enormous quantities of propane and butane, present in the natural gases from the wells, available for synthesis.

Perhaps one of the most interesting processes is aromatisation, which by subjecting liquid petroleum fractions to high temperature, usually in the presence of a catalyst, yields the aromatic series of hydrocarbons, including benzene, toluene, xylenes, styrene, naphthalene, anthracene, and higher bodies such as phenanthrene, chrysene and pyrene, together with considerable quantities of the olefine gases—ethylene, propylene, and the butylenes. This process may be of great utility for the preparation of the aromatic compounds when pure products are required, as the petroleum derived bodies are almost entirely free from sulphur, oxygen and nitrogen compounds, thus making their isolation a comparatively simple operation. It will be seen that this type of synthesis opens up the entire field of organic chemistry, and with it, consequently, the possibility of almost unlimited further development.

The petroleum chemical industry is dependent on the refinery gases, and as the latter cannot be economically transported, this means that the resulting chemical industry can only exist alongside the refineries. As this development of the oil business promises to be of vital interest to the nation, it is necessary to assess the possibilities and economies of introducing refining into this country. The pre-war consumption of petroleum products in the United Kingdom was 11·7 million tons. Most of this was imported in the form of finished products, but a quantity of 2·2 million tons was distilled in this country in 1939. Actually the quantity distilled here should not be taken as representative of general petroleum refining, as about half of the crude oil treated in this country is asphaltic oil which undergoes the comparatively simple process of distillation to an asphalt residue. This class of refining has been carried out for many years on our side of the Atlantic, as there are very obvious economic advantages already mentioned. A proportion of crude oil, probably about half, however, is subjected to proper refining in this country.

The refinery gases are products of the cracking process, and in a normal refinery, making the quota of motor spirit required for this country, approximately 50 per cent. of the total refinery throughput would be subjected to cracking. The yield of gas from cracking plants varies very considerably, a minimum figure being in the region of 10 per cent. by weight, while high-temperature aromatisation yields approximately 50 per cent. by weight. Normal established practice gives about 15 per cent. when working to liquid residue, 27 per cent. when working to coke, and about 21½ per cent. when reforming naphthas for the raising of anti-knock qualities. The catalytic processes yield somewhat less gas, and an average figure for all forms of cracking would be in the region of 20 per cent. on the input of the process, or about 10 per cent. on the refinery throughput. On a refinery capacity of 10 million tons this would mean 1,000,000 tons of gas. This gas contains approximately 50 per cent. by weight of C_3 and C_4 hydrocarbons and about 5 per cent. by weight of ethylene. With efficient recovery one might expect a sufficient quantity of propane and butane to cover the demands for bottle gas (at present only about 4,000 tons, but increasing), and a yield of over 300,000 tons of C_3 and C_4 fractions, of which nearly half would be in the unsaturated state (olefines). Such a quantity would be in excess of any immediate requirements of the organic chemical industry, but any surplus would be used for the manufacture of aviation spirit, which is made from these gases by polymerisation or alkylation. The cracking processes are flexible, and generally the quantity of gas made can be adjusted over fairly wide ranges.

(*To be continued.*)

* Paper entitled "Liquid Fuels and Organic Chemicals from Coal and Home-Refined Petroleum," presented to the Institute of Fuel on Tuesday, February 1, 1944. Abridged.

AUXILIARY GENERATING PLANT FOR AIRCRAFT.

A CHARACTERISTIC feature of the modern multi-engined aircraft is the abandonment of the practice of driving the numerous auxiliaries from the main engines and the adoption of independent generating units for supplying the auxiliaries with current. An example of such a unit is illustrated on pages 266, 267 and 270, the designers and manufacturers being Messrs. Rotol Limited. The aircraft auxiliary equipment necessitates the provision of compressed air for operation of instruments and brakes and of hydraulic power for the retraction of the undercarriage and the movement of the gun turrets. The compressors and pumps are motor-driven and, in addition, current is required for a variety of other purposes. The completely independent and self-contained plant described below is a skilful and effective solution of the problems involved in providing for the power requirements of a large aircraft. Obviously, light weight and small bulk are essential, and the production of noise, fumes, or vibration in the body of the aircraft cannot be tolerated while, moreover, the unit must be capable of operation by remote control. It will be clear that to meet these requirements the auxiliary unit must differ considerably from a conventional generating set.

The unit consists of a six-cylinder petrol engine rated at 60 brake horse-power at a governed speed of 3,750 r.p.m. and a rated altitude of 12,000 ft., the engine driving a 20-kW alternator and a 3-kW direct-current generator, the latter having, in tandem, a 0·75-kW exciter for the alternator. The total weight of the unit, including the casing in which it is housed and the base framing, is 500 lb. The overall dimensions of the casing are 3 ft. 6⅜ in. long by 2 ft. 4½ in. high by 2 ft. 4 in. wide. A good idea of the compactness of the unit may be gained from Figs. 1 and 3, page 266, the first of which shows the casing with its hinged lid propped open to exhibit the plant within and the second shows the casing in the condition in which the unit normally functions. The casing, which is soundproof as may be inferred from the lagging visible on the inside of the lid in Fig. 1, is not, of course, hermetically sealed; there are two openings at one end. These openings are just visible on the right in Fig. 3, and comprise a vertical duct for the escape of hot air and exhaust gases and a horizontal duct at the crankshaft level through which cooling air is drawn by a fan. The tubular structure seen at the bottom of the casing in Fig. 3 is a three-point support which is attached to the aircraft body. The shell of the casing is double, and there is an air space between the outer and inner skins, the sound-damping lagging being attached to the latter and the air space preventing objectionable radiation of heat. The casing is fireproof as well as soundproof. The fittings seen towards the left in Fig. 3, are a filler cap and dipstick for the engine lubricating oil tank.

The general arrangement of the unit will be clear from Fig. 2. This shows the heads of three of the engine cylinders, which are horizontal and opposed, the exhaust pipes from each bank of cylinders, the air-cooling fan on the right, and, on the left, the alternator surmounted by the direct-current generator. In this view the unit is slightly tilted so as to show the bottom surface. The three projecting pins seen on the bottom are the bolts for fixing the unit to the base frame. These are carried in rubber blocks to damp out vibration, which, since the rotating parts are in virtually perfect balance, is very slight so that no vibration is transmitted to the aircraft. The disc on the right, above the forked exhaust pipe, is the carburettor flame trap. The position of the magneto can be identified by the sparking plug leads. The horizontal cylindrical body seen below the exhaust manifold and having a projecting cross-handle is the lubricating oil filter. Part of the crankcase sump is also visible in this region. The details of the engine and transmission are best shown by the sectional drawings, Figs. 4 and 5, page 267, while the two external views, Figs. 6 and 7, page 270, show the generator and fan ends of the unit, respectively. Figs. 8 and 9 show the transmission and timing gears, Fig. 9, in addition, indicating the staggered disposition of the two opposed banks of cylinders.

Reference to Fig. 4 will show that the cylinders are air-cooled and that sleeve-valves are employed. The cylinder bore is 3⅜ in., and the stroke 3 in., the swept volume being 161 cub. in. (2·64 litres). The compression ratio is 7·8 to 1. The cylinders are of aluminium alloy and the centrally-split crankcase to which they are bolted is of light alloy. The inlet manifold is seen at the top and the exhaust manifold at the bottom. The cylinder heads are of aluminium alloy and are fitted with two rings. Provision is made for two sparking plugs in each head. The crankshaft is mounted in four lead-bronze lined steel-shell bearings and has three pairs of cranks at 180 deg., an arrangement which will be clear from Figs. 4 and 5. To the right of the cylinders in Fig. 5 the shaft carries a driving pinion and is then supported in a large ball bearing, beyond which it is continued into the spindle of the alternator rotor. A

AUXILIARY GENERATING PLANT FOR AIRCRAFT.

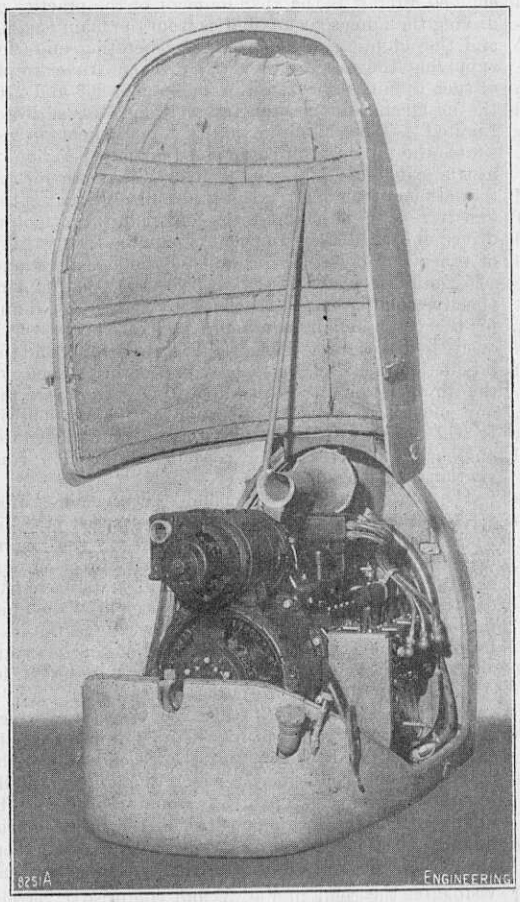


Fig. 1. Casing with Cover Raised.

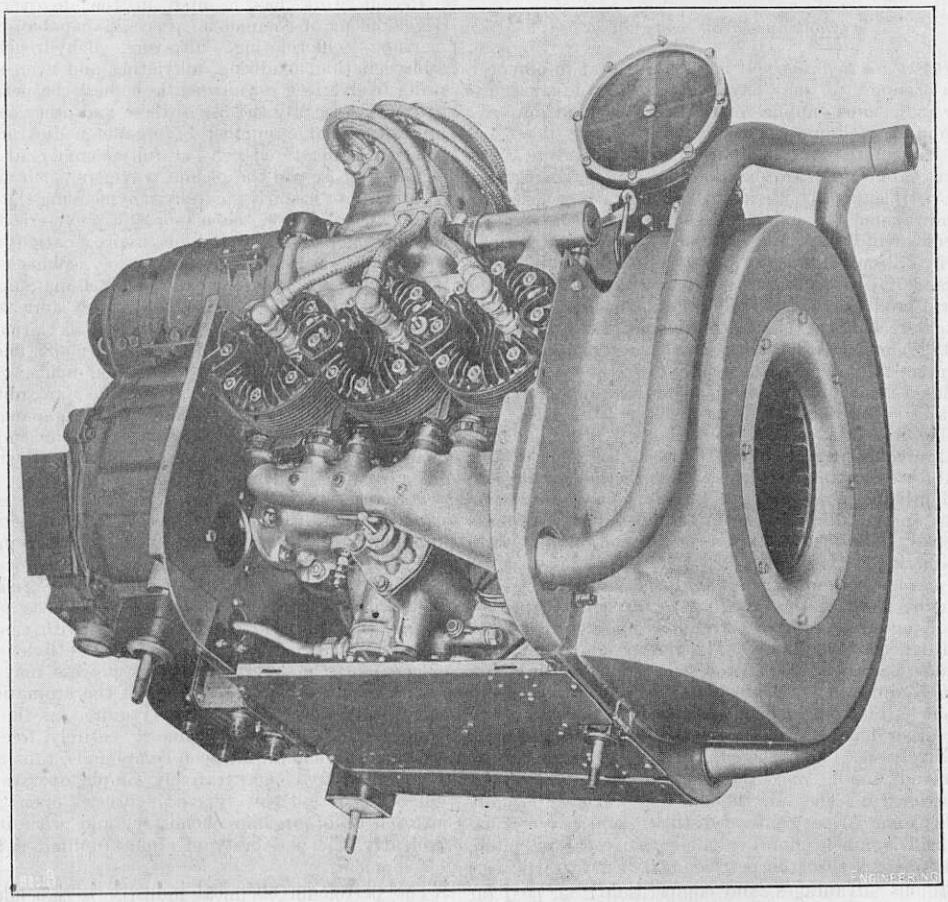


Fig. 2. Engine and Generator Unit.

short extension of the shaft carries the cooling fan, the connection between the extension and the fan disc being through splines and a bonded rubber ring, the latter acting as a damper, though the shaft is notably free from torsional vibration. The shaft journals and crankpins are hollow and stoppered, as shown in Fig. 5, oil being supplied to the crankpins from the journals by the usual drilled passages. Both the crankpins and shaft journals are nitrogen-hardened. Referring again to Fig. 4, it will be noticed that the connecting rods, which are of drop-forged steel, have big-end caps of the half-round type. The shells are of steel, lined with lead-bronze, and the mating surfaces of the caps and rod end are serrated in order to remove bending stresses from the cap studs. The connecting-rod small ends have bronze bushes. The gudgeon pins are of the hollow floating type. The pistons are of light alloy and have two gas rings and two scraper rings.

The sleeve valves are actuated by crankpins on spur wheels on a vertical axis and have, therefore, an oscillating rotary as well as a reciprocating motion. One of the crankpins is indicated at *a* in Fig. 4, with its ball connection to the sleeve. The wheel *b* is fitted, opposite to the crankpins, with an adjustable balance weight *c*. These weights are clearly visible in Fig. 9, which shows the train of gears for the two banks of cylinders. The pinions between the two lower wheels in Fig. 9, on each side, drive the trains, the upper pinions being idlers only. Each driving pinion is mounted on a vertical shaft which, at its lower end, drives the scavenge and pressure lubricating oil gear-type pumps in the crankcase sump. This arrangement is not shown in Fig. 4, though the pump casings, visible on each side of the sump, may be recognised. The vertical shafts are rotated through bevel gears by horizontal shafts driven through helical gearing from the crankshaft pinion. The driving wheels of these two shafts are seen at the bottom of Fig. 8 with idler pinions interposed between them and the shaft pinion. This pinion also drives the direct-current generator through a pair of idlers seen vertically above it and also shown in Fig. 5. It will be seen that the sleeve-driving pinion on the right of Fig. 4 has at the upper part of its hollow spindle an inserted spindle carrying a small pinion which meshes with a larger one driving the shaft of a vertical generator for the electric tachometer, *d*, which runs at a quarter of the engine speed.

The sleeve-driving pinion on the left of Fig. 4 is shown fitted to receive the spindle of the vertical governor *e*, which operates the carburettor throttle and controls the engine speed within fine limits from

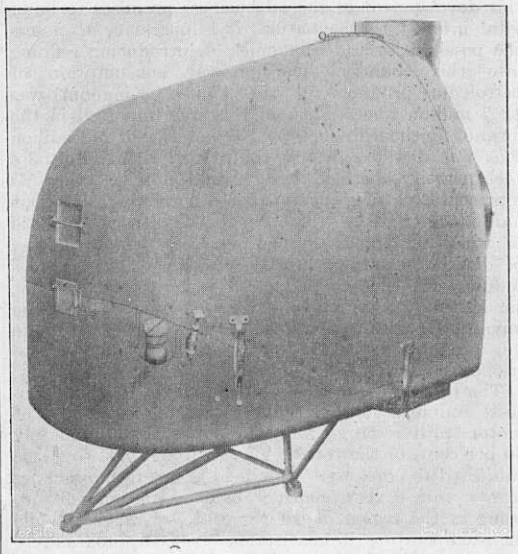


Fig. 3. Exterior of Casing.

no-load to overload. Another of the sleeve-driving pinions provides the drive for a screened six-cylinder magneto mounted vertically and lettered *f*, in Figs. 4 and 5. All these drives are by splined connections to the sleeve-driving pinions. The magneto can also be readily identified in Fig. 6, and the tachometer generator in Fig. 7, just in front of the sparking plug leads leaving the magneto. The governor can be distinguished in Fig 6, partially obscured by the sparking plug leads. The carburettor is prominent in both Fig. 6 and Fig. 7, and is lettered *g* in Fig. 5. It is of the down-draught type and feeds branch pipes *h*, Fig. 4, leading to the cylinders, the cylinder connections being of oblong contour, as shown in Fig. 9. The dark openings seen in the centres of these slots are ports in the sleeve valve, two of which are also visible on the right in Fig. 4. The carburettor has a built-in automatic altitude control which will function satisfactorily up to 25,000 ft. Part of the flame trap is seen as a disc in several of the illustrations, but its complete form is shown in Fig. 1, where a trumpet-mouthed opening forms the intake, and shows that the air is drawn from the interior of the casing. The exhaust manifolds, visible in Fig. 2, are lettered *i* in Fig. 4. To protect the cylinders from radiated heat the manifolds are surrounded by perforated aluminium shrouds to guide the cooling air from the fan as desired, thus maintaining the manifolds at a satisfactory temperature. With the same object of deflecting the entering air stream, baffles are fitted on the tops of the cylinders, and can be seen near the air inlet branches in Fig. 6.

The fan, seen at *j* in Fig. 5 and on the left in Fig. 7, is of the multi-vane type. It draws air through the lower of the two openings in the casing, as previously mentioned, this air being directed to cool the engine cylinders, the oil cooler, the alternator and the direct-current generator. One stream of air flows over the cylinder fins and then escapes to the upper part of the casing. Another stream is led to the two generators and similarly escapes after circulating through them, while a third stream is passed through the oil cooler situated below the alternator and lettered *k* in Fig. 5. This air is then employed to create a strong current in the rear of the casing, and this current sweeps the hot air escaping from the engine straight out of the upper exit duct and maintains a low temperature round the electrical machines. The upper and lower ducts can be formed to join in a single streamlined " blister " on the exterior of the aircraft body. The engine exhaust manifolds are coupled by flexible joints to twin tail pipes, as seen in Fig. 7. These pipes join into a single pipe situated within the upper air duct in which, if desired, an exhaust silencer can be fitted.

The alternator, *l*, Fig. 5, is seen on the left in Fig. 6. It may be pointed out that the curved construction seen in this figure on the right of the alternator and terminating in a square flange is not a branch pipe, as might be supposed, but is simply one leg of the supporting structure of the engine assembly. The alternator consists of a stator bolted to the end of the engine crankcase and a rotor with a spindle keyed to the crankshaft. A light-alloy cover closes the end of the stator and carries a roller bearing for the rotor spindle. The bearing housing is prolonged to form a guard for the dog clutch provided for hand starting the engine. The crankcase end, or rather the gear case, has openings through which the cooling air is forced through the alternator to escape into the casing by openings in the cover ; these openings, as seen in Fig. 6, also give access to the slip rings and brushes, the field windings being carried on the rotor and supplied with exciter current from the direct-current generator. The alternator supplies three-phase current at 110 volts and 250 cycles. The normal rating is 20 kW at 3,750 r.p.m., with a

AUXILIARY GENERATING PLANT FOR AIRCRAFT.

Fig. 4.

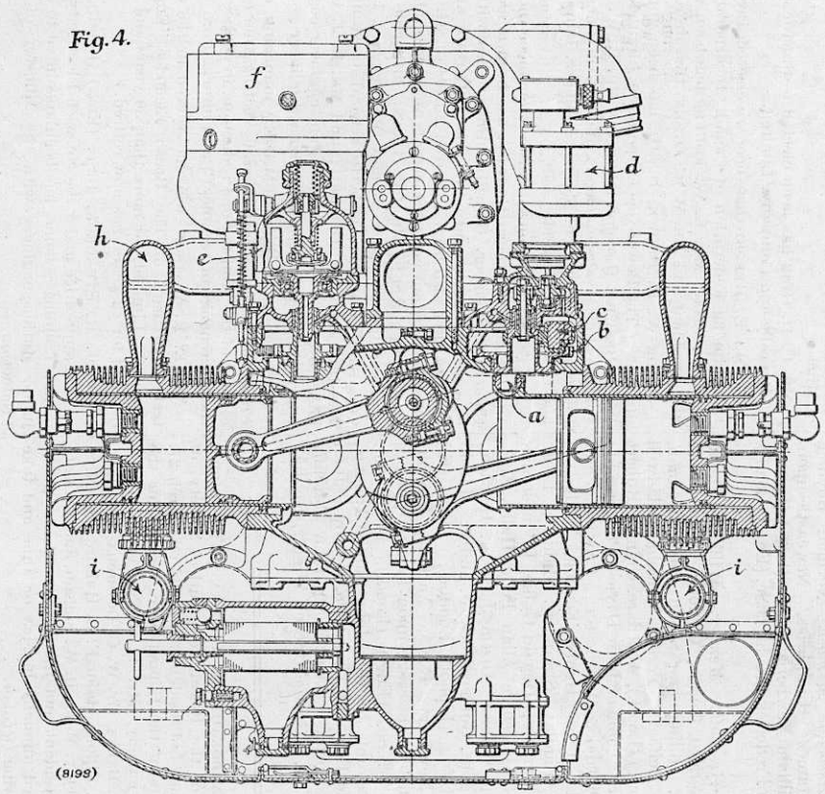
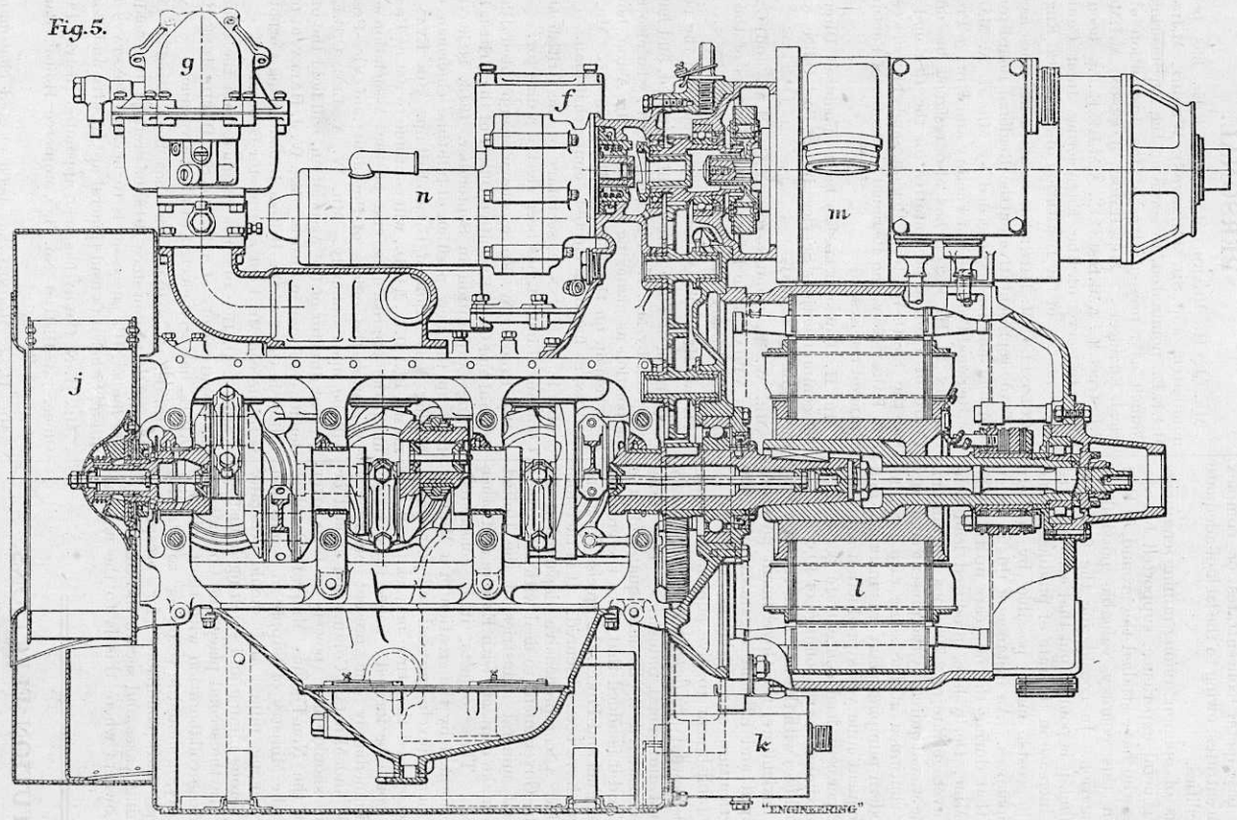


Fig. 5.



power factor of 0·83, but the machine is rated at a maximum of 32 kW for 5 minutes at the same speed.

The direct-current generator, which is the upper machine in Fig. 6 and is lettered *m* in Fig. 5, is of unusual length, this being accounted for by the fact that it consists, in reality, of two machines in tandem, namely, an exciter with an output of 0·75 kW, and the generator proper, which supplies current at 29 volts; it has a normal rating of 3 kW and a maximum 5-minute rating of 4·8 kW, both at 4,600 r.p.m. As will be apparent from an inspection of the driving gear train in Figs. 5 and 8, the generator speed is stepped up from that of the engine, and as shown in Fig. 6, this generator is out of the line of the cooling air stream through the engine. The air, however, is directed from the bottom of the engine to the generator casing by the light-alloy pipe seen on the extreme right of Fig. 7, the air then escaping to the casing through the openings visible in Fig. 6, which also give access to the commutator. The electric motor for starting the engine is lettered *n* in Fig. 5, and the engaging dog clutch is easily distinguishable in the upper part of the figure. At this point, the method of control may be briefly described. On large aircraft it is customary to provide two auxiliary units, each capable of handling the whole requirements and housed in an auxiliary engine room in the body of the aircraft. Local control panels are provided in this room, together with an interconnected electrical system by which the load may be switched from one unit to the other, without stopping them or interfering with the electrical services, in the event of accidental damage or injury from enemy action to one unit. At the engineer's station a remote-control panel is provided from which either set can be started or stopped or the load transferred from one to the other. The sets are otherwise entirely automatic in action and will run for long periods without attention.

The engine is, of course, pressure lubricated. A deep sump, of the contour clearly shown in Figs. 4 and 5, is attached to the crankcase. It is divided into upper and lower chambers by a coarse gauze tray, one of the two gear-type oil pumps drawing from the lower chamber. The relation of the pumps to the sump is shown in Fig. 4. The pump on the right removes the filtered oil from the sump and returns it to the oil tank by way of the oil cooler. This is provided with a thermostatically-controlled by-pass valve which ensures an adequate time, by short-circuiting, for the temperature of the oil to fall to its working limit before it is re-circulated through the engine by the pressure pump on the left of the sump in Fig. 4. This pump, the suction of which is connected to the tank by a flexible pipe, delivers the oil under pressure to the self-cleaning filter visible near it. Should the filter become choked, a safety valve by-passes the oil. The filter is also provided with a spring-loaded ball relief valve, which is set so that the delivery pressure lies between 40 lb. and 50 lb. per square inch. The capacity of the pump, however, is such that the relief valve is always a little open, the excess flow being returned to the sump.

After leaving the filter, the oil is led to the gallery seen in Fig. 4 at the lower part of the crankcase above the filter. This runs for the full length of the crankcase and from it passages lead to the four main bearings and to a pair of subsidiary galleries in the sleeve crank gear covers. These passages supply pressure oil to the upper bushes of the sleeve crank gear wheels and this oil on leaving the bushes accumulates in the pockets of the wheels whence it is flung by centrifugal force to lubricate the gear teeth and the lower bushes. The bearings of the spindles in the gear train between the sleeve crank wheels and the crankshaft are supplied with pressure oil by passages in the crankcase communicating with the main oil gallery. The idler gears between the crankshaft and the direct-current generator are carried in plain bearings lubricated by splash. The oil tank is rigidly attached to the soundproof casing in the vicinity of the generator end of the engine and is connected to the engine and the oil cooler by flexible pipes. The capacity is 3 gallons, excluding air space, the supply being sufficient for 24 hours' running. It is fitted with a filler cap and dipstick, accessible from outside the casing, as already stated, and also with a drain plug, a breather pipe and an electrical immersion heater. The heater is controlled by a self-contained thermostat, the function of which is to maintain the oil at a working temperature while the engine is not running. It is wired from the alternating-current mains and consumes 250 watts, the circuit being kept alive by the other engine. The stationary engine can, therefore, be readily started while the aeroplane is in flight.

The fuel supply is external to the unit, the tank being situated so as to give a head of not less than 4 ft. to the carburettor and the connecting pipe arranged so that the acceleration of the aircraft will not interfere with the supply. Alternatively, an electrically-operated pump can be fitted in the supply pipe, its circuit being inter-connected with the engine ignition switch. The consumption of 87-octane or 100-octane petrol is 3 gallons per hour per unit at normal rating. The lubricating oil consumption is 0·80 pint per hour.

The designer of the unit is Mr. D. R. Pobjoy, of Messrs. Rotol Limited. The sleeve-valve construction was adopted, not to give additional power as is the case in the larger engines, but to reduce to a minimum the attention required for maintenance. The power rating of the engine, given earlier, is conservative; at full throttle and normal speed at ground level it will develop 95 brake horse-power. Magneto ignition was adopted to facilitate the starting of the engine by hand in the event of the aircraft batteries being discharged, though the batteries normally supply current to the electric starter. The enclosing casing, in addition to being soundproof, prevents heat from the engines reaching the interior of the aircraft. As a safety device, an automatic fire extinguisher is provided inside the casing and comes into action immediately should an excessive rise of temperature occur. In addition to the duties required from the alternator and direct-current generator mentioned earlier, it may be noted that the alternator provides current for such services as lighting and radio throughout the aircraft, the operation of the kitchen cooker and the radiators in the sleeping quarters, and current is also drawn from it for starting the main engines. The direct-current generator supplies current for charging the stand-by

batteries, among other duties. These auxiliary units are designed to run continuously for very long periods without any attention and to adjust themselves automatically to the demand. They are in operation not only while the aircraft is in flight, but may also be required to function in harbour or at an aerodrome; great care has, therefore, been exercised to ensure reliability and durability.

POST-WAR METALLIFEROUS MINING IN GREAT BRITAIN.

One of the main points emphasised in a memorandum on "The Production of Non-Ferrous Metals and Minerals, other than Coal, in Great Britain," prepared by the Council of the Institution of Mining and Metallurgy and submitted to the Minister of Reconstruction, is the need for adequate relief from present taxation. It is added that unless such relief can be granted, the other recommendations contained in the memorandum will lose their significance and the matter is considered so important that, at the suggestion of the Institution, an independent committee, representative of the British mining industry at home and overseas, has been formed and is preparing a memorandum on the taxation of mining enterprise for submission to the Government. Reviewing the present position in home non-ferrous metal mining, the Institution's memorandum states that among contributory causes of the gradual decline of the industry during the past 40 years, other than inequitable taxation, are the difficult and costly process of securing title, the arbitrary nature of Royalty charges, the delay in the production of detailed geological surveys of the mineralised areas, and, to some extent, the absence of adequate facilities for smelting and refining. To these, it is pointed out, must be added the discovery of cheaper sources of ore in other countries, sharp fluctuations in metal prices, the emigration of skilled employees, increasing costs of labour, coal and power, and also the Government's indefinite attitude to the industry in the past, with the consequent lack of a centralised organisation to deal with it.

The compilers of the report contend that whereas almost every commission or investigation on supplies or reserves of coal has called for, and has received, help from the Geological Survey, it was not until 1937 that any considerable effort was made to examine metalliferous deposits. On the outbreak of the present war, however, the existing programmes were cancelled and effort concentrated on the mineral industries, namely, coal, iron and non-ferrous metal mining, and the water supply industry. It is emphasised that much remains to be done before the essential appraisal of the prospects of the mineralised areas can be made, and, further, that the completion of the programme can be accomplished only if adequate staff is provided to meet the various needs of the Geological Survey. The Council of the Institution therefore recommend that, firstly, the Survey should undertake the mapping, on a suitable scale, of all areas in the United Kingdom known or suspected to be mineralised, and that it should examine the mineral occurrences by all known means of investigation, including geophysical methods, and, where desirable, by air photography. The work should be undertaken with special reference to the finding of new beds of ore and useful minerals and to the extension of ore-bearing ground, both laterally and in depth, around mines which are no longer operating. The Council's second recommendation is that in order to prevent the loss of valuable information, it should be compulsory for the management of a mine which is about to cease operations, to send prior notification to the Geological Survey. It should then be an obligation of the Survey to examine all working and exposed faces in the mine and to file a record of the examination for attachment to the plans. Finally the Council recommend that the staff of the Survey be strengthened and that funds be made available to meet the undertaking of these duties.

With regard to ore treatment and metal production, the report states that, in spite of the enormous expansion in the world's metal production and consumption, there has been no corresponding growth of the non-ferrous metallurgical industry of Great Britain, an industry capable of giving employment to many people. That this has not been due to lack of skill or technical ability is indicated by the fact that methods and processes initiated in this country are now widely used abroad. There is thought to be little doubt that the re-establishment of metallurgical facilities in this country would encourage home mining enterprise and, at the same time, help to meet the home consumption of metals which, at present, is almost wholly dependent upon imported supplies. This is stated to be particularly the case in respect of copper, zinc and lead. At present no electrolytic copper or zinc is produced in this country and large supplies of these materials have to be imported. Moreover, many British mines overseas are unable to market, in this country, products such as base-metal concentrates or complex gold-bearing concentrates, owing to the lack of adequate metallurgical facilities.

The concensus of opinion among mining engineers with local and general experience, supported by economic geologists who have studied the ground, is that there remain in this country valuable possibilities awaiting investigation. In considering the future of home metal mining, it is pointed out that account must be taken of the increase in the rate of production, and the reduction in costs, made possible by modern methods and appliances. An instance of this is given, it being stated that during the 60 years up till 1920, the Mill Close Mine, Derbyshire, produced lead concentrate at the average rate of 2,700 tons per annum. In 1920, the mine was acquired by the present company and production continued at the same rate for nine years. Then modern pumping plant was installed, and during the subsequent nine years production averaged 24,670 tons of 82 per cent. lead concentrate per annum and reached a maximum yearly tonnage of 40,000.

The report concludes with the statement that whereas, in the realm of agriculture, the Government possesses a highly developed and efficient organisation in the Ministry of Agriculture and Fisheries, there is no corresponding establishment to give equivalent attention and service to what are described as the equally important mineral and metal industries. The Mines Department is considered to be inadequate for the services required and it is added that, since the creation of the Ministry of Fuel and Power, the precise functions of the Department have been obscured. It is therefore recommended that a comprehensive department be established by the Government to deal with all aspects of the metal and mineral industries of the United Kingdom and to make contacts with Empire and other countries overseas. These objects, it is considered, could best be performed by the creation of a Ministry of Metals and Minerals (excluding coal and petroleum). It is, however, recognised that time may elapse before such a Ministry could be formed; hence it is recommended that, immediately the present emergency permits, a Metals and Minerals Commission should be appointed. This should have power to take over the functions of the Non-Ferrous Mineral Development Control of the Ministry of Supply in connection with existing producing mines, and should generally foster the metalliferous mining and smelting industries in this country. In the second place, the Commission should work in close collaboration with the Geological Survey, and, thirdly, it should have power to establish reasonable terms and conditions for prospecting licences and mining leases and secure the concurrence of mineral-right owners where this is to the national advantage.

INSTITUTION ELECTIONS.

Institution of Mechanical Engineers.

Associate to Associate Member.—Norman Boydell, Eastbourne; James Humphries, Newcastle-upon-Tyne; Cyril William Newberry, B.Sc. (Eng.) (Lond.), Derby; William Frederick Proehl, B.Sc. (Eng.) (Lond.), Byfleet.

Graduate to Associate Member.—William David Mendis Abeysekera, Colombo, Ceylon; John Crowe Bissett, Wh.Sc., Gillingham; John Basil Brennan, M.Sc. (B'fast), Belfast; Percy Malcolm Gladwell Brown, B.Sc. (Eng.) (Lond.), Aberdare, Glam.; Robert Noel Close, York; Thomas John Davies, Pontypridd; Jack Craven Dinsdale, Manchester; Cristian Peter Dunkel, Oxford; Cyril Henry Fennell, Bridgend; George Harland Findlay, Stanmore, Middx.; Leslie Edmund Frost, London; Donald Gallie, Livingstonia, Africa; Lieut. (E.) George Allan Fenn Hally, M.A. (Cantab.), R.N.; William Austin Jackson, Ipswich; Shauti Sarup Jagota, Golden Rock, S. India; Harold George Jones, B.Eng. (L'pool), London; Lieut. (E.) Henry Charles Newberry, R.N.; Anthony Procter, B.Sc. Tech. (Manch.), Newcastle-upon-Tyne; Kenneth Arthur Sherwin, B.Sc. (Eng.) (Lond.), Frodsham; Thomas John Tarrant, Neath; John James Thomas, Newport; Harold Dewhirst Thompson, Harrow; John Aubrey Vivian, Purley; Lieut. (A.) John Ratcliffe Whitaker, R.N.V.R.; George Gordon Wigley, Rugby.

The Royal Aeronautical Society.—The annual general meeting of the Royal Aeronautical Society, of which Mr. A. Gouge is President, was held on March 27. Ten new members of the Council were elected for the session 1944-45, namely, Mr. E. J. N. Archbold, Air Commodore F. R. Banks, Mr. W. C. Devereux, Mr. G. H. Dowty, Mr. A. G. Elliott, Major F. B. Halford, Mr. N. S. Muir, Mr. G. E. Petty, Major B. W. Shilson, and Mr. C. C. Walker. The President and the vice-presidents of the Society are elected annually in May or June and take office in the following October.

PERSONAL.

Mr. J. R. Beard, M.Sc., M.I.E.E., has been renominated, and Sir Johnstone Wright, M.Inst.C.E., M.I.E.E., nominated, to serve on the Engineering Joint Council as representatives of the Institution of Electrical Engineers. Mr. Harry Jackson, M.I.Mech.E., M.I.Struct.E., A.M.Inst.C.E., A.M.I.E.E., has been nominated to serve on the Engineering Joint Council as representative of the Institution of Structural Engineers.

Colonel C. J. Hirst has resigned his office as Board of Trade representative on the Regional Board for Scotland and has been succeeded by Mr. R. A. Maclean, the Regional Controller of Factory and Storage Premises. Captain B. H. Peter has also resigned his office as Board of Trade representative on the Regional Board for the South-Western Region, and his successor is Mr. Barry Kay, the Regional Controller of Factory and Storage Premises.

Mr. H. Townshend has been appointed Director of Telecommunications Services in the Post Office, as from the beginning of May.

Mr. W. M. Codrington, M.C., M.A., and Captain Hugh Vivian have been elected directors of the Great Western Railway Company.

Mr. J. Herbert Aston has retired from the position of chairman of Tube Investments, Limited, and has been succeeded by Mr. I. A. R. Stedeford, who also retains his position as managing director. Mr. Aston, however, is to remain on the board of the company. Mr. G. S. Maginness has been elected deputy chairman.

Mr. L. S. Kinnear, secretary of the British Oxygen Company, Limited, has been elected a director.

Mr. Robert W. Foot, who was appointed Director-General and Chief Executive Officer of the British Broadcasting Corporation in September, 1943, is leaving to take up the new position of full-time chairman of the Mining Association of Great Britain. Sir Evan Williams, Bt., D.L., LL.D., will continue to act as President until the approaching end of the Association's year. Thereafter, the offices of President and Vice-President will be filled annually. Mr. W. A. Lee, C.B.E., the present director of the Association, will hold the office of deputy chairman in future. Mr. W. J. Haley, at present Editor-in-Chief of the British Broadcasting Corporation, is to succeed Mr. Foot as Director-General.

Mr. G. D. H. Cole has resigned from the Council of the Royal Society of Arts, and Sir David Meek, C.I.E., O.B.E., has been elected to fill the vacancy.

Mr. E. G. Sahlin, who has been Swedish Consul-General in London since 1918, has retired on reaching the age limit. His successor is to be Mr. Constans Lundquist, hitherto Consul-General at Calcutta and Bombay.

Mr. H. N. Corry has been appointed District Pitwood Officer, at District No. 3, Commerce House, Paragon-street, Hull.

Mr. D. J. Mooney has been elected chairman, and Mr. Francis Allen, J.P., and Mr. J. R. Farquharson deputy-chairmen, of the Council of the Nigerian Chamber of Mines.

Mr. C. D. Gibb has been elected a director of Messrs. A. Reyrolle and Company, Limited.

Mr. L. E. Reford has been re-elected President of the Shipping Federation of Canada Incorporated, Montreal, for 1944. Mr. E. W. Foulds has been re-elected vice-president and Mr. W. C. Olsen, treasurer.

Major W. R. Brown, D.S.O., has been appointed a director of The Power-Gas Corporation, Limited, and Mr. W. R. Beswick (London manager), Mr. R. W. Rutherford (technical sales manager), and Mr. Charles Robson (secretary), directors of Messrs. Ashmore, Benson, Pease and Company, Limited.

Mr. Conrad Gribble, assistant engineer (new works and bridges), Southern Railway, has been made Deputy Chief Civil Engineer. He will continue to deal with matters concerning bridges and new works. Certain alterations in titles have also been approved: Lt.-Col. G. L. Hall, hitherto assistant engineer (signals and telegraphs) is now Signal Engineer; Mr. A. Dean, hitherto assistant engineer (maintenance) is now Maintenance Engineer; Col. A. B. Chester, hitherto general assistant, is now Assistant Engineer (General); and Mr. L. J. Boucher, hitherto chief assistant to assistant engineer (signals and telegraphs) is now Assistant Signal Engineer.

Mr. Geoffrey Smith, M.B.E., managing editor of *Flight* and *Aircraft Production*, is visiting America, at the request of the Ministry of Production, in connection with the interchange of technical Press information.

Mr. E. R. Watson, who has served in the electrical test department of The Brush Electrical Engineering Company, Limited, for more than 50 years and has been its chief for 42 years, has now retired.

Mr. J. R. Sturgeon, B.Sc. (Eng.) (Lond.), departmental apprentice under the Norwich Electricity Department's Training Scheme, has been appointed to a post as junior station engineer with the Ministry of Aircraft Production.

NOTES FROM SOUTH YORKSHIRE.

SHEFFIELD, Wednesday.

Iron and Steel.—Quieter times are being experienced in some Sheffield steel and engineering works as a result or irregular supplies of coal and changes in the types of products ordered. Manufacturers had difficulty in carrying on with the 10 per cent. reduction, but the strikes of miners have increased the cut. A considerable amount of town's gas is used in various processes of steel manufacture, and the supply of gas has been fairly adequate in spite of reduced supplies of coke-oven gas from some coking plants. Power from the electricity grid is extensively used, and the supply of current is being maintained satisfactorily. Plans have been made for a two days' break at Easter. At the majority of works, the holiday will extend over Easter Monday and Tuesday, but in the case of one of the biggest concerns in the district, the second day's holiday will be staggered so that production may not be unduly disturbed. Arrangements have been made for the maintenance staffs to work through the holiday period and carry out the more extensive repairs that have become necessary. Satisfactory progress has been made with the execution of the numerous orders for farm and garden tools and implements. Good deliveries have been made and supplies are now larger than has been the case for a long time. The engineers' small tools industry also has reduced the arrears of deliveries.

South Yorkshire Coal Trade.—The coal supply position has deteriorated. The strikes have greatly reduced production and, in spite of constant direction of the limited production, it has not been possible to meet requirements. There are best South Yorkshire hards or washed and graded steams for early delivery, and the less essential users have had to be content with modest deliveries of inferior fuels. Washery fines have been in keen demand, and outcrop coal has proved to be a useful substitute for pit coal. The demand for house coal has diminished and it has been possible to divert some house-coal qualities to the steam-coal market. The supply of coking coal has been short, and the blast-furnace coke available has not been easily allocated ; the reserves of patent-oven coke and gas coke have been considerably depleted. No export business has been possible except that of a high priority character.

NOTES FROM THE SOUTH-WEST.

CARDIFF, Wednesday.

The Welsh Coal Trade.—The serious drop in production in South Wales during the war years was emphasised by Mr. Thomas Williams when he was installed chairman of the South Wales branch of the National Association of Colliery Managers. He pointed out that, between 1939 and 1943, the output in the district had declined by about 10,750,000 tons, or 28 per cent., as against a fall of 13 per cent. in manpower. Earnings per man-shift had increased from 11*s.* 6*d.* to about 18*s.* 9*d.* during the same period, yet output per man-shift was down from 21·80 cwt. to 18·15 cwt. Mr. Williams ascribed these drops to increased absenteeism and slackening in effort on the part of the miners. Business was still difficult to negotiate for ordinary industrial users on the Welsh steam-coal market during the past week. Collieries, as a rule, were engaged to practically full capacity in maintaining supplies for the essential war factories and the public-utility undertakings who were taking supplies not only to meet their daily needs, but were also rebuilding stocks which had been depleted by the strikes. As a result, there was little coal offering for delivery during the next few months for the ordinary home users or for general export. What shipments were made were in respect of Government-directed business. The demand from neutral sources was active ; and some of the inferior qualities were available for export to these markets, but the lack of suitable shipping held business in check. All the large descriptions were well placed with forward bookings and were firm in tone. The acute scarcity of sized and bituminous small grades was pronounced and with a keen demand for these the tone was strong. Best dry steam smalls were active, but inferiors were plentiful. Gas cokes were in little demand ; there were numerous orders for the foundry grades.

Swansea Steel-Sheet Industry.—The weekly market report of the Incorporated Swansea Exchange states that a fair volume of business continues to be transacted in tin-plates and their substitutes and that orders on makers' books are growing into a substantial figure. Steel sheets remain active, and manufacturers are operating to capacity. There is a good demand for most descriptions of iron and steel scrap, but the pressure for deliveries is slightly easier. The prices of iron and steel products are unchanged.

JAMES FORREST LECTURE.—The James Forrest Lecture of the Institution of Civil Engineers will be delivered at 5.30 p.m. on Tuesday, June 13, by Professor C. E. Inglis, O.B.E., F.R.S., who has chosen as his subject "Mechanical Vibrations."

NOTES FROM THE NORTH.

GLASGOW, Wednesday.

Scottish Steel Trade.—Steel is to be employed to a greater extent for the construction of private houses, so that the iron and steel industries can anticipate continued full-scale production for some time. The steel-producing capacity at present is estimated at about 16,000,000 tons of ingots per annum, and if a large export trade is to be added to the housing programme this capacity may have to be increased. Production in Scotland is again increasing, and the output should reach the full capacity as soon as fuel supplies become normal. Order books are filling up steadily and there will be a particularly busy period ahead for plate and sheetmakers and re-rollers. Current quotations are as follows :—Boiler plates, 17*l.* 12*s.* 6*d.* ; ship plates, 16*l.* 3*s.* ; sections, 15*l.* 8*s.* ; medium plates, ⅜ in. and thicker, rolled in sheet mills, 21*l.* 15*s.* ; black-steel sheets, No. 24 gauge, 22*l.* 15*s.* ; and galvanised corrugated sheets, No. 24 gauge, 26*l.* 2*s.* 6*d.*, all per ton, for home delivery.

Malleable-Iron Trade.—There is no new feature in the malleable-iron trade, and, as raw materials are in adequate supply, work is continuing normally.

Scottish Pig-Iron Trade.—Hematite remains in somewhat short supply, but basic and foundry irons are fairly plentiful. Orders are coming to hand steadily.

NOTES FROM CLEVELAND AND THE NORTHERN COUNTIES.

MIDDLESBROUGH, Wednesday.

General Situation.—New business is on a moderate scale only. Buyers of iron and steel have substantial contracts against which to draw and are not desirous of placing further orders, but the early renewal of market activity is anticipated. Native ironstone is still plentiful and imports of overseas ores show some further improvement. Most descriptions of pig iron are in good supply and there is no shortage of semi-finished iron and steel. There has been some reduction in the deliveries of steel semies, rendering it necessary to draw slightly on reserve supplies which consist largely of imported commodities. Finished-steel producers are dealing satisfactorily with most of the delivery claims of priority buyers.

Foundry Iron.—The consumption of foundry pig, which has not been heavy for some time, is on a further reduced scale. Stocks held by users are substantial and, to reduce transport difficulties, delivery allocations are subject to restrictions. The make of Cleveland qualities is still small and foundries in this area continue to use Midland brands.

Basic Iron.—The output of basic iron is rather in excess of the requirements of the makers' own consuming departments, but there is no tonnage on the market. Producers believe that the requirements of their steel plants will increase and are retaining the whole of the make of the basic blast-furnaces.

Hematite, Refined and Low-Phosphorus Iron.—Hopes of some expansion in the limited production of hematite are encouraged by the better supplies of ore of a quality needed for its manufacture which are now coming to hand. In the meantime, consumers are obtaining allocations of parcels to meet their immediate needs. Outputs of low- and medium-phosphorus grades of iron and of refined qualities are steadily taken up.

Manufactured Iron and Steel.—The semi-finished iron branch of trade shows no new feature. Finished-iron manufacturers have few orders for the lighter commodities but are busy on contracts for heavy descriptions of material. Re-rollers are running their mills at full capacity and have work in hand that will keep them busily employed for the next month or two. They continue to demand maximum deliveries of prime and defective billets and bars. Plates and sheets are needed in quantities that ensure full activity of the producing plants to the end of June and afterwards. Light and medium sections are sold well ahead and makers report substantial forward inquiries. Railway and colliery requisites are still in good demand. Heavy joists and sections are in little request, but makers are busily engaged on the production of other commodities.

Scrap.—Users of good steel scrap, heavy cast-iron scrap and machinery metal are urging merchants to increase deliveries.

PROPOSED HATFIELD MEMORIAL LECTURE.—In the course of his address at the 63rd general meeting of Messrs. Thos. Firth and John Brown, Limited, held on March 29 at Sheffield, the chairman, the Rt. Hon. Lord Aberconway, C.B.E., stated that it had been proposed to commemorate the work of the late Dr. W. H. Hatfield, F.R.S. The suggestion was to establish, with the University of Sheffield, the Royal Society, and the Iron and Steel Institute, an annual lectureship on studies in the fields which Dr. Hatfield had made peculiarly his own.

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 MECHANICAL ENGINEERS.—*South Wales Branch :* Tuesday, April 11, 3 p.m., The Mackworth Hotel, Swansea. "Generation and Utilisation of Steam in the Heavy Industries," by Mr. G. E. Hider. *Southern Branch :* Saturday, April 15, 2.15 p.m., The Royal Pavilion, Brighton. Joint Meeting with the *Southern Association* of THE INSTITUTION OF CIVIL ENGINEERS. Symposium of short papers dealing with aspects of civil engineering contractors' plant, by Sir George M. Burt and others. *Midland Graduates' Section :* Monday, April 17, 7 p.m., The James Watt Memorial Institute, Birmingham. "The Development of the Reciprocating Steam Engine," by Mr. David Waine. *Institution :* Friday, April 21, 5.30 p.m., Storey's-gate, St. James's Park, S.W.1. Informal Meeting. Discussion on "Planning an Aero-Engine Production Programme," to be opened by Mr. E. Fairbrother.

INSTITUTE OF MARINE ENGINEERS.—Tuesday, April 11, 5.30 p.m., 85, The Minories, E.C.3. "Some Notes on Welded Ship Construction," by Mr. James Turnbull.

INSTITUTION OF ELECTRICAL ENGINEERS.—*Scottish Centre :* Tuesday, April 11, 6.15 p.m., The Royal Technical College, Glasgow. Annual General Meeting. "Industrial Fire Risks," by Messrs. W. F. Cooper and F. H. Mann. *Transmission Section :* Wednesday, April 12, 5.30 p.m., Savoy-place, Victoria-embankment, W.C.2. "Copper Conductors for Overhead Lines," by Messrs. G. W. Preston and H. G. Taylor. *South Midland Wireless Group :* Wednesday, April 12, 6 p.m., The James Watt Memorial Institute, Birmingham. Annual General Meeting. "A Survey of the Problems of Post-War Television," by Mr. B. J. Edwards. *Installations Section :* Thursday, April 13, 5.30 p.m., Savoy-place, Victoria-embankment, W.C.2. "The Electrical Aspect of Farm Mechanisation," by Mr. C. A. Cameron Brown.

INSTITUTE OF WELDING.—Wednesday, April 12, 6 p.m., The Institution of Civil Engineers, Great George-street, Westminster, S.W.1. "Factors Controlling the Weldability of Steel," by Dr. L. Reeve.

INSTITUTION OF CIVIL ENGINEERS.—*Birmingham Association :* Thursday, April 13, 5.45 p.m., James Watt Memorial Institute, Birmingham. (i) "Use of Plastics in Structures," by Mr. S. L. Daniel. (ii) "Use of Plastics in Fittings and Furnishings," by Mr. A. W. Jones. (iii) "Decorative Use of Plastics," by Mr. N. W. Knewstubb. *Yorkshire Association :* Saturday, April 15, 2.30 p.m., Royal Victoria Station Hotel, Sheffield. "Plastics : Applications and Limitations," by Mr. W. Astle.

INSTITUTE OF METALS.—*London Local Section :* Thursday, April 13, 6.30 p.m., The Junior Institution of Engineers, 39, Victoria-street, Westminster, S.W.1. Annual General Meeting. "Quality Control, with Particular Reference to Metallurgical Inspection," by Dr. B. P. Dudding and Mr. W. J. Jennett.

INSTITUTION OF CHEMICAL ENGINEERS.—Friday, April 14, Connaught Rooms, Great Queen-street, W.C.2. Annual Corporate Meeting at 11 a.m. and 3 p.m. Luncheon at 1 p.m. For programme, see page 249, *ante.*

NORTH-EAST COAST INSTITUTION OF ENGINEERS AND SHIPBUILDERS.—Friday, April 14, 6 p.m., The Literary and Philosophical Society, Newcastle-upon-Tyne. Discussion on "Radiological Testing."

JUNIOR INSTITUTION OF ENGINEERS.—Friday, April 14, 6.15 p.m., 39, Victoria-street, Westminster, S.W.1. Ordinary Meeting. "The World of Print," by Mr. A. E. B. Kearsey.

MANCHESTER ASSOCIATION OF ENGINEERS.—Friday, April 14, 6.30 p.m., The Engineers' Club, Albert-square, Manchester. Lecture : "The Manufacture of Glass," by Mr. R. F. Taylor.

INSTITUTION OF PRODUCTION ENGINEERS.—*Lincoln Sub-Section :* Friday, April 14, 6.30 p.m., Technical College, Lincoln. "The Foreman as Manager," by Mr. W. Puckey. *London Section :* Friday, April 14, 7 p.m., The Institution of Civil Engineers, Great George-street, S.W.1. "Some Aspects of the Production Engineer's Problems in the Post-War Re-Establishment," by Mr. H. W. Bowen. *Preston Section :* Saturday, April 15, 2.30 p.m., Canteen, Messrs. British Northrop Loom Company, Limited, Daisyfield, Blackburn. Colour films on "The Manufacture and Use of Abrasives."

INSTITUTE OF BRITISH FOUNDRYMEN. — *Sheffield Branch :* Friday, April 14, 7 p.m., The Royal Victoria Hotel, Sheffield. "Some Ground Work on a Flying Casting," by Mr. M. Brown.

INSTITUTE OF ECONOMIC ENGINEERING.—*Midland Section :* Saturday, April 15, 3 p.m., Grand Hotel, Birmingham. "Post-War Standardisation of Engineering Economics," by Mr. H. C. Main.

DERBY SOCIETY OF ENGINEERS.—Monday, April 17, 6.30 p.m., School of Arts, Green-lane, Derby. Annual General Meeting. Various short papers.

AUXILIARY GENERATING PLANT FOR AIRCRAFT.

(*For Description, see Page* 265.)

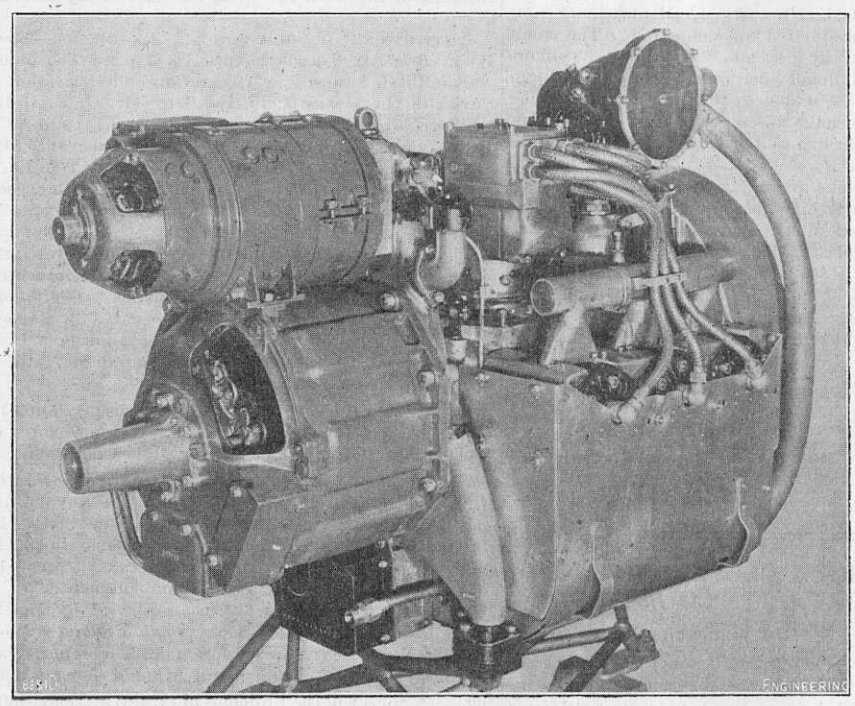


Fig. 6. Generator End of Unit.

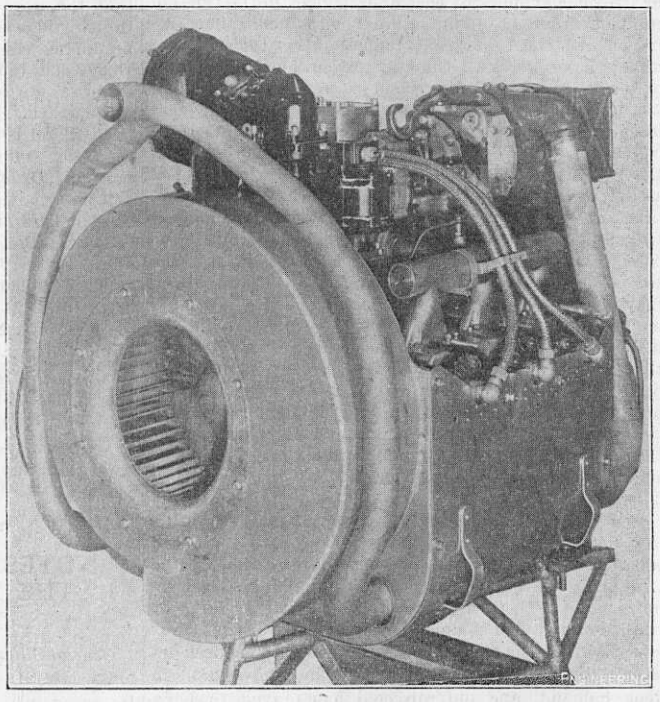


Fig. 7. Fan End of Unit.

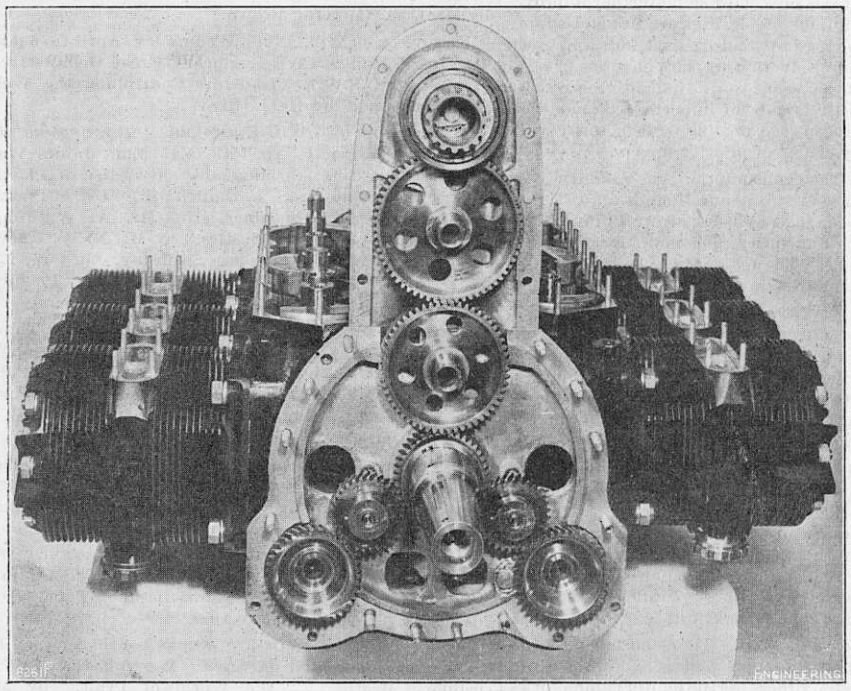


Fig. 8. Gear Train for Generator and Timing Gears.

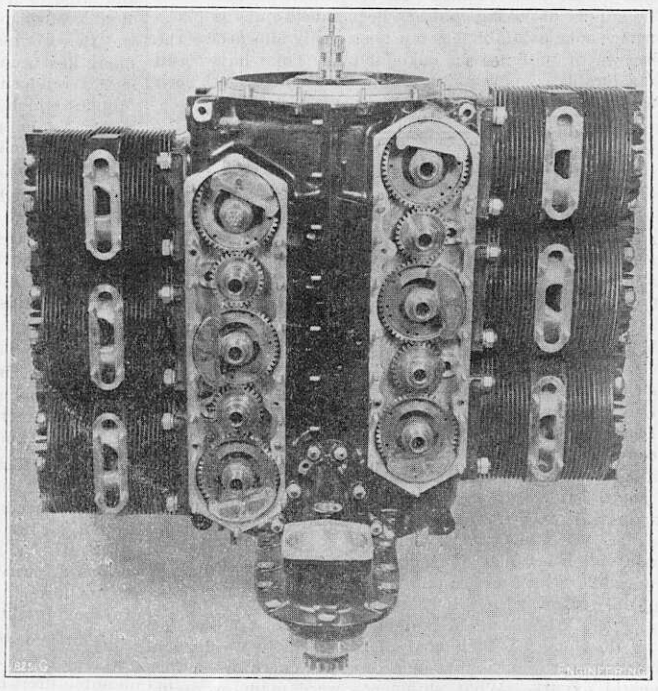


Fig. 9. Timing Gears with Covers Removed.

TRACK MAINTENANCE BY WELDING.

Repairs to a busy main-line track have to be carried out expeditiously in order to minimise the delay of trains. On the railways in Great Britain, traffic was intense before the war, so that permanent way maintenance was well organised, the work being done by new methods whenever these seemed suitable and economical in labour. So well were platelayers and other operatives drilled in peace time in the application of modern techniques that enemy bombing did not find them unprepared; few instances of damage to the railways have occasioned delays of more than half a day. What has perhaps become more serious is the general deterioration of permanent way as a whole which has resulted from heavy war time increase of traffic coupled with the partial suspension of normal maintenance activities.

The need has therefore arisen for repair or reconditioning processes that can be carried out rapidly with the smallest practicable number of men, and this need has been met to some extent by welding, the application of which has been greatly extended since the outbreak of war. In this time the number of welders engaged on track work by the London Midland and Scottish Railway has been doubled, the number at present employed being 80, which includes both electric-arc and oxy-acetylene welders; in addition to 20 grinders. Instead of being replaced with new material, an operation requiring the services of many platelayers, worn points and crossings are being welded and re-surfaced *in situ*. This work can be carried out by one man during intervals between the passing of trains, so that it is economical in labour and obviates the suspension or diversion of traffic. The operatives engaged on this work have been selected from the platelaying staff and given a special training prior to their allocation on the system. Of necessity they are widely distributed, the number allowed each district engineer depending on the mileage of track under his control, taken in conjunction with the average density of traffic. Of the total number of welders, two are reserved for carrying out work in a reclamation depot on points and crossings that have become too far worn or damaged to be dealt with *in situ*; in such comparatively rare cases the immediate need has still to be met by replacement. In the ordinary way an attempt is made to give components which are subjected to wheel batter the same length of life as other and less severely treated rails in the immediate vicinity. When components were allowed to fall into a bad state of repair, neighbouring parts suffered from the battering that was set up, and replacement of the entire crossing or point layout soon became necessary. By keeping in good condition those parts most susceptible to wear, it has been found possible to equate the life of the whole layout to the life of the most enduring parts. Reconditioning of the parts by welding *in situ* has one great advantage over reconditioning in a central depot: it enables due allowance to be made for the lie of adjacent parts that have become bedded down and consolidated in service. Before the work of reconditioning crossings or points by welding is commenced the rails are examined for flaws, fractured components are replaced, bolts, keys, and chair fastenings are tightened, and sleepers are packed. Surfaces to be welded are cleaned and rendered free from metal excrescences that may have resulted from the splaying action of wheel batter and hammer blow. These preliminaries remove some of the causes to which past wear is attributable and give to components that have been re-surfaced by welding the best chance of showing a long and satisfactory service life in future.

ENGINEERING.

Offices for Publication and Advertisements, 35 & 36, Bedford Street, Strand, London, W.C.2.

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

TELEGRAPHIC ADDRESS { "ENGINEERING," LESQUARE, LONDON.
TELEPHONE NUMBER—TEMPLE BAR 3663 (2 lines).

The Editorial and Publishing departments have now returned to the permanent offices at the above address, and the temporary premises at Hayes, Middlesex, have been vacated. ALL COMMUNICATIONS SHOULD BE ADDRESSED, THEREFORE, TO 35 & 36, BEDFORD STREET, STRAND, LONDON, W.C.2.

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

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ADVERTISEMENT RATES.

The charge for advertisements classified under the Headings of Appointments Open, Situations Wanted, Tenders, &c., is six shillings for the first four lines, or under, and one shilling and sixpence per line up to one inch. If use is made of a box No., the extra charge is 1*s.* per insertion, with the exception of advertisements appearing under Situations Wanted. The line averages six words. When an advertisement measures an inch or more the charge is 18*s.* per inch. Payment must accompany all orders for single advertisements, otherwise their insertion cannot be guaranteed Terms for displayed advertisements on the wrapper and on the inside pages may be obtained on application. The pages are 12 in. deep and 9 in. wide, divisible into four columns, of 2¼ in. in width. Serial advertisements will be inserted with all practicable regularity, but cannot be guaranteed.

TIME FOR RECEIPT OF ADVERTISEMENTS.

Classified advertisements intended for insertion in the current week's issue must be delivered not later than first post on Wednesday. Alterations to standing advertisements must be received at least 10 days previous to the day of publication. Passed proofs must be in our hands by Friday morning, otherwise they will be taken as correct. The Proprietors will not hold themselves responsible for blocks left in their possession for more than two years.

All accounts are payable to "ENGINEERING," Ltd. Cheques should be crossed "The National Provincial Bank, Limited, Charing Cross Branch." Post Office Orders should be made payable at Bedford Street, Strand W.C.2.

INDEX TO VOL. 156.

The Index to Vol. 156 of ENGINEERING, (July-December, 1943) is now ready and will be sent to any reader, without charge and postage paid, on application being made to the Publisher. In order to reduce the consumption of paper, copies of the Index are being distributed only in response to such applications

CONTENTS.

	PAGE
Flow-Control Weir at Niagara Falls (*Illus.*)	261
Literature.—The Missing Technician in Industrial Production. Modern Synthetic Rubbers	262
Substitutes for Silk Insulation of Fine Wires	263
Liquid Fuels and Chemicals from Coal and Petroleum	265
Auxiliary Generating Plant for Aircraft (*Illus.*)	265
Post-War Metalliferous Mining in Great Britain	268
Institution Elections	268
Personal	268
Notes from South Yorkshire	269
Notes from the South-West	269
Notes from the North	269
Notes from Cleveland and the Northern Counties	269
Notices of Meetings	269
Track Maintenance by Welding	270
Light Engineering Industries in Scotland	271
Wear in Oil Engines	272
Notes	273
Letters to the Editor.—Surveys for the Reconstruction of Tube Stations (*Illus.*). The Simple Trussed Beam (*Illus.*)	274
Obituary.—Sir Charles V. Boys, F.R.S. (*with portrait*)	275
Floating Concrete Bridge at Hobart	275
Fundamentals of the Marine Screw Propeller (*Illus.*)	276
Labour Notes	277
Notes on Magnesium-Alloy Technology (*Illus.*)	278
"ENGINEERING" Patent Record (*Illus.*)	280

ENGINEERING

FRIDAY, APRIL 7, 1944.

VOL. 157. No. 4082.

LIGHT ENGINEERING INDUSTRIES IN SCOTLAND.

THOSE who remember the difficulties that attended the re-establishment of normal industrial operations after the last war need no urging to consider in good time the methods of approach to the fundamentally similar, but vastly greater and more complex problems presented by the restoration of manufacture and commerce when this war eventually comes to an end; for, apart from the much more serious disorganisation of production and trade on the Continent, amounting in many cases to almost complete elimination, the changes that have taken place in the character and distribution of industry within the British Isles are of a nature and on a scale to which there are no parallels in industrial history. Factories have been dispersed, their personnel scattered, their markets allowed to disappear: and it is a reasonable assumption that, because a resumption of trade cannot be deferred until the *status quo* has been restored (which, in some cases, must depend on the provision of new housing in the neighbourhood of the factories) attempts will be made to take advantage of the surplus accommodation offered by former munitions plants, even though these may be in relatively remote districts. In short, one of the major problems, and one which must be tackled at a very early stage, will be to decide whether the work is to be taken to the workpeople or vice-versa; and in this it is very necessary to take a long view, though the actual decision to implement the conclusions reached may have to be taken at comparatively short notice.

It is a characteristic of such reconstruction schemes that they present one fundamental difference from the normal growth of local industries in peace time, in that they are governed primarily by the desire to make use of existing conditions, equipment and labour, the presence of which has been dictated by circumstances which no longer obtain; so that it may well be that the buildings, plant, situation or available labour are not of the types that would have been selected if there had been freedom of choice, influenced only by the desire to achieve the most efficient production and distribution. It is true that many businesses, now of considerable size, were founded in a small way by individuals who paid little attention to such factors; but it is also true that an expanding business may gradually create its own favourable environment by attracting to its neighbourhood the necessary ancillary trades and a reserve of suitable labour, whereas an undertaking set up primarily to obviate local unemployment often starts under initial handicaps that may take years to overcome.

The nature of the problems to be faced is well illustrated, directly or indirectly, by a report recently prepared by the Light Engineering Committee of the Scottish Council on Industry. The terms of reference of the committee were to survey the light engineering industry, including the manufacture of electrical appliances, and to consider what action was required to promote a wider diversification and a greater development of light engineering in Scotland. They also took into consideration the use that might be made of the special machine tools likely to be released for other purposes after the war. The chairman was Mr. J. B. Lang, chairman of Messrs. John Lang and Sons, Limited, machine-tool makers, of Johnstone; and the members included representatives of the engineering, shipbuilding and other industries, of various trade unions and of Government departments, and Lord Elgin, the President of the Scottish Development Council.

The first essential was to define "light engineering," a task of some difficulty as there is no clear line of demarcation; but eventually the committee agreed, as an approximation, that the term might be taken as representing the manufacture of articles by mass-production or batch methods, though it was recognised that this definition would exclude various general-engineering firms whose function is primarily to undertake jobbing work. The criterion adopted was the type of engineering which has developed particularly in the Midlands, including the "supply industries," necessary to its maintenance, which specialise in the production of components; though the committee found it difficult to determine whether the multiple-production units had developed round the light engineering industries or whether their existence had influenced the establishment of the latter. Probably both views are correct, in varying degrees in particular cases. They came to the conclusion, however, that it would be necessary, if light engineering were to be developed in Scotland, to include such supply industries as die casting and stamping, the production of rolled strip, the moulding of plastics, and repetition lathe and press work. Appended to the report are lists of 21 light industries already successfully established in Scotland, a further 24 which have been established there more recently and should be encouraged to remain, and 18 which, in the opinion of the committee, might be started with a good chance of success. The use of the term "industry" in connection with some of these is open to question—in several cases, "manufacture" would appear to be a more suitable word; and it is probable that at least half of the 18 proposed new "industries" could be quite well undertaken by existing firms as departmental sidelines, using their present factories, plant and personnel. In the text of the report, indeed, the items in the third appendix —namely, the 18 types of manufacture which might be regarded as suitable for introduction—are referred to as "products"; and it is mentioned that various firms now engaged on war material will have considered their post-war plans already. It is possible that some of them are contemplating the manufacture of one or more of the 18 items as supplementary lines.

As a broad principle, the committee are of opinion that "the prime consideration should be the selling of the products of Scottish brains and labour" and, to that end, the best policy would probably be to concentrate on products in which the cost of labour is a high proportion of the total, rather than on those of lower grade, made in very large quantities. No doubt the committee were guided to this conclusion by statistics which, in time of war, cannot well be placed at the disposal of the general public; but it would seem that there are possible counter-arguments of some weight. A product which is made in "very large quantities" may not require so much highly skilled labour in proportion to its cost as do specialised articles such as, for example, scientific instruments; but it provides a great deal of employment for a type of labour which is much more plenti-

ful, and is likely to contribute more effectively to the general prosperity of a populous district. Moreover, if it is of a type which is in steady demand, and can be produced in a district already largely dependent on a manufacture that is subject to fluctuations of demand, it may be of great value in tiding over temporary industrial slackness. A large part of the problem of unemployment is traceable to the dependence of industrial areas upon a single kind of manufacture, coupled with restrictions—partly economic, but partly quite artificial—which prevent the temporary transference of labour from one occupation to another.

The second part of the report enumerates the chief factors to be considered in the establishment of new industries: markets, finance, factory accommodation, rating, raw materials, fuel and power, transport, labour, housing, and the facilities for education and research. At the outset, it is expected that various forms of Government control of raw materials and of industry as a whole will continue for a period, and will be framed so as to encourage new enterprises which are felt to be desirable on national grounds; but, the committee wisely observe, in the long run no firm will succeed unless it is able to stand on its own—and that will depend on efficient management and the production of marketable goods. So far as markets are concerned, it is felt that, while the present tendency is for buyers from overseas to land in the south of England, this disability may be overcome by proper representation in the south and, perhaps, by the development of air transport. Evidence before the committee indicated that, with the right type of product Scottish firms were quite able to compete successfully in the English market; and, so far as concerned trade with America, they would be at no disadvantage, because no part of Scotland likely to have any industrial future was far from a port.

On the question of rating, the report points out that many districts in Scotland, suitable for light engineering works, have local rates which are lower than those in the industrial areas in England, though direct comparison is difficult in the absence of a uniform system of rating throughout Great Britain; but the experienced industrialist is unlikely to attach great weight to that consideration or, anyway, to regard it as a condition of any permanence. With regard to raw materials, it is recommended that no light engineering industry should be established in Scotland if imported raw material forms the greater proportion of the total cost of the product; a principle which, however, still leaves a wide field to be explored, since all forms of iron and steel are made in Scotland, and the aluminium industry is well established. Coal and oil are readily available, though industrial supplies of gas are not so easily obtained; and the projected hydro-electric developments are expected to provide a direct inducement towards the establishment of light engineering works.

Transport charges are rather a handicap in Scotland, and it is suggested that concessions in this respect, already granted to certain classes of trader, should be extended to Scottish industry generally. This proposal, however, seems to be rather at variance with the recommendation, previously mentioned, that the policy should be to develop more particularly those manufactures in which the labour cost is relatively high; such products—for instance, small electrical devices, laboratory balances, etc.—are usually light and compact in proportion to their value, and their transport is not a serious addition to the prime cost. The question of facilities for technical education and research, also, is one which can be regarded as more or less settled in advance; Scotland is relatively well endowed in both respects. Machine-tool capacity also should now be ample for the developments visualised. As is pointed out in the report, some of these tools, such as those installed for the production of shells, may be of only limited utility for peace-time production; but many of the others now in use in Scottish factories are of standard types, applicable to a variety of purposes, and it is suggested that these should form a pool, to be drawn upon for the equipment of new light-engineering industries. They can be easily transferred wherever they are needed, and it is recommended that this should be done, unless they are situated in areas which are obviously best for the new manufactures.

WEAR IN OIL ENGINES.

Researches carried out during recent years to discover the causes of wear in internal-combustion engines, more particularly automobile engines, have pointed to frequent stopping and re-starting as being more injurious to cylinders, pistons, and other parts than prolonged running under load. Protective films of oil are lost when an engine is stopped, and these do not become re-established until several revolutions have been accomplished. Metal-to-metal contact occurs in the first few seconds of working and the resulting abrasion, repeated often enough, leads to the rapid destruction of the working surfaces. A powerful contributory factor is corrosion arising from condensation on cooled surfaces of combustion products. Water inevitably appears in an engine that is stopped and allowed to become cold; this is destructive by itself, but when sulphur compounds give it an acid nature the mischief it can do is greatly augmented. Deterioration of the lubricating oil, as a result of dilution with fuel, is more rapid while an engine is cold than after it has become hot, and consequently the engine that is frequently started from cold is liable, even when running normally, to suffer after a time from the want of proper lubrication by oil of the correct viscosity. This is a matter that can be remedied by changing the oil more frequently, or by the inclusion of an oil rectifier as part of the equipment of the engine; but quite commonly no extra consideration is shown for the engine that has to work intermittently, with the result that it is liable to suffer physical deterioration at a rate which is out of all proportion to the work it is called upon to do. Operators of omnibus fleets noticed many years ago that engine life was less in vehicles which ran over a relatively short and easy route, and therefore spent much time standing at terminal points, than in vehicles which performed an onerous service over a long and difficult route. Whereas the one engine never became fully heated, and constantly fell to an undesirably low temperature, the other became thoroughly hot and retained enough heat to make a satisfactory start after prolonged stops at turning points.

Stationary engines for such service as generating electricity, driving air compressors, or pumping water, are usually kept at work for lengthy periods; but, in the absence of any information regarding the causes of wear, a plant operator with engines to spare might consider it desirable from the point of view of prolonging engine life to share the work among all the engines and to take each unit out of service for inspection at regular and fairly frequent intervals. It would not occur to many operators in the happy position of having plant to spare that the better policy would be to keep the same engines constantly at work at or near full load for the longest possible time, yet such is indeed the case. To be over-cautious, and to keep shutting down plant in order to ascertain that all is well, may clearly prove more harmful eventually than trying to discover the safe limit of endurance and letting each engine work continuously to within a small margin of this limit. In normal times, the fear of inviting a major breakdown might be expected to militate against the pursuit of such a policy, but under the stress of war conditions the engineer's hand may be forced; a rising load, in conjunction with the impossibility of obtaining new plant, may compel the operator of internal-combustion engines to keep every unit working at or near full load until there are clear indications that trouble may arise.

Evidence that this sort of thing is actually happening to-day, and that it is leading the users of large stationary internal-combustion engines to revise their ideas regarding the permissible length of non-stop runs for such engines, was provided in a paper presented and discussed on March 23, 1944, at a meeting of the Diesel Engine Users Association. This paper was by Mr. Robert P. Kay and was entitled "Some Operational Aspects of the Oil Engine Plant Operated by the Tavua Power Pty., Limited, Vatukoula, Fiji." The engines operated by this concern are engaged on supplying compressed air and electric power to neighbouring mines. The plant, originally installed in 1936, consisted of three seven-cylinder vertical oil engines, each of 770 brake horse-power at 375 r.p.m., direct-coupled to 525-kW alternators, and one five-cylinder vertical oil engine of identical cylinder size (15·5 in. diameter by 18 in. stroke) but of 440 brake horse-power, running at 300 r.p.m. and direct-coupled to a two-cylinder double-acting air compressor. All engines are of the four-stroke single-acting type with oil-cooled pistons and solid injection. Under onerous war conditions extremely good running results have been given by all the engines, but the achievement of the five-cylinder engine driving the air compressor calls for particular attention.

An additional engine and compressor, ordered in 1939 to meet an increasing need for compressed air, were lost on the way to Fiji, due to enemy action, with the result that the original set was forced to operate, as far as was practicable, 24 hours a day and seven days a week. In the words of the author, "the inspection routine had, of necessity, to be curtailed considerably, but the engine was shut down every 1,000 hours for valve changing. At the same time, all bolts were examined for tightness and an internal inspection of cooling pipes, bearings, caps, etc., was carried out. Christmas and Easter holidays occasionally provided opportunities to draw and clean pistons, but the periods between piston inspections would average 10,000 hours. On one occasion this period was doubled, the pistons running for 20,000 hours without inspection or cleaning because mining activities required air over holiday periods. Atomisers were tested and set about every 3,000 hours, but have given very little trouble. Fuel pumps have required no attention except for periodical adjustments for timing." In the last year for which running data are available, the engine was started 36 times and ran an average of 233·3 hours per start. The total running time of 8,399 hours was 96·1 per cent. of those possible. In the year 1939-40, only 24 starts were made and the running time of 8,471 hours was 97 per cent. of those possible. The hours run per start works out in this instance to nearly 353. This figure and the one given above are averages; the author explained that the engine frequently ran as much as 1,000 hours between starts. The load factor throughout was approximately 80 per cent. and, as has already been pointed out, operation was not at 375 r.p.m., the speed of the alternator sets, but at only 300 r.p.m.; therefore, except that it was in almost constant use, the engine was not worked unduly hard.

After 37,734 hours of service the cylinder liners were examined for wear. Only three of the five original liners were still in service, the other two having been replaced owing to damage by failure of pistons through a weak section of the skirt. The greatest wear occurred near the top, transversely, and was 0·012 in. Longitudinally, or parallel to the crankshaft, the greatest wear was 0·011 in. This is very much less than the figure of 0·001 in. per 1,000 hours sometimes given as a criterion, and is certainly excellent. Following approximately 15,000 hours of service, the seven-cylinder engines gave main-bearing trouble, which was eventually attributed to crankshaft whip. The journals having become slightly oval had given freedom to the crankshaft in one plane, 0·016 in. beyond the normal bearing clearance. This trouble was overcome by correcting the journals and re-fitting the bearings with finer clearances. The only other bearings to give trouble were the comparatively small single-row ball races on which the governor fly-weights oscillated. These broke or wore out fairly quickly. Larger double-row bearings of the self-aligning type proved more successful, but the author doubted whether ball races were really suitable for partial radial motion. These doubts were shared by several speakers in the discussion on Mr. Kay's paper and, not for the first time at a meeting of the Association, hard things were said about the behaviour of ball bearings in Diesel engines. The construction of pistons in two parts was another design feature which called forth generally unfavourable comment, the almost blameless record of the five-cylinder engine having been marred by the failure of two pistons of this type. There seems to be no way of ensuring that the two parts will not eventually work loose. While rendering full account of shortcomings and mishaps, Mr. Kay emphasised that the performance of his British-built engines had been a very fine one.

NOTES.

RESEARCH IN JET-PROPULSION.

AN important announcement regarding the future of jet-propulsion for aircraft was made by the Ministry of Aircraft Production on March 31: namely, that the Government had decided to acquire, in the national interest, the business of Power Jets, Limited, the company formed by Group Captain Frank Whittle and his associates to develop his invention of the jet-propulsion engine. The existence of this engine, and its successful employment in aircraft, was disclosed on January 6, and was discussed in an article on page 31 of our issue of January 14. The original engine was built in collaboration with the British Thomson-Houston Company, Limited, who had investigated the possibilities of various gas-turbine cycles as long ago as 1933 and had acquired considerable experience regarding materials suitable for very high stresses and temperatures in combination; notably with the 10,000-kW steam turbo-alternator supplied by them to the Detroit Edison Company, which operated at an initial temperature of 1,000 deg. F. The British Thomson-Houston Company were approached by Group Captain Whittle in January, 1936, and the first jet-propulsion unit was run on test in April of the following year. Much additional experimental work has been done since then, and, according to the present announcement, development has now reached such an important stage that it has been decided to establish a national experimental station for jet-propulsion research in which engines can be designed, built and tested. The proposal is to use the present works of Power Jets, Limited, as the nucleus of this new establishment. The agreement to purchase the business is subject to ratification by the shareholders; but this, presumably, is largely a formal matter, especially as the Government already hold a considerable proportion of the company's shares.

THE FUTURE OF CORNISH MINING.

For the past two years, the Cornish Tin Mining Advisory Committee have met at least once a month in pursuance of their main function of advising Sir William J. Larke, K.B.E., the Controller of Non-Ferrous Mineral Development, regarding Cornish mining, the scope of their interests including not only the tin for which Cornwall has been noted for some 2,000 years, but also wolfram ore, which is the source of tungsten, one of the most important "strategic materials" in war and peace. As the war has progressed, the Committee have been naturally led to consider the post-war prospects of the Cornish mining industry, and they have now produced a memorandum on "Post-War Reconstruction: Cornish Metalliferous Mining," which has been submitted for the official attention of Lord Woolton, the Minister for Reconstruction, and other members of the Government. It seeks to show, in the first place, why British metalliferous mining is worth preservation—even, it appears, in defiance of economic considerations—and why it is in danger of extinction; and suggests the steps that, in the opinion of the Committee, should be taken to preserve the industry in Cornwall. The arguments for its preservation are principally the provision of employment in the county; the value of Cornwall as a training ground for mining engineers and of the engineers themselves, when they take posts abroad (as so many have been obliged to do in past years, for lack of suitable employment at home) as promoters of British trade overseas, especially in mining equipment; and the desirability of exploiting the natural mineral wealth of this country in preference to the importation of minerals from other countries. It is claimed that several of the mines which even now are idle in the country could again become productive at reasonable cost if reopened with proper equipment and sufficient capital to undertake exploratory work, and that there are still considerable quantities of tin ore available, as well as of wolfram; though it is admitted that, within the past 50 years, "substantial amounts of new capital have been raised by private enterprise for mines in Cornwall, and to a large degree the money has been lost." The main reason for the decline of British mining, it is considered, and of Cornish mining in particular, lies in the system of taxation as applied to wasting assets; at present, the Committee state, a mining company desiring to make financial provision to recover arrears of development at a later period must allocate 3,000*l.* of profits to cover 1,000*l.* worth of post-war development work—a burden which the mines cannot bear. The Committee propose the adoption of the percentage depletion method of taxation, with a sufficient allowance for pre-production expenditure, and stress the desirability of exemption from taxation during the first three years of development. They urge also that the Government should set up a Metalliferous Mines Commission, to foster this industry and metallurgy in general, and to be supplied with funds in block grants from the Treasury, to enable them to carry out long-term policies. The Commission should have powers to give financial assistance, on their own terms, to approved private mining or metallurgical enterprises; they should have the full assistance of the Geological Survey in planning development programmes, and should have the sole direction of such programmes; and they should have the duty of investigating the present ore-treatment processes used in the production of Cornish tin, with a view to encouraging improved methods of extraction. An abridgment of the memorandum on the production of non-ferrous metals and minerals in Great Britain, prepared by the Council of the Institution of Mining and Metallurgy and submitted to Lord Woolton, will be found on page 268.

THE INSTITUTION OF CIVIL ENGINEERS.

The Council of the Institution of Civil Engineers have decided to establish a Maritime Engineering Division of the Institution on lines similar to those of the other Divisions, namely the Road Engineering, Railway Engineering, and Structural and Building Engineering Divisions. The main objects of the new Division are, firstly, the advancement of the science and art of engineering in relation to the development of harbours and ports, the construction of docks and quays, coast and estuary protection, and the reclamation of land from the sea, and, secondly, the fostering of research relating to maritime engineering developments. It is further proposed to hold meetings of the Division, during the course of the Institution session, for the reading and discussion of communications upon subjects relating to maritime engineering. The papers and communications presented before the Division will be published in the *Journal* of the Institution or will be otherwise dealt with as may be subsequently directed. If thought desirable, summer or autumn meetings of the Division in London or elsewhere, and visits to engineering works, will be organised. Corporate members of the Institution, resident in Great Britain and Ireland, who wish to apply for registration as members of the new Division, should inform the secretary by postcard, giving their name in block letters, their address and the grade of their membership in the Institution. Members resident overseas will be able to obtain, on application, copies of the papers read at meetings and, when conditions permit, they will be informed regarding the procedure for their registration in the Division.

THE INVENTOR OF THE PELTON WHEEL.

In the April, 1942, issue of *The Newcomen Quarterly Bulletin*, the news sheet of historical technical information circulated to members of the Newcomen Society, an inquirer asked where references were to be found to the life and work of Lester Allen Pelton, inventor of the Pelton wheel. Various members responded to the inquiry with particulars which were printed in the issue for July, 1942, from which it appeared that Pelton was born in Vermilion, Ohio, on September 5, 1829, and died at Oakland, California, on March 14, 1908. Further information was given, it was stated, in *Mechanical Engineering*, the Journal of the American Society of Mechanical Engineers, in April, 1930, by Mr. E. M. Breed, President of the Pelton Water Wheel Company; and in the same periodical, vol. 61, pages 447-454 and 510-518 (1939) in a paper on "The Pelton Water Wheel." The latest *Newcomen Quarterly Bulletin*, for March, 1944, contains an additional note, contributed by Mr. C. O. Becker, who quotes the October, 1929, issue of *Progress*, published by the Pacific Gas and Electric Companies, to the effect that, shortly before that date, the Camptonville Masonic Lodge had been instrumental in causing a monument to be erected on the site of Pelton's workshop, with a bronze tablet bearing the inscription: "On this spot in 1875 Lester Allen Pelton invented the Pelton Water Wheel." The *Bulletin* adds that the Pelton Water Wheel Company changed hands several times and is now a subsidiary of the Baldwin Locomotive Works.

THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS.

The annual report of the Council of the American Society of Mechanical Engineers for the year 1943 provides some statistics which may prove of interest, at least to the members of the corresponding British organisation, the Institution of Mechanical Engineers. The membership of all grades of the Society is given in the report as being 17,485 on September 30, 1943, the figure on the same day of 1942 being 16,613, that is, there was a net increase for the year of 872 members of all grades. The total for the Institution on December 30, 1943, was 17,404, and on the same day of 1942 was 15,876, a net increase of 1,528. It may be noted, however, that the classification as to grades of membership is not the same in the two institutions. In both, however, the roll is headed by the Honorary Members, 28 in number in each case. Then, in the Society's roll comes a classification of "Fellows," forming less than 1 per cent. of the total and having no counterpart in the Institution. Then come "Members," these amounting, in the Society, to 48·35 per cent. of the total and in the Institution to only 18·27 per cent. Next to the "Members" in the Society's roll comes the grade of "Associates," rather more than 1 per cent. of the total. This grade may be compared with the grades of "Companion" and "Associate" in the Institution which, however, rank below that of "Associate Member" and constitute about 2·72 per cent. of the total. Below the "Associates" in the American Society are three grades of "Juniors," which may be taken to correspond with the grades of "Associate Member" and "Graduate" of the Institution. The three grades of "Juniors" in the Society account together for 49·55 per cent. of the total membership. There is no specific heading of "Student" in the Society's membership list, though this grade is included in the membership of the Institution, the three grades of "Associate Member," "Graduate" and "Student" forming 78·82 per cent. of the total. The most striking feature of this comparison is that, whereas in the Society, "Members" constitute nearly half the total list, the corresponding figure in the Institution is only between one-fifth and one-sixth. A movement has been initiated in the Society to create an "Associate Member" grade between the "Members" and the "Juniors," and it is also proposed to substitute the term "Affiliate" for that of "Associate" as representing a grade for persons whose training and experience does not qualify them for corporate membership. This latter seems a commendable suggestion, as the simultaneous use of "Associate Member" and "Associate," which occurs in more than one British organisation, does not always convey the correct distinction between the two classes. The report, which is published in the January issue of *Mechanical Engineering*, contains other interesting information. One item may be singled out, namely, that in the Engineering Societies Library from October, 1942, to June, 1943, a total of 27,653 photostats had been ordered by 817 borrowers. This facility, as far as we are aware, is not, at present, available in any British technical institution, possibly owing to considerations of copyright.

THE ILFORD COLLISION.

The failure of a driver to observe due caution in a thick fog was considered to be the main cause contributing to the serious collision which occurred on January 16 at Ilford station, on the London and North Eastern Railway, according to the report submitted to the Minister of War Transport by Sir Alan Mount and Major G. R. S. Wilson, who conducted the inquiry into the accident. The collision

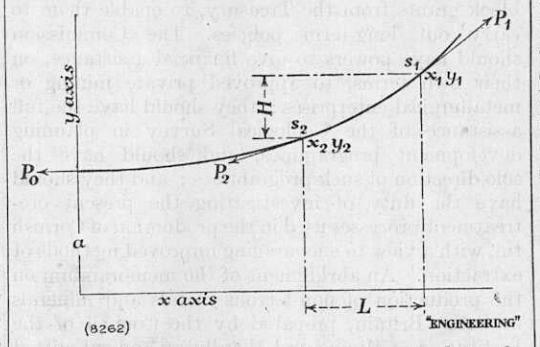
took place at about 7.20 p.m. in darkness and dense fog, the 2.40 p.m. express passenger train from Norwich to Liverpool-street passing a series of signals at danger and colliding, at a speed estimated to be between 20 miles and 25 miles an hour, with the rear of the 2.38 p.m. express passenger train from Yarmouth, which had stopped near Ilford West signal box. Nine passengers lost their lives and a further 38 received injuries or suffered from shock. The engine of the Norwich train demolished the last coach of the Yarmouth train almost completely, and some damage was caused also to the coach ahead of it. Dense fog had persisted throughout the previous night, but it cleared shortly after midday and the fogmen were dismissed; between 6.30 and 7 p.m., however, the fog descended again, necessitating the recall of the fogmen, but none of the posts had been manned on the up through line, which was the one concerned, when the collision took place, by which time visibility was reduced to a few yards. The report expressed doubt whether the oil lamps of the up through semaphore signals in advance of Ilford station could have been seen from footplate level; the driver of the Yarmouth train, though his position was on the left-hand side of the footplate, did, in fact, miss three signals. The third signal was provided with a co-acting detonator placer, but he heard no detonators explode and it was only when he saw the lower co-acting red light of the Ilford West starting signal that he pulled up his train, going forward on foot to the Ilford West box to report its presence. The Norwich train was driven, from the right-hand side of the footplate, by a driver of 16½ years' experience, who had worked regularly into Liverpool-street for more than three years and was well acquainted with the road. His fireman, however, was not familiar with it and did not know of certain modifications to the signalling; he was not the driver's regular fireman. Unfortunately, the driver did not know that the fireman's experience was so limited, and relied on his observation of the signals, which was inaccurate. No criticism was made of the operations of the signalmen in the boxes concerned in the up through approach to Ilford; but the block sections there are short, and they could take no effective action to stop the Norwich train, especially as the boxes were not provided with emergency detonator placers. The report suggested that an apparatus of this kind at the Ilford Carriage Sidings box might have enabled warning to be given in time to the driver of the Norwich train; but, apart from such equipment, it appeared likely that nothing less than automatic train control, in the form of a warning brake application, would have prevented the collision. Sir Alan Mount and Major Wilson added to their report some remarks on the subject of automatic train control, which was considered by special committees in 1921 and 1927, and again reviewed after the Castlecary accident in 1937. Close attention was being given to this subject in the years preceding the outbreak of war. The Great Western Railway had practically completed the equipment of their system with an automatic control of the warning (contact) type, which they had been developing for some 30 years; the London Midland and Scottish Railway were experimenting with a warning control of the non-contact type and are still doing so; and the London and North Eastern Railway had been investigating similar apparatus until the war intervened. The 1927 committee summarised all cases of accident, from 1911 onwards, into which Ministry inquiries were held, and found that, in the ten years ended September 30, 1921, automatic train control would have proved effective in 37 per cent. of the 193 accidents reviewed; in the next eight years, the figure diminished to 29 per cent., representing only 50 cases, although the average annual train mileage had increased from 372 millions to 392 millions. In the ten years ended September 30, 1939, during which 134 inquiries were held, the proportion was further reduced to 25 per cent., though the average train mileage had risen to 430 millions. The improvement was due in part, it was suggested, to the extension of warning control, and in part, also, to the more general use of colour-light signalling, including colour-light distant signals on high-speed main lines; but colour-light signals could not be regarded as a complete substitute for automatic train control.

LETTERS TO THE EDITOR.

SURVEYS FOR THE RECONSTRUCTION OF TUBE STATIONS.

To the Editor of Engineering.

Sir,—Referring to the appendix to the article by Mr. T. M. Megaw which appeared on page 85 of your issue of July 31, 1942, and to his letter published in Engineering, January 15, 1943, on page 55, the same problem confronted the writer in 1932 and the method shown below and illustrated by the accompanying diagram may be used to verify Mr. Megaw's solution. Its usefulness will be limited to checking the more common methods.



Using the author's notation, noting that the x axis has been dropped, and given H = 50 ft., $P_1 = 10{\cdot}25$ lb., $s = s_1 - s_2 = 100$ ft., and $w = 0{\cdot}01$ lb. per foot; then

(1) $y_1 = \frac{P_1}{w} = \frac{10{\cdot}25}{0{\cdot}01} = 1{,}025$ ft.

(2) $y_2 = y_1 - H = 1{,}025 - 50 = 975$ ft.

(3) $s_2 = \frac{y_1^2 - y_2^2 - s^2}{2\,s} = \frac{1{,}025^2 - 975^2 - 100^2}{200} = 450$ ft.

(4) $a = \sqrt{y_1^2 - s_1^2} = \sqrt{y_2^2 - s_2^2} = \sqrt{1{,}025^2 - 550^2} = \sqrt{975^2 - 450^2} = 864{\cdot}942$ ft.

(5) $\tanh \frac{L}{2\,a} = \frac{s}{y_1 + y_2} = \frac{100}{2{,}000} = 0{\cdot}05$

(6) $\frac{L}{2\,a} = 0{\cdot}05 + \frac{0{\cdot}05^3}{3} + \frac{0{\cdot}05^5}{5} = 0{\cdot}050{,}004{,}129$

(7) $L = 2\,a \times 0{\cdot}050{,}004{,}129 = 86{\cdot}5013$ ft.

(8) $\bar{y} = \frac{a\,s}{L} = \frac{864{\cdot}942 \times 100}{86{\cdot}5013} = 999{\cdot}919$ ft. nearly.

(9) $P_m = w\,\bar{y} = 0{\cdot}01 \times 999{\cdot}919 = 9{\cdot}999$ lb. nearly.

$\frac{P_1 + P_2}{2} = \frac{9{\cdot}75 + 10{\cdot}25}{2} = 10$ lb., the assumed mean tension.

(10) $\bar{y} = \frac{s_1\,y_1 - s_2\,y_2 + a\,L}{2\,s} = 999{\cdot}093$ ft. (correct).

$P_m = w\,\bar{y} = 0{\cdot}01 \times 999{\cdot}093 = 9{\cdot}991$ lb.

∴ Error in mean tension = $10{\cdot}000 - 9{\cdot}991 = 0{\cdot}009$ lb.

The accuracy of the above depends on knowing the correct s length and P_1. Its usefulness is thereby limited, since H, s and P_1 may be slightly in error.

Yours faithfully,
Allen H. Brownfield,
Assoc. Mem. A.S.C.E.

Sacramento,
California, U.S.A.
January 23, 1944.

THE SIMPLE TRUSSED BEAM.

To the Editor of Engineering.

Sir,—With reference to Mr. G. Key's letter in your issue of March 3, 1944, on page 174, I have no experience of trussed beams subject to vibration, such as in rolling-stock underframes. For those of your readers who wish to work out, approximately, the forces in the members of the simple trussed beam and so arrive at suitable sections which can be checked, if considered necessary, by the exact method, I would recommend, for the case of a uniformly-distributed load over the whole span, the method suggested by Mr. F. M. Bowen in your issue of November 19, 1943, page 414, *i.e.*, by assuming a pin joint at the centre of the beam. The space and force diagrams will then be as in Fig. 1, and the B.M. diagram as in Fig. 2. We then get force in strut = ½ W; pull in tie = ¼ W cosec θ; and thrust in beam = ¼ W cot θ; where θ is the angle made by the tie with the beam at the end; and W = total load on the beam. The maximum B.M. will be $\frac{1}{32}$ Wl. The stresses due to thrust and bending in the beam can then be found and added to give the maximum stress. A concentrated load should be converted into an equivalent uniformly-distributed load, *i.e.*, that uniformly distributed load over the whole span which will cause the same deflection at the centre.

Applying these rules to the case of the trussed beam of 20 ft. span carrying a uniformly distributed load of 0·4 ton per foot run over the whole span, the maximum stress in the beam is found to be 1,382 lb. per square inch, as compared with the correct figure of 1,353 lb. per square inch: an error of about 2 per cent. In the case of the same trussed beam with a load of 4 tons concentrated at the centre, if we substitute a uniformly distributed load of 6·4 tons, the maximum stress totals 1,106 lb. per square inch, against a correct figure of 1,045 lb. per square inch, an error of about 6 per cent. It will

Fig. 1.

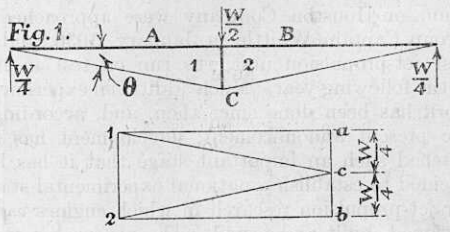
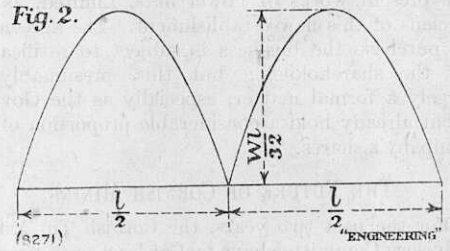


Fig. 2.



be noted that in both examples the error is on the safe side, *i.e.*, the actual stress is less than the value assumed.

If it be required to give initial camber, it will be seen, from your issue of October 15, 1943, page 303, that the centre sinks below the ends an amount equal to the downward deflection when the strut is removed, less the upward deflection due to the force in the strut = $\frac{5\,W\,l^3}{384\,E\,I} - \frac{8\,R\,l^3}{384\,E\,I}$, where R = force in the strut. Now, by the approximate method, R = ½ W. Hence, downward deflection at the centre = camber to be given = $\frac{W\,l^3}{384\,E\,I}$. Applying this to the case of the beam of 20-ft. span, carrying a uniformly distributed load of 0·4 ton per foot run, we get deflection = 0·878 in. against a correct figure of 0·817 in., an error of about 7 per cent.

As has already been pointed out, it is customary not to calculate for stresses due to camber. If, however, it be decided to allow for this, the load at C, in Fig. 1, should be increased to ⅝ W. The maximum B.M. will still be $\frac{1}{32}$ Wl.

Yours faithfully,
17, Ashridge-crescent, J. J. O'Donovan.
London, S.E.18.
March 28, 1944.

"British Machine Tool Engineering."—We have received from Messrs. Associated British Machine Tool Makers, Limited, a copy of the January-March, 1944, issue of their journal, *British Machine Tool Engineering*, the greater part of which is devoted to the work of the Corps of Royal Electrical and Mechanical Engineers. A foreword is contributed by Major-General E. B. Rowcroft, C.B., C.B.E., the Director of Mechanical Engineering, War Office. The issue provides the most complete survey that we have seen of the work of the Corps, which, constituted on October 1, 1942, brought under a single direction the whole of the engineering personnel previously in the Royal Army Ordnance Corps, a proportion of the maintenance engineers of the Royal Army Service Corps, and the mechanical maintenance and electrical technicians of the Royal Engineers.

OBITUARY.

SIR CHARLES V. BOYS, F.R.S.

WE regret to record the death of Sir Charles Vernon Boys, which occurred on March 30 at his home at St. Mary Bourne, Andover, after a short illness. Sir Charles was regarded as the doyen of physicists, and not only possessed great experimental skill but was a master craftsman and an ingenious mechanic. Charles Vernon Boys was the son of the late Rev. Charles Boys and was born at Wing, Rutland, on March 15, 1855; he was thus in his 90th year. He was educated at Marlborough and entered the Royal School of Mines, London, in 1873. After three years' study he obtained the Associateship of the School (A.R.S.M.), in mining and metallurgy, and became private assistant, first to the late Dr. John Percy, F.R.S., and afterwards to the late Dr. F. Guthrie, F.R.S. In 1881, he was appointed demonstrator, and in 1889, assistant professor of physics at the Royal College of Science and Royal School of Mines. Professor Boys, however, gave up teaching in 1897 on his appointment as a Metropolitan Gas Referee, which position he held for 40 years. Very early in his career, Boys began to write papers, dealing mainly with mechanical and geometrical questions connected with physics or with minute and exact measurements, and these were presented before the Royal Society and the Physical Society. For his work in this sphere he was elected a Fellow of the Royal Society in 1888 at the early age of 33.

One of Boys's earliest researches concerned the photographing of rifle bullets in flight and the method he adopted was sufficiently sensitive to show clearly the disturbed state of the air in front of and behind the bullet. His work on this subject served as a basis for further experiments conducted in the United States during the war of 1914-18. Another of Boys's early researches culminated, in the late 'eighties of last century, in the successful production of "quartz fibres." These, which were extremely fine vitreous-silica threads and were characterised by uniformity of diameter, remarkable elastic properties and high tensile strength, were employed in many delicate instruments. Using rock crystal or pieces of broken transparent silica ware as the raw material, fine rods, about 1 mm. in diameter, were first drawn. A piece of this rod was attached by means of sealing wax to an arrow made of straw, some 10 cm. long. The arrow was then fitted into a cross-bow and the flame of an oxy-hydrogen burner applied near one end of the rod, the other being held in the operator's hand. When part of the rod had become soft, the arrow was released from the bow by a treadle and a fibre from 20 ft. to 30 ft. in length was obtained stretching from the arrow to the piece of rod held by the operator. With practice, the operator could make the fibre "fine" or "coarse" at will, the diameter of these being 0·0001 in. and 0·0005 in., respectively. By the use of these fibres Boys was able to eliminate most of the errors of the famous Cavendish experiment, and succeeded in determining the density of the earth and the constant of gravitation with great accuracy.

Boys also employed quartz-fibre suspension in the construction of his radiomicrometer, an instrument of truly remarkable sensitivity with which, when used in combination with a reflecting telescope, he was able to detect the heat radiation from the flame of a candle at a distance 216 metres. In connection with this experiment he pointed out that, given perfectly transparent air, the apparatus could detect the minute radiation from a candle flame at a distance of from 3 to 3¾ miles. He also used the instrument for investigating the radiation from the moon, planets and stars, and though he was able to detect considerable differences in the radiation from various parts of the moon's surface, Mercury, Venus, Mars, Jupiter and Saturn failed to give any deflection on his apparatus. Boys also carried out considerable research on the blowing of soap bubbles and his experiments, given in his interesting book, *Soap Bubbles, their Colours and the Forces which Mould Them*, will long be consulted by young and old alike. Others of his activities included improvements in telescope design, the construction of sun dials, a photographic device for following a flash of lightning throughout its course, a simple method of extracting square roots, and a "rainbow" top which produces a striking sequence of colours in a rotating soap film.

As a Gas Referee, Boys was responsible for the control of the conditions under which gas is supplied to the public, and a calorimeter described by him, in a paper presented to the Royal Society in 1905, was adopted for official tests by the authorities when the London Gas Act was passed in 1906. The Gas Regulation Act of 1920 removed certain disabilities as to the quality of the gas from the gas undertakings, but obliged them to supply a gas of a previously declared calorific value. After three years of concentrated study, Boys developed a recording and integrating calorimeter which was designed to safeguard the interests of both the gas manufacturers and the users.* This instrument, which has been in use since 1923 for recording the calorific value of the gas supplied in various parts of this country, incorporates many ingenious devices. One of these, which Boys called the "thinking machine," automatically corrects the volume of the gas consumed in the calorimeter to normal temperature and pressure and continually records the correcting factor.

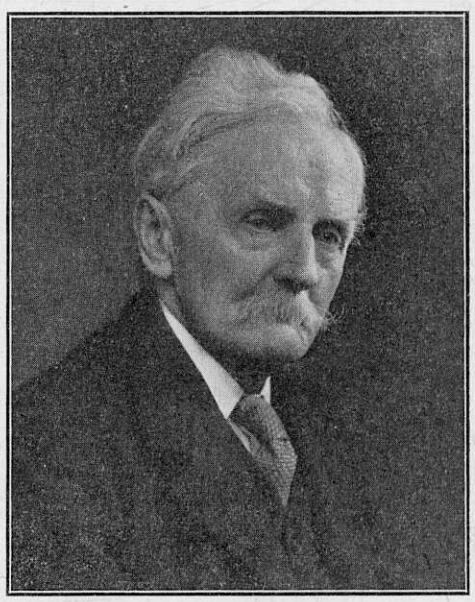


Photo: Lafayette, Ltd.

THE LATE SIR CHARLES V. BOYS, F.R.S.

Boys, who was knighted in 1935, was an Honorary Fellow of the Royal Society of Edinburgh, an Honorary Member of the New York Academy of Sciences, and an Honorary LL.D. of the University of Edinburgh. For his work on the jury of inventions at the Paris International Exhibition of 1889, he was made an Officier de l'Instruction Publique. He joined the Physical Society as a young man and served for many years as a member of the Council, and afterwards as secretary. He was a past-president of that Society and of the Röntgen Society. He was awarded the Royal Medal of the Royal Society in 1896 and the Society's Rumford Medal in 1924. Boys also received the Duddell Medal of the Physical Society in 1925 and the Elliott Cresson Medal of the Franklin Institute in 1939. In addition to his little volume on *Soap Bubbles*, he published a book on how to deal with garden weeds in 1937, and edited and completed a treatise on *Dynamometers* by the late Rev. F. J. Jervis-Smith, F.R.S. His only son, Mr. Geoffrey Vernon Boys, M.A., M.I.Mech.E., M.I.E.E., is the secretary of the Institution of Naval Architects, to which post he was appointed in 1936.

* See ENGINEERING, vol. 115, page 559 (1923).

FLOATING CONCRETE BRIDGE AT HOBART.

ALTHOUGH the floating bridge is one of the oldest methods of carrying a road across a waterway, the floating concrete bridge recently completed to span the River Derwent at Hobart, Tasmania, briefly referred to on page 255, *ante*, by no means adheres to conventional ideas. It is, in fact, a highly ingenious piece of work and a notable bridging achievement. In the first place, it is not carried straight across the river, but follows a circular arc with its convex face presented upstream. It may, therefore, be compared with an arched bridge laid on its side, the loading carried by the deck of the normal bridge being represented in the floating bridge by the pressure of the downstream flow. The result in both cases is, however, the same, the curved member being in compression. The resemblance to an arched bridge is increased by the fact that the two main sections of which the floating bridge is composed are joined together at the centre by a pin, while what may be called the abutments have analogous pin connections. The city of Hobart is situated on the west bank of an estuary and is faced on the east bank by a suburb, Bellerive. The bridge connects the two places, and apart from road traffic, will, in the near future, carry a water main to improve the supply at Bellerive.

The River Derwent is navigable for some distance up, and accordingly passage through the floating bridge has been provided for by a high-lift bridge at the Hobart bank. The total length of the bridge, including the lifting span and approaches, is 4,000 ft., the actual floating roadway being 3,168 ft in length. This roadway consists of 24 reinforced-concrete pontoons connected rigidly together in two sections, of 12 pontoons each, the sections being connected at the centre, by a single pin, 13 in. in diameter. The freeboard of the pontoon parapet is 4 ft. 6 in., but the parapets will be deepened and finished by a lighter structure, the top of which will be 9 ft. above the water level, which should give ample protection from spray in the worst weather. The pontoons are 40 ft. in width, this dimension providing a roadway 30 ft. wide, a footway 6 ft. wide, and sufficient space for the installation of the water main referred to above. The road surface is continuous, since the pontoons have not individual freedom of movement. The depth of the pontoons is 10 ft., and each weighs rather more than 1,000 tons. The anchorage at the abutments consists of a deep steel box girder, triangular in plan, the base of the triangle lying along the end of the floating structure, and its apex being at the abutment. The girder is coupled to the pontoons and abutment by heavy steel pins, the construction forming a hinged connection which allows for vertical movement with the rise and fall of the tides.

The abutment on the Hobart bank is on a heavy reinforced-concrete pier, which forms the base for one of the towers of the lifting span, this pier standing in the stream. The corresponding pier for the other tower is closer to the bank, to which it is joined by the approach span. The lifting span bridge follows more or less conventional lines. It is wholly of steel, the towers being of the open braced-frame type and the span itself being of a modified deep Warren girder design. The installation of the floating bridge was a somewhat difficult undertaking, as may well be imagined, when it is considered that two floating structures, each 1,584 ft. long, measured along the arc, had to be towed to the site, manœuvred into place in a current, and joined together in mid-stream. Each part was, of course, rigid, the component pontoons having been assembled in a bay of the estuary downstream from the bridge site. The ends of the bridge through which the coupling pin passed were first attached to a moored buoy in the centre of the river, so that they could be turned, as if on a central hinge, into correct alignment. The sections being thus anchored at the centre, the shore ends were gradually towed round and secured to the abutments. The final stage was the closing of the gap near the moored buoy and insertion of the pin.

The new bridge was designed by Mr. A. W. Knight, chief engineer of the Public Works Department of Tasmania. The provision of the bridge was undertaken by Messrs. Hobart Bridge Company, Limited, which obtained the right from the Tasmanian Government to collect tolls. The actual building was first entrusted to a private firm, but the work was subsequently taken over by the Public Works Department, with Mr. J. A. Slatter as resident engineer. For the information given above we are indebted to our Australian contemporary, *The Commonwealth Engineer*.

INSTITUTION OF THE RUBBER INDUSTRY.—The 20th annual general meeting of the Institution of the Rubber Industry will be held in the cinema of the Imperial Institute, South Kensington, London, S.W.7, at 6.30 p.m. on Monday, April 17. Afterwards there will be a talk on "Rubber Dinghies," by Mr. C. A. Robertson.

FUNDAMENTALS OF THE MARINE SCREW PROPELLER.*

By Dr. G. S. Baker, O.B.E.

The screw propeller has many facets to its make-up, and each one can be so viewed that it appears to be of great importance, but its characteristics are so mixed that even if some quality is missing, the automatic adjustment of other things present can often cover the deficiency. At the same time, if any physical feature is altered, the working of other features is altered in ways not easy to trace, owing to this interdependence. This complexity has had some peculiar results. The practical man, until recently, has been forced to work from small groups of actual ship results, with one or two basic simple formulæ, but the theoretical man is but little restrained by practical results. Hence we have had no less than seven main theories of propeller action, most of which are still alive, and endless subsidiary ones. It may be informative to use the basic principles of some of these theories to bring out the essential features of propellers. By comparatively simple methods, it may be shown what these things are, how a quantitative measure of the changing importance of the two prime causes of loss in a propeller—pitch and friction is arrived at.

We do not know who first used wheels for water propulsion, though certainly Captain Blasco de Garay did so in 1543; but once side paddle wheels were in use, only one more step had to be taken to reach the screw propeller. The atmosphere was right for it as soon as the marine steam engine had shown its reliability, and this last step in propeller design seems to have developed quite independently in several countries in a very short period of time. Bushnell, in a letter to Thomas Jefferson (1787) states that a screw propeller was used on his submarine built during the American War of Independence. Another, but unsuccessful, attempt on an actual boat was that of Lyttleton on a pilot boat in Greenland Dock in 1794. He fixed a long copper spiral in a frame under the stern quarters (not on the middle line). The work of two men only gave the boat a speed of two knots. Colonel Beaufoy records, in 1818, that "30 to 40 years before" he had seen a model, made in China, of a flat-bottomed boat with such a spiral underneath its bottom, which worked by clockwork. A much more successful attempt was that of Colonel John Stevens in 1802. His propeller was the forerunner of the short four-bladed screw now in use, and gave to a 25-ft. boat a speed of 4 m.p.h. In 1804, with a reciprocating engine and twin screws, he was able to maintain a speed of 4 m.p.h. on a boat 25 ft. long, and to do a spurt of 7 m.p.h. to 8 m.p.h. The blades were adjustable in pitch.

Yet another and spontaneous successful attempt at screw propulsion, was that of Josef Ressel of Trieste. In 1827, he was granted a patent for a screw propeller on the middle line of a ship with the rudder abaft it.† Ressel appears to have recognised the gain to be derived from the ship wake, as his application reads: "It is advisable to fix the wheel at the stern, since the back water of the ship might promote its action." He constructed a vessel, La Civetta, 60 ft. long by 11 ft. beam, with a screw propeller consisting of two "half turn" blades, 5·1 ft. in diameter, placed on the middle line as described above. This was done in 1828, and he is stated to have obtained 6 knots with 6 h.p. What appears to be almost a copy of this propeller, was patented in this country by Cummerow in 1829, but came to nothing. Another and again spontaneous effort was that of Crirck, who exhibited a model hull, with screw propeller on the middle line aft, having blades of short length, first at Edinburgh in November, 1829, and in London in 1830. F. P. Smith (1836) came eight years after Ressel's successful trial; in 1839 he built the Archimedes, a vessel of 237 tons, with a steam-driven screw propeller, and his results with this large vessel compelled attention. Practically at the same time, John Ericsson (1836) brought out his screw propeller and this, being fitted to a fair-sized ship, was a success. These two types of propeller differed considerably, Smith's being a very long single-blade helix of one convolution (afterwards replaced by several shorter blades), whereas Ericsson's consisted of a number of short helical blades fixed to a cylindrical hoop, supported by arms from a central boss. The latter screw was at first used in pairs arranged one behind another on co-axial shafts, turning right and left, the after one having a higher velocity than the forward one to enable it to act in water already set in motion by the forward screw. These two screws were placed abaft a quite small rudder, and the first ship built in this way was unmanageable. When the rudder was put aft the screw, and the after screw removed, the result was satisfactory. From then onwards, over a period of ten or fifteen years, a variety of types of screw propellers are on record, covering various ideas which still engage inventors—screws of various blade outlines; of diameter varying from leading to trailing edge (even expanding diameters); blades of increasing pitch in all directions; swivelling and even flexible blades; bird-wing and fish-tail blades; screws with long and short shrouding cases. So far as can be ascertained, during this period, only one inventor gave thought to the shape of the cross-section of the blades.

The success of Smith's propeller on the Archimedes left the naval engineers with the problem of designing a screw propeller. Only general appreciation of friction and the forces on an inclined plate existed. Naval powers therefore set about accumulating a mass of data by full-scale tests. The Admiralty carried out tests of 50 propellers in the five years 1843-48, and the French tried some 53 propellers on the Pelican during 1847-48 and others on the Napoleon. Some of these tests were very thorough, but an immense amount was useless owing to the absence of any guiding theory as to what to try or what to do with the data obtained. It is interesting to note that after trying many variations, the best type found was practically the simplest. In

Fig. 1.

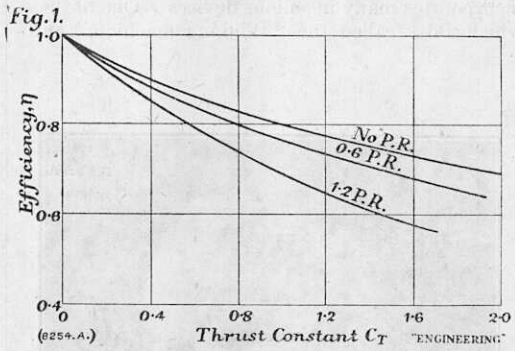
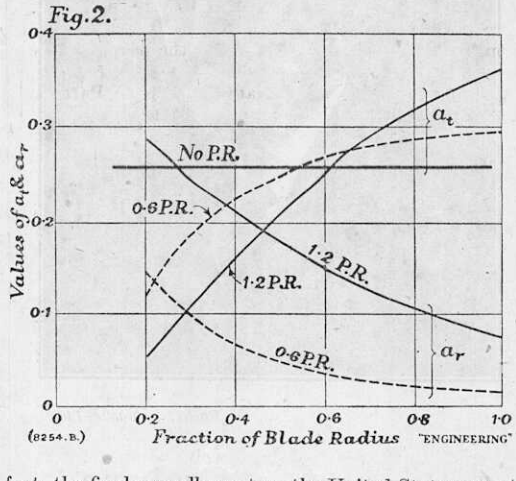


Fig. 2.



fact, the final propeller put on the United States vessel Princeton had six blades very like those of Stevens's original propeller. Various attempts have been made to formulate scientific methods of design. Scott Russell in his great work on naval architecture lays down the principles that "the diameter is the chief element of its power, the breadth of blades . . . and their number being secondary. The width of the blade should be simply that for strength." The propeller which he fitted on the Great Eastern had blades of nearly constant width, with circular back sections, the outer portion of the blades being relatively thin, so that accidental contact did not deprive the ship of all its propeller. He suggests increasing the number of blades as diameter is increased, and quotes M. Dupuy De Lome as using eight-bladed screws on the Napoleon and other vessels. To this day experimental data have kept well ahead of theory, and propellers are still designed for aeronautical and marine purposes from charts of methodical test data, theory being used simply to establish the form in which such data shall be plotted.

Various attempts have been made to deal mathematically with a marine screw propeller. The first investigations were on two independent lines. In the momentum theory propounded by Rankine (1865) and generalised by R. E. Froude in 1889, the propeller forces are deduced from the motion of the fluid, acquired as it passed through the screw (with a deduction in the case of Rankine's work, for blade friction). In the blade element theory given by W. Froude in 1878, the propeller thrust and torque is determined from the forces acting on the blade, due to its advance and rotary speeds—the water movement being an incidental result. To assess these forces, the blade was assumed to be made up of elementary strips moving on helices at known small angles and known velocities. This theory requires a knowledge of the lift and drag forces on such inclined strips, and both this and Rankine's original theory is full of uncertainty due to imperfect knowledge of the actual or intake velocity of the water at each part of the blade. Both theories also make no allowance for interaction between adjacent blades, or for the flow near the blade tips. But R. E. Froude's generalised momentum theory and the principles of the strip theory still serve a useful purpose in that they afford a basis on which practical formulæ can rest; and in the later forms to which they have been developed, with accurate knowledge of blade force characteristics, they can be used for the broad study of propeller action. In recent years they have been supplanted by the more accurate vortex theory, which allows of the calculation of the induced translational and rotary velocities at each part of the blade from the forces acting on the blade. No designer depends entirely upon it, its use lying mainly in the estimation of the effects of variation from known results. As usually applied it ignores the contraction of the race both before and abaft the screw, hence its accuracy diminishes with heavy thrust. The interaction between finite blades is dealt with by assuming the latter to be replaced by a similar number of helicoidal vortices. Results for such a case can be worked out only for small lifts. It demands, as before, a knowledge of blade characteristics which is somewhat difficult to meet, as the effective aspect ratio for which these lift and drag values should be taken is difficult to assess with wide-bladed screws, particularly near the blade tips. When the blade characteristics have been correctly assessed at any radius, the thrust and torque are obtained by integration, as in the simple blade-strip theory.

The underlying basis of facts in the theories is that the rotating screw blades throw back a column of water, and the energy in this moving column or race is part of the price paid in developing the thrust of the propeller, irrespective of how the actual blades produce it. Great weight was attached to this argument in the early days of the propeller, and it led to the use of very large-diameter slow-revolving screws, until W. Froude pointed to the other losses due to pitch and friction. For an actual blade to produce axial thrust by a rotary motion it must be inclined, or be given a pitch, and as the water reaction of the blade is nearly normal to its surface, the thrust must be accompanied by a side or rotary force, and this must be overcome to keep the blades rotating—again involving some loss of energy. Also, since the propeller blades are never smooth, and have a definite body or form, their movement through the water involves a resistance along the blades always opposed to the motion, varying only slowly as thrust is varied. This resistance consists mainly of the skin friction drag, to which must be added the increase in this drag due to the changes in velocity arising from the thickness of the blade; and the sum of these is usually called the profile drag. This has a small component reducing the actual thrust, and a much more serious component adding to the torque. The only additional force acting is that due to the "spilling" of the pressure at the blade tips. This causes an outward flow on the driving face and inward flow on the back, producing a long spiral of marginal vortices at the blade tips. The latter motion causes a drop in thrust, but the effect depends on the lift of the section, being nil when the lift is nil and varying as the square of the speed. Hence it can be neglected at small lifts, but at a lift coefficient of 0·2, it adds 15 per cent. to 25 per cent. to the drag for a blade of 6·0 aspect ratio in open water, but less than half this as a blade of a screw.

A study of the three main causes of loss of energy in a propeller—from slipstream, from pitch, and from friction—enables a general idea to be formed of the maximum possible efficiency in any case, and the relative extent to which any of the three causes is responsible for loss of efficiency. Such an examination can be made in stages from a mixture of the vortex, momentum and strip theories. The nomenclature is as follows:—

V = speed of ship in knots.
$V_1 = \frac{V}{1+w}$ = speed of advance of screw through wake water in knots.
v_1 = speed of advance of screw, ft. per sec.
a_t = intake fraction of screw at any thrust.
$v_1(1+a_t)$ = translational flow through screw in feet per second.
a_r = intake rotary velocity at propeller.
N = revolutions of propeller per minute.
n = revolutions of propeller per second.
T = thrust of screw in pounds.
ρ = density of fluid in which the screw works = 1·94 for fresh water, and 1·99 for salt water.
D = diameter of screw in feet.
$(1+w)$ = froude wake factor = ratio$^{-1}\left(\frac{V}{V_1}\right)$.
$(1-t)$ = thrust deduction factor $= \frac{\text{pull to tow ship}}{\text{thrust to propel it}}$.
$(1+w)(1-t)$ = hull efficiency.

* Sixteenth Thomas Lowe Gray Lecture delivered before the Institution of Mechanical Engineers on Friday, January 28, 1944. Abridged.

† See ENGINEERING, vol. 3, page 16 (1867).

Disc area ratio = d.a.r.
$$= \frac{\text{sum of developed area of blades}}{\text{disc area of screw}}.$$
H = thrust horse-power derived from the screw $= \frac{Tv_1 \times 60}{33{,}000}$.
S = shaft horse-power absorbed by screw.
η = efficiency of screw $= \frac{H}{S}$.
C_T = thrust constant $= \frac{T}{D^2 {v_1}^2}$.
δ = Taylor revolution speed constant $= \frac{ND}{V_1}$.
B_P = power constant $= \frac{NS^{0.5}}{{V_1}^{2.5}}$.
Pitch ratio $= \frac{\text{pitch}}{\text{diameter}}$ = P.R., in accompanying curves.

Taking first the loss in the slip race, this can be assessed from the Froude axial momentum theory. All the water passing through the screw is regarded as moving fore and aft, and as having the same velocity over the propeller disc; and by supposition there is no loss of energy at the propeller. It can be shown that

$$\text{efficiency} \qquad \eta = \frac{1}{1 + a_t} \quad . \quad . \quad . \quad (1)$$

$$\text{and thrust } T = \rho {v_1}^2 \left(\frac{\pi}{4} D^2\right) 2a_t(1 + a_t) \quad . \quad . \quad (2)$$

The thrust constant

$$C_T = \frac{T}{D^2 {v_1}^2} = \pi (a_t)(1 + a_t) \quad . \quad . \quad (3)$$

The curve of efficiency for a frictionless screw, the efficiency being constant for all parts of the disc, is shown in Fig. 1, opposite, to a base of C_T. By far the greater number of screws work between abscissa values of 0·6 to 1·8; and for these, therefore, there is an inevitable loss varying from 15 per cent. to 30 per cent., respectively, without including any losses in the blades.

The thrust has so far been considered as exerted in a fore-and-aft plane, and the next step is to imagine the thrust being exerted by a pitched surface. For this we imagine the motion to be set up by a large number of inclined surfaces in the plane of the propeller, inclined so that along any radial line they have a common pitch, all of these imaginary planes being frictionless. It can be shown that, for minimum loss of energy in a lightly loaded propeller, the efficiency should be constant at all radii, and for a screw of uniform pitch, this efficiency is related to the intake velocities by the two formulæ

$$a_t = \frac{x^2 \eta (1 - \eta)}{1 + x^2 \eta^2} \quad \text{and} \quad a_r = \frac{1 - \eta}{1 + x^2 \eta^2} \quad . \quad (4)$$

from which

$$\eta = \frac{1 - a_r}{1 + a_t} \quad . \quad . \quad . \quad (5)$$

where x the ratio of rotary to advance velocity of the screw at any radius. The thrust is still given by formula (2), and these equations enable an estimate of the loss of energy to be calculated for varying thrust loads as represented by the C_T term. As the real slip angles in practice are never more than one or two degrees relative to the face pitch, this can be taken as defining the velocity ratios; and if all the elements of the blade conform to a uniform pitch, then at any radius r

$$x = \frac{2r}{D} \cot \theta$$

where θ is the pitch angle at the blade tip and $\cot \theta = \pi/\text{pitch ratio}$.

Two cases of screws having pitch ratios of 0·6 and 1·2 have been taken for illustration. The analytical work has been done by assuming efficiencies, finding the corresponding intake velocities, and obtaining thrusts for these by integration over the disc. The resulting curves of efficiency over a range of thrust loading are given in Fig. 1. The translational and rotational intake velocities for the two chosen pitch ratios at roughly the same thrust loadings (C_T values of 1·03 and 1·05, respectively) are shown in Fig. 2. The distribution of velocities is representative of what happens at all slips. The rotational intake velocity diminishes towards the blade tips, but the reverse holds with the translational intake velocity. The curves show the maximum efficiency conditions without friction or tip losses. For pitch ratio of 1·2, $C_T = 1{\cdot}05$ and $\eta = 0{\cdot}678$. For pitch ratio of 0·6, $C_T = 1{\cdot}02$ and $\eta = 0{\cdot}76$. It will be noticed that the drop in efficiency as pitch ratio is increased in Fig. 1, is mostly accounted for by the increase in rotary velocity set up by the screw. These theoretical results ignore the falling-off of thrust near the blade tips; but actually a_t and a_r fall together and the effect on efficiency of such a drop is usually small.

(To be continued.)

LABOUR NOTES.

THE Insurance Statutory Committee report that at the end of last year, the balance standing to the credit of the general account of the Unemployment Fund was 224,741,394*l.* including 72,475,849*l.* accumulated during 1943. The year's receipts were 77,782,284*l.*, of which all except 4,247,904*l.* was composed of insurance contributions by employers, insured persons and the State. The cost of benefit was 2,709,000*l.* and the cost of administration 2,339,941*l.* As compared with 1942, contributions from employers and employed persons were 2,275,247*l.* less, the decrease being the net result of the withdrawal of men and women into the forces and the substitution of uninsured part-time workers for insured whole-time workers, while, on the other hand, there was a decline in unemployment and an influx of new insured workers. The Treasury contribution being proportionate to the net contributions from other sources, decreased by 1,137,750*l.* No contributions were received from the Defence Departments in respect of men discharged from the forces, these contributions being suspended until an assessment can be made.

Attention is drawn in the Committee's report to the fact that, even after more than three full years of war, over 2,750,000*l.* (on the general and the agricultural accounts) was spent on benefit. This shows, the Committee say, that, even in a community working as the British community has worked in 1943, at full stretch, "there are intervals of not working due to changes of programme and methods and other inevitable causes." "Indeed," it is added, "the expenditure probably gives an inadequate idea of such intervals which, under war conditions, are not always fully reflected in a payment of unemployment benefit."

A number of interesting proposals are on the agenda for the annual conference of the United Textile Factory Workers' Association which opens at Blackpool on April 24. In one of three resolutions sent in by the Weavers' Amalgamation, it is declared that the provision of a high standard of living for the people of this country should be "the immediate post-war target of the Government." The National Labour Party is requested to urge the Government to take an early census of the country's industrial capacity for production, to promote the necessary increase of production, and to ensure "that scientific knowledge, the most modern machinery and the services of scientists and inventors shall be used to their maximum capacity to establish and maintain that standard."

The Spinners' Amalgamation has sent in a resolution calling upon the Government to introduce legislation giving members insured under the National Health and Pensions Acts, "the same additional benefits irrespective of society," and joins with the Cardroom Amalgamation in a resolution welcoming improvements in the rights of workmen to compensation effected last year, but expressing the opinion that the twelve months' limitation is too arbitrary and should be immediately extended to provide for workmen disabled through industrial disease, after that period, where it can be proved that the disease "has been caused by the employment to which the disease is normally due."

The claim of the shipyard trade unions in the Confederation of Shipbuilding and Engineering Trade Unions for a substantial increase of wages was heard by the National Arbitration Tribunal on Wednesday last week. On Friday, it was announced that the tribunal had awarded an increase of 4*s.* a week, beginning with the next full pay period.

Replying to a question in the House of Commons last week, Major Lloyd George, Minister of Fuel and Power, said that it was estimated that during the 26 weeks ended March 11, 1,508,000 tons of coal had been "lost" owing to disputes in the mines.

According to more or less official accounts, the voting in the mineworkers' ballot on the Government's wages stabilisation plan has been close and hopes are entertained that the national margin is on the side of acceptance of the agreement. At the time of writing, unofficial strikes on one pretext or another, are in progress in several important areas, and the colliers are showing no disposition to listen to the warnings of their leaders that the loss of production may seriously affect the allied war effort.

In Yorkshire, where about 90,000 operatives were on strike at the beginning of this week, the trouble has arisen on the question of the miners' "home coal." Discussing the difference, the other day, Mr. Brass, the chairman of the South Yorkshire Coalowners' Association, claimed that in making deductions for home coal from the pay of adult workers who benefited under the Porter award, the owners had acted strictly in accord with the terms of the Greene award, accepted as applicable to the Porter award by the National Negotiating Committee and by agreements between the representatives of his Association and the Yorkshire Mineworkers' Association.

In the negotiations, Mr. Brass continued, the owners agreed, first, to cancel altogether the deduction from those who did not receive the coal; then they agreed to the low figure of 3*s.* 6*d.*, and finally reduced it to 2*s.*, which the miners' leaders regarded as generous and less than half the estimated value. The coal owners, Mr. Brass added, could not be held in any way responsible for the deplorable situation which had arisen.

The opinion of the average trade unionist, used to constitutional procedure in labour affairs, is no doubt, that this widespread Yorkshire difference could easily have been adjusted without a stoppage. Of the various strikes of apprentices much the same might be said; important shipbuilding and engineering trade unions, in fact, had the matter in hand before the trouble became accute. The original object of the youths' organisation was to safeguard the interests—in blunter language, the wage rates—of the apprentices. Now, under the influence of outsiders—"irresponsible mischief-makers," Mr. Bevin called them the other day—the principal aim seems to be to secure complete exemption of all apprentices from liability to direction to the mines.

Strong claims are made by building-trade operatives to the exclusive right to assemble the prefabricated houses which the Prime Minister mentioned in his recent broadcast speech. A prominent London official of the National Federation of Building Trades Operatives said last week, for example, that there would be the biggest row in the history of industry if the job was not confined to their crafts. Speaking at a luncheon of the National Federation of Demolition Contractors, Mr. Coppock was critical of the Government's emergency plan to build 360,000 houses. The building industry, he declared, could produce not 360,000, but half a million normal houses each year.

Addressing a meeting of the London Brick Company last week, Sir P. Malcolm Stewart examined the question of how the programme of prefabricated houses would affect the trades concerned with the production of the traditional form of dwelling. The new competition, he said, had big initial advantages in speed of assembly, and, possibly, lower first costs. Prefabricated houses were avowedly to be built to provide temporary accommodation, and had been allotted a limited life; but, in his view, the time test of their survival would depend upon the degree of satisfaction they gave and the opportunity of changing to something better.

Sir Malcolm, therefore, called for preparation to meet the threatened competition by reducing the cost and improving the design and amenities of the traditional brick house. Bricks, he said, would survive competition, as they had done for a thousand years, so long as they were fitted to the purpose to which they were put.

The Conciliation Committee for the weaving section of the cotton industry sat in Manchester last week to hear the claim of the General Union of Associations of Overlookers for a standing wage for all overlookers. At present, only a small number receive a standing wage; the great majority are paid on the basis of a 50 per cent. starting point, with a 50 per cent. poundage on the earnings of the weavers. Sir Charles Doughty, K.C., presided as independent chairman.

The case for the overlookers was presented by Mr. Proctor, the general secretary of their organisation, and Mr. Lord, the President, and the reasons for opposing the claim were stated by Mr. Ashurst, director of the employers' association, and Mr. Frank Longworth acting for Sir John H. Grey, the chairman, who was not well enough to be present. At the close of the meeting, Mr. Ashurst explained that, after hearing arguments on both sides, Sir Charles Doughty had asked whether each of them was willing to accept an award. The operatives replied that they were, and the employers that they were not. Under the rules of the conciliation agreement, all that the chairman can do in such cases is to consult the assessors and make a recommendation to the parties. Such a recommendation is to be sent to the two organisations within the subsequent week or two.

NOTES ON MAGNESIUM-ALLOY TECHNOLOGY.*

By F. A. Fox, M.Sc.

(*Concluded from page* 260.)

Choice of Casting Alloy.—Those alloys used for stressed parts are of the magnesium-aluminium-zinc type. Elektron A 8, the 8 : 0·4 : 0·3 aluminium, zinc manganese containing alloy, has the following special points :—It has good as-cast properties, particularly ultimate tensile strength ; it responds readily and uniformly to heat-treatment ; and as solution-treated it has the best elongation of all the neighbouring alloys ; its ultimate tensile strength is also much improved. Elektron A Z 91, the 9·5 : 0·4 : 0·3 aluminium, zinc, manganese containing alloy, has the following special points :—It has a good proof stress as cast, though its ultimate tensile strength is not so good as that of Elektron A 8 ; its castability is excellent, being rather superior to that of Elektron A 8, and it is particularly suitable for die-casting ; its freedom from microporosity is particularly good ; its proof stress can be improved by 50 per cent. by a solution and precipitation treatment ; its ultimate tensile strength is good, but its elongation is low in the precipitated state ; its heat-treatment characteristics are not quite so good as those of Elektron A 8 ; its higher aluminium content makes it slightly more difficult to homogenise. The two alloys are similar as regards their corrosion resistance.

These points indicate clearly why British practice has tended to call for Elektron A 8 for structural parts for aircraft, and Elektron A Z 91 for engine parts. The latter's outstanding castability and freedom from microporosity makes it well suited for the very complex castings demanded by engine designers, and the high proof stress that can be obtained, after precipitation treatment, makes it desirable from the high performance standpoint. Elektron A 8 is well suited to structural parts, which are not so complex, and for which the safety margin provided by its high elongation value—as solution treated—makes it particularly valuable. It can be seen from the foregoing that, from the point of view of mechanical properties, there is little point in solution-treating Elektron A Z 91, since an outstanding elongation figure (which is the particular feature of the solution-treated state) is not obtained with this alloy in this condition. Similarly there is little point in precipitating Elektron A 8, since the proof stress of this alloy in this state is below that for precipitation-treated Elektron A Z 91.

Wrought Alloys.—The wrought magnesium alloys are similar in type to those for casting, and the stronger alloys contain aluminium, some zinc, and some manganese for corrosion resistance. The alloys used in this country are as shown in Table IV. The manganese-containing sheet and extrusion alloy is readily weldable and has good corrosion resistance. The wrought alloys used in the United States are also of the same types, but while, in this country, the tendency is to produce only one sheet alloy (of the Elektron A M 503 type) American manufacturers also make sheet of the aluminium-containing alloys. Moreover, forgings are made in aluminium-containing alloys with lower alloying contents than in this country. Data are given in Table V. The high-purity alloys also appear in American specifications for wrought alloys.

Comparison of the British and American specification requirements shows a fairly close similarity as far as mechanical properties are concerned. The aluminium-containing sheet alloys are not so readily rolled as the Mg-Mn alloy, and the gas-weldability is not as good. Magnesium-base alloy sheet shows the peculiarity that the properties in the longitudinal direction are liable to be worse (if there is directionality present at all) than in the transverse direction of rolling. Directionality can be readily eliminated by proper control of the reheatings and rolling directions ; where it does occur it affects the proof stress, ultimate stress and elongation. This peculiarity is probably connected with the observed fact that the scatter of the basal plane orientation is greater in the longitudinal than in the transverse direction ; the full explanation for it has not yet been forthcoming. The sheet alloy used in this country is readily weldable with an oxy-acetylene torch and suitable flux, and ultimate tensile strength figures of well above the A.I.D. requirement of 8 tons per square inch can be obtained across an unhammered weld. Development work is proceeding in the United States and in this country on the arc welding of magnesium-alloy sheet, using an inert gas instead of a flux. In the United States this has been termed the Heliarc process, helium being used as the inert "blanket." In this country helium is not available, and argon is used instead for development work. The advantage claimed for this process is that the heating is so local that there can be no deterioration and little stressing of the sheet near the weld, and hence reduced distortion and higher strengths may be expected ; also that as no flux is used, none can be included in the weld. The danger of flux inclusions left behind after the normal oxy-acetylene welding is negligible for ordinary sheet welding processes but may become serious if unorthodox lap-welds are attempted. The welding-fluxes used contain deliquescent chlorides which, if exposed to the air, promote strong corrosive attack on the weld metal. This danger is guarded against by immersing welded assemblies in hot baths containing chromates ; tiny flux inclusions are then dissolved out by the hot liquid.

The rolling and extrusion of magnesium alloys follow the usual lines for other light alloys, and cast rolling slabs of the Elektron AM 503 type can be given severe rolling reductions. The extrusion alloy used in this country, Electron AZM, is a useful general purpose material. Extruded pieces in this 6 per cent. aluminium material are not quite so strong as those in a higher aluminium alloy would be ; it can, however, be extruded faster than the latter alloy. The forging alloy is the most generally used here contains 8 per cent. aluminium, and this gives a good combination of elongation and strength properties. It can be die-forged in the cast state under hydraulic presses at temperatures of between 350 deg. and 400 deg. C., and gives forgings which are very useful for small highly-stressed aircraft components. Magnesium-alloy sheet (Elektron AM 503) can be formed and drawn at temperatures of between 300 deg. and 400 deg. C., using heated dies. This method of fabrication is used considerably for making aircraft components, and, here again, there is much scope for development. This sheet alloy fortunately does not appear to have critical temperatures of working, and excessive grain growth does not occur until temperatures of the order of 500 deg. C. are approached ; there is therefore considerable latitude in drawing and forming operations and also opportunities to induce local flow as required by local heating. Magnesium-alloy punches may be used ; these have the advantage of easy machineability. The Elektron AM 503 type of sheet may be bent through 90 deg. over a radius of 1 T (where T is the thickness of the sheet) at temperatures above about 320 deg. C., and deep drawing to a depth of cup equal to 1·5 times its diameter, in one operation, is possible at the same temperatures.

Surface Protection.—The two standard protective treatments used in this country are already fairly

TABLE IV.—COMPOSITIONS AND PROPERTIES OF BRITISH MAGNESIUM-BASE WROUGHT ALLOYS.

Type.	Nominal Alloy Content	DTD Specification.	Trade Designation.	DTD Impurity Requirements. Maximum Value of Elements Specified.					State.	Average Tensile Properties.		
				Al.	Zn.	Cu.	Si	T.I.*		0·1 per cent. Proof Stress.	Ultimate Tensile Stress.	Per cent. Elongation on 2 in.
				Per cent.	Per cent.	Per cent.	Per cent.	Per cent.		Tons per sq. in.	Tons per sq. in.	Per cent.
Mg-Al-Zn ..	6 per cent. Al, 1 per cent. Zn., 0·3 per cent. Mn	259	Elektron AZM ..	—	—	—	—	1·5	Extruded bar	15·0	20·0	12·0
	6 per cent. Al, 1 per cent. Zn, 0·3 per cent Mn	348	Elektron AZM ..	Cu + Si + Fe, 1·5 maximum					Tube	9·5	16·0	7·5
	8 per cent. Al, 0·4 per cent. Zn, 0·3 per cent. Mn	88B	Elektron AZ 855 ..	—	—	—	—	1·5	Forging ..	15·0	22·0	12·0
								T.O.I.†				
Mg-Mn	1·5 per cent. Mn	142	Elektron AM 503 ..	0·2	0·2	0·2	0·4	0·5	Extruded ..	10·0	19·0	5·0
	1·5 per cent. Mn	118	Elektron AM 503 ..	0·2	0·2	0·2	0·4	0·5	Sheet ..	8·0	15·0	7·0

* T.I. = Total impurities. † T.O.I. = Total other Impurities.

TABLE V.—COMPOSITIONS AND PROPERTIES OF MAGNESIUM-BASE WROUGHT ALLOYS IN USE IN THE UNITED STATES.

Type.	Nominal Alloy Content.	Specification.	Trade Designation.	Specification Impurity Requirements. Maximum Value of Elements Specified.					State.	Typical Tensile Properties.		
				Cu.	Si.	Fe.	Ni	T.O.I.*		0·2 per cent. Proof Stress.	Ultimate Tensile Stress.	Elongation on 2 in.
		U.S. A.A.F.†		Per cent.	Per cent.	Per cent.	Per cent.	Per cent.		Tons per sq. in.	Tons per sq. in.	Per cent.
Mg-Al-Zn ..	6·5 per cent. Al, 1 per cent. Zn, 0·3 per cent Mn	11332	AM 57S, Dow J ..	0·05	0·3	0·005	0·005	0·3	Tubing ..	9·4	17·8	13
	6·5 per cent. Al, 1 per cent. Zn, 0·3 per cent. Mn	11335	AM 57S, Dow J ..	0·05	0·3	0·005	0·005	0·3	Extrusions ..	13·4	20·0	17
	8·5 per cent. Al, 0·5 per cent. Zn, 0·3 per cent. Mn	11321A	AM C58S, Dow O ..	0·05	0·3	0·005	0·005	0·3	Forgings ..	14·3	20·5	10
	3 per cent. Al, 3 per cent. Zn, 0·3 per cent. Mn	ASTM No. 15	AM 74S, Dow XI ..	0·05	0·3	0·005	0·005	0·3	Forgings ..	12·5	18·7	16
	3 per cent. Al, 1 per cent. Zn, 0·3 per cent. Mn	11340	AM C52S, Dow FS ..	0·05	0·3	0·005	0·005	0·3	Sheet ..	9·4	16·5	21
	6·5 per cent. Al, 1 per cent. Zn, 0·3 per cent. Mn	11338	AM 57S, Dow J ..	0·05	0·3	0·005	0·005	0·3	Sheet ..	11·6	18·7	16
Mg-Mn	1·5 per cent. Mn	11336	AM 3S, Dow M ..	0·05	0·3	—	0·01	0·3	Extrusions ..	11·6	16·9	7
	1·5 per cent. Mn	11339	AM 3S, Dow M ..	0·05	0·3	—	0·01	0·3	Sheet ..	8·0	14·7	17

* T.O.I. = Total other impurities. † U.S. A.A.F. = United States Army Air Force.

* Lecture delivered before the Midland Metallurgical Societies, Birmingham, on Tuesday, January 18, 1944. Abridged.

MAGNESIUM-ALLOY TECHNOLOGY.

Fig. 8.

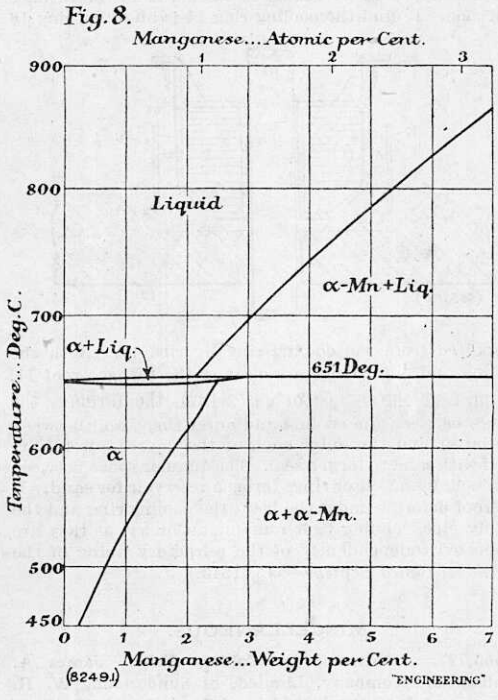




FIG. 9. "HALIFAX" UNDERCARRIAGE-WHEEL BRIDGE.

well known—the acid chromate dip and the half-hour boiling bath immersion known as the R.A.E. (Royal Aircraft Establishment) treatment. Of these the former removes a small amount of metal (about 0·0005 in. per face or per side exposed), but is rapid in operation—of the order of one minute; the latter removes no metal, but is longer in operation. Baths closely similar to these are used by the Dow Chemical Company in the United States. Neither of these protective treatments is as effective as the anodic protection of aluminium alloys, and the films formed have no mechanical hardness utility. The coats should be regarded essentially as paint bases and as a preliminary in a protection scheme for magnesium alloys rather than as true protective treatments in themselves. This is an important point, as people familiar with the powerful protection given by the aluminium anodising treatment are apt to think that "protected" magnesium alloys will withstand any corrosive conditions. If the corrosive conditions to which the "protected," but unpainted, pieces are exposed are not severe, the protection will have been of benefit; if the conditions are severe, "protected" pieces may actually behave worse than unprotected metal. The reason for this is that when magnesium or magnesium-base alloys are corroded by sodium chloride solution (the standard corrosion-testing medium), a large proportion of the insoluble corrosion product remains firmly attached to the metal surface; when specimens which have received a protective treatment are corroded in this way, the corrosion product is loose and non-adherent. It is thus to be expected that untreated metal will corrode more and more slowly as the film of corrosion product spreads and thickens; with treated metal, unrestricted and continuous corrosion will take place at discontinuities in the protective film, causing severe pitting and gradual undermining of the film. It is apparent that the protected specimens will begin to corrode in the manner of unprotected pieces as soon as the protective film has been completely undermined. Another protective treatment involving the use of selenious acid is in use to some extent in this country and in the United States. It has the advantage that it can be applied locally, by swabbing, to "patch" defects in the films put on by dipping; this is a very useful feature.

Much work has been done to evolve initial treatments for magnesium alloys which give improved protection. Anodic treatments of many kinds, treatments with fluorides, phosphates, tungstates, molybdates, and autoclave treatments in caustic solutions have all been proposed, but none has given such outstanding results as to make a change from the present simple schemes worth while. Even though the initial treatment is not so protective as that for aluminium alloys, the completed scheme, dip and primer and finishing coats, gives good corrosion resistance. This has been shown conclusively by service records, and by the examination of magnesium-alloy parts from crashed German aircraft even when these have been rescued from the sea. The corrosion of magnesium alloys, even when exposed unprotected to atmospheric attack, is slower than for ordinary mild steel, which also requires protecting. Many attempts have been made to plate magnesium alloys, but so far these have been conspicuously unsuccessful as far as improving the corrosion resistance is concerned. A nickel film can be put on, but its value is decorative and not utilitarian. The difficulty has been to obtain firstly a metallic coat which will adhere, and secondly to produce a sufficiently non-porous plating. If the plating is porous to any great extent or should a scratch or a cut edge expose both metals together to corrosive attack, the galvanic action is so severe that the magnesium is rapidly eaten away.

Table VI gives an indication of the corrosion rates of magnesium in electrolytic contact with other metals.

TABLE VI.—*Relative Corrosion Rate of Magnesium Coupled to Other Metals.*

Second Metal of Couple.	Relative Corrosion Rate of Magnesium.
Platinum	19·40
Aluminium	15·90
Iron	9·85
Nickel	7·70
Copper	5·46
Lead	4·31
Manganese	2·70
Zinc	1·62
Magnesium alone	1·00 Arbitrary Standard.

This indicates how necessary it is to insulate magnesium alloys from dissimilar metals when constructing assemblies. It has been found that the aluminium-base alloy M G 5 produces a less harmful effect on magnesium than does Duralumin, but insulation is again desirable. Attempts have been made to "clad" magnesium-alloy sheet; these however have proved to be difficult and not worth while, for the same reasons as operate against plating magnesium. Magnesium alloys are, in general, free from intercrystalline corrosion.

Machineability.—Magnesium alloys can be machined astonishingly freely without lubrication. Their machineability greatly exceeds, in fact, that of any other metallic material, and cutting speeds of 10,000 ft. per minute are readily attained on a lathe, with a feed of 12 in. per minute and a cut of at least $\frac{1}{8}$ in. The fire risk is very small provided that the cutting tool is kept sharp and that heat is not allowed to develop by friction. The inflammability of small pieces of magnesium becomes dangerously great only when the particle size is greatly reduced. Thus magnesium powder, the particle size of which is near 240 mesh, will rise in temperature only a few degrees even when wetted. Extremely fine magnesium powder, of the order of 10^{-5} cm. particle size, is pyrophoric or even explosive on exposure to air. In commercial practice the machining of magnesium alloy components may be aided by the use of jets of compressed air to keep the cutting edges cool. Special attention must be given to dust disposal in grinding, since suspensions of powder are ignitable by a spark. Recommended systems usually depend on the continuous removal of the dust in an air stream and "drowning" it in a large excess of water; this system has, in fact, been made compulsory by a recent Factory Inspectorate Regulation.

Recent Research and Development Work on Magnesium Alloys.—Some attention has been attracted by a paper by J. L. Beilschmidt, which appeared in the *Journal of the Royal Aeronautical Society*, vol. 46, page 161 (1942), on "The Stresses Developed in Sections Subjected to Bending Movement." In this paper the author deals with the consequences of a departure from the straight-line law between stress and strain as applied to the engineering theory of bending. The standard bending formula, $f = \frac{My}{I}$, assumes that the stress is proportional to the strain; Beilschmidt considers the case of a material of which the effective stress-strain diagram is not straight (deviation from a straight line is implicitly assumed in every case where the proof stress is quoted for a material rather than the limit of proportionality, since the former involves plasticity and hence curvature, by deformation). Various correction factors are put forward to modify the standard formulæ to account for the "stress unloading" effect introduced by the curving diagram. The interest of this work in this context lies in the fact that Beilschmidt has selected magnesium alloys for consideration in this way, since it appears that they show fairly large correction factors. He quotes an interesting example of the operation of this curvature effect by describing the result of a bending test made on a circular ring section member, the proof stress of the material of which was 4·5 tons to 5 tons per square inch, and the ultimate tensile strength 13 tons to 16 tons per square inch. This member, on bending, developed an apparent M/Z (Z being the section modulus) of 14 tons to 17 tons per square inch without showing any noticeable permanent set. The M/Z was then increased to 28 tons per square inch without causing absolute failure of the fibres. These results are thus 200 per cent. and 100 per cent. better than would be expected from the simple tension properties.

This kind of work is also going on in the United States, where Cozzone, last year, published work on magnesium and aluminium-alloy members tested for bending strength in the plastic range. While Beilschmidt assumes that the stress-strain diagram is a smooth curve to which a formula of the type $y = a x^n$ (in which the stress is proportional to the strain raised to same power) can be fitted, Cozzone assumes that the area under the curve can be regarded as a trapezium. Such analysis is of considerable interest, and marks another step towards reducing the factor of ignorance in design where high performance materials are involved. Somewhat similar work is that published in the United States, last year, by Kutsay and Yorgiadis* on the torsional damping capacity of magnesium-alloy rod, and in the *Journal of the Institute of Metals* by Stanton and Thompson† on the damping capacity of some magnesium and aluminium alloys. The latter workers found that the magnesium-base alloys had a distinctly higher damping capacity than the aluminium-base alloys examined, at all stresses and at all temperatures investigated (−50 deg. C. to 280 deg. C.). They found also that, for equal fibre stresses, both the magnesium-base and the aluminium-base alloys have much greater damping capacities than has steel. The results of Kutsay and Yorgiadis were generally in agreement with those of Stanton and Thompson; they found also that the higher the cold working stress in a magnesium alloy piece, the lower is the damping capacity. A useful contribution to knowledge of magnesium alloys was also made recently by the publication of a paper by Grogan and Haughton‡ giving the magnesium-manganese equilibrium diagram as determined by them. This is rather difficult to determine because of gravity segregation effects, but is directly valuable because of the use of this system in the alloys of the Elektron AM 503 type. Their diagram is shown in Fig. 8.

Applications.—During the last two or three years there has been a shortage of magnesium alloys in this country and this has, to some extent, restricted the increase in their applications; in a few cases, even well established applications for magnesium alloys were temporarily abandoned in favour of aluminium alloys. This trend is, of course, now reversed, as the figures quoted earlier indicate, and there is much more magnesium available both in this country and in the United States. The present engineering use of magnesium. nevertheless, is still almost entirely restricted to its application to aircraft. An examination of captured and crashed German aircraft would probably show that the proportion of magnesium used in enemy machines is rather higher than that used in Allied planes. The total weight of the Messerschmitt Me. 110 in service in 1940 was approximately 990 lb.; of this about 300 lb. were magnesium parts. Similarly, the gross weight of the Junkers Ju. 88 plane, in service

* *Aero Eng. Rev.*, vol. 2, page 21 (1943).
† Vol. 69, page 29 (1943).
‡ *Jl. Inst. Metals*, vol. 69, page 241 (1943).

at about the same time, was about 24,000 lb. The weight of magnesium parts in this machine totalled about 850 lb., of which 350 lb. were in the engines. The compositions of the alloys used in German aircraft are of the magnesium-aluminium-zinc-manganese type and also of the magnesium-manganese type similar to those used in this country and the United States. The German use of forgings, at least on the Me. 110 and Ju. 88, is probably greater than is the practice in this country. Forgings are employed, for example, for engine bearers, in both the Ju. 88 and Me. 110, for dive brakes in the Ju. 88 (an alloy similar in composition to Elektron A Z M is used) and for the supercharger impeller. It has been noted also that both the Messerschmitt 110 and Junkers 88 carry hammer forgings of the Elektron A M 503 type. This is of interest, as it contrasts with the usual German method of producing magnesium-alloy forgings by hydraulic pressing. It has been remarked in several quarters that no serious corrosion has been observed on magnesium parts salvaged from German aircraft, despite the fact that the protection schemes are sometimes not very satisfactory.

For most British machines the engine probably absorbs the greater proportion of weight of magnesium parts in an aircraft, although there are notable "heavy-weight" exceptions in the application of magnesium alloy to the landing wheels even for the largest machines, and the "Halifax" undercarriage-wheel bridge is a magnesium alloy casting. This part, which is shown in Fig. 9, on page 279, weighs over 2 cwt., as finished, and is probably the heaviest magnesium casting in regular production in this country. Similarly, air-frame parts, such as control brackets, are also frequently made of magnesium alloys. Magnesium-alloy sheet is probably increasing in use in British aircraft and the trend in this country is probably towards the heavier-gauge material. The welding of magnesium-alloy sheet offers advantages for such applications as fuselages, control surfaces and wing construction, and it is here that the just-developing helium-arc or argon-arc process may be advantageous. Development work in this direction is proceeding in America where this method is being tried out for monococque welded magnesium structures; these would have the advantage of a perfectly smooth surface resulting in reduced drag. An extensive application of magnesium-alloy tubing in this country is in the manufacture of pilots' seats of welded construction. The tubing used is Elektron A Z M, and high weld efficiencies are obtained with the usual oxy-acetylene methods.

Before the war there were, of course, many uses of magnesium for purposes other than aircraft. This included the application to many high-speed revolving or reciprocating small parts in machinery where inertia effects had to be kept low. An example of this was in the textile industry. Magnesium-alloy core boxes and moulding boxes were also frequently used in many foundries because of their lightness and durability. The use of press dies in Elektron alloys was increasing in the last few years. This was another application in which the machineability and light weight of the alloys were of special value. Die-cast or pressure die-cast magnesium-alloy binocular frames were also made, both in this country and abroad, and indeed were standardised for some models by Zeiss. A somewhat unexpected use of magnesium was as a material for bottles in which hydrofluoric acid could be stored. This application was perfectly satisfactory, provided the concentration of hydrofluoric acid exceeded 5 per cent. The bottles were very convenient in comparison with those made of paraffin wax or gutta percha. This use was based on the protective nature and high degree of insolubility of the magnesium fluoride coat. Applications in the motor-car industry were also increasing and tests on car and omnibus wheels had shown very good results. What is presumably a present-day outcome of the application to omnibus wheels has been found in magnesium-alloy gun-carriage wheels captured from the Italians in North Africa.

Canadian Railways.—The combined gross operating revenue of the Canadian Pacific Railway and the Canadian National Railways, during the first 11 months of 1943, reached the unprecedented level of 671 million dols., two and a quarter times the total for 1938.

Economy in Lubricating Oil.—The maintenance of lubricating oil in effective condition, both from the point of view of the performance of the machine concerned and from that of conservation of supplies, is dealt with in an industrial bulletin entitled *Economical Lubrication of Steam Turbines and Reciprocating Steam Engines*, issued by the Ministry of Fuel and Power (Coal Division), Dean Stanley-street, London, S.W.1. The subject is treated in a practical and comprehensive manner and the bulletin should prove of definite service to those responsible for the operation of any type of the two classes of prime mover referred to. Copies may be obtained free of charge by such persons on application to the Public Relations Officer at the address given above.

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AERONAUTICS.

556,784. Aircraft Gun Mounting. A. V. Roe and Company, Limited, of Manchester, and G. Beardshall, of Manchester. (3 *Figs.*) May 13, 1942.—The invention is a mounting for automatic guns or cannon for aircraft and its object is to provide a mounting which enables the cartridge cases and the clip fittings which hold the cartridges together to form an endless belt to be collected whatever be the firing position of the gun. The annular drum *a* is pivotally supported by a bracket *b*, which is part of a gun turret. The pivotal support permits the drum or frame to be swung in a horizontal plane. The bracket *b* may be arranged to have vertical adjustment movements to raise or lower the drum *a*. A divided drum *c* is mounted inside the drum *a* and this, together with two frames *d*, are bolted together. The drum *c* with any parts attached to it is free to turn about the axis of the drum *a*. Each frame *d* carries a front gun support *f* and one frame has a fixed rear gun support *g*, while the other frame has a rear gun support at *s* having screws to give both vertical and lateral or

Fig.1.

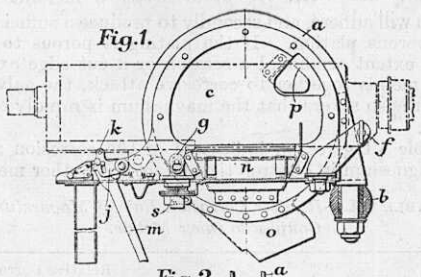
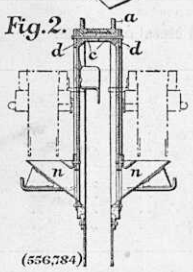


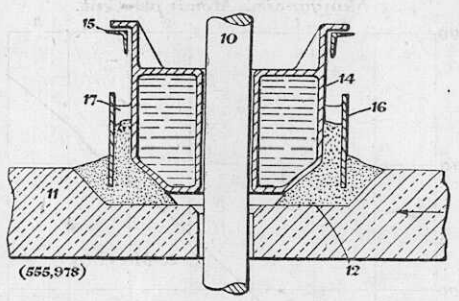
Fig.2.



horizontal adjustments to enable the guns to be harmonised. Across the rear end of the frames, and mounted in bearings therein, is a shaft on which are mounted two levers *j*, one of which is fixed on the shaft while the other forms a portion of the trigger mechanism. Rollers *k* on the levers *j* depress the gun sears when the trigger lever *m* is pulled. On each frame *d*, in a position which is beneath the gun mounted on the frame, is a chute *n*, into which the empty cartridge cases are ejected by the guns, the cases passing into the hollow drum *a* and out through the neck *o* attached to such drum. A telescopic chute may be fitted beneath the neck *o* to guide the cases to a suitable receptable. In each side of the divided drum *c*, at the level of the link ejection slides of the guns, are holes *p* communicating with the inside of the drum *a*, and a link deflector is fitted opposite the two holes *p* to deflect the links which secure the cartridges together in belt form downwards through the drum *a* to the neck *o* and so to the receptacle which receives the cases. To move the guns in azimuth or elevation and depression, handles are grasped and moved as required, the whole mounting turning about the pivot *b* for the azimuth motion, and the divided drum *c* moving inside the drum *a* for elevation and depression. (*Accepted October* 21, 1943.)

ELECTRICAL APPARATUS.

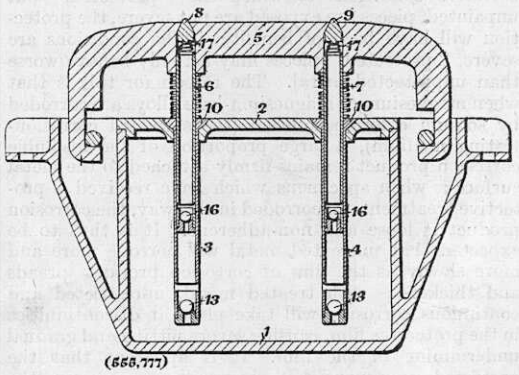
555,978. Electric Arc Furnace. H. A. Brassert and Company, Limited, of London, and R. Nissim, of London. (4 *Figs.*) February 6, 1942.—The invention is a means for cooling the electrodes of an electric arc furnace. At each point where an electrode 10 passes through the furnace roof 11 the latter is dished at 12. Round the electrode and partly within the depression, lies a cooling ring 14 supported by beams 15 carried from the furnace roof ring. Round the cooling ring 14 is an outer ring 16



supported from the cooling ring by ribs 17. Both the cooling and outer rings are clear of the furnace roof 11. To prevent the escape of gases from the furnace, the spaces between the cooling and outer rings, and between the latter and the outer edge of the depression 12, are filled with sand to form a seal. The annular space between the cooling and outer rings forms a reservoir for sand. If the roof deforms under the heat, the cooling ring and the supply pipes leading to it remain stationary, as they are supported independently of the refractory lining of the roof. (*Accepted September* 15, 1943.)

MISCELLANEOUS.

555,777. Lubricator for Colliery Tubs. James A. Jobling and Company, Limited, of Sunderland, W. R. Graves and J. C. Breckenridge, of Sunderland. (2 *Figs.*) June 19, 1942.—The invention is a multi-lubricator for the axles of colliery tubs. The lubricator shown consists of a lubricant tank 1 with a cover plate 2, which carries the cylinder components 3, 4 of a pair of plunger pumps. A spring-supported axle contactor bar 5 carries the plunger components 6, 7 of the pumps and is provided with lubricant applicators 8, 9. The arrangement is such that each axle to be lubricated rides over and depresses the contactor bar 5 and actuates the pumps, whereby lubricant is applied to each axle first by the applicator of one pump, and then by the applicator of the other. The cylinder components 3, 4 are each suspended from the cover plate 2 by a ball-and-socket joint 10. The lower end of each cylinder is provided with an inlet port controlled by a non-return ball valve 13. The lower end of each plunger has an inlet port plunger controlled by a non-return ball valve 16. Each lubricant applicator 8, 9 consists of a conical plug, which is supported by a spring 17 at the upper end of the respective plunger. The upper end of each applicator normally



projects above the surface of the contactor bar 5 to be engaged by the axle. In operation, the axle to be lubricated contacts with and depresses one end of the contactor bar 5, so that the plunger adjacent to this end moves down into its cylinder. On the downward movement of the plunger, lubricant passes from the cylinder through the ball valve 16 into the plunger so that the plunger is charged with lubricant. The axle, after depressing the contactor bar 5, rides over it and depresses the applicator of the first pump, so that oil passes from the upper end of the plunger of the first pump past the applicator on to the axle. Continued riding of the axle on the bar 5 depresses the other end so that the bar is wholly depressed. The axle then depresses the applicator of the second pump and oil passes from the upper end of the plunger of the second pump past the applicator on to the axle. As the axle approaches the rear end of the contactor bar 5 the front end rises and always presents one primed pump in readiness for succeeding axles, regardless of the speed at which they follow each other. When the axle leaves the bar, it returns to the normal "up" position. This raises the plungers and recharges the cylinders through the valves 13. (*Accepted September* 7, 1943.)