IRRIGATION IN THE JORDAN VALLEY.

The River Jordan rises in the neighbourhood of Mount Lebanon in Syria and flows through Lake Huleh and Lake Tiberias, terminating in the Dead Sea, the level of which is some 380 m. below that of the Mediterranean and which has no outlet, surplus water being lost by evaporation. Lake Tiberias is frequently known as the Sea of Galilee. The Jordan Valley, with which this article is concerned, covers the section of the river between Lake Tiberias and the Dead Sea. The valley has a length of some 140 km. and in that distance the river has a fall of about 186 m. The floor of the valley is formed by a narrow strip of land flanked on both sides by high escarpments; these features are well shown in Figs. 1 and 2, herewith. At the foot of the escarpments, on both sides of the river, there are flat terraces known as the Ghor. On the eastern side, the width of the Ghor varies from 2 km. to 5 km., and it has a transverse slope towards the river ranging from 1 in 20 to 1 in 200. The Ghor on the western side is generally similar, but in some parts of the valley is very narrow. Both Ghors tend to widen out, with easier slopes, at the Dead Sea end. Through this relatively flat valley floor, the river has eroded a secondary trough, some 60 m. deep, at the bottom of which it meanders in an alluvial plain, which is subject to flooding. This plain, which varies in width from 200 m. to 500 m., is known as the Zor.

The climate of the valley is sub-tropical to tropical and a wide range of cereals, vegetables and fruit can be grown. It is only in the neighbourhood of Lake Tiberias, however, that the rainfall is adequate for farming. Elsewhere artificial irrigation is necessary. As will be seen from the map of the the valley reproduced in Fig. 3, on page 482, a number of side streams, termed *wadis*, join the river on both the eastern and western sides. Some of these are perennial and serve small farming communities; many have only a seasonal flow. Owing to the inadequate water supply, the population of the valley is relatively small, and it has long been realised that it would support very many more people and become a valuable agricultural area if the waters of the Jordan, now running to waste in the Dead Sea, were utilised for properly controlled irrigation. Events of recent years have greatly accentuated the desirability of such a development. The proper utilisation of the potentialities of the Jordan Valley is of most direct interest to the Kingdom of Jordan, in view of the influx of some three-quarters of a million Arab refugees from Israel. The matter is, however, also of interest to this latter country in view of the very great increase in population which it has achieved since it came into existence in 1948. Part of the western bank of the Jordan lies in Israel.

Fig. 1. Aerial View of Valley.

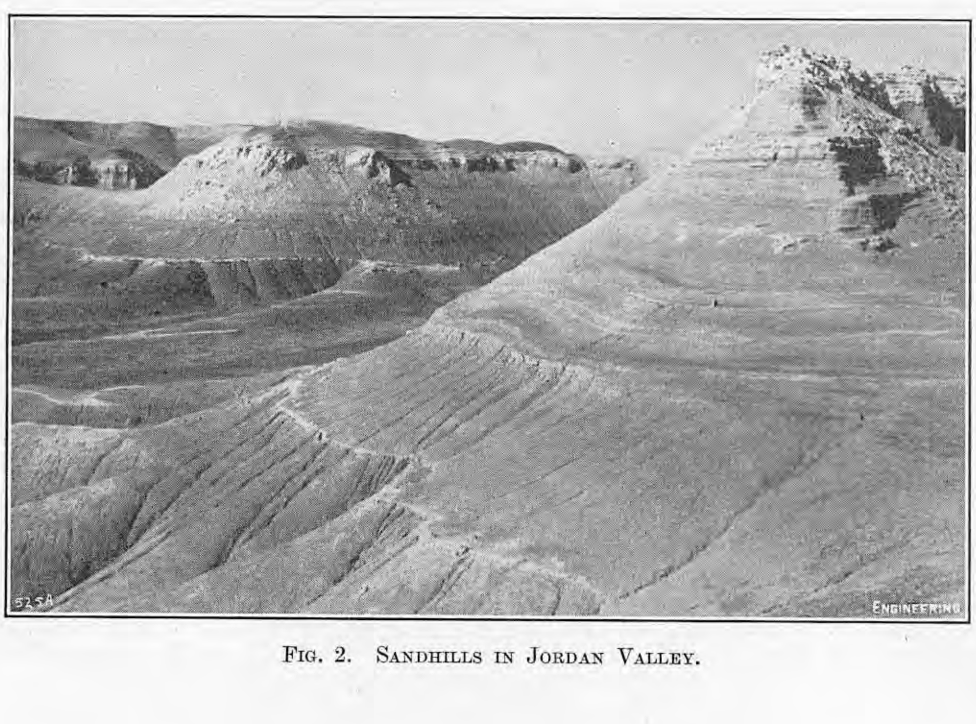


Fig. 2. Sandhills in Jordan Valley.

The proper utilisation of the waters of the Jordan, and of its main tributary, the River Yarmuk, which joins it some 8 km. south of Lake Tiberias, is an engineering problem which unquestionably could be satisfactorily solved. Unfortunately, the whole situation is dominated by political considerations. The unfriendly relations existing between the Hashemite Kingdom of Jordan and the State of Israel make it unlikely that any agreed scheme of development is likely to be adopted, at least in the early future. Considered as a problem in political geography, the situation is very complicated. The River Jordan immediately north of Lake Tiberias lies in the territory of Israel, as does the west bank of the river south of the lake down to the frontier line shown in Fig. 3. South of this, the west bank is in the Kingdom of Jordan. The triangle of land between the south end of Lake Tiberias and the River Yarmuk is in the territory of Israel. The exact position of the frontier of this area is apparently a matter of dispute between the two countries. The area to the east of this triangle, and the upper waters of the River Yarmuk lie in the Republic of Syria. The effect of this state of affairs is that Israel is in a position to control the waters of the River Jordan, and Arab interests, represented by Jordan and Syria, those of the River Yarmuk.

Both of these main rivers have a seasonal flow, and what might almost be called the obvious basis of controlled irrigation in the Jordan Valley must be the use of Lake Tiberias as a storage reservoir. As will be clear from Fig. 3, the River Yarmuk does not flow into Lake Tiberias, but any major irrigation scheme must utilise its waters, and its diversion into the lake or some type of reservoir or control basin, at the confluence of the two rivers, would appear to be necessary features of any project. Such a basin would be operated in conjunction with the Lake Tiberias reservoir. The flow of both rivers varies greatly from year to year, but the importance of the Yarmuk relative to the Jordan is shown by the figures for recent years. In 1944-45, the total flow of the Jordan was 781 million cub. m., and that of the Yarmuk 730 million cub. m.; for 1945-46, the flows were 576·6 million and 359·6 million. The great variation from year to year emphasises the importance of storage. In 1935-36, the flow of the Jordan fell to 297·6 million cub. m.; in that year the flow of the Yarmuk at 283·9 million was almost the same.

The possible use of Lake Tiberias as a storage reservoir is hampered by many political considerations. As mentioned above, both banks of the River Jordan north of Lake Tiberias lie in Israel and that country has put forward a scheme to divert the waters of the river north of the lake to a canal lying to the west of the Jordan Valley and to utilise them for the irrigation of the Negeb, the desert area lying in the south of Israel. This project clearly raises important questions of international water rights, which quite possibly could not be solved by the United Nations. This control of the waters of the River Jordan by Israel is balanced by Arab control of the waters of the River Yarmuk. With Syrian agreement, the Kingdom of Jordan could divert the River Yarmuk in such a way that its waters would serve only Arab territory. Apart from questions of irrigation, such a procedure would face Israel with a difficult question in its relations with the Palestine Electric Corporation. That company has a hydro-electric station at the confluence of the Jordan and Yarmuk, and although the station is not now in operation, the concession under which it was built still has some fifty years to run.

Although a satisfactory solution of the complicated territorial problems involved is a matter for statesmanship—if there is any left in that part of the modern world—no scheme could be agreed on without investigation of the engineering possibilities and an appraisement of the relative roles of the two main rivers in any irrigation project. In order to obtain fuller information than was previously available about the possibilities of controlled irrigation in the Jordan Valley, the Hashemite Kingdom of Jordan, in 1949, appointed Sir Murdoch MacDonald and Partners, of 72, Victoria-street, London, S.W.1, as consultants to report on "the development and extension of irrigation in the Jordan Valley." The results of the survey carried out and the proposals to which they have led are contained in an informative report.*

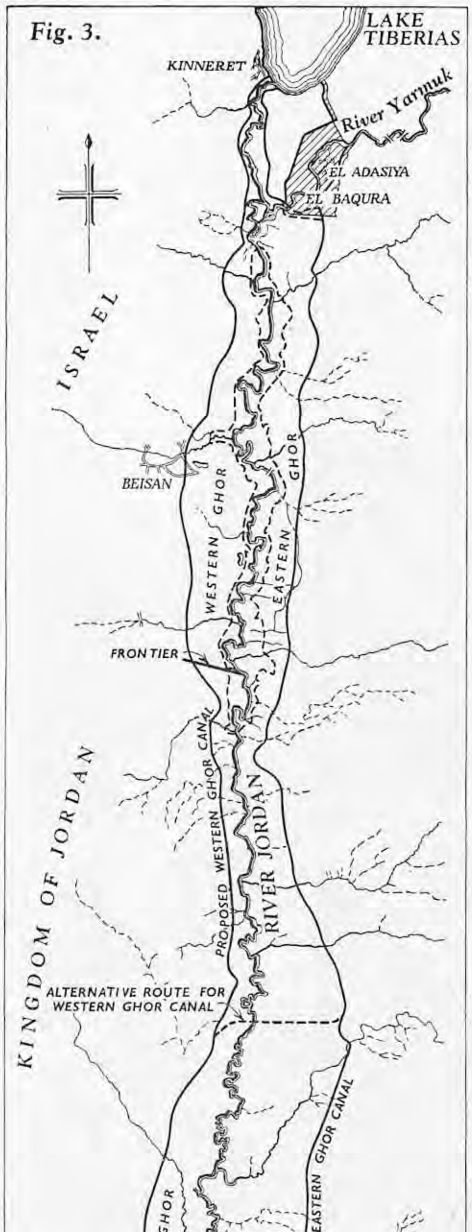
It was clearly no part of the duty of the consultants to intervene in the political disputes centring around the engineering problems with which they were concerned but they, none the less, permitted themselves to state in the report that the "proposals are based on the general principle, which to our mind has an undoubted moral and natural basis, that the waters in a catchment area should not be diverted outside that area unless the requirements of all those who use, or genuinely intend to use, the waters within the area have been satisfied." Disinterested opinion is, in general, likely to share the sentiment expressed in this statement.

The report prepared by Sir Murdoch MacDonald and Partners is not the first dealing with the subject of irrigation in the Jordan Valley. In particular, a comprehensive report, prepared by Mr. M. G. Ionides was published in 1939. Some account of the findings embodied in that report will be found in an article contributed to these columns by Mr. Ionides, which appeared in our issue of September 13, 1946. The MacDonald report pays tribute to the importance of the Ionides report and many of the data on which the latest proposals are based are taken from it. Mr. Ionides' report was concerned with what was, at that time, the country of Transjordan, a wholly Arab state, and his proposals were confined to the country to the east of the River Jordan. He suggested a main feeder canal lying approximately parallel to the river on the east bank, and a comparison of Fig. 3, herewith, with Fig. 5 of Mr. Ionides' earlier article will show that the eastern canal proposed in the MacDonald report occupies approximately the same position. The Ionides report did not contain any reference to a western canal such as is proposed in the MacDonald report. The west bank of the River Jordan was, in 1939, part of Palestine, a country with which Mr. Ionides was not concerned.

The basic features of the MacDonald proposals are indicated in Fig. 3. The total cost of the complete scheme put forward is estimated at 23,330,000*l*.P. and it is clear that for financial and other reasons it would have to be undertaken in stages. Four of these are suggested. In Stage I, the River Yarmuk would be diverted to a canal 70 kilometres long on the east side of the Jordan plain. This proposal, if carried out, would presumably deprive Israel of any use of the water of the River Yarmuk. This stage is estimated to cost 6,800,000*l*.P. It does not provide for any storage and in dry years some curtailment of the summer crop would be necessary, but there would be ample water in the winter both for irrigation and washing saline land. This latter point is of importance. Much of the land in the valley is saline, but experience has shown that it can be made suitable for agricultural production by leaching. At the Jewish settlement, Beit Harava, north of the Dead Sea, lands of high salinity, after leaching, are now successfully farmed.

It is estimated that Stage I would provide irrigation water for an area of 47,000 acres. This would permit of the establishment of some 6,000 holdings, each of 7½ acres. There are at present some well-established holdings in the area, supplied from *wadis*; these would not be disturbed. From what has been said about the configuration of the valley, it is clear that the higher up the sloping banks the main canal can be placed, the greater the area of

Fig. 3.



land that can be served with irrigation water. It is stated in the report, however, that the configuration of the country allows little choice in determining the position of the canal. It would, in any case, have to traverse very varied types and levels of terrain. A large number of small dry ravines, as well as a number of perennial *wadis* would have to be crossed and various forms of syphons and aqueducts would have to be built. Extensive detail surveys would be necessary before the precise location of the canal could be determined.

Although it has apparently not been examined in detail, it is suggested that areas lying above the canal, which could not be watered by gravity flow, might be served by pumping. At some points on the main canal it would be necessary to introduce a vertical drop of some metres, and small hydro-electric plants at such points might furnish power for pumping. Similar plants might possibly be built on some of the permanent *wadis*. All these proposals in connection with power development are made only in broad outline; no details have been worked out. The main canal would feed a series of open laterals which in turn would supply field channels, effectively covering the farming area. Head regulators at the canal end of the laterals would be necessary, together with control arrangements for the field channels. Lateral drains discharging to the river also form part of the proposals. This matter of final distribution of the irrigation water to the land is treated in considerable detail in the report, which puts forward an alternative scheme with piped laterals.

The work which it is proposed should be carried out in Stage II of the whole scheme is estimated to cost 1,900,000*l*.P. This is a relatively small part of the total. Stage II would in effect be an extension of Stage I. The main canal would be lengthened by 26 kilometres and an additional 27,500 acres on the east side of the Jordan in the Dead Sea region would be served. Again, no arrangements would be made for water storage and supplies could be furnished only during the winter. Stage III, costing 1,300,000*l*.P., represents, in part, an extension of the two earlier stages. It would add 14,000 acres to the area served and would complete the distribution system on the east side of the Jordan.

Stage III, however, also covers work which would possibly raise international difficulties. The work already described in connection with Stages I to III could presumably be carried out by Arab interests without reference to Israel, but Stage III also includes arrangements for water supplies which could be used for the irrigation of the Jordan-Yarmuk triangle which lies in the State of Israel. Although development in that area would clearly be of benefit to the inhabitants of that country, the consultants were apparently not permitted to make detail inspection. To serve this area and to increase the supply to the eastern canal, to permit of perennial irrigation in the eastern Ghor, a canal would be constructed on the east side of the River Jordan diverting that river to the eastern canal. This connecting canal is indicated in Figs. 3 and 4. There is a dam at the Jordan outlet from Lake Tiberias and it is anticipated that the existing arrangements would permit of storage enabling the flow of the Jordan to be regulated and the supply of irrigation water to be controlled. This connecting canal would have to run through Israel territory and it is presumed that compensation would have to be paid for this easement and for the use of the Lake Tiberias dam and reservoir.

Stage IV, estimated to cost 9,440,000*l*.P., is the most expensive of all. It covers the construction of the western canal 110 km. long and envisages the conversion to perennial irrigation of the whole of the Jerico plain. The first 38 km. of this canal would be in the territory of Israel. Some 50,000 acres in the Jerico area would be irrigated and about 500 established holdings would be furnished with a permanent supply. To give an all-the-year-round supply to the whole area commanded by the two main canals, it would be necessary to arrange for the storage of the winter flow of the River Yarmuk. It is suggested, however, that even with this provision the supply might possibly have to be cut by 25 per cent. in dry years. One method of storing the winter flow of the Yarmuk would be to divert that river into Lake Tiberias. If this were done, the existing dam at the outlet of the lake would have to be remodelled to permit of a total variation of 5 m. in the level of the lake. It is stated that a large volume of water could be impounded by a relatively small increase in the water level.

* *Report on the Proposed Extension of Irrigation in the Jordan Valley.* Government of the Hashemite Kingdom of Jordan. Crown Agents for the Colonies, 4, Millbank, London, S.W.1. [Price 30s. sterling.]

IRRIGATION IN THE JORDAN VALLEY.

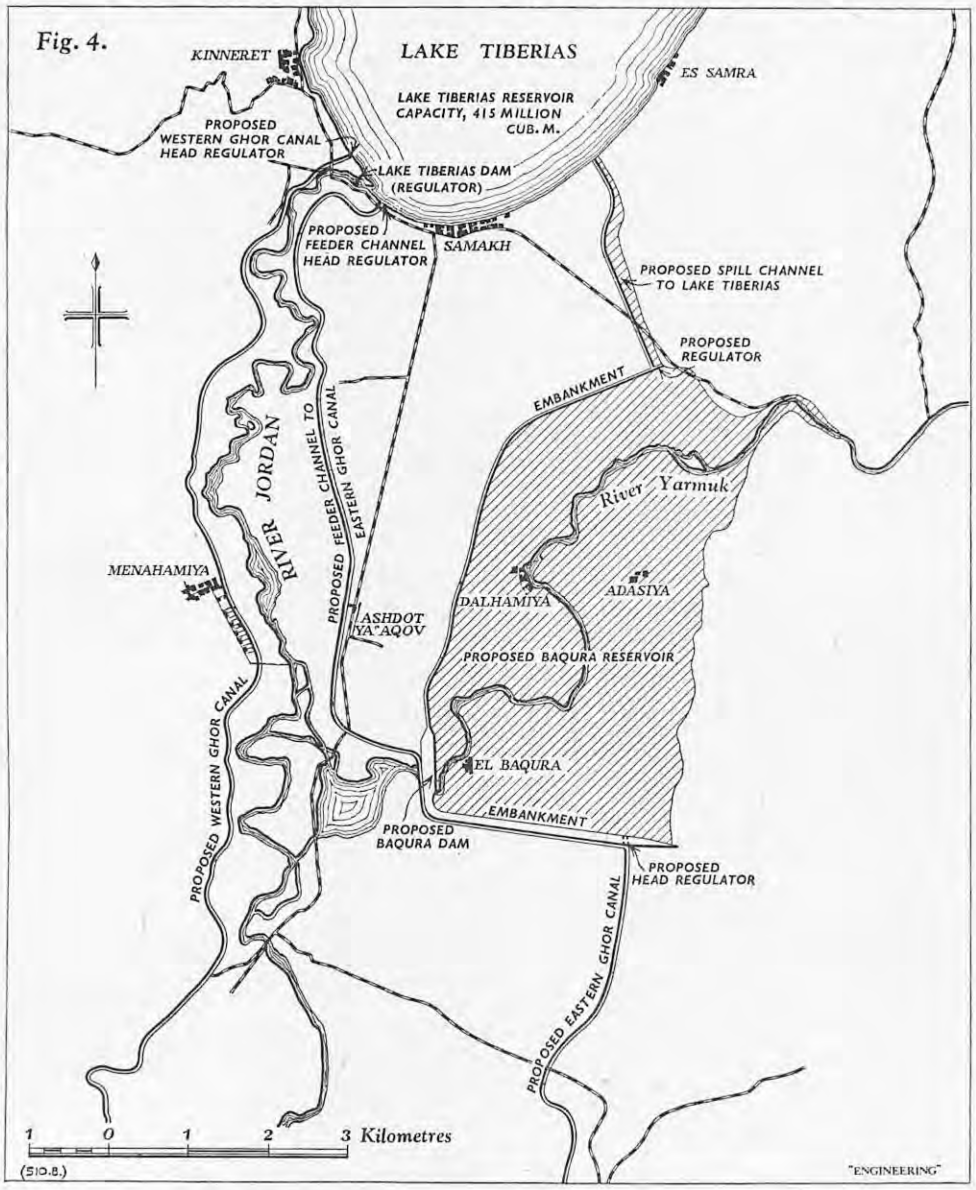


Fig. 4.

This proposal to use Lake Tiberias as a main storage reservoir for the whole scheme raises the question of international relations in an acute form. It is not considered that there would be any practical difficulty in raising the level of Lake Tiberias, but the extent to which it could be raised without incurring heavy liabilities has not been determined. The consultants were not able to inspect the lake. Working on figures given in the Ionides report, the consultants considered that by increasing the height of the existing dam to permit of a variation of 5 m. in the level of the lake, sufficient storage water would be provided, except in unusually dry years. Lake Tiberias has in the past been used as a storage reservoir for the Ruthenberg power station of the Palestine Electric Corporation, the winter flood waters of the Jordan being stored for use during the summer, and the waters of the Yarmuk being used to run the station in the winter. It is stated in the report that the station is now wrecked, but the Electric Corporation's concession still has many years to run. It would appear, however, that even if the station were rebuilt it could not be effectively operated without the consent of the Kingdom of Jordan, as that country is in a position to control the flow of tne River Yarmuk. A mere glance at the map given in Fig. 3 will suggest that the use of Lake Tiberias as a main reservoir and the diversion of the River Yarmuk into it is the most obvious way of providing an all-the-year-round water supply and the report states that this proposal is "recommended as being the most satisfactory."

In view, however, of the political situation and the unfriendly relations existing between Jordan and Israel, the consultants have put forward two alternative schemes. The first of these is for the construction of a dam across the River Yarmuk at Baqura. This would form a reservoir with a live storage of about 300 million cub. m. The reservoir is shown in the map reproduced in Fig. 4, herewith. The advantage of this scheme from the point of view of the Kingdom of Jordan is that the headworks would be under its direct control. A disadvantage would be that about 1,500 acres of the best cultivated and well-irrigated land existing at present in the eastern Ghor would be flooded. Some land lying on the north bank of the Yarmuk, and presumably in Israel, would also be flooded, but it is understood that the international boundary has not yet been delineated in this area. The proposed reservoir could probably be arranged for a variation in level up to 20 m. An earth or rock-fill dam is proposed with a height above the river bed of about 45 m. The actual arrangements would naturally depend on borings and tests of available material.

It is suggested that surplus flood water from the Baqura reservoir should be diverted into Lake Tiberias. The spill channel is shown at the north of the reservoir in Fig. 4. It is thought that the useful life of this proposed reservoir might be limited by silting and this aspect of the matter would require careful study before final decisions were taken. It is considered that the existing dam at the outlet from Lake Tiberias is sufficiently high to provide storage for the winter flow of the River Jordan, and the purpose of the Baqura reservoir would be to provide similar arrangements for the River Yarmuk, failing agreement to increase the height of the Tiberias dam. It will be clear, however, from Fig. 4, that the alternative proposals would still require some form of agreement between Israel and Jordan. Both the spill channel and the feeder to the eastern canal would cross Israel territory.

The second, alternative proposal is that a concrete gravity type dam should be built across the Jordan Valley at the mouth of the Wadi Malih, about 15 km. south of Beisan. A dam about 50 m. high to the spillway would form a reservoir with a storage capacity of about 450 million cub. m. and a live storage range of 15 m. The extent of the reservoir formed is indicated by a dotted line in Fig. 3. The dam would be situated in Jordan territory, but, as will be seen from this figure, a large part of the area which would be flooded lies in Israel; much of this area is rich land. This Jordan Valley reservoir is not recommended as a substitute for the storage of the winter flows of the Jordan and Yarmuk in Lake Tiberias. It is only recommended if the raising of the Tiberias dam could not be carried out. It could, however, be considered as a complement to the Lake Tiberias scheme, serving as storage for the combined spill of the Tiberias reservoir and the winter flows of the Yarmuk.

In case no arrangement could be reached with the State of Israel, some alternative arrangements are suggested for consideration by the Kingdom of Jordan. The River Yarmuk could be diverted to feed the eastern canal. If no storage was provided, it would appear that this project could be carried out entirely in the territory of Jordan. For storage, the Baqura reservoir would be necessary. This would presumably result in the flooding of some land in the Tiberias-Yarmuk triangle, but, as mentioned above, the position of the frontier in this area has not been determined. As an alternative, the Kingdom of Jordan might build the Wadi Malih dam, as it would be situated in its territory. It would, however, lead to the flooding of some land in Israel. Actions of this kind by Jordan alone are not recommended by the consulting engineers.

The relations between Jordan and Israel are so strained at the present time that it is possible that schemes for the better irrigation of the Jordan Valley will not even be discussed. The matter is of such great social and economic importance to both countries, however, that sooner or later something must be done. The report of Sir Murdoch MacDonald and Partners is a valuable contribution towards the ultimate solution of a problem which in many aspects is of international interest.

LITERATURE.

Travaux Maritimes. Vol. III.—Ouvrages Intérieurs et Outillagée des Ports.

By Professors G. de Joly, C. Laroche, P. H. Watier and A. de Rouville. Second edition. Dunod, 92, rue Bonaparte, Paris, 6me. [Price 3,500 fr.]

The publication of this monumental treatise on dock and harbour works has been dogged by a certain amount of misfortune. The appearance of the original edition was retarded by the death of Professor de Joly, as long ago as 1919; and his successors, Professors Laroche and Watier, also did not live to see the completion of their work. Professor de Rouville—who is, like his predecessors, associated with l'Ecole des Ponts et Chaussees, and is also the head of the French lighthouse service—managed to complete it by 1939; a date which requires to be borne in mind, as it implies (as an editorial note confirms) that references to "the war" in the main body of the text refer to the war of 1914-18. To bring the work up to date for a second edition would have involved such an extensive rewriting (and resetting of type) that the alternative has been adopted of adding a new section of 106 pages to the 693 pages of the original text, to cover the principal developments since 1940 in the internal arrangements and the equipment of ports. The previous volume, it should be mentioned, dealt with the exterior works and the approaches to ports.

To attempt to describe all that the present volume contains would be to list every type of port equipment, including wharves and quays, docks, floating pontoons, cranage, etc., etc.; and the list would extend even to such administrative matters as the

TOOTH SURFACES OF CREEP-CUT HELICAL GEARS.

Fig. 1.

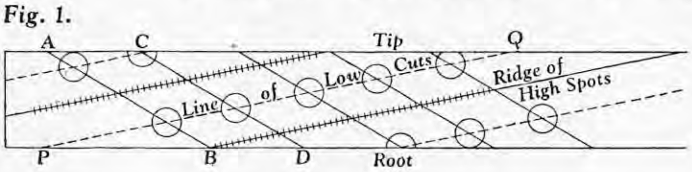


Fig. 2.

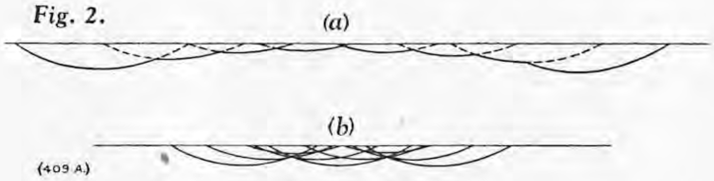


Fig. 3.

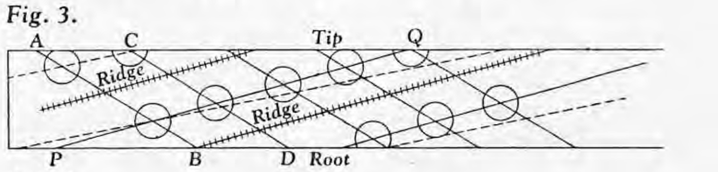


Fig. 4.

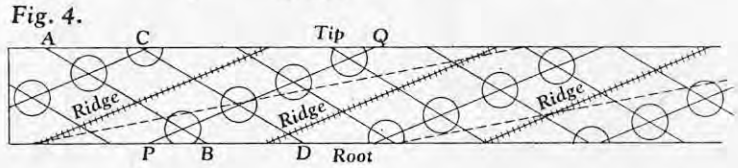
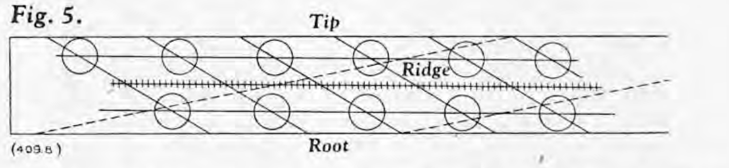


Fig. 5.



organisation of police surveillance. It would appear preferable, therefore, to confine present attention to the "addendum" describing recent practice. This deals briefly with a number of schemes for post-war reconstruction of damaged harbour works, new developments of existing ports, up-to-date dredging plant of various kinds—this is, perhaps, the most important section—and the provision of such facilities as special harbours for handling bulk oil traffic, and for fishing fleets. Most of the sections are fairly well illustrated, though some would be improved by a more liberal treatment in this respect; and, unfortunately, many of the line diagrams and drawings have been so much reduced that a great deal of the detail is lost. For example, even a powerful lens fails to reveal the dimensions in the "coupe transversale d'un bollard," on page 171. This particular instance is of small moment, but there are others of more importance. As a general survey, however, the work is a useful guide, which may be supplemented, if more detail is desired, by the reports of the periodical Navigation Congresses and papers read before the professional institutions.

Mathematical Solution of Engineering Problems.

By J. Jennings, B.Sc., M.I.Mech.E. E. and F. N. Spon, Limited, 22, Henrietta-street, London, W.C.2. [Price 25s.]

The name of Mr. J. Jennings will be recognised by many readers of Engineering as that of a commentator on various matters of engineering design particularly in connection with centrifugal pumps, sundry references to which appear in the course of this book. As he explains in the preface, the purpose of the work is to provide a practical text for the practical engineering designer, intermediate between the elementary text-book, covering the field from plain arithmetic to the calculus, and "the advanced book, treating higher mathematics, with which only the research worker is likely to be concerned." The mathematical knowledge assumed in the reader is merely that required for the Ordinary National Certificate, plus some acquaintance with differentiation and integration, from which the author proceeds to a discussion of approximations, nomograms, dimensional analysis, the mathematics of periodic phenomena, statistical methods, etc.; subjects which, as he observes, he has himself "found to be of great practical utility and, at the same time, to be familiar to very few."

An engineer's outlook on mathematics, as the author truly remarks, is different from that of a mathematician, for whom the subject is a sufficient end in itself and its practical utility of secondary interest. By contrast, an engineer, being concerned almost invariably with practical applications, is generally prepared—and, indeed, must be prepared—to accept the truth of much of the mathematics he employs without rigid proof. This does not alter the fact, however, that most engineers know and use too little mathematics and could with profit learn more. It is obvious from a reading of this book, that the author has given considerable thought both to the subject matter of his book and to its presentation. The material has been judiciously selected, although there may be some who will cavil at the author's allocation of the longest chapter to the subject of nomography which, despite many attempts to popularise it, has never really caught on. Possibly, if the basic theory were more widely studied—and the book contains an excellent introduction to it—nomograms would prove more popular, but we suspect the aversion from them lies deeper. Nevertheless, the author gives several examples of nomograms having considerable utility.

The chapter on approximations is very well done and merits close study, as does the chapter on dimensional analysis. In the chapter on periodic phenomena, it appears that the author is really concerned with the vibration of elastic bodies or systems but, even with this restriction, it is surely too sweeping to say, as he does, that vibrations are caused by the application of a sudden, or shock, force or a periodically varying force unless the latter term is intended merely to imply a force varying with time. Elsewhere in this chapter, there is evidence of somewhat hasty writing or revision in the section headed "free damped vibrations" for instance. An important slip occurs on page 170, where the omission of the factor 4 from a term under a square root—which, incidentally, ought to be bracketed—invalidates both the formulæ and Fig. 69, on the succeeding page; and the statement, on page 169, that, when the vibration is undamped and the disturbing force has the natural frequency of the system, the vibration is 90 deg. out of phase with the external force, is incorrect, as may easily be shown by solving the original equation when $c = 0$.

The penultimate chapter contains an introduction to statistical methods which are finding increasing application in mass-production engineering. In his discussion of simple sampling, the author departs from current parlance by referring to the binomial distribution of Bernoulli as the Poisson Binomial distribution, whereas the latter term is usually confined to the special case where the probability varies between successive samplings. On the other hand, the limiting form of the Bernoullian distribution when the probability of the occurrence is small—which was deduced by Poisson and is generally known as Poisson's distribution—is correctly attributed to him. Such slips as occur however, are minor blemishes in a book which has much to commend it and which is likely to be in considerable demand among both students and teachers. A word of praise must also be given for the printing and general lay-out of the book, which, in these days when a number of unattractively printed works on mathematics are appearing on the market, are wholly excellent.

The Institution of Sanitary Engineers.—The next half-yearly examination for the associate membership of the Institution of Sanitary Engineers will be held in London and at other centres, as may be found necessary, on November 22, 23 and 24. The closing date for entries is November 8. Subsequent examinations will be held in May and November, 1952. Further particulars are obtainable from the secretary of the Institution, 118, Victoria-street, London, S.W.1.

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

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

The creep principle, introduced into hobbing-machine design some 40 years ago, was so successful in producing quietly-running helical gears (as then understood) that for a long time it was unnecessary to consider any niceties in its application. Since then the demands on high-speed gearing have become more and more exacting and the utmost refinement in design and construction has become essential. Various opinions have been held as to what value should be given to what has been called the "creep fraction" but a need arose for a rational analysis. Early steps in this direction were taken by the late Dr. G. A. Tomlinson, of the National Physical Laboratory, and further work, recorded in this article, was carried out by the Admiralty Vickers Gearing Research Association.

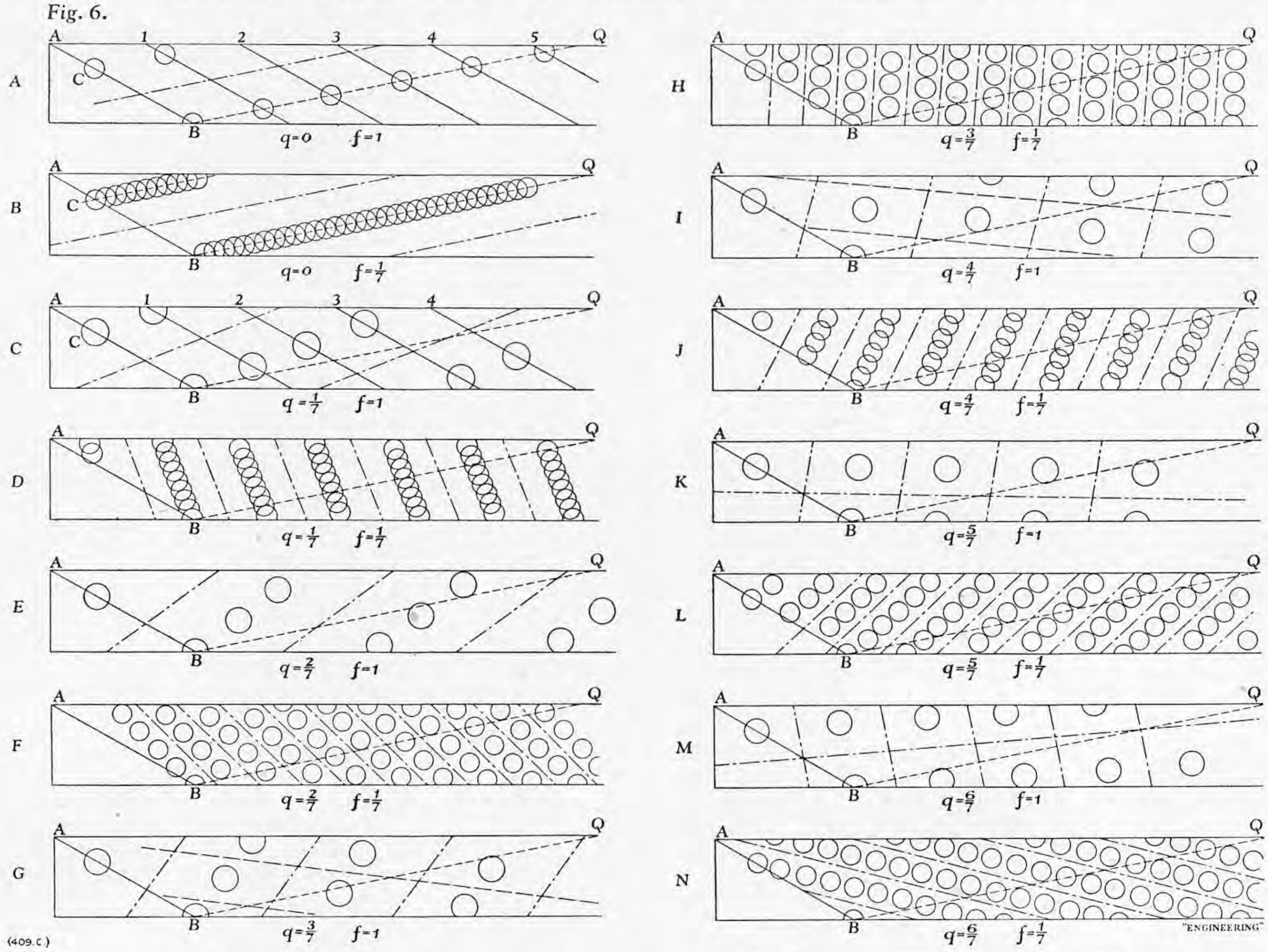
The ideal form of the flank of a tooth of an involute helicoidal gear with a large number of teeth is a smooth surface which, over limited areas, approximates to a plane. Because of the nature of the cuts made by the separate teeth of a hob, the gear-tooth form produced by hobbing on a perfectly accurate machine is a system of shallow depressions the lowermost points of which lie on a surface of the ideal form. The depressions are of approximately elliptical form and their lines of intersection define the "high-spots" of the actual tooth flank. The height of a high-spot above the surface defined by the low-spots is determined by the radii of curvature of the surfaces of the depressions in the vicinity of the high-spot and by the distances between the centres of curvature. In practice, unavoidable errors in certain parts of the hobbing machine cause the cuts of different hob teeth to be of different depths, and the sweeping action of the teeth causes "low-cuts" to obliterate the surfaces left by adjacent "high-cuts" and "medium-cuts." Thus the finished surface tends to be defined by the intersections of low cuts and, as these constitute perhaps only one-sixth of the total number of cuts, the surface is rougher than that which would be produced by a perfect machine in that the high-spots are higher and the pitch of the irregularities is greater.

As in any particular gear, the radii of curvature of the depressions are defined by the dimensions of the hob, the heights of the high-spots produced by intersection of depressions can be conveniently reduced only by reducing the distance between adjacent depressions. In other words, the surface of the tooth may be made smoother and more closely approximating to the ideal form by increasing the number of hob-tooth cuts in any given area, provided that the cuts are uniformly distributed

* Professor of Applied Mechanics, University of Sheffield.

TOOTH SURFACES OF CREEP-CUT HELICAL GEARS.

Fig. 6.



over the area concerned. With this last proviso, an exceedingly fine feed during the finishing cut could produce much more accurate tooth surfaces than is possible with a coarse feed on the same machine. Although the number of cuts in a given area of tooth can be increased by reducing the feed of the hob saddle per revolution of the gear blank during the final cut, the general nature of the distribution of the cuts cannot be so altered as it is determined by the kinematics of the gear-cutting machine. In designing the machine it is desirable to bear this in mind.

During the passage of a single tooth of the gear through the zone of contact with the hob, the effective teeth of the hob make cuts the deepest points of which lie on a line A B (Fig. 1, opposite) inclined at an angle of about 30 deg. to the tip of the tooth (See Appendix I.) A periodic error in the motion of the dividing worm results in the production of high-spots and low-spots on the line A B. Two adjacent low-spots are indicated by circles; the distance between them depends on the circumferential movement of the gear at the pitch circle during one revolution of the worm. During the next passage of the tooth through the zone of contact with the hob, similar cuts are made on a straight line C D parallel to A B and separated from it by a distance depending on the feed of the hob saddle during the revolution of the work. On the line C D there will be (in general) the same number of low-cuts as on A B and it is important to know how they are situated in relation to the low-cuts on A B. If the gear-cutting machine is of the non-creep type, low-cuts during successive revolutions of the table are located as shown in Fig. 1 on lines such as P Q inclined at about 11 deg. to the tip of the tooth. (See Appendix I.) A section of the surface through any line such as A B therefore shows two deep depressions corresponding to the low-cuts (shown in full lines in Fig. 2) with an intervening ridge left by the overlapping of intermediate not-so-low cuts (shown dotted in Fig. 2 (*a*)). If the distance between adjacent low-cuts is small compared with their radii of curvature, the low-cuts tend to overlap and thus to obliterate the effects of the other cuts, as shown in Fig. 2 (*b*).

In either case, low-cuts closely spaced on parallel lines leave, on intervening parallel lines, high-spots that form corrugated ridges. The height of such ridges depends on (*a*) the difference, g, in depth between high-cuts and low-cuts; (*b*) the pitch, k, of the low-cuts; and (*c*) the radius of curvature, R, of the cuts. The height is equal to $\frac{k^2}{8R}$, if that is much less than g, or equal to g if $\frac{k^2}{8R}$ is much greater than g. An important point to note is that if the low-cuts are sufficiently closely spaced (i.e., if k is small enough) the height of the ridges is independent of the magnitude of the machine-error that produces the difference in depth of cuts. (See Appendix II.)

On teeth cut by a "non-creep" machine, the direction of the ridges is precisely the same as that of the contact line between the tooth if it were perfect, and a perfect mating tooth. In the following, the ideal contact line is referred to as "the generator." As mating gears rotate, the generator sweeps the surface of the tooth, and the impacts of the generator on irregularities determine the intensity of noise and vibration produced. In a "non-creep" gear, the setting of the ridges parallel to the generator is the worst possible one from the point of view of noise production because it means that the generator strikes each ridge over its full length at once and afterwards may fall right into the succeeding trough.

It may be noted that finish-cutting with a specially-fine feed does little or nothing to improve matters as it merely spaces the low-cuts more closely on lines such as P Q (Fig. 1) but does not reduce the spacing on lines such as A B. It thus has the effect of smoothing the bottoms of the troughs and the tops of the ridges but it makes no appreciable difference to their effective height. The smoother nature of the ridges means that the teeth "bed" together more closely and the tendency to local stress concentration is reduced. This is advantageous to load capacity, but makes no difference to the tendency to noise production. It may also be noted that while alteration of the ratio of the number of teeth in the work to the number of revolutions made by the worm per revolution of the table alters the number of ridges that intersect a line perpendicular to the tip of the tooth, it makes no difference to the direction of the ridges. Adoption of a fine-pitch table gear improves smoothness of operation of the gears by reducing the pitch of the ridges and (probably) their heights but introduces no possibility of any "overlapping" of generator and ridges; they still remain parallel to each other.

It is natural to consider possible means of avoiding the unfavourable low-cut distribution that is characteristic of gears cut on the conventional hobbing machine in which the worm makes an exact whole number of revolutions during one revolution of the table. One way is to build the machine so that the wormwheel is not attached to the table but drives it through gears that lack the proneness of the worm gear to periodic errors of high frequency, and that have such a velocity ratio that the worm does not make an exact number of revolutions during one revolution of the table. Such a machine is a "creep machine" and its essential kinematic characteristic is that during one revolution of the table the dividing worm makes a whole number of revolutions plus a fraction q called the "creep fraction" or more properly, the "worm creep fraction." The distinction is made because every rotating part of the machine has its own creep fraction and each machine therefore has several creep fractions. Where a creep fraction is specified without qualification, it may usually be taken to refer to the worm, but the point should really be made clear.

A creep fraction may have any value between 0 and 1. For a non-creep machine the creep fraction is 0 or 1 whichever way one cares to regard it. Since $S + q = (S - 1) + (1 + q)$ any creep fraction q means the same thing as $(1 + q)$ and so any creep fraction quoted as negative is at once convertible to the equivalent positive quantity; for example, $q = -0{\cdot}4$ means the same thing as $q = 1 + (-0{\cdot}4) = 0{\cdot}6$. The velocity ratio of any component of the machine relative to the work table is denoted by $S + q$ where S is a whole number and q is a fraction less than unity. It is the creep fraction for the component concerned. Broadly, the purpose of the creep mechanism is to spread low-cuts in a less unfavourable manner than does the non-creep machine. For a given rate of feed during the final cut, the number of low-cuts on any given area of tooth is fixed, but their distribution depends on the creep fraction. A suitable value will not only improve the distribution of a given number of cuts, but will permit the use of a feed finer than usual to offer much greater advantage than is possible with zero creep fraction.

Referring to Fig. 1 it will be clear that no possible variation in creep fraction for the worm can make any appreciable difference to the spacing of low-cuts on a line such as A B because all the cuts on such a line are made while the hob completes two or three revolutions, whereas the complete effect of the creep fraction is shown only after a complete revolution of the table, corresponding (usually) to several hundred revolutions of the hob. The effect of creep is shown, however, in the positions of the low-cuts on C D in relation to those on A B, because a whole revolution of the table takes place between the production of cuts on those lines. Now if the creep effect is very small, the positions of the low-cuts on C D will differ but little from those produced without creep. Consequently, the effect of a small creep fraction is slightly to displace the low-cut lines similar to P Q. This is shown in Fig. 3, page 484, where the direction of the generator (i.e. of the low-cut lines without creep) is indicated by a dotted line.

The tooth action of this creep-cut gear will be smoother than that of the corresponding non-creep gear because the generator, in traversing the tooth surface, strikes each ridge at one end only and finally loses contact with it at the opposite end; the full-length impact with the ridges of the non-creep-cut tooth is avoided. But although the creep-cut tooth shown in Fig. 3 is an improvement, it leaves something to be desired, inasmuch as the generator does "drop" between losing contact with one ridge and establishing it with the next. If a somewhat greater creep-fraction is used (see Fig. 4) the angle between ridges and generator becomes large enough to allow the leading end of the generator to reach one ridge before its trailing end has left the preceding one. In that case, the generator is always touching a ridge: it therefore suffers no rise and fall beyond that associated with the relatively small corrugations on the tops of the ridges. The noise effect is therefore very small. The determination of a creep fraction that shall produce an effect of this nature on any number of ridges is considered in Appendix IV.

Application of a creep fraction of the opposite sign to that required to move the lines of low-cuts from the non-creep position in the direction indicated by Fig. 4, causes the low-cut lines to become more nearly parallel to the tip of the tooth than is the generator. A particular value of q (see Appendix III) will cause the low-cut lines to lie parallel to the tip of the tooth as shown in Fig. 5, page 484. This clearly causes the generator always to lie across at least one ridge and therefore leads to low noise-effect. Along any line parallel to the tip of the tooth there is no surface irregularity comparable in height with the ridge between the lines of low-cuts. A test confined to this direction might therefore suggest that the tooth surface was much smoother than was actually the case. This is a particular example of the general fact that on a tooth surface, however rough, it may be possible to draw a straight line that misses the greatest irregularities and gives a false impression of smoothness.

Fig. 6A, page 485, shows the distribution of low-cuts on a tooth cut with $q = 0$ and feed $f = 1$. The low-cuts are closely set on lines parallel to the generator, and between them lie intervening high-spots forming a ridge the crest of which is indicated by a chain-dotted line. Noise-effect is great, but, owing to the relative smoothness of the crest of the ridge, local stress concentrations are low, although impact loading is high. In Fig. 6B conditions are the same as for 6A except that f has been reduced to one seventh of its original value. To produce Fig. 6B each of the low-cuts in Fig. 6A is moved in the direction Q B so that its distance from A B is reduced to one-seventh of its original value. The result is that the low-cuts are placed very close together, but they are on the same lines as before and the intervening ridge is unaltered, except that it has smoother slopes and crests.

Fig. 6C shows the effect of cutting with worm-creep fraction $\frac{1}{7}$. The low-cuts on each of the lines 1, 2, 3, 4, etc., have the same pitch (measured parallel to B Q) as in Fig. 6A but they are staggered in the direction of A B by one-seventh of the length B C. The low-cuts on the tooth as a whole are situated on well-defined lines inclined to the direction of the generator and separated by parallel ridges the height of which is comparable with that for Figs. 6A and 6B because the pitch of the ridges (measured from trough to trough perpendicular to their direction) is about the same in all three cases. A generator in any position in Fig. 6C lies across at least one ridge and so noise will be produced only by the finely-pitched small corrugations on the crests of the ridge, but local stress concentrations at the points of contact with the ridges may be severe.

Fig. 6D shows 6C modified by the reduction of the feed rate to one-seventh of its original value. It will be noted that (*a*) the direction of the ridges is altered, (*b*) the pitch of the ridges is reduced, (*c*) the height of the ridges is reduced because of (*b*), (*d*) a generator always crosses at least five ridges, (*e*) there is no perceptible tendency to ridging parallel to the generator, and (*f*) the spacing of the low-cuts in the direction B Q is about the same as in Fig. 6A. Because of (*a*), (*b*), (*c*) and (*d*), very quiet running may be achieved and because of (*f*), local tooth loading is about the same as for Fig. 6A. Thus a reduction in feed rate produces a great improvement in Fig. 6C but not in 6A. In Fig. 6E the effect of $q = \frac{2}{7}$ is recorded. Again the direction of the ridges is changed and a generator crosses at least two of them in any position.

Reduction of feed rate to one-seventh of its original value (Fig. 6F) causes the low-cuts to be distributed in a remarkably even manner quite unlike any of the preceding cases. Each "high-spot" in Fig. 6F is adjacent to four low-cuts which may be expected to be effective in reducing its height considerably. A method of calculating the extent of this effect is given in Appendix II. In Fig. 6G the effect of $q = \frac{3}{7}$ is indicated. A generator in any position crosses three ridges as against two for Fig. 6E. As the low cuts are situated in approximately rectangular formation, a second system of "ridges" may be discerned but these also are not parallel to the generator. The surface represented by Fig. 6G is composed of depressions separated by crests that run to peaks in the centres of the parallelograms defined by the depressions, so that the term "ridge" is not strictly applicable to it except in so far as it may be accepted as describing a chain of peaks. Attention is drawn to this surface as one in connection with which the term "wave-length" is obviously meaningless unless a direction is specified. Fig. 6H represents Fig. 6G modified by division of the feed-rate by 7. Again the distribution of low cuts is notably even and there is little to choose in this respect between Figs. 6F and 6H. The effects of the creep fractions $\frac{4}{7}$, $\frac{5}{7}$ and $\frac{6}{7}$ are shown in Figs. 6I to 6N. It will be seen that for $f = 1$, the low-cuts occur in roughly rectangular formation and in each case two ridge systems may be distinguished. For $f = \frac{1}{7}$, however, $q = \frac{4}{7}$ and $q = \frac{5}{7}$, produce inferior results to that of $q = \frac{3}{7}$, but $q = \frac{6}{7}$ shows a recovery towards uniform distribution.

An important point made clear by Figs. 6A to 6N is that the distribution of low-cuts varies very considerably with change in creep-fraction or in feed-rate. The creep fraction is (usually) unalterable in any given machine (apart from extensive reconstruction) but the feed-rate is easily changed and it would seem advantageous to select its value very carefully for each particular job. It must be emphasised that Fig. 6 is diagrammatic, in that the relation between the spacing of successive low cuts and the spacing of adjacent lines of cuts does not necessarily represent any practical case. Consequently, it must not be concluded (for example) that because the value $q = \frac{3}{7}$ gives the most favourable low-cut distribution of those depicted in Fig. 6 it is necessarily a specially advantageous value of q to adopt in designing hobbing machines. As is shown later, that is not the case. What Fig. 6 does show is the great effect of variation of feed-rate on the distribution of low-cuts.

In Figs. 6A and 6B a generator in passing from C to B crosses one ridge. In all cases in Figs. 6C to 6N the low-cuts crossed by the generator during the corresponding motion are situated on seven lines parallel to it. The generator therefore encounters seven "high-spots" and the rise (proportional to the square of the pitch of the "high-spots," see Appendix II) from the highest to the lowest position is only about $\frac{1}{7^2}$ times that for the non-creep tooth. The impacts are therefore greatly reduced in intensity although their frequency is multiplied by 7. It seems reasonable to suggest that the noise effect (using the term in a rather vague general sense) may be proportional to the product of the rise at each impact and the frequency of the impacts. On that basis, use of any creep fraction with denominator 7 multiplies the noise effect by $\frac{7}{7^2} = \frac{1}{7}$.

In general, noise effect may be expected to be inversely proportional to the denominator of the creep fraction. There are exceptions to this rule, as, for example, $\frac{333}{1000}$, which although having a large denominator is practically equal to $\frac{1}{3}$. The effectiveness of a creep fraction is clearly affected by its proximity to any fraction with a much smaller denominator.

(To be continued.)

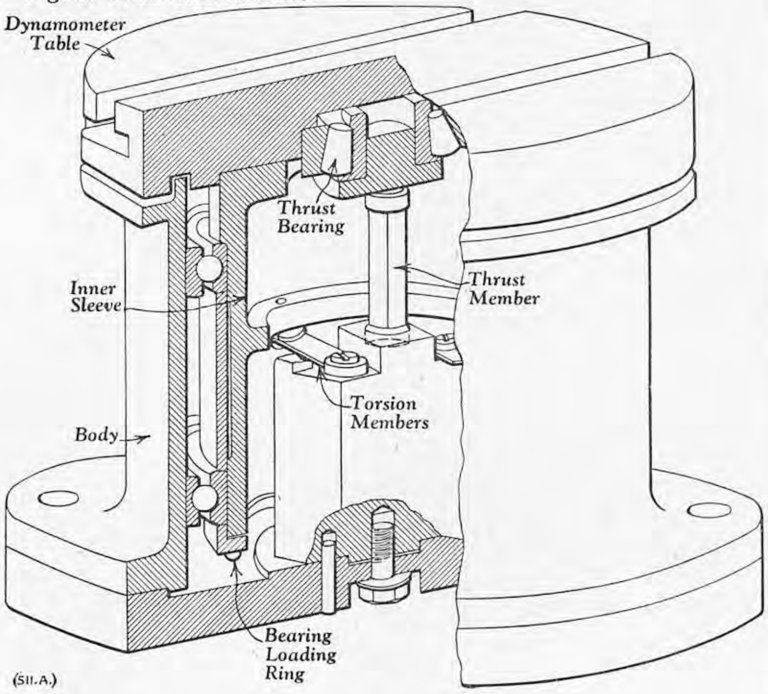
Exhibition of Permanent-Way Equipment.—British Railways are arranging a public exhibition of permanent-way mechanical equipment, to be held at Marylebone goods depot, Rossmore-road, London, N.W.1, from 1 p.m. to 4 p.m. on Wednesday and Thursday, October 31 and November 1.

Institution of Engineers and Shipbuilders in Scotland.—At their general meeting on October 9, the Council of the Institution of Engineers and Shipbuilders in Scotland made a number of awards in respect of papers read before the Institution during the 1950-51 session. These comprise the W. W. Marriner Premium to Mr. N. V. Pestereff for his paper "Alternating-Current Supplies for Auxiliary Plant on Board Ship," and Institution Premiums to Mr. G. Laing for his paper, "Theory and Practice of Thermal Insulation," and to Dr. J. F. Shannon for his paper, "Research, Design and Development Problems in Gas Turbines."

The Late Mr. G. F. Ross.—Mr. George Frederick Ross, who died on September 20, at Maidenhead, Berkshire, was on leave of absence at the time, prior to retirement from the works managership of the Regents Park, New South Wales, factory of Babcock & Wilcox of Australia, Pty., Ltd. He was born in Melbourne and took a diploma of engineering at Melbourne Technical College. Subsequently, he was engaged as the assistant electrical engineer at that city's electricity supply station. In 1911 he was injured in a railway accident, and it was when he was recovering from his injuries that he obtained a post with Babcock & Wilcox, Ltd., in Sydney. During the first World War he came to this country, where he was offered a position in the parent company's tube mills at Dumbarton. From 1918 to 1921 he was engaged on the construction of a new works for the firm at Bilbao, on the Bay of Biscay. After that work was finished, he was similarly engaged on the erection of the Regents Park works in Australia. Later, he became works manager there.

DYNAMOMETER FOR TORQUE AND THRUST DUE TO DRILLING.

Fig. 1. DYNAMOMETER UNIT.



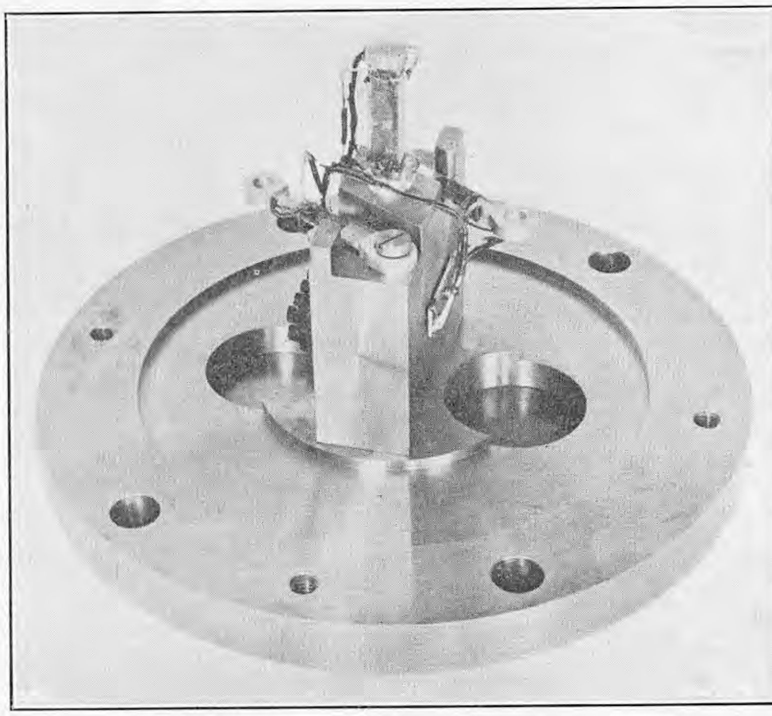
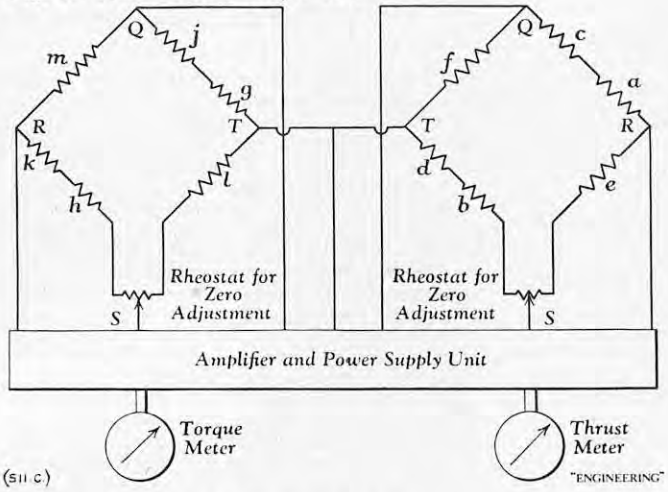


FIG. 2. STRAIN-GAUGE ASSEMBLY.

Fig. 3. STRAIN-GAUGE CIRCUIT DIAGRAM.



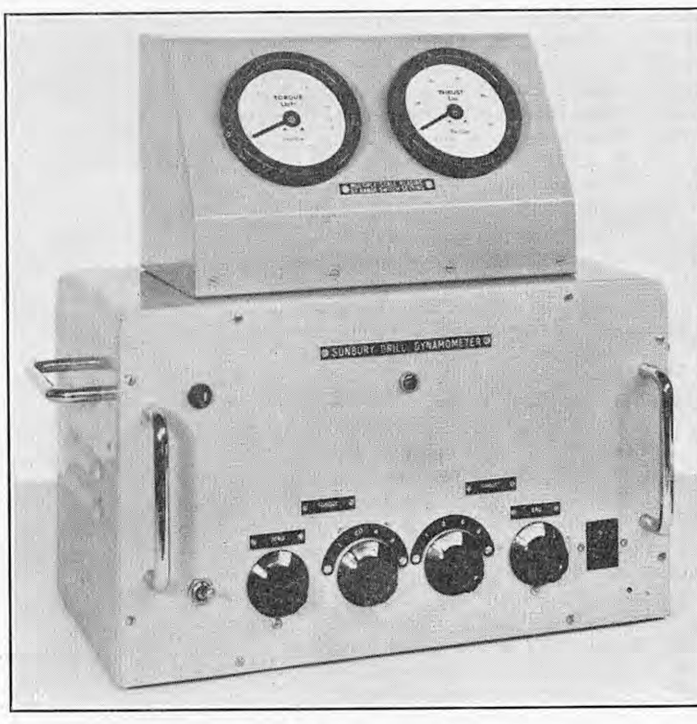


FIG. 4. AMPLIFIER UNIT.

DYNAMOMETER FOR TORQUE AND THRUST DUE TO DRILLING.

By R. C. BRAIN, B.Sc. (Eng.) G.I.Mech.E., and H. J. HULF, Grad. I.E.E.

THIS article describes the "Sunbury" drill dynamometer which has been designed and constructed at the Sunbury research station of the Anglo-Iranian Oil Company, Limited, by whose permission these particulars are published. It is used for measuring torque and thrust loads exerted by twist drills, and has proved to be of considerable value in research into the behaviour of cutting fluids during drilling operations. The dynamometer has a working capacity of 4,000 lb. thrust and 100 lb.-ft. torque, but the system of measurement is adaptable to any loads. Strain gauges are used as the load-sensitive elements. They were chosen because they permitted accurate compensation for changes in ambient temperature and the construction of a unit with a high natural frequency of vibration. The forces exerted by the drill are separated mechanically by the dynamometer into their components of torque and thrust. The torque is resisted by two tension links, and the thrust by a strut. The strain gauges fixed to these loaded members are subject to changes in resistance which are proportional to the applied loads. These changes in resistance are utilised to produce voltage signals which are amplified and applied to meters calibrated in units of torque and thrust.

The instrument consists of a dynamometer unit, and a power-supply, amplifier and meter unit. The dynamometer table (Fig. 1) on which the test material is clamped is $10\frac{1}{2}$ in. in diameter. The table is fixed to an inner sleeve which is located in the main body of the dynamometer by two ball bearings. These bearings are lightly pre-loaded by a ring, as shown, and the whole assembly is arranged to be an easy sliding fit within the body. Fixed also to the table is a taper-roller bearing which is supported by the central thrust member to which drill thrust loads are transmitted. The two torsion members resist the rotation of the table, and in doing so become loaded in tension. The thrust and torsion members, constituting the measuring unit, are mounted on a central block which is bolted to the dynamometer base plate. The torsion and thrust members are made of aluminium alloy to specification D.T.D. 683, having an elastic modulus of 10×10^6 lb. per square inch. This material allows strains of 0·002 at stresses within the elastic limit, and permits the use of sections of substantial size.

Electrical strain gauges are fixed with a Bakelite cement to the flat sides of the thrust and torsion elements, and the complete assembly with its terminal block and temperature-compensating gauges is wired as a unit, as shown in Fig. 2. It can be seen from Fig. 3 that the gauges are connected as two Wheatstone-bridge circuits for thrust and torque, respectively. Each load-sensitive arm of each bridge is made up of two identical strain gauges cemented to opposite sides of the loaded members, so as to compensate for any bending which would

Key to Fig. 3.

Gauge.	Resistance, ohms.	Position.		
a	5,000	Left-hand		Thrust member.
b	,,			
c	,,	Right-hand		
d	,,			
e	10,000	Temperature-compensation		
f	,,			
g	5,000	Top	Link 1	Torque member.
h	,,	Bottom		
j	,,	Top	Link 2	
k	,,	Bottom		
l	10,000	Temperature-compensation		
m	,,			

result from an eccentric loading of the members. Temperature-compensating elements *e* and *f* in the thrust circuit are cemented to a piece of aluminium alloy which, although arranged to be in close thermal contact with the thrust member, is not subjected to strain when the dynamometer is loaded. Temperature-compensating elements *l* and *m* in the torque circuit are similarly mounted, and located close to the central block. These can be seen in Fig. 2.

The total resistance of the gauges in each arm of the bridge is 10,000 ohms, and each gauge has a sensitivity of 2·2. Gauge sensitivity is the change in unit resistance per unit strain, i.e., gauge sensitivity $P = \frac{\delta R}{eR}$ where δR is the change in resistance of a gauge of R ohms caused by the application of a strain *e*. The change in resistance for the maximum strain of 0·002 is therefore $\delta R = P e R =$ 44 ohms, in each sensitive arm of the bridge. Therefore, with the supply of 85 volts from the power pack (Fig. 6) applied across the bridge circuits, an approximate out-of-balance of 120 millivolts results. As the dynamometer was to be used in the presence of soluble cutting fluids, where the humidity would be likely to affect the insulation resistance of the strain gauges and cause electrolytic corrosion of the gauge wires, steps were taken to protect the gauge assembly against the ingress of moisture. The gauges, connecting wires and terminals were coated with a cellulose-acetate cement and a protective wax. A nine-core cable connects the strain gauges to their power supply, amplifiers and meters.

The amplifier unit, which is shown in Fig. 4, contains a voltage-stabilising power pack and two separate but identical amplifiers with their separate indicating meters. Fine and coarse rheostats are provided for balancing each bridge circuit. The unit has been designed for maximum stability and freedom from inherent noise signals. For each amplifier circuit, a four-position range switch is provided on the front panel, giving ratios of voltage-from-bridge to voltage-to-amplifier of 1 : 2 : 4 : 8. The amplifiers have been designed to give a full scale reading of 1 milliampere alternating current on the indicating meters when only 15 millivolts direct current (one-eighth of the maximum out-of-balance voltage) is produced by the bridge. The overall gain of the amplifiers is approximately 2,000 with the first two stages stabilised to a gain of 600 by negative feed-back from a gain of 7,000 without degeneration. A variable potentiometer in the input circuit to the amplifier gives the control of gain required for calibration purposes.

Fig. 5 shows the circuit diagram of one amplifier and Fig. 6 the common power-supply unit. The direct-current out-of-balance voltage from each bridge is converted into an alternating-current signal by a Carpenter relay which connects the amplifier input alternatively to each side of the bridge (i.e., to points Q and S, Fig. 5) at mains frequency. The rectangular alternating-current waveform produced is then applied to the three-stage linear and stabilised amplifier, consisting of valves V_1, V_2 and V_3 with their associated circuits. The output from the anode of valve V_3 is coupled to the indicating meter, which is a rectifier moving-coil instrument, calibrated directly in units of thrust or torque. The meter reading is directly proportional to the variations in strain-gauge resistance, which in turn is directly proportional to the torque or thrust loads applied. The meters are graduated from 0 lb.-ft. to 12½ lb.-ft. torque and 0 lb. to 500 lb. thrust, respectively, and are read in conjunction with the four-position range switch multiplying factors of 1, 2, 4 and 8, giving maximum capacities of 100 lb.-ft. torque and 4,000 lb. thrust.

Initial calibration of the indicating meters was carried out by applying equal increments of voltage through a load equivalent to that of the valve circuit in which the meters operate. The gain of each amplifier circuit is set to give a meter scale reading equivalent to an applied static load. In practice, maximum working torque and thrust loads are applied through lever systems and the gain of the amplifiers adjusted to give full-scale deflection of the indicating meters on the least sensitive range. For thrust calibration, a 40 : 1 lever is used, so that a total load of 100 lb. gives a full-scale deflection of 4,000 lb. on the maximum thrust range. For torque calibration, the dynamometer is mounted with its axis in an horizontal position, and loads are applied to the end of a lever mounted on the dynamometer table. The lever is 2 ft. long, and a total load of 50 lb. is required to give a full-scale deflection of 100 lb.-ft. torque on the maximum torque range. The levers, load carriers and weights used in these operations have themselves been accurately calibrated. At the time of writing, the dynamometer has been in constant use for about six months. Periodical checks on calibration have revealed only very small drifts, and operation has been entirely satisfactory.

DYNAMOMETER FOR FORCES IN DRILLING.

Fig. 5. AMPLIFIER.

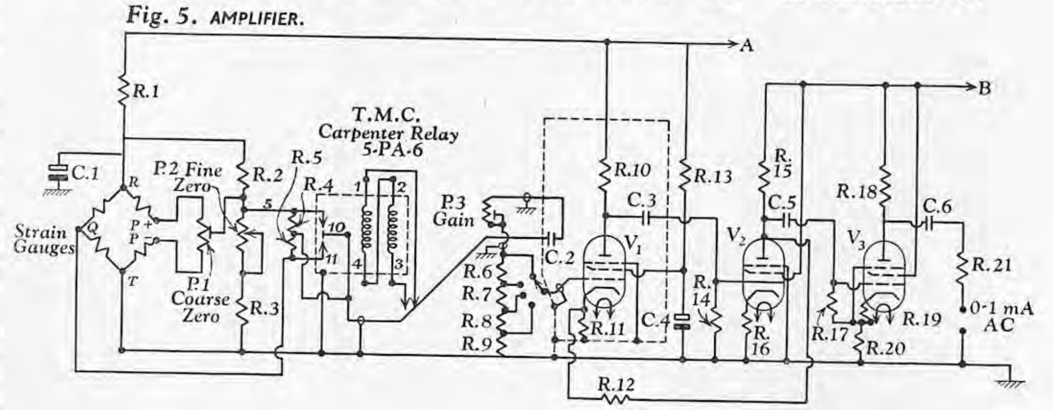
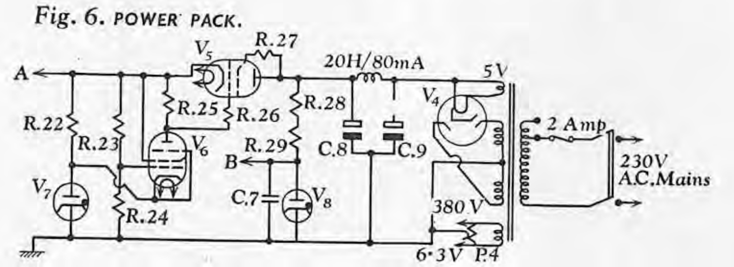


Fig. 6. POWER PACK.

	Valves
1	EF 37
2	EF 50
3	EF 50
4	5Z4
5	6V6
6	65J7
7	VR150
8	85AI



(S.I.E.) "ENGINEERING"

Resistors.	Ohms.	Type.
R.1, R.21 ..	7·5 × 10³	± 10 per cent. cracked carbon
R.2, R.3 ..	2 × 10⁶	± 10 per cent. cracked carbon
R.4, R.5 ..	33 × 10³	± 10 per cent. carbon
R.6	60 × 10³	± 1 per cent. cracked carbon
R.7	30 × 10³	± 1 per cent. cracked carbon
R.8, R.9 ..	15 × 10³	± 1 per cent. cracked carbon
R.10	220 × 10³	± 10 per cent. carbon
R.11, R.20 ..	10³	± 10 per cent. cracked carbon
R.12	10⁶	± 10 per cent. cracked carbon
R.13, R.14, R.25	10⁶	± 10 per cent. carbon
R.15	10 × 10³	± 10 per cent. carbon
R.16, R.19, R.27	150	± 10 per cent. carbon
R.17	470 × 10³	± 10 per cent. carbon
R.18	10 × 10³	± 10 per cent. cracked carbon (1 watt)
R.22	15 × 10³	± 10 per cent. carbon
R.23, R.26 ..	47 × 10³	± 10 per cent. carbon
R.24	68 × 10³	± 10 per cent. carbon
R.28	3·3 × 10³	± 10 per cent. wire wound (6 watt)
R.29	4·7 × 10³	± 10 per cent. wire wound (6 watt)

Potentiometers.	Ohms.
P.1, P.4	500
P.2	5 × 10³
P.3	100 × 10³

Condensers.	Microfarads.	Type.
C.1, C.4, C.8, C.9	8·0	500-volt working electrolytic
C.2	0·25	T.C.C. C.P.L.20
C.3, C.6	2·0	Waxed paper
C.5, C.7	0·1	Waxed paper

High-Voltage Air-Blast Circuit Breakers: Erratum.—We regret that the illustrations in the article on "High-Voltage Air-Blast Circuit Breakers," which appeared on page 417 of our issue of October 5, were wrongly described. Fig. 1 shows one phase of a 165-kV four-break air-blast circuit breaker, and Fig. 2 a 220-kV circuit breaker of the same design installed on a Finnish network. In the oscillogram reproduced in Fig. 3, the circuit breaker was operating with only two of the four interrupters in circuit.

CHAPMAN'S LOCOMOTIVES, 1812-1815.*

By E. A. Forward, A.R.C.S., M.I.Mech.E.

(*Concluded from page 458.*)

Until recently, the foregoing was the total knowledge of Chapman's chain-engine, but, in 1934, the visit of this Society to Derby brought to light, in the Derby Library, a set of drawings of a design for a locomotive, emanating from the Butterley Company. The description accompanying the drawings is headed, "Explanation of Plans of Locomotive Machine, Feb. 3rd 1813." These hitherto unknown drawings were recognised by the late C. F. Dendy Marshall as showing a Chapman chain-haulage engine, and are our only evidence of what such an engine may have been like. Dendy Marshall thought the drawings represented the Heaton engine, as built, but when critically examined, they reveal difficulties which incline the author to think that they represent a design only.

The date, February 3, 1813, on the description, is very near that of the patent application, and before the enrolment of the specification. Buddle was obtaining stationary engines and cast-iron rails from the Butterley Company shortly before this, so that he may have asked them to consider the making of an engine combining Chapman's chain-haulage arrangement with the six-wheeled bogie frame shown in the patent. Buddle, in his letters, writes as though William Brunton was then in charge of the firm's engine department, so that the proposed Chapman engine would demand his attention, and this circumstance may have led the latter to invent the "leg-propelled" locomotive which he patented in May, 1813.

The drawings illustrate a six-wheeled bogie engine, with a cast-iron return-tube boiler, made in two lengths bolted together, and with two vertical cylinders, both on the same half of the boiler and sunk into it in the same manner as practised by Trevithick and his followers. No valves or valve gearing are shown, but the cylinders are stated to be 8 in. diameter by 24 in. stroke; the boiler pressure was 60 lb. per square inch. Each cylinder has a long transverse crosshead, without guides, and from their ends pendent rods connect with the ends of two pairs of horizontal side levers pivoted near the end of the boiler, at the level of its centre. A crankshaft is mounted above the chain-wheel, in bearings attached to wooden pillars rising from the main frames. It has quartered cranks which should be connected by rods with the outer ends of the side levers, but these rods are not shown. The truck or "bogie" has two side frames connected together by a massive cross-member which has at its centre an iron pot provided with a steel plate at the bottom on which the spherical-ended pivot, cast on the boiler, rests. The axles themselves are square iron bars let into and bolted to the side frames, while the wheels run loose on their turned ends. The engine is shown mounted on iron edge-rails 2 in. wide, and having a gauge of 53 in. Although it would appear that the

* Paper read before the Newcomen Society at a meeting held in London on October 10, 1951. Abridged.

whole load on the truck was intended to come on the central pivot, yet the conical rollers between the truck and main frame are retained. The chain wheel is 38 in. diameter, and its rim is shaped to fit an ordinary link chain. A notable point about the design is that, while the general views are sketchy, the drawing of the chain-wheel and its binding wheels gives considerable detail and is dimensioned.

When the drawings are closely examined, however, it is found that the driving gear shown would not be workable, because the levers of the end cylinder would foul the axle of the chain-wheel. This could be corrected by placing the chain-wheel some 10 in. farther from the boiler. At the end of the description of the engine there is a schedule of weights which reads as though the figures given refer to something actually made, but they do not agree with the engine as drawn. The schedule includes only four "waggon wheels," which from their weight would have been about 30 in. in diameter, instead of 40 in., as on the drawings. The dimensions of the boiler agree nearly with those of the drawings, but its weight is given as 34 cwt., whereas the calculated weight, with the thickness of 1·5 in. shown, would be 55 cwt. The weight of water is given as about 26 cwt., as against a calculated figure of about 16 cwt., but the 26 cwt. appears to be a figure adopted to make up the total weight to 6 tons. The weight of wood is said to be at least 2 cwt., but the calculated weight of the timber framing shown would amount to 13 cwt.

It would thus seem that the scheduled weights relate to an entirely different four-wheeled engine, with, perhaps, some kind of iron framing to carry the chain mechanism. This suggests that before February, 1813, or even before the patent application, Chapman was having constructed, probably at Phineas Crowther's foundry, a four-wheeled chain-haulage engine substantially like that shown on the revised patent drawing. Also, that he or Buddle had sent to the Butterley Company the design for the proposed six-wheeled engine, with its descriptive matter, and including the schedule of weights belonging to the four-wheeled engine, the chain-wheel of which was probably incorporated in the design.

Referring again to the revised patent drawing, it is found that a scale of 1 to 100 would make the chain-wheel 38 in. in diameter, as in the Butterley design, while the running wheels would be 30 in. diameter, in agreement with the schedule. The boiler would be somewhat larger, that is, 50 in. external diameter by 9¾ ft. long, instead of 42 in. diameter by 7 ft. The cylinders and driving gear would, no doubt, be similar to those of the six-wheeled design. The use of two cylinders to drive cranks at right-angles on a single shaft was an important improvement in engine design, and Trevithick had included such an arrangement in his patent of 1802. The Butterley design would appear to be the earliest contemporary evidence of its use on a locomotive, and, if the attribution of that design to Chapman is correct, then we might expect the same plan to have been used on the original Heaton engine.

Although load equalisation on the wheels was an important part of Chapman's invention, yet it does not appear in the four-wheeled engine of the specification. That drawing shows the boiler mounted symmetrically over the axles, so that its weight would be evenly distributed, but the chain-haulage mechanism overhangs so much at one end that the axle nearest to it must carry more load than the other. This drawing shows the rims of the chain-guiding pulleys close to the under-side of the main frame. The chain from the one nearest to the boiler passes above the axles of the running wheels, and would rest on them when slack. It then passes over a small pulley mounted on the opposite end of the frame, at the same height as the other, and thence passes down to the road forks.

When the engine was moving with the chain-wheel in front, there would be a downward component of the chain drag tending to tilt the engine forward, and still further overload the front axle. When travelling in the reverse direction, the downward chain-pull would act on the leading end of the frame, so increasing the load on the axle at that end, so that the axle load would be both variable and unequal. If the engine weighed something like the schedule amount of 6 tons, an adverse effect on the wooden rails at Heaton colliery could be understood. To equalise the axle loads in the Butterley design would require the axle at the chain-wheel end to be placed at the end of the frame, and the middle axle to be moved in the same direction until under the centre of gravity of the whole. This would involve a lengthening of the total wheelbase by some 6 ft., which was perhaps more objectionable than the defects of the designed arrangement.

Even if the chain-engine at Heaton was soon abandoned, the locomotive, as such, was not, as William Losh, writing to Edward Pease on November 3, 1821, recommending the use of Losh and Stephenson's cast-iron rails on the Stockton and Darlington Railway, stated that the large engine at Heaton broke the ordinary cast-iron rails, but not those made under their patent of 1816. It would thus seem probable that the original chain-engine at Heaton was a four-wheeled one, and that it was rebuilt as a six-wheeled or eight-wheeled adhesion engine, which was still in use in 1821. From Losh's letter it may also be inferred that the wooden rails had been replaced by cast-iron rails before 1816. The line was relaid with Birkinshaw wrought-iron rails in 1821.

A recent discovery has a possible bearing on this subject. In February, 1931, the late R. N. Appleby-Miller found at Newcastle an early mining plan, adjudged to date between 1821 and 1846, bearing a vignette picturing a six-wheeled geared locomotive, which he considered might be a hitherto unknown George Stephenson engine. Appleby-Miller described this vignette in *The Engineer* for September 18, 1931, and Dendy Marshall discussed it in his *Early British Locomotives*. The latter was of opinion that the vignette represented an actual engine, as certain peculiarities in it could hardly have been invented by the artist; he also agreed with Appleby-Miller's attribution of the engine to Stephenson. While the present author agrees in thinking that an actual engine is illustrated, he thinks it probable that it was the Heaton engine of 1813, rebuilt as a six-wheeled bogie engine, and was, in fact, the "large engine" spoken of by Losh in 1821.

The drawing shows a six-wheeled engine, seemingly running on an edge-railway. The three axles are equally spaced and placed symmetrically under the boiler. Each axle carries a spur wheel, while between each pair there is a layshaft carrying a smaller spur wheel which engages with those on each side of it. The central spur wheel also serves to keep the cranks on the ends of the two layshafts at right angles to one another. Two cylinders are sunk in the boiler on the centre line, in the Trevithick manner, with return connecting rods from long transverse crossheads, reaching down to the cranks on the layshafts. The most striking peculiarity of the engine is that each main frame is composed of a pair of overlapping beams, placed one on top of the other. This double frame suggests that the drawing might represent a Chapman bogie engine, the rear part of the lower beam being really the frame of a bogie.

On close examination a peculiar feature appears. The rear cylinder has its crank on the top centre with the connecting-rod in line, the cylinder being directly over the crankshaft, as would be essential if a bogie was applied at that end. At the front end, however, although the centres of the crankshafts must be 4 ft. 3 in. apart, yet the crosshead guides are 5 ft. apart, so that its connecting-rods have an oblique drive with an offset of 9 in. That this offset was real is shown by the fact that the crosshead guides rise from the boiler barrel, and not from lugs on the cylinder top flange, as was usual with this cylinder arrangement. Still more peculiar is the position of the axis of the front cylinder, which is 6 in. forward of the crosshead and 15 in. ahead of its crank. These features suggest that the engine as shown was a rebuild. If it was a new engine, both cylinders would naturally be placed vertically over their crankshafts.

Another point about this engine is that the two crankshafts appear to be hung on brackets fastened to the upper frame member. This feature confirms the view that this is really a bogie engine, as such an arrangement would be unnecessary with a rigid-framed engine, but would be essential for the driving crankshaft of a bogie. The cranks appear to be outside the wheels. It is easy to see that if the original four-wheeled Heaton chain engine had the same cylinder arrangement as the Butterley design, but with a longer boiler, as indicated by the revised patent drawing, moving the second cylinder to the opposite end of the boiler, over the bogie pivot, might well produce the peculiar features noted. Seeing that there is considerable evidence for the view that the Appleby-Miller engine was really a six-wheeled Chapman adhesion engine, and probably a rebuild of the four-wheeled chain-engine of 1813, it might reasonably be identified with the large engine at Heaton mentioned by William Losh in 1821. Such rebuilding might have taken place between 1813 and 1816.

The first news of the trial of Chapman's second locomotive appeared in the *Newcastle Chronicle* of December 24, 1814, and the *Tyne Mercury* of January 3, 1815, in identical paragraphs. These included the statement that the engine was built by Phineas Crowther. These paragraphs formed the first part of a more complete account which was published in the *Repertory of Arts* early in 1815, except that Crowther's name is omitted. This reads as follows:—

"Account of a locomotive engine, executed by Messrs. Chapman of Newcastle-upon-Tyne, according to their Patent, dated December 30th, 1812, contained in a letter to the editor.

"On the 21st of December, 1814, a locomotive engine was set to work on the waggon way of John George Lambton, Esq., leading from his collieries to the river Wear. It drew after it eighteen loaded coal-waggons (weight about fifty-four tons) up a gentle ascent, rising five-sixteenths of an inch to a yard, or at the rate of forty-six feet in a mile, and went nearly at the speed of four miles an hour. The engine was mounted upon eight wheels, by means of which the weight is so far reduced as to avoid the great expense of relaying ways with stronger rails, which in many instances has been done to obtain the vast annual saving between the use of locomotive engines and horses. The cast-iron rails of Mr. Lambton's way were only calculated to carry waggons of three tons weight, inclusive of their loading; and the locomotive engine, with its water, was nearly six tons; so that upon four wheels this way could not have borne it.

"The acting power of the engine was applied to the wheels supporting it, and their resistance to slipping upon the way was the utmost it could exert in drawing waggons after it which, in this instance, was carried to the extreme; for although the friction was equal to the driving forward the train of eighteen waggons after they were fairly in motion, it did not overcome their vis inertia in drawing them from a state of rest until after a considerable slipping of the wheels of the locomotive carriage. The power of the engine was sufficient to take more waggons after it; but it could not have moved the present number up a greater ascent without having recourse to the second part of Messrs. Chapman's invention, which consists in having a chain laid along the way, where the steepness of ascent requires it, which is then laid over a sprocket wheel, like that of a chain-pump, and this wheel (receiving a similar degree of motion with that of the carriage wheels of the engine) draws it forward without slipping; and when arrived at the head of the ascent the chain disengages itself by being hauled or lifted off the iron Y in which it was inserted.

"The method is simple and useful, and the charge for the use of it very moderate. In their Specification they explain the use of the stretched chain, and in describing the outline of their mode of reducing the ill effects which, prior to their invention, simple as it is, had been laboured under from the great weight of locomotive engines . . . It appears highly probable that this invention must prove a great saving, both in public and private railways, from the great number of horses and men which one single engine may be substituted for. It is obvious that in ways formed of very light rails for smaller waggons, engines of proportionately less power and weight may be used."

This description shows that the Lambton engine worked by simple adhesion, and was tested on a gradient of 1 in 115. Its eight wheels were presumably arranged in two pivoted trucks, if made in accordance with the patent. It would seem that the drive adopted in the six-wheeled Appleby-Miller engine would apply equally well here, though it would involve the addition of two axles with their accompanying running and toothed wheels. There would thus be a train of seven toothed wheels connecting the axles and crankshafts. William Hedley's patent specification of March, 1813, appears to claim the coupling of engine wheels by such gearing, but this claim could hardly be valid, as Trevithick had used the system in 1804-5.

An eight-wheeled double-bogie locomotive with two vertical cylinders, sunk in the boiler as usual, would necessitate placing the cylinders over the bogie pivots, or about 8 ft. apart, thus entailing a boiler length of at least 10 ft. As in the six-wheeled engine, the crankshafts and the central gearwheel shaft would be mounted in bearing brackets pendent from the main frame, so that the trucks could turn on their pivots between them. Objection has been made by some writers to this toothed-wheel coupling arrangement as being impracticable, but this view is discounted by the long existence of the eight-wheeled Wylam engines, and by the fact that the Neath Abbey Company, some years later, built some successful double-bogie engines with the wheels so coupled. The chief objection to this system would arise from the train of fine-toothed wheels connecting the two crankshafts. A similar connection, but with only three spur wheels between the crankshafts had been used by John Blenkinsop in his rack locomotives, in 1812, where it seems to have given no particular trouble. George Stephenson applied the same arrangement to his first Killingworth engine of 1814, having no doubt copied it from Blenkinsop. Seeing that Chapman had a free hand in the design of his eight-wheeled Lambton engine, and had already adopted the single driving shaft with quartered cranks in the Butterley design, and presumably in the Heaton chain-engine also, we might expect that its manifest advantages would lead him to continue its use. In this case, however, the drive to the axles would involve a transverse crankshaft carrying the central toothed wheel of the gear train, while the cylinders would have to be taken out of the boiler and mounted beside it. The central gearwheel shaft of each truck would be mounted on its own frame, instead of on the main frame. This arrangement is much like that arrived at in the eight-wheeled Wylam engines.

There are three known varieties of Wylam engine illustrations. The earliest appeared in the first edition of Nicholas Wood's *Treatise on Railroads*, in 1825. About it, Wood said that he had "been favoured with a drawing of one of the engines at present used upon the Wylam Colliery railroad, previously noticed, which in its construction is different from the Killingworth engines, and adapted for a plate railway, and also supported by eight wheels." Wood had previously dealt with the work of Blackett and Hedley at Wylam, as well as with Chapman's chain-engine, and continued: "Mr. Chapman, in his patent for the application of a chain, described a plan of placing the weight of the engine upon two frames, supported by six or eight wheels; and the Wylam engines, being heavier than the rails would bear, were placed upon eight wheels; but the complication attendant on so many wheels, and the unwieldly nature of such a length of framing, formed altogether so many objections, as to render them almost useless, as a species of moving power."

The second variation appeared in C. F. Partington's *Historical and Descriptive History of the Steam Engine* (2nd ed., 1826), where he describes it "as a view of a steam carriage employed at Wylam Colliery, Newcastle, for which we are indebted to Mr. Hedley, an extensive coal viewer and mineral surveyor in that district." This drawing differs from Wood's in details, particularly in the form of its wheels. The third illustration appeared in Alexander Gordon's *Journal of Elemental Locomotion*, in 1832. This drawing was almost certainly copied from Wood, but includes variations and some definite errors, so that, in itself, it is valueless. Gordon attributes this engine to the Chapman brothers. Wood omitted the engraving of the eight-wheeled engine, and its description, from his second edition of 1831, which encourages the supposition that the drawing was not a true representation of the actual Wylam engines. There is no doubt that the drawing shows Chapman's patented method of providing an engine with eight wheels mounted on independent, and pivoted, four-wheeled trucks.

What is thought to be an independent description of a Wylam engine was given by the two Prussian mining engineers, H. von Decken and K. Von Oeynhausen, who visited England early in 1827, as follows: [Translation] "The locomotive engine at the Wylam colliery near Newcastle, runs upon a plate railway of cast-iron; its wheels are without flanges. It has eight such wheels and a wooden frame, on which the cylinders stand upright beside the boiler. The engine wheels are coupled together by a train of toothed wheels which are set in motion by a toothed wheel on whose axle the cranks are fixed. It is probably the only locomotive engine which runs on such a railway. The eight wheels distributed the weight of the engine over more points of the railway, which, otherwise, would have been too weak to support it." This description does not appear to have been copied from Wood's treatise, but we cannot be sure whether they were speaking of an actual engine, or of Wood's engravings. They do not seem to have noticed whether the wheels were mounted on two independent trucks, but, knowing the eye for detail generally displayed by these two engineers, this omission suggests that they were writing of an actual engine in which this feature was present in a less noticeable form.

The eight-wheeled Wylam engines continued to work down to 1828, in which year Robert Stephenson and Company supplied to Wylam some cast-iron edge rails of the Losh and Stephenson type, as patented in 1816, which indicates that the line was then being, or about to be, relaid as an edge railway. We do not know who was responsible for the new cylinder arrangement, but it is possible that Phineas Crowther, who built the Lambton engine and was an engine maker of repute, was the author of the whole design of the engine.

The trucks should, according to Chapman's patent, be pivoted at their centres, while the two central shafts, shown one above the other, would have to be mounted on the main frame. The drawing shows the shafts so mounted, which indicates that some relative motion between the trucks and main frame was definitely envisaged.

After considering the available evidence, the author concludes that the first useful engine produced by William Hedley, for Wylam, was a single-cylinder one, and that it commenced regular working about March, 1814, on the evidence of Christopher Blackett. William Hedley, in his oft-quoted letter to Dr. Lardner, of 1836, made no mention of any two-cylinder engines in describing his early experiments. When sending this letter to the *Newcastle Chronicle* for publication, Hedley added that: "Several of the engines constructed at first were placed upon four wheels; but in consequence of the plate-rails being too slight, they were afterwards placed upon eight-wheels. The railroad is now laid with edge rails, and the same engines may be seen on four wheels at this day." In view of the latter statement, it has been difficult to reconcile the existing Wylam engines, which ceased work about 1862, with the Wood plate of 1825.

Apart from the wheel arrangement there are some obvious differences between the 1825 drawing and the existing engines. First, the 1825 drawing has the Watt parallel motion, whereas the existing engines, and the 1839 sketch, have the Freemantle parallel motion, patented in 1803. Secondly, the cylinders of the existing engines are placed nearer to the spherical end of the boiler, so displacing the pair of boiler supports at that end. They are also supported in pockets formed on the sides of the boiler, so as to be steam-jacketed, instead of being hung on the boiler barrel. Such a difference could hardly arise unless the boiler was an entirely new one, fitted when the engine was rebuilt as a four-wheeler. The parallel motion might reasonably have been altered at that time. Thirdly, the valves of Wood's drawing appear to be driven by unseen eccentrics on the crankshaft, but on the existing engines they have tappet motion, worked from the engine beams. With these changes it could hardly be said, in 1836, that the engines then running were the same as the eight-wheelers used up to 1828.

The author had much discussion in 1942 with Dendy Marshall on the Wylam engine problem. The latter then concluded that the Wood drawing of 1825 did not represent the Wylam engines as actually built, but was only a design which might have been used as a basis for their construction. While now agreeing with this view, the author is inclined to think that the 1825 drawing was more probably based on Chapman's eight-wheeled Lambton engine of 1814.

Although Buddle had sponsored Chapman's invention, and recommended the use of locomotives on new or altered railroads with which he was connected, we know of no other definite examples. The rebuilt Heaton engine was probably still in use in 1821, and there is some reason to believe that the Lambton engine was still running in 1827. The more extensive use of Chapman's engines during the life of the patent may have been prevented by the growing tendency to strengthen the tracks so that heavier simple-adhesion locomotives could be used thereon.

Some remarks made by Robert Stephenson to Zerah Colburn, however, make it appear likely that there were other bogie engines of which there is no record. Colburn wrote, in 1869: "In 1828 the engineers of the Baltimore and Ohio Railroad visited England, and the late Robert Stephenson once informed the author that he suggested to them, what is now the chief distinguishing feature of all American railway rolling stock, viz., 'Bogie,' to be applied to the engines intended to work round curves of 6 chains radius, at that time proposed to be adopted. The bogie, which had grown out of William Chapman's invention of 1812, was then Mr. Stephenson stated, in regular use upon the quays of Newcastle." If this statement is correctly reported, it would imply that, in 1828, there were other engines besides those at Wylam and Heaton incorporating Chapman's bogie. If his remarks included the Wylam engines, then it would confirm that those were definitely bogie engines. The firm of Robert Stephenson and Company, founded in 1823, did not build any bogie locomotives until 1833.

This close examination of Chapman's locomotives leads fairly to the conclusion that his special contributions were the invention of the "Bogie," now in world-wide use; load-equalising arrangements, now rendered redundant by the use of springs; and, with Crowther, the application to the locomotive of two cylinders to drive a single shaft with quartered cranks, now universal.

Developments in Germanium Triodes: Erratum.—In an article on developments in germanium triodes, which appeared on page 329 of Engineering (September 14), a reference was given in the first line to a previous article on the Transistor amplifier. This reference should have read "page 630 of our 166th volume (1948)."

Heavy-Duty Engine Oils.—The Ministry of Supply have set up an advisory panel on heavy-duty engine oils, which will be responsible for recommending approval of oils submitted under a new specification governing the quality of such oils for the Services. Engine tests will be carried out and the panel will make its assessments after studying reports of these tests and of inspections. The new Heavy Duty Oil Specification issued by the Ministry of Defence (DEF/2101) will soon be on sale at H.M. Stationery Office. The members of the panel are as follows: Dr. F. T. Barwell, chairman (Department of Scientific and Industrial Research), Mr. D. I. Baddeley (War Office), Mr. J. Calderwood (British Internal Combustion Engine Manufacturers' Association), Mr. A. Larkin (Vauxhall Motors, Limited), Mr. G. R. Oliver (Motor Industry Research Association), Mr. R. Stansfield (Institute of Petroleum), Lt. A. E. Urell (British Internal Combustion Engine Association), Mr. A. T. Wilford (London Transport Executive), and Mr. G. Kinner, secretary, Dr. P. J. Udall and Mr. A. Watson (Ministry of Supply).

TWENTY YEARS OF OIL-ENGINE DEVELOPMENT.*

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

The credit for originating the development of the automobile oil engine in Great Britain belongs to the late Lord Ashfield, chairman of what was then the London General Omnibus Company and of its manufacturing subsidiary the Associated Equipment Company, who, realising the immense saving in fuel cost which would follow the production of a successful compression-ignition engine suitable for vehicle work, gave orders in October, 1929, that every possible effort was to be expended in that direction.

Several systems showing promise were already in existence in Germany. Some preliminary experiments at the A.E.C. during 1928, with a converted petrol engine, had given encouraging results when using the Acro system, sponsored by the Robert Bosch A.G., and a licence for that system was secured. Those early experiments had shown that the way to success did not lie in the direction of converted petrol engines, and it was decided to produce an entirely new engine. That engine, which it was the author's good fortune to be called upon to design, was the first high-speed oil engine, intended specifically for road transport work, to reach the production stage in this country.

Six of these engines were made in the experimental department, and the first had been running for only a very short time when Lord Ashfield, realising that a satisfactory engine would emerge only from extensive service experience, ordered, in May, 1930, one hundred of these engines, to be produced as quickly as possible as an extended experiment, and distributed as widely as possible over the road transport field so as to obtain experience under all conditions of service. Unfortunately, those two important words "extended experiment" seemed to get forgotten and the engine was expected to behave as if it had already undergone a prolonged period of development; this, plus the inexperience of the users, caused a good deal of disappointment.

On the other hand, the instructions to distribute the batch widely over the transport field was obeyed all too literally. In the enthusiasm of the moment several were sold to a firm in the east of the United States of America, whence they were sent even farther afield to the Pacific coast. One engine, at least, went to the Phillipine Islands. One reached the Land of the Rising Sun, whence it reappeared a few years later in an article entitled "Oil Engine Development in Japan," its description and photograph appearing in company with those of a number of its contemporaries, both British and Continental, all under Japanese names but easily recognisable. By the time this happened the original combustion system of our engine had long been changed for a more efficient one.

The design was, of necessity, based upon current commercial-vehicle petrol-engine practice, but, although stiffened up and more generously proportioned in many directions, it was soon found to be anything but adequate for oil-engine conditions. In preparing the design it was felt that, if the oil engine was to become the successful rival of the petrol engine, it had to be equal to it in speed range. The engine was therefore ungoverned as to maximum speed, only an idling governor being provided, and the design was based upon a maximum of 2,750 r.p.m. This figure was reached and even exceeded under service conditions, but it very quickly seemed that if we were to avoid, or at least minimise, bearing and other troubles, the maximum speed had to be reduced. The limit was therefore placed at 2,000 r.p.m. and remained at this figure until the time arrived when, the petrol engine having been virtually driven from the heavy-vehicle field, the different types of oil engine were competing against each other in respect of fuel consumption.

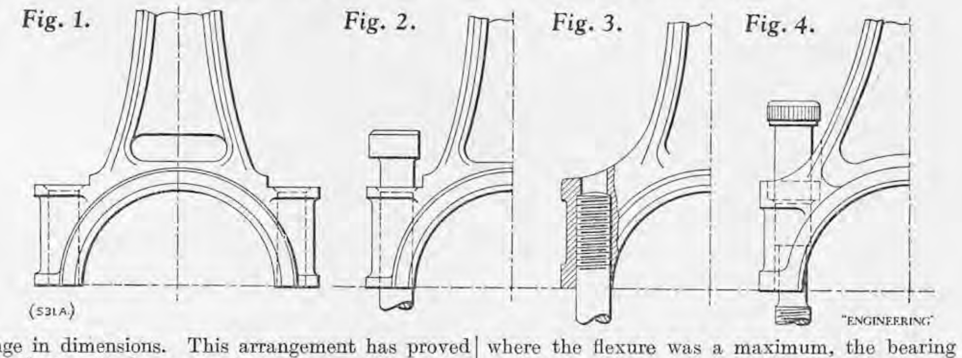
During the early period of development the mechanical troubles were numerous but, fortunately, the saving in fuel cost was so great that the operators were prepared to persevere in the hope that, ultimately, the engine would prove as reliable as its rival. In this the fact that petrol alone was taxed was a great help and this state of affairs remained just long enough to allow the worst troubles to be overcome. In some quarters much opposition was experienced from prejudice and ignorance, and a favourite habit was to attribute to the engine every fault on the vehicle, but, in the end, the enormous saving in fuel cost put an end to all this.

The first real troubles were with the connecting-rod bearings, both at the crank-pin and gudgeon-pin end; the latter was more easily put right. The original arrangement was that the gudgeon pin was clamped in the eye of the rod and worked directly upon the aluminium of the piston. Both seizures and excessive wear in the piston bosses took place, but these were cured by using a fully-floating gudgeon-pin with no

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

OIL-ENGINE DEVELOPMENT.

Fig. 1. *Fig. 2.* *Fig. 3.* *Fig. 4.*



change in dimensions. This arrangement has proved as nearly trouble-free as anything mechanical can be, despite loadings which to-day reach a figure of 6,000 lb. per square inch, with splash lubrication only. Curiously enough, the fully-floating pin arrangement had been deleted from the petrol engine because of difficulties in locating the pin. Meanwhile, however, a really satisfactory proprietary Circlip had appeared.

Not all of the problems were solved as easily, the troubles at the other end of the rod being a case in point. The big-end bearing was made in babbit, run directly into the connecting rod. Unlike the petrol-engine rod, which was made in a medium nickel steel, the oil-engine rod was made, for lightness, in a nickel-chrome steel. It soon appeared that there is a material difference between the adhesion of babbit to a nickel-chrome steel and that of babbit to a less highly alloyed steel, and, after a relatively short period of service, the babbit left the steel completely without leaving the least sign of the original tinning on the surface of the steel. At first the factory was blamed, but the most careful work and various changes to the surface finish of the steel failed to produce any real improvement, about 16,000 miles being the maximum life obtained from this type of big-end bearing. The rod was then provided with separate bearing shells. Experience with aircraft engines during the 1914-18 war having shown that babbit and mild steel had a much better adhesion than babbit and cuprous alloys, the shells themselves were made in mild steel.

This change produced some improvement, but the results were still far from being a commercial proposition. Every avenue was explored, and different types of white-metal were tried (lead base as well as tin) in addition to different methods of applying the lining. As it seemed likely that the manufacturing methods which produced bearings capable of standing up to the big-end loading of a radial aircraft engine should be of some advantage to an oil engine with only a single piston load on the crankpin, an appeal was made to the Bristol Engine Company, who, besides generously allowing us to study their method, actually trained one of our men, putting him through a course of instruction and retaining him until he had acquired the degree of proficiency necessary for their work. Even this availed little, and the life that could be depended upon from white-metal big-end bearings never exceeded about 24,000 miles. Extreme accuracy and care in fitting the shells, both the shell and the rod being ground to fine limits, gave some improvement, but did not provide a solution. Among the devices tried was that of making the big-end bearing as a floating bearing, but as it was, of necessity, in two halves it refused to float with any degree of certainty, and as failure to float meant no improvement in life, this expedient was abandoned.

Much discussion took place on what actually caused the failure. In every case, this took the form of cracking of the babbit, accompanied by the separation of the white-metal from the steel, the latter almost invariably being free from any signs of the original tinning. Two lines of thought were put forward, one that it was owing to a flexure of the rod end and the other that it was owing to shock. The trouble always started at the crown of the shell and quickly extended across the whole width of the bearing, spreading farther and farther around the circumference.

To determine which of the two theories was correct, an interesting experiment was tried; the web of the rod was machined away at the point where it joined the bearing housing, leaving the big end attached to the rod by the flanges of the H section only, as shown in Fig. 1, herewith. It was argued that, if flexure was the cause, the trouble would be accentuated by the reduction in rigidity at the crown; but if shock was responsible, the springiness introduced at the crown of the housing should suffice to eliminate the shock and help to spread the load more evenly over the surface. This experiment proved shock to be the culprit. The bearing failed after about the same mileage, but in a different place, the failure taking place beneath the two points, one each side, where the flanges of the H section joined the bearing housing. At the crown, where the flexure was a maximum, the bearing was perfect.

At this point, copper-lead bearings became available and instantly provided a solution. The first set fitted, when examined at 80,000 miles, was found to be in perfect condition. The original source of supply for these bearings was one of the aero-engine firms, but as they naturally did not wish to supply them as a regular thing, nor did we wish to pay aircraft prices, we set about developing our own method of manufacture. This has proved highly successful, and although the bearings are relatively expensive they have given excellent service on a normally heat-treated nickel-chrome steel shaft having a Brinell hardness number between 275 and 300. Service mileages running to 250,000-300,000 miles are not unknown.

At first the connecting rods themselves gave a certain amount of trouble. As initially designed, they were provided with D-headed bolts, which were more or less orthodox at that time, with the flat of the D fitting against a check machined on the rod, as shown in Fig. 2, herewith. This check really constitutes a notch in the rod, and although this arrangement had never previously given any trouble, some fatigue failures, starting at the corner of the check, were experienced with the oil-engine rod. The nickel-chrome steel used for these rods was rather more notch-sensitive than the medium-nickel steel previously used, and, although the failures were not numerous, the large amount of incidental damage following a rod failure made it necessary to make an alteration. As many stampings were in hand, it was desirable to make use of them if at all possible, and studs were substituted for bolts, the need for the check being thereby eliminated and the section at the critical point increased, as shown in Fig. 3.

The new arrangement proved even less satisfactory than the original one had been, as failures of the studs themselves took place and these were not only more numerous but also occurred after an even shorter period of service. These failures also were due to fatigue. Wisdom after the event suggested that to use a stud where there was a chance of bending coming on to it was to court failure owing to the notch effect of the thread producing a heavy stress concentration at the very point where the combined bending and tensile stress would reach its maximum. On paper, there was no bending stress; but the original failures of the rod indicated that some bending must be taking place and would certainly be transmitted to the studs or bolts securing the bearing caps.

A solution was found in the use of a bolt having a circular head of relatively small diameter, with the head fitting into a counterbore machined in the connecting rod. This not only eliminated the notch effect of the original check, but enabled the existing stamping to be used. There was still a more or less square cover at the bottom of the counterbore, but this did not extend all the way across the rod, and it varied in distance from the centre of the rod. The turning of the bolt during the tightening of the nut was prevented by giving the head a coarse knurl and driving it into the counterbore. The fit obtained was such that not only was the bolt stopped from turning while the nut was being tightened, but it was held firmly in place when the cap was being passed over the bolts. This arrangement, which is illustrated in Fig. 4, has proved so satisfactory that it is still in use. To allay any doubts on the point, it is well to add that the knurl does not cut into the rod material, so there is no swarf to get between the bolt head and the rod. The knurl serves really as an easy way of producing what amounts to a drive fit.

(*To be continued.*)

THE LATE DR. ANTON PHILIPS.—The president of the board of directors of Philips Electrical Industries, Eindhoven, Holland, Dr. Anton Frederik Philips, died on October 7 at the age of 77. Dr. Philips had been with the firm since the time when he took charge of its commercial side a few years after it had been founded, in 1891, by his brother, the late Gerard Philips.

FROTH FLOTATION OF COAL.

ONE result of the extension of mechanised coal-mining within recent times has been the production of greatly increased quantities of coal in the form of fines. Much of this coal is removed in the process of coal washing—a practice which is much commoner now than it was formerly—and finds its way into washery slurries, where it is mixed with a high proportion of dirt and has often been regarded as practically valueless. It has long been known, however, that fine coal, in common with other minerals, can be separated from dirt by froth flotation, a process which is commonly employed in ore-mining. As normally practised, this involves agitating and aerating slurry to which a small amount of one or more chemical agents has been added. The air bubbles in the liquid have a considerable affinity for the coal particles, but almost none for the dirt which, in consequence, remains in suspension or sinks to the bottom, whereas the coal is borne upwards by the air and held in the froth which forms on the surface of the liquid. Subsequently, it is collected, filtered and dried.

At present, only some 5 per cent. of coal-washeries in Great Britain are equipped with froth-flotation plants for up-grading slurries, but, with the spread in the practice of coal-washing and the paramount importance of obtaining the maximum yield of coal from the mines, increasing attention is being given to the mechanism of the flotation process and the number of froth-flotation plants is growing rapidly. In the past, the cost of the process has proved a deterrent to its use, but the present situation in the coal industry is such that it may prove economic to spend several shillings a ton on slurries if, by so doing, a product having a good market value for briquette making or boiler fuel can be produced. In 1945, no fewer than 2,395,000 tons of fines were recovered at 32 froth-flotation plants in Britain and, in recent years, froth flotation has found a limited but important application in the production of the super-clean coal used in the production of electrode carbon. There are two plants in operation in Britain for this purpose, one at Dumbreck in Scotland and the other at Crook, Co. Durham, which have a combined capacity of 20,000 tons per annum.

The application of froth flotation to coal-cleaning dates from about 1918. The equipment, which had been used since the beginning of the century for the similar treatment of mineral ores, was adapted to the purpose without any major modification in its design, and, since then, the process has remained largely empirical in spite of its simplicity and the fact that coal is more suited to froth flotation than most mineral ores. Lately, however, it has been studied on an experimental scale by the scientific staff of the Scottish Division of the National Coal Board, and, as a result, plant of improved design has been evolved, the operation of which was demonstrated to us recently at the Board's laboratories in Leith. A description of the research is also to be found in a paper entitled "Froth Flotation of Coal," which was read by Mr. E. Hindmarch and Dr. P. L. Waters, Area Chief Scientist and Divisional Analyst, respectively, at a meeting of the Mining Institute of Scotland held in Glasgow on September 19.

The "floatability" of a coal particle, or other substance, which is denser than water and, therefore, does not float naturally by buoyancy, depends on its resistance to wetting. This is a property determined by the physical and chemical nature of its surface and by the particle's internal structure; in particular, whether it is porous or not. Substances which resist wetting are termed "hydrophobic" and are chemically non-polar. A powder of such a substance sprinkled on a water surface will remain there. By contrast, chemically-polar compounds are hydrophilic, that is, they have an affinity for water and are easily wetted. Clays belong to this class, so that a clay powder sprinkled on a water surface will not remain dry but will become wetted and sink. Many substances, including coal, have intermediate properties. Owing to their complex structure, they are partly polar and partly non-polar, and their floatability is variable. The hydrocarbons in coal are non-polar and give the substance a natural floatability which, however, varies considerably with the rank of the coal. Low-rank coal contains a higher proportion of hydrophilic matter than high-rank coal and is, therefore, less readily floatable. The degree of porosity, which varies considerably in coals, also affects the floatability, since many coals contain clay minerals colloidally dispersed within them.

The angle of contact which an air or gas bubble, attached to the surface of a particle in a liquid, makes with the surface is a convenient measure of the force of adhesion between the bubble and the solid and, therefore, of the floatability of the solid in the liquid. The angle in question is that between the tangent planes to the surface of the solid and the bubble at each point of the contour of contact. For a homogeneous element of surface, the bubble, which may be considered small, has axial symmetry and the conditions approximate to

FROTH FLOTATION OF COAL.

Fig. 1. ANGLES OF CONTACT OF AIR BUBBLES IN WATER ON COAL, WAX AND CLAY.

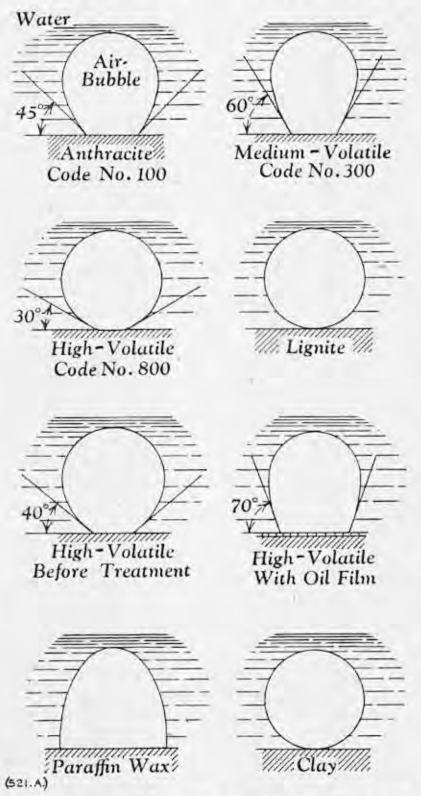


Fig. 2. EXPERIMENTAL LABORATORY FROTH-FLOTATION UNIT.

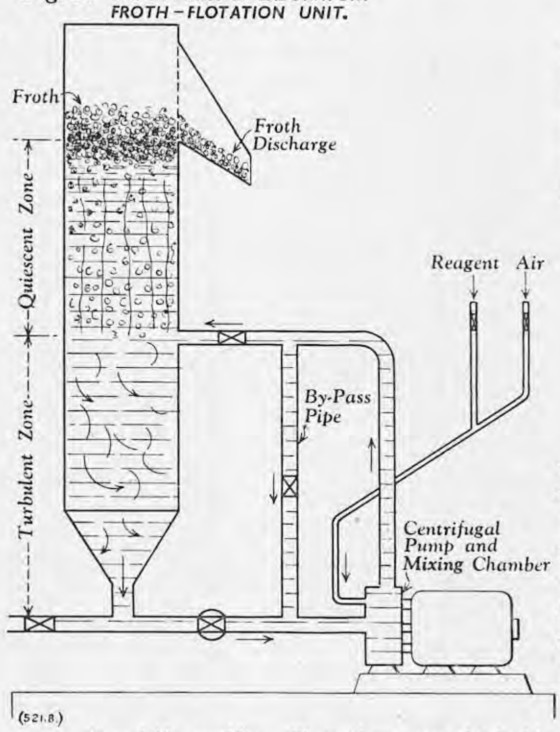
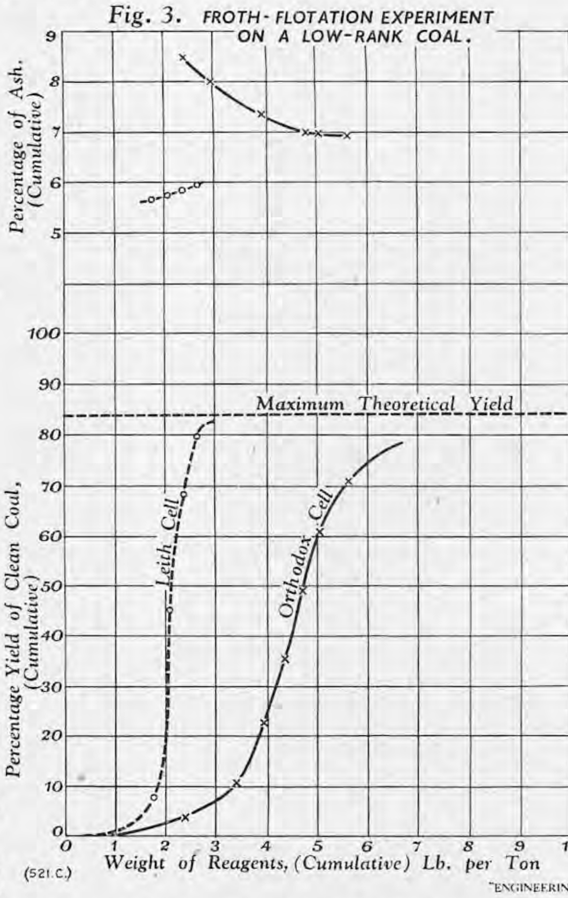


Fig. 3. FROTH-FLOTATION EXPERIMENT ON A LOW-RANK COAL.



those shown diagrammatically in Fig. 1, on this page. It will be seen that the angle in question is smaller for low-rank coals in contact with air and water than for those of higher rank, and that in the case of clay or shale particles, it is practically zero. For paraffin wax, however, it is almost 90 degrees and, in consequence, this substance is strongly hydrophobic. Clay and shale, on the other hand, are strongly hydrophilic; bubbles of air never become strongly attached to them and they are not floatable.

As has been mentioned already, the froth-flotation process involves aerating a liquid containing a mixture of particles having varying degrees of floatability, as defined above. The air bubbles tend to attach themselves to those particles which are strongly hydrophobic and these, in consequence, are lifted to the surface, while the hydrophilic constituents remain in suspension or sink to the bottom. Although coal is naturally hydrophobic, its affinity for air must be increased artificially before it can be floated satisfactorily. This is done by adding to the slurry mixture a small amount of oil, or other suitable agent, which coats the surface of the coal particles with a water-repellent film, but leaves the dirt and clay unaffected. Although, in theory, it would be necessary to add only sufficient agent to cover the particles with a monomolecular layer, in practice, the amount must be many hundred times more, possibly because much of the additive is absorbed within the interstices of the coal. Even so, the quantity is comparatively small and inexpensive. The floatability of any particular coal is somewhat variable and may be reduced considerably by weathering and storage which result in oxidation of coal surface. In such cases, it may be necessary to increase the amount of additive to secure a satisfactory yield from the froth-flotation plant, but the trouble does not occur regularly as flotation plants normally work continuously on freshly-mined coal.

In practice, a small amount of a frothing agent is added to the slurry in addition to the coating agent or "collector" mentioned above. Its purpose is to promote the formation of fine bubbles and a stable froth. Cresols, cresylic acid and pine oil are commonly used for the purpose and, in the case of higher-rank coking coals, may be employed as collectors as well as frothers. Other agents, known as depressants, are sometimes used to promote wetting of undesirable constituents, such as pyrites, which would otherwise float with the coal. Lime has been used for this purpose, although it tends to inhibit the floation of the coal. The main considerations in the choice of additives are cost and availability. Gas, Diesel, paraffin and fuel oils, as well as creosotes and other refined carbonisation oils, make suitable collectors on account of their good spreading properties and low viscosity, and also because they are insoluble in water and emulsify readily. Since these are obtainable from coke-ovens and gasworks, which are often close to washeries, they are commonly employed in flotation plants.

There are various types of plant which may be classified on the basis of the method employed to aerate the slurry. In the open type of cell, which is the one commonly used, the air is drawn down a central pipe into the eye of an impeller rotating in a horizontal plane at the base of the cell. The impeller agitates and circulates the slurry, and the amount of air entrained depends on the speed of rotation. The froth which forms on the liquid surface is discharged over a weir. One objection to this type of cell is that the unstable vortex created by the impeller terminates on the surface of the liquid, where it causes constant commotion and disturbs the froth. In the closed type of cell, a reduced pressure is maintained over the liquid and results in the release of dissolved air from the latter and gas from the porous interior of the coal. Another process, still in the experimental stage as applied to coal-flotation, is the pneumatic one. In this case, air under pressure enters the liquid through a porous membrane in the bottom of the container.

The experiments made in the Leith laboratories of the National Coal Board have been aimed at improving the process, and, in particular, at making it suitable for the treatment of low-rank coals. To achieve the maximum yield and efficiency, it is obviously necessary to be able to control accurately the quantities of air and additives and to ensure efficient mixing and aeration. Moreover, the time factor is important, since it has been established that there is both a minimum time necessary for efficient conditioning and mixing, and a maximum beyond which an excessive amount of additive is absorbed in the coal with a consequent reduction in efficiency.

There are several ways in which the air and additives may be introduced. If the slurry is pumped to the cell, a Venturi contraction may be installed in the pipe and the air taken in there directly from the atmosphere. Alternatively, an arrangement similar to that used in a vacuum filter-pump may be adopted, the air being drawn in at the contraction through a pipe fixed centrally within the other. This method was tried at Leith and found to give good mixing, the Reynolds number in the pipe being above the critical one for turbulent flow. The arrangement adopted finally was that shown in Fig. 2, on this page. The slurry is circulated by means of a centrifugal pump, and the air and reagents are drawn in at a point of low static pressure in the fluid, the turbulence arising in the impeller resulting in good mixing. The inlet to the cell is half-way up one side and, since the vorticity introduced at the pump is damped out by the time the flow has reached this point, the coal-laden bubbles are able to rise to the surface through a zone free from disturbance.

The cell, which was demonstrated to us in operation, has given very promising results. By comparison with orthodox laboratory cells, it is more efficient in many ways and gives better yields with less than half the amount of reagent normally necessary. The conditioning time is also reduced as a result of the more efficient mixing, and almost the maximum theoretical yield is obtainable in a short time, the product being also cleaner and more consistent in quality. Apart from the improved efficiency, the cell is of simpler design and easier to control than earlier types. The results obtained in the course of tests of the cell on low-rank coals (Group code numbers 800 and 900) derived from the Lothians coalfield are compared with those obtained using an orthodox cell in Table I, and in the graph, Fig. 3, on this page. It must be remembered, however, that the quantity of reagents required and the percentage yield depend not only on the coal but also on the average particle size, the range of sizes, the pulp density, and the pH value of the water, which must be strictly controlled.

TABLE I.—*Oil Required for Flotation.*

Coal.	Oil Required lb. per ton.		Group Code Number.
Anthracite	1	2½	100
Low-volatile .. .. .. Medium-volatile .. High-volatile, coking ..	— ¼ —	— 2 —	200 300 400
High-volatile, medium rank	1¼	5	500, 600, 700
High-volatile, low rank ..	4½	10	800, 900

It will be seen, from Fig. 3, that the yield is very sensitive to the amount of reagent added, particularly in the case of the Leith cell. It was shown that, in either case, the process could be divided into three stages In the first, the addition of a relatively large amount of reagent gave only a small yield of very fine coal. Then, when only a very little more reagent was added, a heavy middle fraction of low-ash coal was obtained which constituted the bulk of the yield. The addition of greater amounts of reagent gave only a small additional yield of larger-sized particles which were floated with difficulty. Whichever cell was employed, it was clear that a high yield of coal of less than 10 per cent. ash-content could be obtained by flotation methods from the slurries of the coals examined, and that the cost of reagent would not exceed 1*s.* 6*d.* per ton. The additional plant required for preparing the fine coal and disposing of the tailings, however, might prove sufficiently costly to make the whole process uneconomic.

As previously mentioned, flotation methods are also employed to produce super-clean coal of one per cent.

STANDARD 12-TON COVERED GOODS VAN.

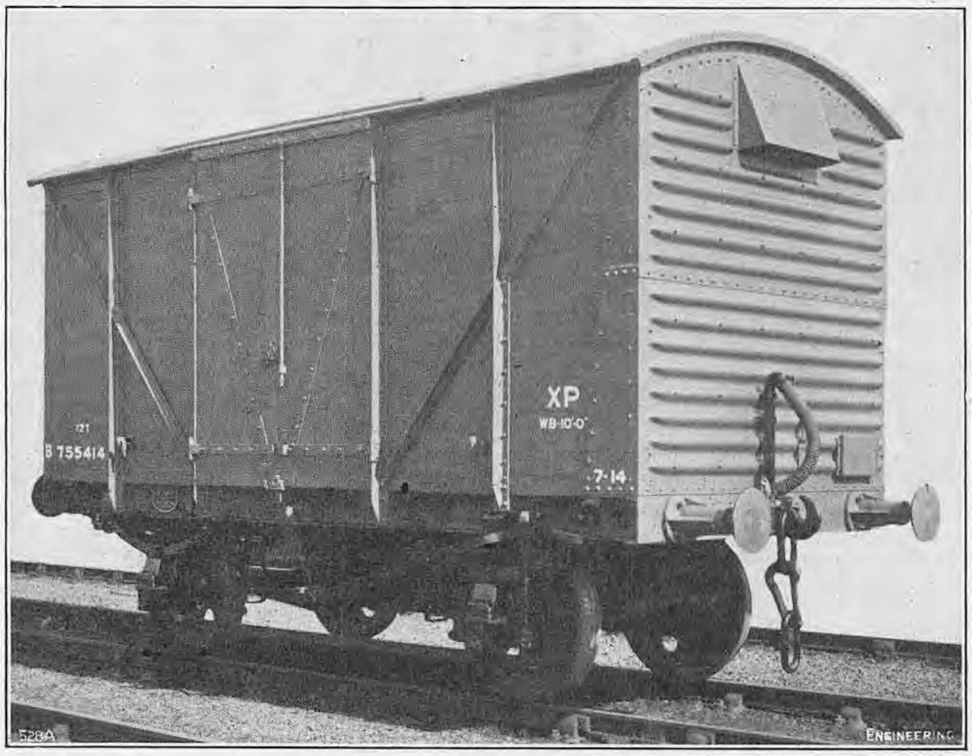


FIG. 1.

Fig. 2.

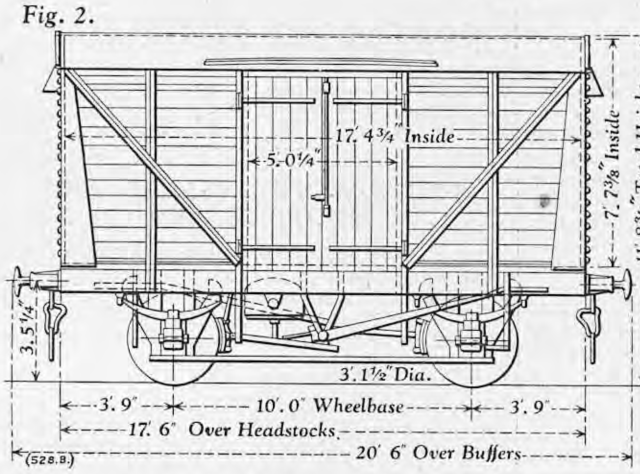
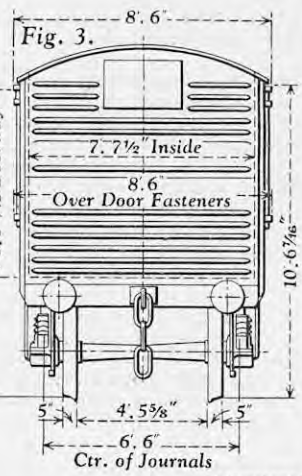


Fig. 3.



or less, ash content. Relatively few coals, of course, are suitable for cleaning to this degree, and the process inevitably involves preliminary grinding of the coal to the stage where the interbanded dirt is liberated. It is also important, however, that the particles should be of a size suitable for flotation, if froth flotation is to be employed for cleaning purposes. Milling down to very fine sizes is undesirable, since it consumes considerable power and results in the formation of a slime during frothing. In order to determine the optimum particle size and the point at which the interbanded dirt, as distinct from the inherent mineral matter in the coal, is liberated, the laboratory referred to undertook tests on a sample of the coal used in Scotland for the production of super-clean coal, namely, Kilsyth coking coal from Gartshore, Dunbartonshire. This had an ash-content of 9·2 per cent. and it was found that yields of coal exceeding 50 per cent. of the maximum possible and having an ash-content of less than one per cent. could be obtained by grinding the coal to sizes less than 20 mesh. Crushing the coal to very fine sizes did not greatly increase the yield.

Although the research has shown that most, if not all, ranks of fine coal can be up-graded satisfactorily by flotation methods and that the efficiency of the process, as practised at present, can be greatly improved, there are other factors to be considered. The economic one has already been mentioned. The authors of the paper, above referred to, think that if fines are required for briquetting, and a good price can be obtained for the briquettes, it may be worth spending 5*s.* to 10*s.* a ton to produce a coal having an ash-content less than 8 per cent. On the other hand, if the fines are merely to be used in a hand-fired Lancashire boiler, the cost of improving the coal can be set against the reduced boiler availability and the increased ash-handling when the untreated fines are used directly. The water-content of the froth-flotation product is slightly less than that of the untreated slurry, but the quantity and properties of the ash are more important considerations.

The authors hope to continue their experiments on a larger scale and, meantime, have prepared a sketch-plan of an improved flotation plant for the production of super-clean coal.

IRON AND STEEL PRODUCTION IN GREAT BRITAIN.—Statistics issued by the British Iron and Steel Federation, Steel House, Tothill-street, London, S.W.1, show that the production of steel in the United Kingdom, during September, was at an annual rate of 15,749,000 tons, compared with 13,855,000 tons in August and 16,964,000 tons in September, 1950. The output of pig iron was at an annual rate of 9,854,000 tons in September, compared with 9,409,000 tons in August, and 9,712,000 tons in September, 1950.

PACKING RAILWAY TRACK BALLAST.—Electric hammers have been used for some time on the Western Region of British Railways for consolidating ballast under the timbers of points and crossings. It has been found that this method is superior to the normal use of shovels, as the spaces between the timbers are narrow and there is not much room between the rails. The regional authorities have therefore decided to obtain a further 60 hammers, which are made by Kango Hammers, Ltd. The tamping tool used in the hammer is a ⅝-in. diameter steel shaft with a cranked end and a tamping head, the purpose of the cranking being to reach under the timbers. The ballast around the timbers is first removed; the track is then raised by jacks, and the ballast underneath is consolidated, usually by pairs of hammers, one on each side of the timber.

STANDARD 12-TON COVERED GOODS VAN, BRITISH RAILWAYS.

ONE of the first types of British Railways standard wagons to appear is that shown in the accompanying illustrations—a 12-ton covered ventilated goods van for normal merchandise traffic. It has been designed at the Western Region offices at Swindon, and 3,000 vans of this design are to be built at the Wolverton works of the London Midland Region this year.

Though there was not much standardisation of wagons as between the railway companies before nationalisation, wagon details were standardised to a considerable extent under the ægis of the Railway Clearing House and there was also a limited range of standard vehicles, mainly for private owners. Thirty-four new designs for complete wagons, incorporating the best practices of the former companies, have been prepared to the requirements of Mr. R. A. Riddles, member for mechanical and electrical engineering of the Railway Executive, in conjunction with the Wagon Standards Committee.

The general layout and chief dimensions of the new wagon are shown in Figs. 2 and 3. It is 17 ft. 6 in. long over the headstocks and, like most of the earlier wagons of this type, has a 10-ft. wheelbase. The tare weight is 7 tons 11 cwt., the cubic capacity is 940 cub. ft., and the load is, of course, 12 tons. The van is mainly of riveted construction; the underframe and body members are of B.S. rolled-steel sections, and the body ends are of steel plate pressed to a corrugated section and formed with a wide flange which is bolted to the side "quarters." Each end plate is in two parts, the upper ⅛ in. thick and the lower $\frac{3}{16}$ in. thick, which are riveted together horizontally. Spindle-type buffers of the standard type are fitted; they are provided with either rubber or steel coil springs behind the headstocks. The short drawgear embodies either rubber or rubber-and-steel springs. "Instanter" couplings are fitted, allowing either long or short connections; this type of coupling has now been standardised for almost all vacuum-brake stock for future construction, in place of screw couplings.

The brake gear consists of an 18-in. diameter vacuum-brake cylinder for fast freight working and a Morton hand-brake actuated from either side of the wagon; both hand and power braking applies one brake block per wheel. Solid-rolled steel wheels, 3 ft. 1½ in. in diameter, are fitted on axles with 9-in. by 4½-in. journals, which run in either cast-iron axleboxes of the spigot type or open-fronted axleboxes of fabricated construction. The bodies are sheeted in softwood, a double layer of ⅝-in. boards on the quarters, with a single-thickness lining inside the steel ends. Hardwood rails are fitted on the side quarters on top, bottom and intermediate portions. The floor is of 2⅞-in. boards, and the roof, of ⅞-in. boards covered with roofing canvas, is laid on hardwood hoop-sticks bolted to the steel carlines. As an alternative to the ⅞-in. roof boards, ⅝-in. resin-bonded plywood, scarf-jointed to form one panel, may be fitted over the whole roof. A hooded ventilator is provided at each end.

"THE OLD N'IONS."—The Northampton Engineering College (Clerkenwell) Past Students' Association, known as "The Old N'Ions," are to hold their 24th annual dinner and reunion on Friday, November 30, at the Connaught Rooms, London, W.C.2. The guests of honour will be Dr. W. G. Radley (engineer-in-chief, G.P.O.) and Mr. C. I. Orr-Ewing (technical director, Messrs. A. C. Cossor, Ltd.). Past students of the college can obtain tickets from Mr. R. W. C. Gilbert, 6, Ella-road, London, N.8.

ACCIDENT TO DAKOTA AIRCRAFT AT MANCHESTER.—On March 27, a Dakota transport aircraft operated by Air Transport (Charter) (C.I.), Limited, on a night newspaper service between Manchester and Belfast, crashed immediately after taking off; the aircraft did not catch fire. The pilot and first officer, the only occupants, were both killed. At the time of take-off, snow was falling, the air temperature was 34·2 deg. F., and the relative humidity was 97 per cent.—conditions favourable to rapid ice formation in the carburettor. In his *Report on the Accident to Dakota (C.47) G-AJVZ which Occurred on 27th March, 1951, near Ringway Airport, Manchester*, published recently by H.M. Stationery Office, Kingsway, London, W.C.2 (price 1*s.* 6*d.* net), the Chief Inspector of Accidents concludes that the aircraft was unable to gain height after becoming airborne; this is attributed to loss of engine power caused by ice formation due to the aircraft captain's failure to use the carburettor heat controls (which, when operated, direct hot air to the carburettor intake from a duct behind the cylinders into which snow cannot enter). It is also suggested that the facts that the undercarriage was not retracted and that snow had not been cleared from the wings before take-off might have been contributory factors.

NOTES FROM THE INDUSTRIAL CENTRES.

SCOTLAND.

SCOTTISH STEEL PRODUCTION.—Steel production in Scotland is still seriously handicapped by an insufficiency of scrap, and makers have difficulty in maintaining ingot outputs at the 80 per cent. standard introduced in May of this year. Pig-iron production has been improved, however, as a result of better imports of iron ore. Few steel consumers have now any appreciable reserve stocks at their disposal as a result of the cut in supplies, despite a reduction in exports during the past two quarters. Some apprehension exists among those not participating as fully as others in rearmament work as the time approaches for the introduction of the new rationing scheme on December 3.

GAS AND ELECTRICITY CONSUMPTION.—The mild conditions this autumn were reflected in an appreciable drop in the consumption of gas in Scotland recently, as compared with 1950. The decline amounted to 2 per cent. in the last week of September and to 1 per cent. in the subsequent week, as opposed to an average increase of some 4 per cent. since the beginning of the year. Electricity generation was similarly affected, and, for most of September, was just under last year's level. This contrasted with an average increase of around 9 per cent. since January.

ELECTRICITY-SUPPLY DIFFICULTIES.—"Teething troubles" at the new generating stations of Clydesmill, Braehead, and Portobello were forecast by Mr. Charles Murdoch, chairman of the Scottish Board for Industry, presiding at a meeting of employers and trade-union representatives, held in Glasgow on September 29, in connection with electricity supplies during the winter. He emphasised that if industry made the 20 per cent. reduction of consumption asked for between November and February it did not necessarily mean there would be no load shedding or cuts. There was every reason to believe that November and December were going to be difficult months in Scotland.

EXTENSION TO HOOVER WORKS.—A second factory extension at the Cambuslang works of Hoover (Electric Motors), Ltd., is planned to come into operation towards the end of this year. Output, which rose by 50 per cent. with the first extension 18 months ago, is expected to increase again at about this same rate. Home sales, this year, are so far about 85 per cent. above the corresponding sales of 1950, and exports, which are about 60 per cent. of production, have risen by more than 150 per cent. The Cambuslang factory now also supplies the motors for the firm's output of washing machines built in Wales.

THE PRODUCTION OF STYRENE.—Forth Chemicals, Ltd., who are constructing a plant at Grangemouth for the production of monomeric styrene, have decided to proceed with an extension to increase substantially the production of this material, for which there is a large potential demand in the plastics industry. The original plant is expected to come into production next year, and the extension about two years later. Ethylene, one of the raw materials of monomeric styrene, will be supplied from the new cracking plant recently commissioned by British Petroleum Chemicals, Ltd.

DUNOON-GOUROCK FERRY.—It has been announced that a new ferry boat proposed to be built for service between Dunoon and Gourock will be able to handle vehicles of 7½ tons weight, instead of 6 tons as proposed at first. The future of Dunoon, Cowal and the West Highlands would depend on the successful operation of this ferry, it was stated at a meeting of Dunoon Town Council. The question of ferries is to be discussed at the Clyde Coast conference at Gourock at the end of this month.

CLEVELAND AND THE NORTHERN COUNTIES.

TEES-SIDE IRON AND STEEL INDUSTRY.—Iron and steel producers in the Tees area are still seriously hampered by the scarcity of raw materials and of cast iron and sheet-steel scrap. Present conditions maintain outputs of pig iron and of semi-finished and finished iron and steel much below customers' current heavy requirements and an early material improvement in the unsatisfactory position is not yet in sight. On the other hand, stocks of foreign iron-ore are accumulating at a rate that promises to provide ample supplies over the winter months, when imports are usually smaller.

A. REYROLLE & CO., LTD.—Nearly 500 employees of A. Reyrolle & Co., Ltd., having 25 or more years service with the company, were entertained to dinner by the directors on Wednesday, October 10, at the Old Assembly Rooms, Newcastle-on-Tyne, when the chairman, Sir Claude D. Gibb, C.B.E., D.Sc., F.R.S., presented gold wristlet watches to 38 employees who had completed over 40 years service.

LANCASHIRE AND SOUTH YORKSHIRE.

MINING MAN-POWER SHORTAGE.—The recruitment of miners in Yorkshire is now approximately counter-balancing wastage. The man-power target set for Yorkshire mines is another 3,500 before the end of the year, but even if this is achieved there will be fewer miners in the county than there were two years ago. The lowest total for many years was reached in November, 1950, when numbers fell to 134,000. Now the total has risen by 2,000 only. The big disappointment is the continued opposition, in many parts of the coalfield, to the entry into the pits of Italians, who have been specially trained at Maltby, South Yorkshire, at considerable expense.

CONTINUED SHORTAGE OF STEEL.—Many users of steel, in Sheffield, Rotherham and elsewhere, are still short of supplies, and the output of melting materials is not increasing sufficiently to justify the restarting of open-hearth furnaces which were shut down some little time ago. It is understood that Belgium has been asked to send to this country an additional 50,000 tons of steel.

LOAD-SHEDDING PLAN.—The deputy chairman of the Yorkshire Electricity Board, Mr. F. Newey, states that the Board hope to operate a very much better load-shedding system this winter than last, when power was cut on 142 days. There will be, however, no lessening of the shortage of generating capacity at peak periods; as during last winter, the demand is expected to exceed the supply by 20 per cent. The Board may have to refuse additional industrial loads and the provision of supplies to some mining villages where an adequate supply of gas is available.

TREES TO MASK A TIP.—As a result of discussions between the Sheffield and Peak District branch of the Council for the Preservation of Rural England and representatives of Samuel Fox & Co., Ltd., steelmakers, Stocksbridge, near Sheffield, trees are to be planted to mask the southern end of a tip which extends along the Don Valley to Morehall, near Deepcar. The necessary arrangements have to be made with land-owners. The trees will hide the tip from the roadway and from the entrance to the Ewden Valley, a noted beauty spot.

NOVEL PIT LOADER.—A new type of underground power loader is operating up and down a shallow seam having a gradient of 1 : 4, at Silverhill Colliery, Nottinghamshire. It is known as the multi-disc loader and is built on a normal coal cutter, so that coal is cut and loaded simultaneously.

TELEPHONE EXCHANGE AT MANCHESTER VICTORIA STATION.—The combined manual and automatic telephone exchange at Victoria Station, Manchester, has been renewed and modernised at a cost of 27,000*l*. The new equipment includes a 10-position manual switchboard and a 450-line automatic exchange, and has been made and installed by the General Electric Co., Ltd., Coventry, with the assistance of British Railways staff and under the supervision of Mr. S. Williams, signal and telecommunications engineer of the London Midland Region.

THE MIDLANDS.

STUDY OF AMERICAN INSPECTION METHODS.—A productivity team of eight, which left England on October 9 to study American inspection methods, contains four members from the Midlands. They are Mr. A. Heward, of W. and T. Avery, Ltd., Soho Foundry; Mr. S. W. Nixon, of the Rover Co., Ltd., Solihull; Mr. F. J. Mills, of James Booth & Co., Ltd., Nechells, Birmingham; and Mr. P. R. Snadden, from the Rugby works of the British Thomson-Houston Co., Ltd.

THE INSTITUTE OF VITREOUS ENAMELLERS.—Dr. H. Hartley, chairman of Radiation, Ltd., Birmingham, has been elected to succeed Dr. J. E. Hurst as President of the Institute of Vitreous Enamellers. He will take office next year when Dr. Hurst retires from the office of President.

THE TALYLLYN RAILWAY.—The Talyllyn Railway Preservation Society, which was formed by a Birmingham group of light-railway enthusiasts to prevent closure of the railway, has issued its first annual report. The report shows that, though it was only possible to run trains on five days a week, because maintenance and repair work carried out by volunteers occupied the week-ends, 358 trains had been run, and 15,628 passengers carried. The line has been put into repair for its whole length, from Towyn, Merionethshire, to Abergynolwyn, a distance of seven miles. Traffic has now been suspended for the winter months, during which further maintenance work and improvements will be effected.

BIRMINGHAM CITY AIR TERMINAL.—A new building has been erected in Birmingham for a city air terminal, and will be opened on October 30. It is adjacent to the Civic Centre, in Cambridge-street, and will act as a centre for passengers travelling to and from the City Airport at Elmdon. Representatives of the three air lines using the Airport—B.E.A., K.L.M., and Air France—will be accommodated at the terminal.

AN UNUSUAL PIPE-LAYING OPERATION.—The preparation of a trench for an 18-in. diameter gas main across the River Neath, in Glamorgan, was accomplished on October 9 by simultaneous detonation of two lines of explosive charges laid in the river bed. Site conditions made conventional methods either impracticable or too expensive, and the instantaneous blasting of the trench, to accommodate a pipe-line nearly 300 ft. long, was decided upon as an alternative. The explosion took place at low tide, and about 1,000 lb. of explosive were used. Some 120 separate charges were laid, the weights of individual charges being varied according to the nature of the ground, which was partly mud and gravel, and partly rock.

THE LATE MR. W. B. PARKER, F.R.I.C.—We regret to record the death, on October 12, of Mr. William Bayley Parker, who was chief chemist and metallurgist of the British Thomson-Houston Co., Ltd., from 1902 until 1943, when he was appointed consultant chemist and metallurgist. He was 77 years of age. Mr. Parker, who was a native of Smethwick, received his technical training at the Birmingham Central Technical School, where he was awarded a Priestley Scholarship in 1897, which enabled him to continue his studies at Mason's University College (now the University of Birmingham). He spent seven years with the Patent Borax Company before joining the B.T.H. staff. He was a Fellow of the Royal Institute of Chemistry and of the Chemical Society, and was one of the oldest members of the Institute of Metals and the British Institute of Foundrymen.

SOUTH-WEST ENGLAND AND SOUTH WALES.

COAL OUTPUT STATISTICS.—Man-power in the South Wales coalfield on September 29 was 101,099, a drop of 155, according to official statistics. The output of coal, in the week ended October 6, was 471,247 tons, compared with 463,324 tons in the previous week, and 463,935 tons in the corresponding period of last year.

REGIONAL COLLEGE OF TECHNOLOGY, SWANSEA.—Following consultations with the Ministry of Education, Swansea is to establish a regional college of technology, to be built in the centre of the town, at an estimated cost of 250,000*l*. It was reported at a meeting of the town education authority that work would be started soon, and that the Ministry had stipulated that the work should be carried out by a private architect.

RE-OPENING OF WHITFORD WORKS.—The Whitford Works, Briton Ferry, of Richard Thomas and Baldwins, Ltd., which became redundant last July, have been converted for light-alloy production. The plant will become a fabricating works, similar to the group's Cwmfelin press and fabricating works at Swansea. Work has begun, according to an official, "in a modest way" by training employees.

PUBLIC WORKS IN CARDIFF.—Tentative estimates of next year's expenditure on capital works already in progress or planned for 1952-53, presented to Cardiff Corporation public works committee, included a total of more than 248,900*l*. for road improvements and street works in the city. A sum of 18,000*l*. has been earmarked for the widening of Hill's-terrace, in the centre of the town, by filling in a stretch of the old Glamorganshire Canal.

THE LATE ALDERMAN G. WILLIAMS, C.B.E.—Last year's Lord Mayor of Cardiff, Alderman George Williams, C.B.E., who was one of those who suggested the formation of the Treforest Trading Estate as a means of attracting new industry to South Wales, died in Cardiff on October 7, at the age of 71. He was the author of the scheme for financing light industries which led to the formation, by the Government, of the Special Areas Reconstruction Association. He was chairman of the National Industrial Development Council of Wales and Monmouthshire from its inception in 1931. On the City Council he had been chairman of the estate committee (responsible for the building of Corporation houses), the development committee, and the airport committee.

NOTICES OF MEETINGS.

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

INSTITUTION OF ELECTRICAL ENGINEERS.—*Institution:* Monday, October 22, 5.30 p.m., Savoy-place, London, W.C.2. Informal Discussion on "The Place of Electricity in a National Fuel Policy," opened by the President. *North-Eastern Centre:* Monday, October 22, 6.15 p.m., Neville Hall, Westgate-road, Newcastle-upon-Tyne. "The Performance of the British Grid System in Thunderstorms," by Dr. J. S. Forrest. *Mersey and North Wales Centre:* Monday, October 22, 6.30 p.m., Town Hall, Chester. "Electrical Control of Dangerous Machinery and Processes: Part II—Electrically Interlocked Guards on Machines," by Mr. W. Fordham Cooper. *Measurements Section:* Tuesday, October 23, 5.30 p.m., Savoy-place, London, W.C.2. Chairman's Address, by Mr. F. J. Lane. *North Midland Centre:* Tuesday, October 23, 6 p.m., Lighting Service Bureau, 24, Aire-street, Leeds. Discussion on "Visual Aids—Help or Hindrance?" opened by Mr. D. Polak. *East Midland Centre:* Tuesday, October 23, 6.30 p.m., Gas Department Demonstration Theatre, Nottingham. "The Planning of an Electricity Board's Distribution System," by Mr. G. O. McLean. *Scottish Centre:* Tuesday, October 23, 7 p.m., Institution of Engineers and Shipbuilders, 39, Elmbank-crescent, Glasgow. "The Protection of Electrical Power Systems—A Critical Review of Present-Day Practice and Recent Progress," by Messrs. H. Leyburn and C. H. W. Lackey. *South Midland Centre:* Tuesday, October 23, 7.15 p.m., Winter Gardens Restaurant, Malvern. "The Determination of Time and Frequency," by Mr. Humphry M. Smith. *Southern Centre:* Wednesday, October 24, 6.30 p.m., Dorset Technical College, Weymouth. "The Sutton Coldfield Television Broadcasting Station," by Messrs. P. A. T. Bevan and H. Page. *Utilisation Section:* Thursday, October 25, 5.30 p.m., Savoy-place, London, W.C.2. Chairman's Address, by Mr. A. H. Young. *Scottish Centre:* Thursday, October 25, 7.15 p.m., Temperance Hotel, Lint Riggs, Falkirk. "Lightning," by Professor F. M. Bruce.

INSTITUTION OF PRODUCTION ENGINEERS.—*Manchester Section:* Monday, October 22, 7.15 p.m., College of Technology, Sackville-street, Manchester. "Some Tapping Experiments—Accurate Thread Production and Breakage Elimination," by Mr. E. Johnson. *Coventry Section:* Tuesday, October 23, 7 p.m., Geisha Café, Hertford-street, Coventry. "Factory Layout," by Mr. R. Gore. *South Wales Section:* Thursday, October 25, 6.45 p.m., South Wales Institute of Engineers, Park-place, Cardiff. "The Craftsmanship of Output as Applied to the Processing of American Brassfoundry Work," by Mr. F. E. Rattlidge.

CHEMICAL SOCIETY.—*Oxford Section:* Monday, October 22, 8.15 p.m., Physical Chemistry Laboratory, South Parks-road, Oxford. Alembic Club Lecture, "Some Equilibria and Reactions of Sulphur," by Dr. G. Gee. *Liverpool Section:* Thursday, October 25, 4.30 p.m., Chemistry Lecture Theatre, The University, Manchester. Joint Meeting with ROYAL INSTITUTE OF CHEMISTRY, SOCIETY OF CHEMICAL INDUSTRY and BRITISH ASSOCIATION OF CHEMISTS. "Some Recent Work on Large Ring Compounds," by Professor Wilson Baker. *Hull Section.:* Thursday, October 25, 6 p.m., Science Lecture Theatre, University College, Hull. "Some Methods of Measuring Reaction Velocities in Solution," by Mr. R. P. Bell. *Aberdeen Section:* Thursday, October 25, 7.30 p.m., Chemistry Department Marischal College, Aberdeen. Joint Meeting with ROYAL INSTITUTE OF CHEMISTRY and SOCIETY OF CHEMICAL INDUSTRY. "Applications of Electric Dipole Moments to the Determination of Structure," by Dr. L. E. Sutton. *Glasgow Section:* Friday, October 26, 3.30 p.m., Chemistry Department, The University, Glasgow. Joint Meeting with ALCHEMISTS' CLUB and ANDERSONIAN CHEMICAL SOCIETY. "Chemicals as a Source of Energy, with Special Reference to Industrial Applications and to Jet Propulsion," by Dr. J. Taylor. *Birmingham Section.* Friday, October 26, 4.30 p.m., Chemistry Lecture Theatre, The University, Edgbaston. Joint Meeting with the UNIVERSITY CHEMICAL SOCIETY. "Some Aspects of Oxidation and Corrosion," by Dr. U. R. Evans.

INSTITUTION OF CIVIL ENGINEERS.—*Public Health Engineering Division:* Tuesday, October 23, 5.30 p.m., Great George-street, London, S.W.1. "Relation Between Daily Rainfall and Flow of the River Shin," by Mr. R. H. MacDonald. *Midlands Association:* Wednesday, October 24, 7 p.m., Loughborough College, Loughborough. Chairman's Address, by Mr. Vincent Daviss.

INSTITUTE OF REFRIGERATION.—Tuesday, October 23, 5.30 p.m., Institution of Mechanical Engineers, Storey's Gate, St. James's Park, London, S.W.1. "Some Aspects of the Problem of Reciprocating Compressor Design," by Eng.-Commander W. R. Sinclair, R.A.N., and Mr. C. E. Wade.

SOCIETY OF CHEMICAL INDUSTRY.—*Chemical Engineering Group:* Tuesday, October 23, 5.30 p.m., Geological Society, Burlington House, Piccadilly, London, W.1. "Some Sulphur Recovery Processes in Refining Operations," by Mr. G. M. Rowell.

INSTITUTION OF ENGINEERS AND SHIPBUILDERS IN SCOTLAND.—Tuesday, October 23, 6.30 p.m., 39, Elmbank-crescent, Glasgow. "Marine Developments in Aluminium," by Mr. J. Venus.

INSTITUTE OF METALS.—*Sheffield Local Section:* Tuesday, October 23, 7 p.m., Grand Hotel, Sheffield. Joint Meeting with SHEFFIELD METALLURGICAL ASSOCIATION. Lecture by Dr. P. A. Taylor. *Manchester Metallurgical Society:* Wednesday, October 24, 6.30 p.m., Engineer's Club, Albert-square, Manchester. "Recent Developments in Electrically Welded Chains," by Dr.-Ing. H. O. Smerd. *Birmingham Local Section:* Thursday, October 25, 7 p.m., James Watt Memorial Institute, Great Charles-street, Birmingham. Debate on the motion "That in the Opinion of this House Further Encroachment of Metal Physics into the Sources of Instruction would be Detrimental to Training in Metallurgy," opened by Dr. J. W. Jenkin and Mr. H. W. G. Hignett.

INSTITUTE OF ROAD TRANSPORT ENGINEERS.—*North East Centre:* Tuesday, October 23, 7 p.m., Dunelm Hotel, Durham City. "The Repair and Maintenance of Vehicles by Oxy-Acetylene Processes," by Mr. J. Lewis.

JUNIOR INSTITUTION OF ENGINEERS.—Wednesday, Thursday and Friday, October 24, 25 and 26, 9.30 a.m. to 7.30 p.m. (last day to 8.30 p.m.), 39, Victoria-street, London, S.W.1. Exhibition, further particulars of which are given in a paragraph on page 500, in this issue. Friday, November 2, 6.30 p.m., 39, Victoria-street, London, S.W.1. Film evening, "Concrete" and "Moving Earth," introduced by Mr. H. E. Hodgson.

ROYAL UNITED SERVICE INSTITUTION.—Wednesday, October 24, 3 p.m., Whitehall, London, S.W.1. Lecture, "The Land Campaign in Korea," by Major-General B. A. Coad.

INSTITUTION OF STRUCTURAL ENGINEERS.—Wednesday, October 24, 5.55 p.m., 11, Upper Belgrave-street, London, S.W.1. "Some New Developments in Prestressed Concrete," by Dr. P. W. Abeles. *Midland Counties Branch:* Friday, October 26, 6 p.m., James Watt Memorial Institute, Birmingham. Chairman's Address, by Mr. W. H. Veal.

LIVERPOOL ENGINEERING SOCIETY.—Wednesday, October 24, 6 p.m., 24, Dale-street, Liverpool. "The Gerritsen Gear," by Mr. J. J. Gerritsen.

ROYAL STATISTICAL SOCIETY.—*Industrial Applications Section, Birmingham Group:* Wednesday, October 24, 6.45 p.m., Chamber of Commerce, 95, New-street, Birmingham. "Statistics in Trouble Shooting," by Dr. E. A. G. Knowles. *Sheffield Group:* Thursday, October 25, 6.30 p.m., Cavendish Room, Grand Hotel, Sheffield. "A Comparison of Different Methods of Inspection," by Mr. B. H. P. Rivett.

INSTITUTE OF INDUSTRIAL ADMINISTRATION.—*London Centre:* Wednesday, October 24, 7 p.m., Management House, 8, Hill-street, Berkeley-square, London, W.1. "Management in Practice: No. 2. Attitudes," by Mr. S. Waugh.

INCORPORATED PLANT ENGINEERS.—*South Yorkshire Branch:* Thursday, October 25, 7.30 p.m., Grand Hotel, Sheffield. "Steelmaking from the Plant Engineer's Viewpoint," by Mr. F. Hinsley. *Birmingham Branch:* Friday, October 26, 7.30 p.m., Imperial Hotel, Birmingham. "Feed Water Treatment," by Mr. B. Pocock.

INSTITUTION OF MECHANICAL ENGINEERS.—Friday, October 26, 5.30 p.m., Storey's Gate, St. James's Park, London, S.W.1. Discussion on "The Principles of Continuous Gauge Control in Sheet- and Strip-Rolling," by Messrs. W. C. F. Hessenberg and R. B. Sims.

NORTH EAST COAST INSTITUTION OF ENGINEERS AND SHIPBUILDERS.—Friday, October 26, 6.15 p.m., Stephenson Building, King's College, Newcastle-upon-Tyne. "Photography at Sea of Ship-Propeller Cavitation," by Dr. J. W. Fisher.

INSTITUTION OF MINING ENGINEERS.—Saturday, October 27, 11.15 a.m., Prince of Wales Hotel, Harrogate. "Strata Control and the Influence on Underground and Surface Damage," by Major N. E. Webster.

PRODUCTIVITY TEAMS.—A productivity team on the technique of production control, and another on metal-working machine tools, have recently sailed to the United States. The 12 members of the first-mentioned team are led by Mr. G. H. Way (Dunlop Rubber Co., Ltd.); the deputy leader is Mr. T. L. Nuttall (Ford Motor Co., Ltd.), and the joint secretaries are Mr. F. Kay (Forestal Land, Timber & Railways Co.) and Mr. E. J. Thomas (A.E.C., Ltd.). The team which is to study metal-working machine tools consists of 15 members, of whom Mr. R. D. G. Ryder (Thos. Ryder & Son, Ltd.) is the leader and Mr. F. H. Harris (B.S.A. Tools, Ltd.) is the secretary.

PERSONAL.

H.R.H. THE DUKE OF EDINBURGH, K.G., F.R.S., has accepted honorary membership of the British Institution of Radio Engineers, 9, Bedford-square, London, W.C.1.

BRIGADIER P. LE M. S. STONHOUSE-GOSTLING, military commanding officer and deputy chief engineer, Armament Design Establishment, Ministry of Supply, has been appointed vice-president of the Ordnance Board, with the temporary rank of Major-General. The appointment takes effect in February, 1952.

MR. J. A. ORIEL, C.B.E., M.C., B.Sc., M.A., F.R.I.C., M.I.Chem.E., recently general manager of Shell Refining & Marketing Co., Ltd., and MR. G. ORMSBY PEARCE, M.C., recently managing director of African Explosives & Chemical Industries, Ltd., have joined the board of W. J. Fraser & Co., Ltd., chemical engineers, Dagenham, Essex.

MR. H. P. POTTS, M.I.Mech.E., has been appointed managing director of the B.S.A. Tools Group of Companies in succession to the late MR. JAMES E. MACLAREN.

MESSRS. J. D. and D. M. WATSON, 18, Queen Anne's-gate, Westminster, S.W.1, have now taken into partnership MR. G. MARTIN SWAN, B.Sc., A.C.G.I., A.M.I.C.E., M.A.San.I.

MR. C. F. CLEAVER, M.I.C.E., M.I.Mech.E., M.I. Loco.E., having reached the retiring age, has relinquished the office of manager, railcars, but remains a director of A.C.V. Sales, Ltd., Southall, Middlesex.

MR. DONALD KING has been appointed chairman of the Globe Pneumatic Engineering Co., Ltd., 58, Victoria-street, London, S.W.1. COLONEL J. H. ANDERSON, R.E., has also been appointed to the board.

MR. RALPH CREDLAND, assistant managing director of the Widnes Foundry & Engineering Co., Ltd., for the past four years, has been appointed joint managing director.

MR. F. W. COOPER, A.M.I.Mech.E., M.I.P.E., who is at present head of the engineering department at the Chance Technical College, Smethwick, Staffordshire, has been appointed Principal of the College, in succession to MR. H. GARRATT, B.Sc., who retires in December, 1951.

MR. IVOR W. SHELLY, M.I.Mar.E., has joined the staff of the marine sales department of J. Stone & Co. (Charlton) Ltd., Oceanic House, 1A, Cockspur-street, London, S.W.1.

MR. S. A. GHALIB has been appointed assistant chief engineer, electronic control department, Metropolitan-Vickers Electrical Co., Ltd., Trafford Park, Manchester, 17.

MR. S. M. LAWRENCE has been appointed assistant sales manager, unwrought and special products, the British Aluminium Co., Ltd., Salisbury House, London Wall, E.C.2, in place of MR. R. M. WARRINGTON, who is relinquishing his appointment with the company on October 31. MR. O. M. BRUCE PAYNE has taken over responsibility for the technical-service section of the development department, under the development manager, in place of Mr. Lawrence.

MR. E. J. WILSON, until recently assistant engineer to the Port of London Authority, has been appointed London office manager to Richard Sutcliffe Ltd., Horbury, Wakefield, at 235, Vauxhall Bridge-road, S.W.1 (Telephone: VICtoria 0844).

MR. A. T. GRAY, secretary, and MR. H. C. LEACH, works manager, have been appointed to the board of directors of Seagers Ltd., Dartford, Kent.

MR. W. N. DUFFY has been appointed publicity manager of Ferranti Ltd., Hollinwood, Lancashire, in succession to MISS H. S. O'B. HOARE.

MISS ROSEMARY GARLAND has been appointed publicity officer to the Glass Manufacturers' Federation, 17, Manchester-street, London, W.1.

MR. J. M. DRUMMOND has been appointed a deputy chief accountant of the British Electricity Authority.

MR. J. L. VAUGHAN has been appointed director of the process engineering department of the National Research Corporation, Cambridge, Massachusetts, U.S.A.

The new address of RUBBER-STICHTING is Oostsingel 178 (Postbus 66), Delft, Holland.

The firm of FLEXIBLE NON-METALLIC CONDUITS LTD., of Tottenham Court-road, W.1, has been reorganised for increased production, with a change of name to GILFLEX CONDUITS LTD. A trade counter is being set up at 41, The Parade, High-street, Watford, and the main offices are also being moved to this address.

JOHNSON & PHILLIPS, LTD., Charlton, London, S.E.7, are transferring their Ipswich branch, on Monday, October 22, to larger premises at 17, St. Nicholas-street. (Telephone: Ipswich 3417.)

SUNVIC CONTROLS LTD., 10, Essex-street, Strand, London, W.C.2, have made arrangements to manufacture and sell, throughout the British Commonwealth with the exception of Canada, the range of pneumatic process-control instruments made by MOORE PRODUCTS CO., Philadelphia, U.S.A.

DIESEL-ENGINED 50-FT. GENERAL-SERVICE LAUNCH.

JOHN I. THORNYCROFT AND COMPANY, LIMITED, LONDON.

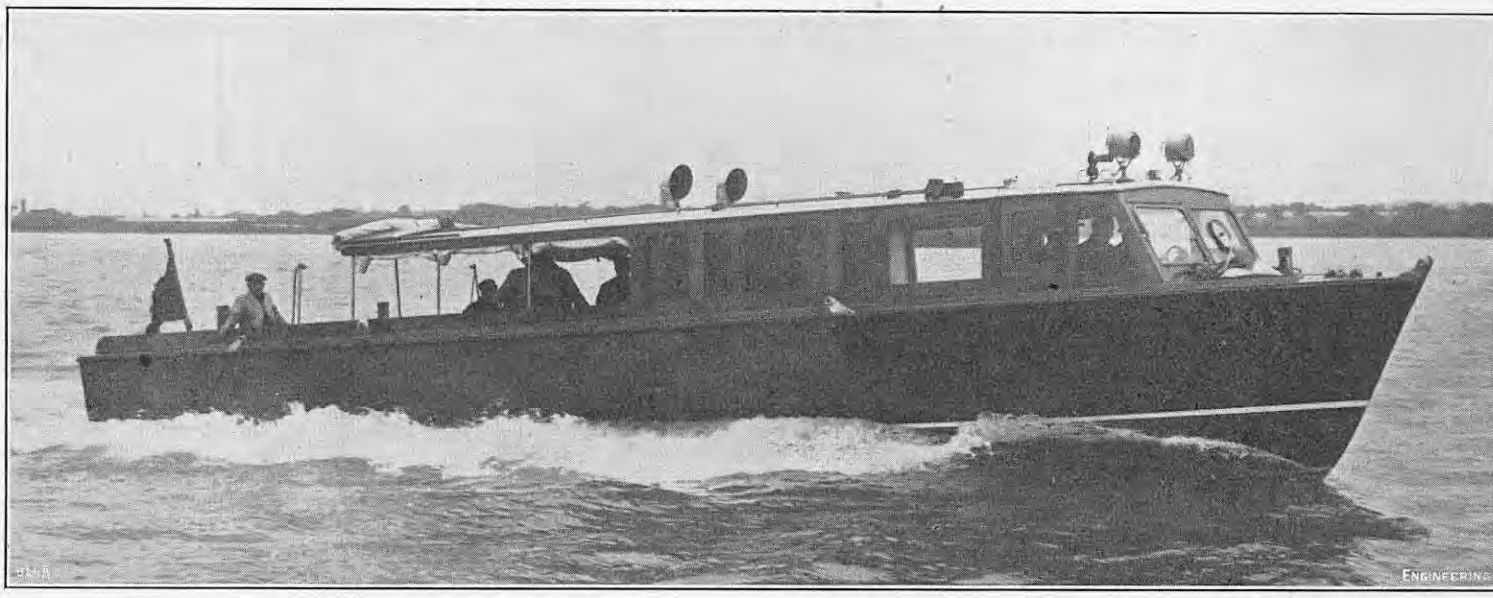


Fig. 1. General View of Launch.

DIESEL-ENGINED LAUNCH.

For a number of years, the lack of a suitable marine Diesel power unit combining high performance with low weight has been a handicap to builders of small fast craft. As a result, however, of work by Messrs. John I. Thornycroft and Company, Limited, Thornycroft House, Smith-square, London, S.W.1, in collaboration with the Rover Company, Limited, and the Self-Changing Gear Company, Limited, a power unit has been evolved which suitably fills the gap. The first of the new units has been installed in the 50-ft. launch illustrated in Fig. 1, above, and the craft recently underwent trials and demonstration runs in Southampton Water. The engine is the Rover Company's eight-cylinder Meteorite Diesel, which was described previously in Engineering, vol. 169, page 341 (1950), and is illustrated as part of the complete propulsion unit in Figs. 2 and 3, on this page. This engine drives the propeller shaft through an oil-operated reverse-reduction gearbox manufactured to Messrs. Thornycroft's specification by the Self-Changing Gear Company, Limited. The engine, which is flexibly mounted, develops 275 brake horse-power at 2,300 r.p.m., at maximum output, and has the low weight-to-power ratio of 11 lb. per net shaft horse-power. The overall dimensions of the unit, as installed, are 7 ft. 5 in. long, by 3 ft. 1 in. wide, by 3 ft. above and 1 ft. 1⅝ in. below the propeller-shaft line. The width between the engine bearers is 2 ft. 1 in.

The cylinder skirts, cylinder head and exhaust manifold are cooled by fresh water, flowing in a closed circuit. A heat-exchanger, employing sea-water as the cooling agent, and mounted at the forward end of the engine, dissipates the waste heat. Water circulation is by centrifugal pumps, and, in the case of the sea-water circuit, part of the water passes through the oil cooler of the gearbox. A thermostatic control in the fresh-water circuit by-passes water entering the heat exchanger to permit rapid warming up and general control of temperature. A bilge pump is also fitted which is identical in design and completely interchangeable with the sea-water pump, should it be required in an emergency. Both units are slow-speed gear pumps of large capacity, constructed of sea-water resisting materials.

The engine is started electrically by means of two 24-volt motors mounted on the gear casing. The batteries which supply the motors are charged from the dynamo, which is a 24-volt 830-watt machine, mounted on top of the reverse gear. A small petrol-engine-driven auxiliary charging set, housed in the box just visible in Fig. 3, aft of the engine, is intended for use in port. The main engine is controlled remotely from the steering cabin by the movement of a single lever, which also controls the clutches of the oil-operated reverse gear. The system incorporates an oil servo which not only simplifies control, but also protects the engine against abuse, since the throttle will not open until either the ahead or astern clutch is fully engaged. An additional hand throttle and emergency gear lever are mounted on the engine. The maximum speed of the craft is 17 knots.

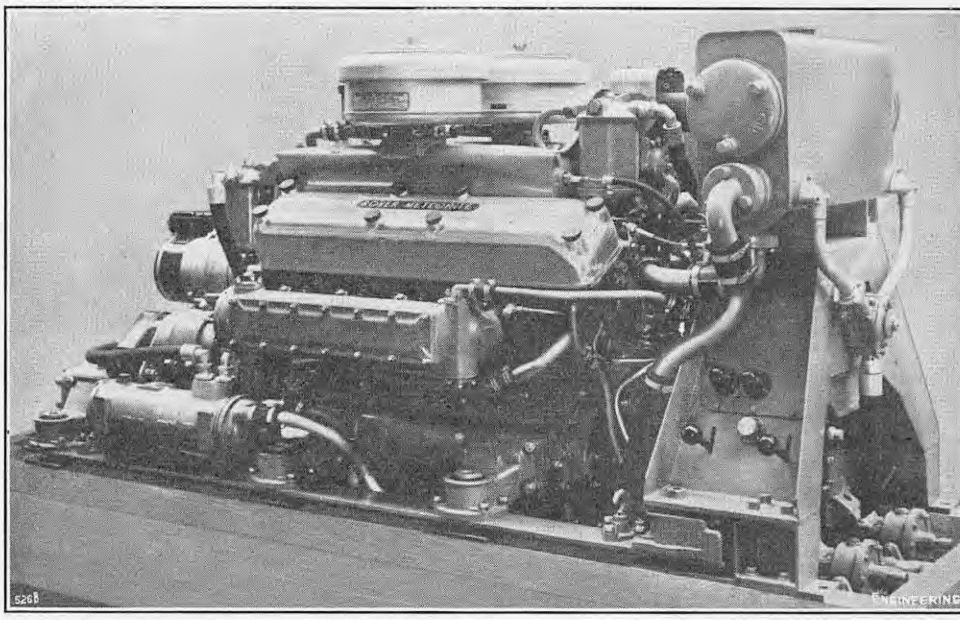


Fig. 2. Rover "Meteorite" Diesel Engine, with Gearbox.

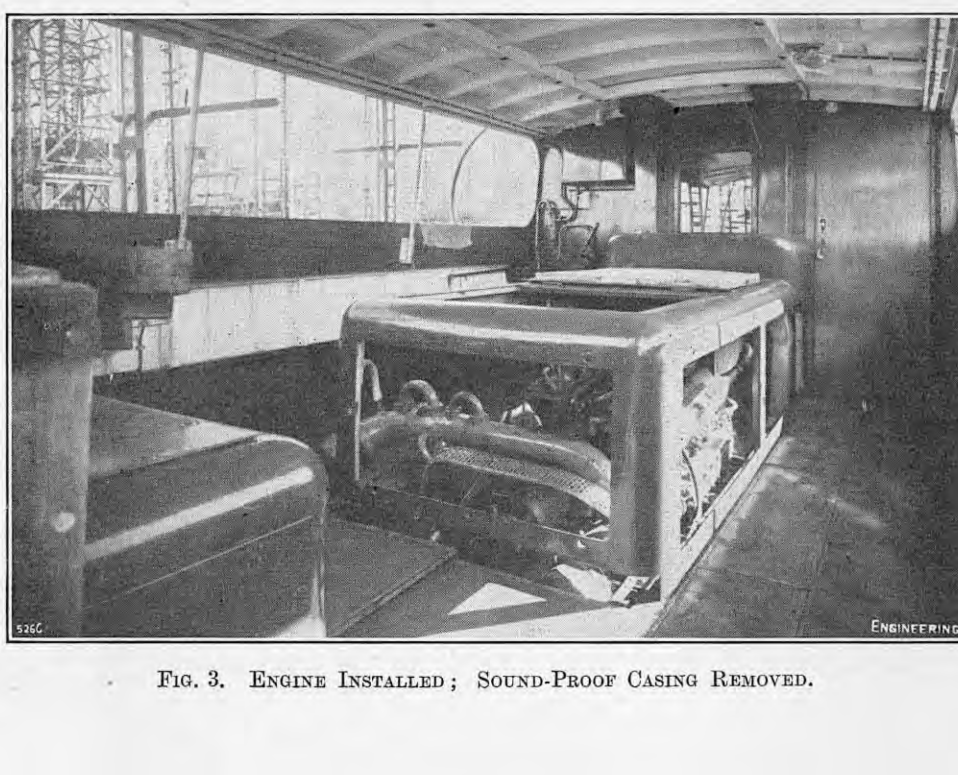


Fig. 3. Engine Installed; Sound-Proof Casing Removed.

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

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CONTENTS.

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ELECTRICAL HAZARDS.

Stated in broad terms, the business of the Fire Research Board is the investigation of the fire-resisting properties of materials, of the influence of building methods on the spread of conflagrations, and on methods of extinguishing fires. Some account of its work on these matters, as recorded in its report for the year 1950, appeared on page 315, *ante.* The Board is not a statistical agency, and it is hardly its concern to investigate the relative importance of, say, gas, electricity and solid fuel as causes of fires. Still less is it its business to relate the respective influence of these agents on the accident rate. The report for 1950, however, contains a table which bears on the subject of electrical hazards and records that, of 42,792 fires in buildings in 1949, 7,228 had an electrical origin. This is not an alarming figure, but it is a substantial one.

It may be held that the 129 fatal electrical accidents in domestic and industrial premises in 1949 were of more importance and gravity than the 7,228 fires. Some of these latter were of a minor nature, but so also, no doubt, were some of the 771 reportable electrical accidents in factories. It would not be correct to assume that a majority of electrical accidents are a by-product of fires, but some are. In the course of the year, a little girl aged seven years came into contact with the unguarded element of an electric radiator. She received burns from which she died and two adults received burns in their endeavours to extinguish the flames. Whether this was an electrical accident or a fire accident must be left to those who compile statistical tables to decide. The fatality might have occurred with a gas or a coal fire, but neither of these appliances has the convenient property of being portable.

The causes of fires are recorded by fire brigades ; there are many of these bodies and it may be that there is no common basis on which returns are based. Electrical accidents in factories, however, are reported to the factory inspectors, so that they can be compared and listed on a common system, and a report* dealing with their incidence during 1949 has recently been published. There is no organisation corresponding to the factory inspectorate of the Ministry of Labour and National Service which is concerned with domestic accidents. The reason for this is obvious ; an inspection system covering every house or flat in the country would be an economic and administrative impossibility. As a result of this, many domestic electrical accidents are probably never recorded. None the less, an attempt is made to compile a list of such events. There is no difficulty in obtaining information about accidents which result in death, and the relative importance of the domestic and industrial fields in this matter is shown by the fact that, of the 129 fatal electrical accidents in 1949, 70 occurred in domestic or similar premises and 59 in industrial premises.

The natural explanation of the leading position occupied by domestic fatalities is that most of the electrical apparatus used in the home is handled by people who are ignorant of electrical matters. This explanation is probably correct, but it is a little weakened by the fact, as recorded in the factory report, that a pilot survey showed that 50 per cent. of the electrical accidents in factories occurred to members of the electrical staff, nearly all experienced working electricians. This suggests that over-confidence plus carelessness, as causes of accidents, are just about equal to ignorance. In fairness to domestic users, moreover, it should be recorded that, of the electrical fatalities last year, some six or more deaths were due to apparatus being wired with the switch in the neutral conductor so that it was alive even when switched off. This is entirely a wireman's fault and accidents due to it cannot be attributed to the ignorance of the general public. Furthermore, many domestic electrical accidents are due to faults in the connecting arrangements, as in the case of a vacuum cleaner in which the live connection had been stripped back, allowing the bare portion to touch the spiral-wire cable entry and thus make it alive ; in addition, the neutral conductor passing down the centre of the handle was pierced by the lower fixing screw of the cover. As a consequence, there was full mains voltage between the cable spiral and the screw. A woman using this appliance was killed, but the accident was due to a careless wireman, not to her ignorance. Before leaving the question of accidents due to burns caused by the ignition of clothing from inadequately-guarded electric fires, it should be recorded that, in the opinion of experienced fire officers, the ratio between fatal cases and those which do not result in death is not less than five to one.

The pilot survey, mentioned above, which showed that 50 per cent. of industrial electrical accidents occurred to experienced workpeople, was restricted to the Sheffield area. The record for the whole country is, however, much the same. A table in the report gives the percentage figures for the years 1944 to 1949, inclusive. These show a fall in the accidents to youths and women from 27 per cent. of the total in 1944 to 8 per cent. in 1949. Intermediate years showed variations, but all were well below the 27 per cent. of 1944. This is very satisfactory ; it may be interpreted as indicating increasing electrical knowledge and judgment on the part of the women and young persons concerned, or it may be taken to indicate that greater attention is being paid by managements to safety and protective arrangements. This latter explanation is the more likely. The table also gives figures for fitters, erectors, crane drivers, etc. This group

* *Electrical Accidents and their Causes,* 1949. H.M. Stationery Office. [Price 2*s.* 6*d.* net.]

apparently represents workpeople who use or operate near electrical apparatus, but who are not themselves electricians. The percentage of accidents occurring to this class of artisan is relatively steady, the figure for 1944 being 46 per cent. and that for 1949, 42 per cent.

The third group listed in the table covers supervisory staff, testing staff and electricians, and its record is highly unsatisfactory and not easy to explain. The percentage of total electrical accidents to instructed workers of these grades in the six years from 1944 to 1949 were 27, 30, 36, 36, 41 and 50. This does not mean that the number of accidents rose at this rate, as the total reportable electrical accidents in factories in 1944 was 1,072, and in 1949 it was 771. The actual numbers of accidents to this class of employees were 289 in 1944 and 385 in 1949. This rise might be explained by increasing use of electrical plant and apparatus in factories, but this does not explain why an increasing proportion of accidents should occur to those who should be in the best position to look after themselves. It is not to the credit of trained personnel that the percentage figures for electrical accidents in 1944 and 1949 were for women and young persons 27 and 8; for non-electrical workmen 46 and 42; and for electrically-trained men, 27 and 50.

It is presumably one of the purposes of the report to explain this unsatisfactory state of affairs, and details are given of a large number of accidents of various types. The records should be studied by those responsible for the electrical installation in any factory and at the present day "any factory" may almost be read as "all factories." It is, naturally, not possible here to reproduce the details of the large number of incidents which are dealt with, but further reference may be made to the type of over-confidence, or carelessness, to which many accidents are due. It is stated that there is a "notable persistence" in working on live conductors or operating switchgear with the covers open, although investigation shows that such practices are usually quite unnecessary, even where production considerations are important. It is suggested that many maintenance men, including experienced electricians, have never seen a flash-over on a heavy power circuit and carry on work on live circuits of that type under the idea that if there is a flash-over it will be the sort of thing they have seen on a lighting sub-circuit. They are also inclined to think of the risk in terms only of possible shock, and as they may previously have experienced a 230-volt shock without serious inconvenience, do not consider a low-voltage shock of great importance. Actually, of the six fatal accidents on switchgear in 1949, five were on apparatus below 650 volts, and only one on gear above that voltage.

In connection with switchgear generally, the report states that before vesting day, when the British Electricity Authority took over, the Inspectors knew many of the supply officers in their areas and where to find them. Under the new régime, they have had to spend much time in locating the executives whom they wished to see. When found, however, these officials showed a greater tendency to agree with any criticism of existing arrangements. As the new officials were, in many cases, not responsible for the design and layout of gear, they were not disturbed by adverse criticism. The point mainly concerned is that "some of the smaller self-contained undertakings delayed attention to their switchgear both by the retention of obsolete designs and the improvisations which were probably unavoidable during the war years." There is no question that gear entirely adequate for a small self-contained area may be the opposite when tied in to a large system. The criticism implied in the report would appear to be justified by a table giving details of 23 switchgear failures. In 19 of these, circuit breakers, presumably of the old type, either exploded or failed to operate properly.

RESEARCH ON RIVER POLLUTION.

The Rivers (Prevention of Pollution) Bill, which became an Act last summer, gives additional powers to the River Boards set up under the River Boards Act of 1948. In the introductory section of the report* of the Water Pollution Research Board for last year, Mr. H. W. Cremer, the chairman of the Board, states that seventeen river boards had held their first meeting by November, 1950. In due course, it may be assumed that the boards will lay down standards of quality for liquid discharged to rivers and streams, although doubtless these will be variable in terms of local conditions. The matter is of importance both to sewage-works authorities and to industrial firms. In the past, apart from exercise of their restricted powers by Fishery Boards, the only method of taking action in case of serious river pollution lay through the law courts.

A well-known example of action of this latter kind was furnished by the injunction laid on the Luton Corporation to improve the quality of the effluent discharged from their sewage works to the River Lee. The original injunction called for improvement within a year. From the first it was obvious that this was too short a time to carry out investigations and install treatment plant, and a number of extensions have been granted by the Courts. The Luton case arose from the action of an aggrieved riparian owner, but as the new River Boards come into action it may well be that other municipalities will find themselves faced with demands of the same type as those which have been directed at Luton.

The report of the Board for the year 1949 dealt in some detail with the use of micro-strainers and of closed pressure filters, for the treatment of sewage effluent. The report for 1950 deals mainly with experiments carried out with open rapid gravity filters, although some information is given about the relative performances of graded sand and graded anthracite in the closed pressure filters. At rates of treatment from 150 to 180 gallons per square foot per hour the treated liquid from the two materials was of about the same quality, but when the rate was increased to a maximum of 270 gallons per square foot per hour, although there was little change in the quality of the effluent from the filter containing anthracite, that from the sand filter showed progressive deterioration. Comparative experiments with anthracite and sand were also made with the open rapid gravity filters, which had arrangements for blowing air through the bed of filtering medium before back-washing. At first, effluents of good quality were obtained with both materials, but after a time the quality deteriorated and it was found that particles of medium had become coated with a gelatinous film. This was removed by filling each filter with a solution containing 0·05 per cent. available chlorine. Up till that time the period during which air was passed through the filters before back-washing was 3 minutes. It was thereafter increased to 10 to 15 minutes and since then chlorination has not been necessary. Later work has covered investigations on the effect of increasing the depth of the bed of filtering medium.

The Water Pollution Research Laboratory has investigated and devised methods of treatment for many types of works effluent, and information of importance to various industries has appeared in earlier reports. Two types of industrial waste water are dealt with in the latest report. The two activities covered are the manufacture of paper and the testing of rocket motors. Some information about the treatment of waste water from paper manufacture was given in the 1949 report and the investigation now referred to represents a further stage in a comprehensive study of the whole matter. In the experiment described, all the waste waters of the mill, mixed in the proportions in which they were produced, were treated in a pilot plant. The mixture included waste water from bleaching and washing pulp, and waste water from the paper machines. After treatment, described in detail in the report, the dechlorinated, aerated and settled waste water was passed to a percolating filter. The final result suggested that an effluent of satisfactory quality could be obtained.

The work on waste waters from testing rocket motors had some reference to the effect of objectionable constituents on fish, and although it is not stated, it may be surmised that these waste waters are being discharged to a river or stream in which the maintenance of reasonable purity is of importance. The waste waters contain hydrogen peroxide, hydrazine hydrate and methyl alcohol, nitric acid and a certain amount of fuel oil immiscible with water. The nitric acid can be dealt with by neutralisation and the fuel oil removed by mechanical methods, but hydrogen peroxide and hydrazine presented more difficult problems and experimental investigation was necessary. Provided there is an excess of hydrogen peroxide, hydrazine could be removed by catalytic oxidation and, by changing the conditions, the excess of hydrogen peroxide could be decomposed. It is added that no simple chemical method is available for the removal of methyl alcohol from dilute solutions and if the concentration of this compound, or its oxidation product, formaldehyde, was too high to permit discharge of the chemically-treated liquid to a river, biological treatment would have to be used as a final stage.

One of the most extensive investigations now being carried out by the Water Pollution Research Laboratory staff is the survey of the Thames Estuary which is being made for the Port of London Authority. The object of the survey is to determine, as far as possible, the causes which lead to the deposition of silt in the central reaches. The Port of London Authority has provided a surveying vessel and a laboratory at Tilbury. Records of the condition of the water of the Thames have been collected by the London County Council during the past 55 years; the records include data on temperature, pH value, concentration of dissolved oxygen, absorption of oxygen from potassium permanganate, and concentration of suspended solids, chlorine, ammonia, nitrate and nitrite at various positions from Teddington seawards. The systematic collection of samples of deposits from the bed of the estuary between Teddington and the seaward limit of the Port of London Authority was completed in the spring of 1950. In general, there is a fairly regular gradation in the constitution of the deposits throughout the length of the estuary. Samples in the central reaches were composed of comparatively fine particles having a low content of silica and a high content of sesquioxides and containing a large proportion of organic matter and sulphide. Samples taken off the Isle of Sheppey contained a high proportion of fine material but low concentrations of organic carbon and nitrogen. As one of the objects of the investigation is to identify the source of the materials which are continually being deposited in the central reaches, a thorough study will have to be made of the composition of the deposits which may be eroded from the bed of the estuary, or the sea, and carried into these reaches by the tide. It is clear that progressive changes are taking place in the river and records show that since 1945 its temperature has increased and its content of dissolved oxygen decreased.

* *Report of the Water Pollution Research Board, with the Report of the Director of Water Pollution Research for the Year* 1950. H.M. Stationery Office, York House, Kingsway, London, W.C.2. [Price 1s. 6d. net.]

NOTES.

The London Motor Show.

The 36th International Motor Exhibition, which opened at Earl's Court, London, on Wednesday, October 17, can only be of academic interest to British visitors, as the chances of obtaining a new car in the near future are, to say the least, remote in the extreme. Nevertheless, the Society of Motor Manufacturers and Traders are right in their decision to hold the Show as it affords an excellent opportunity to focus the attention of motorists on the latest British products and, being truly international in character, permits a comparison to be made with the products of overseas competitors. In general, the Show follows closely the pattern of previous functions of this type and, once again, innovations are scarce. At the present time there is much to commend this lack of novelty in external appearance, as before the war there was a tendency, mainly at the behest of salesmen, to introduce new models for novelty's sake, with the result that many firms manufactured a prodigious number of different types. Although new models are scarce at Earl's Court, this does not mean that the industry has become complacent, as many technical improvements are visible to the discerning eye. There is, however, one outstanding new car, namely, the Austin Seven, which, although the latest of a famous series, bears little resemblance to its predecessors. Basically, it is a smaller version of the firm's Hereford car. It is a roomy four-door saloon providing comfortable accommodation for four adults, but, unlike other Austin cars, it is of unit, or "chassisless," construction. In other respects, however, the new Seven, which actually has an R.A.C. rating of 8 h.p., is of straightforward design and follows accepted practice. The European contribution includes cars from such famous French firms as Panhard and Levassor, Delage, Hotchkiss and Delahaye, the exhibits on the stand of Panhard and Levassor including variations of their well-known two-cylinder light cars. Germany is represented by Porsche and Italy by Lancia, Fiat, Ferrari and Alfa Romeo. American and Canadian firms are well represented, exhibits from this quarter including the Rambler, a small car made by Nash of America. As in previous years, the Show includes sections for component parts and garage-equipment, caravans and motor boats.

The Institution of Civil Engineers.

On Tuesday, October 16, at the Dorchester Hotel, London, W.1, the Institution of Civil Engineers held their first annual dinner since the war. The President, Dr. W. H. Glanville, occupied the chair. Professor E. D. Adrian, O.M., F.R.S., who proposed the toast of "The Institution," said that civil engineers had certainly left their mark on the face of Nature, damming great lakes, levelling mountains, and constructing roads and harbours and airports. "We may complain sometimes," he said, "that we prefer the mountains and lakes as they were before, but we can scarcely deny the 'use and convenience' to man of all these activities." Civil engineers in these days, he continued, had a heavy load to carry. They had to know with great accuracy the deflections which their structures could tolerate, but they had many other and different types of burdens to consider; they could scarcely move without having first obtained the "All Clear" from the experts on the shortage of materials and man-power, on economic pressures, on the needs of national defence and on the beauties of the countryside. Dr. Glanville's work on transport problems was another aspect of "directing the great sources of power in Nature to the use and convenience of man." The Institution had now a Division to look after airport engineering, and so the enlargement of mechanical philosophy took it into fields of which its founders could scarcely have guessed. The President, in reply, said that the character of the Institution had changed and was changing with the times. It had been founded by enthusiastic young men in their twenties, but he could remember the time when the average age of members of the Council appeared to be beyond the allotted span of three score years and ten, and the Institution seemed to be a body quite remote from the young engineer. The professional engineers of those days were largely from Victoria-street, but a great proportion of the members to-day were employed by public bodies, by large firms and by contractors. The emphasis had changed; younger men had been elected to the Council, which was now fairly representative of the structure of the profession. Since that change began, special Divisions had been formed and the meetings had increased in number. Close co-operation had been established with many other engineering institutions, the Institution had taken a more direct interest in research, and more attention was being paid to the younger engineers. In collaboration with the sister Institutions, the Mechanicals and the Electricals, they now had a joint branch in Buenos Aires, and, until recently, a very active one in Abadan, which he hoped was only temporarily out of action. "The whole Abadan affair," the President remarked, "is an engineering as well as a national tragedy." The volume of civil engineering work waiting to be done was greater than it had ever been. At home, the tasks were immense; in the backward countries they almost defied the imagination. Social advances could hardly begin in many cases until the civil engineer had provided the essential background for civilisation. In dealing with all these difficult problems, the professional Institutions had a real part to play. Marshal of the Royal Air Force Lord Tedder, responding to the toast of "The Guests," proposed by Mr. V. A. M. Robertson, said that all engineering was concerned with developments for the benefit and welfare of humanity as a whole, which should be as much for the moral as for the physical well-being of humanity. If engineering were to develop into mere technology, he could see danger ahead. There was much talk about the crying need for technicians, but it was to be hoped that the Institution would do all in its power to ensure that the education of the younger men was not debased into mere technical training or the nation would be flooded with technicians and mechanics, and would have no engineers.

Single-Phase Electric Traction at 50 Cycles.

A conference (Journées d'Information) was held at Annecy (Haute-Savoie) from Friday, October 12, to Monday, October 15, at which a considerable amount of information was given about an interesting experiment in the field of electric railway traction. Of the two most widely used methods at present used for this purpose, direct current, whatever the voltage, has the disadvantage of requiring expensive substations and transmission lines, while the 15-kV single-phase system at a frequency of $16\frac{2}{3}$ cycles necessitates the erection of special transmission lines and frequently of separate generating plant. As the cost of conversion, especially of lightly-loaded sections, may therefore be prohibitive, Mr. Louis Armand, directeur-général de la Société Nationale des Chemins de Fer Francais, therefore initiated investigations into the possibility of using single-phase alternating current at 50 cycles. The section of railway chosen for this purpose lies between Aix-les-Bains and La Roche sur Foron in Savoy, a distance of $48\frac{1}{2}$ miles. It rises steeply from Aix to Evires, nearly 40 miles, whence it falls to La Roche. Power is at present obtained from the three-phase network of the Electricité de France at 42 kV and is transformed to two-phase at 20 kV by a 12-MVA Scott-connected transformer group. This group is installed in a substation at Annecy, about half-way between the terminals. One phase of the Scott connection is taken to the overhead collector line running towards Aix and the other to that running towards La Roche, the two being separated by a short neutral section opposite the substation. The rolling stock consists of a 4,000-h.p. Alsthom locomotive, which has been designed so that it can also be run at a reduced speed on 1,500-volt direct current; and a 2,800-h.p. locomotive, made by the same firm, which is equipped with rectifiers for the same reason. A third 4,300-h.p. locomotive has been constructed by the Oerlikon Company, who have also provided two sets of 1,560-h.p. multiple-unit stock. Finally, there is a French Westinghouse rail coach. All this equipment was made available for inspection during the conference and, in addition, full details of its design and of the experience gained during its operation were presented in 30 papers. As Mr. Armand said, in opening the proceedings, the installation provides a contribution to the solution of the problem of railway modernisation; and the French engineers are to be congratulated on the enterprise they have shown in dealing with the matter so exhaustively.

Centenary of the Royal School of Mines.

Founded on November 6, 1851, the Royal School of Mines, South Kensington, London, is about to celebrate its centenary. The School is now one of the three constituent colleges of the Imperial College of Science and Technology, the other two being the Royal College of Science and the City and Guilds Engineering College. The Imperial College, which is now one of the colleges of the University of London, was built on land acquired from the Royal Commissioners of the Exhibition of 1851. The Royal School of Mines comprises departments of mining, metallurgy, mining geology and oil technology, and in these departments there are 159 undergraduates and 19 post-graduate students in the current session. The department of mining, under Professor J. A. S. Ritson, D.S.O., O.B.E., M.C., gives instruction in the technological branches of the subject and is more particularly identified with metalliferous mining. It owns a mine in Cornwall, which is used for teaching mine surveying, but during the long vacation students can obtain practical experience in mines, including coal mines, in this country and overseas. Travelling scholarships provide increased facilities for gaining mining experience overseas. Professor C. W. Dannatt conducts the department of metallurgy, which deals with the extraction of metals from their ores and with the refining and subsequent fabrication processes. This covers foundry work, thermal and mechanical treatment and welding, as well as chemical analysis, metallography, mechanical testing, spectroscopy and X-ray investigations. An important aspect of both the above-mentioned departments is now known as mineral dressing, which comprises the preliminary treatment of the material as mined to render it suitable for subsequent metallurgical operations. The department of mining geology, of which Professor David Williams is in charge, provides the knowledge required in the search for and subsequent development of new mines. The department of oil technology is under the general direction of Professor V. C. Illing and is concerned mainly with the problems of oilfield exploration and exploitation. Research is in progress in all departments of the School, as an example of which we may mention a special research group in extraction metallurgy, recently set up in the metallurgical department by the generosity of the Nuffield Foundation. To enable those interested to see something of the work in progress, a conversazione will be held at the School on Thursday, October 25, at 8 p.m., when the guests will be received by the Rt. Hon. Viscount Falmouth, chairman of the Governors of Imperial College, Sir Roderic Hill, K.C.B., Rector of Imperial College, Mr. Vernon Harbord, and Mr. D. Griffiths. A booklet giving some notes on the history of the School has been prepared.

Institution of Engineers and Shipbuilders in Scotland.

The James Watt Dinner of the Institution of Engineers and Shipbuilders in Scotland, an annual event at which engineers from Clydeside, and beyond, meet to honour the memory of their great predecessor, was held in Glasgow on Friday, October 12. Were any testimony needed to the vigour of the Scottish institution—which we need hardly add is not so—this annual gathering surely provides it. Once again, the banqueting hall of the Grosvenor Restaurant was filled to capacity when the chair was taken by the President of the institution, Sir Andrew McCance, following the piping in of the platform party. In accordance with custom, the toast of James Watt was proposed by the President and honoured in silence. The principal guest was the Earl of Home, who, in proposing the toast of "Engineering and Shipbuilding," recalled that the day was the anniversary of the discovery of America by Columbus in 1492, and went on to compare and contrast the adventurous spirit and obstinate self-assurance of the Genoese mariner with the studious disposition but insatiable curiosity of the mathematician-turned-engineer from Greenock. The discovery of the former brought a mighty continent within the orbit of the Christian world, and Watt's invention made possible the rapid communication by which the wealth of the world was brought quickly to the aid of humanity. It seemed that history was largely determined by the actions of a few men of genius possessed of that modicum of extra energy and determination which spurred men to action. James Watt's discovery of steam-power had enabled a great civilisation and immense industrial power to be built up. Steam power was also the basis of the British Navy, and he thought it was still true to say—though some disputed it—that the security of Great Britain lay in her Merchant Navy and warships, which should be a first concern of her people and government. There was no doubt that British influence abroad was in proportion to her power and her will to use it. At the present time, there were many who were covetous of British possessions and envious of British authority, but, of late, there seemed to have been some reluctance among British statesmen to exercise that authority. It was worth recalling that, for 100 years, Britain had used her power with discretion and high purpose to keep the peace of the world. If she now declined to use her authority in support of law and order, legal contracts and treaty obligations, she would cease to deserve to lead a great empire and would deserve to be finished as a great Power. Lt.-Col. Lord Dudley Gordon, who responded, recalled that, in the past 150 years, serious inroads had been made into the world's store of raw materials for energy, which had taken millions of years to accumulate. Atomic energy, however, had emerged as a new source of power of great potential value. Just as fire, originally the destroying agent, had been harnessed to the service of man, so, also, atomic energy, which had first been used for destructive purposes, might find its peaceful applications and benefit mankind. There was a great opportunity for the young men of to-day to apply the new discoveries in invention, as James Watt and his successors had done. The toast of "The Guests" was proposed by Mr. T. A. Crowe, vice-president of the Institution, and acknowledged by Sir Amos Ayre, chairman of the Shipbuilding Conference.

Metal Economics.

A general meeting of the Institute of Metals was held at the Park Lane Hotel, Piccadilly, London, W.1, on Wednesday, October 17, to discuss the subject of "Metal Economics." The morning session was devoted to the presentation of three short papers followed by a general discussion on "Primary Resources of Ferrous and Non-Ferrous Metals." Similarly, the afternoon session was given over to the presentation of five papers and a discussion on "Scrap Reclamation, Secondary Metals and Substitute Metals." In an introductory address on the objects of the meeting, delivered at the outset of the proceedings, the chairman, Professor A. J. Murphy, President of the Institute, welcomed the visitors and stated that the metallurgists present hoped to hear the opinions of geologists, economists and manufacturers on the matter under discussion, and long-term as well as short-term views would be most acceptable. As he had stated in his presidential address at the spring meeting of the Institute, a movement of the balance between the supply and the demand of the principal non-ferrous metals had been manifest since the commencement of the present century. The basic forces sprang from three elements, the first being the increasing population of the world, the second the essentially exhaustible, non-renewable characteristic of mineral resources, and the third the world-wide demand for higher standards of living. Of the commonly-used metals, lead, zinc and copper were gradually moving into the class of the relatively scarce materials, while iron, aluminium, magnesium and titanium were likely to remain plentiful for a much longer period of time. The situation could be summed up by posing three questions. In the first place, what could be done to improve available supplies? Secondly, how could better use be made of the present resources? Thirdly, what substitutes could be used in the place of metals which were becoming difficult to supply? It was to be hoped that the discussions would help to clarify some of the problems.

Launch of the Tanker "World Unity."

The tanker World Unity, now under construction at the Barrow shipyard of Messrs. Vickers-Armstrongs Limited for the North American Shipping and Trading Company (London), was launched on Tuesday, November 16, by Mrs. J. W. Platt, wife of Mr. J. W. Platt, a managing director of the Shell Petroleum Company, Limited, and of the Anglo-Saxon Petroleum Company, Limited. The World Unity is the largest tanker ever launched in the United Kingdom and is the first of six tankers of this size and larger, now being built for the same company by Messrs. Vickers-Armstrongs Limited. In addition, there are four smaller tankers of 20,000 tons deadweight under construction at their Naval Yard, Newcastle-on-Tyne. The dimensions of the World Unity are: length, 653 ft. overall and 625 ft. between perpendiculars; breadth, moulded, 86 ft.; and depth to upper deck, 45 ft. 9 in. She is designed for carrying petroleum and, when completed, will have 30 cargo tanks, arranged three abreast in the width of the hull. Longitudinal framing has been adopted for the shell and also on the upper deck from the forepeak bulkhead to the engine-room bulkhead, with transverse framing and beams at the ends. With the exception of the upper-deck stringer bars and the seams of the bilge strakes, the hull is of all-welded construction. She will be propelled by a set of geared turbines of the Parsons type and to Pametrada design, driving a single screw; these will develop a service power of 12,500 s.h.p. at 100 r.p.m., and a maximum output of 13,750 s.h.p. at 103 r.p.m. Steam will be supplied by two Foster-Wheeler type "D" water-tube boilers at a pressure of 450 lb. per square inch and a temperature of 750 deg. F. at superheater outlet. The cargo will be discharged by three turbine-driven pumps, each capable of delivering 850 tons an hour. These will be installed in the after pump room, and the forward pump room will accommodate the fuel-oil transfer pump and the ballast pump.

OBITUARY.

MR. V. W. BONE, M.B.E.

We regret to record the death on October 12, in a nursing home in Lincoln, of Mr. V. W. Bone, formerly chairman and managing director of Messrs. Ruston and Hornsby, Limited, and their associated companies. Mr. Bone, who was 68 years of age, retired in June, 1949, owing to ill-health, and, though he made a partial recovery, had been an invalid for the past two years.

Victor William Bone, who was born on February 17, 1883, received his general education in Ipswich, and his technical education in Ipswich evening classes, while serving his apprenticeship with Messrs. Ransomes, Sims and Jefferies, Limited, from 1900 to 1905. On completion of his apprenticeship, he remained with this firm, who became associated with Messrs. Ruston and Hornsby, Limited, about 30 years ago. His abilities brought him rapid promotion, and in 1911, after some years as a travelling technical engineer on the Continent, he was appointed manager of the company's Parkside Works. He held this position until the end of 1915, by which time the firm had branched out into aircraft production as a a war-time development. Throughout 1916 and 1917, Mr. Bone managed their aircraft works, for the design and layout of which he was personally responsible; and was then made managing director of the Orwell Works, which was employing at that time a personnel of over 4,000.

On the fusion of interests between Messrs. Ruston and Hornsby, Limited, and Messrs. Ransomes, Sims and Jefferies, Limited, in 1922, he went to Lincoln as works director of the former firm; and in 1930, on the formation of Messrs. Ruston-Bucyrus, Limited, he became the managing director of that associated company, with whom he continued until 1944, when, on the retirement of the late Mr. G. R. Sharpley from the managing directorship of Messrs. Ruston and Hornsby, Mr. Bone succeeded him. Mr. Sharpley continued as chairman until his death in January, 1948, when Mr. Bone assumed that responsibility also. He remained a director of Messrs. Ruston-Bucyrus, Limited and of Messrs. Ransomes, Sims and Jefferies, Limited, and up to the time of his retirement was chairman, in addition, of Messrs. F. H. Lloyd and Company, Limited, of Wednesbury, and their associated undertakings in Burton and Derby; and a director and vice-chairman of Messrs. Davey, Paxman and Company, Limited, Colchester, of which firm his son, Mr. G. W. Bone, is now a director.

Mr. Bone was a member of the Institution of Mechanical Engineers, to which he contributed several papers on the development of excavators and other contractors' plant, the last being one of the series of special lectures arranged to mark the centenary of the Institution in 1947. He was also active in the support of local engineering societies, being the founder of the Lincoln Engineering Society (of which he was President for three years)

and intimately concerned, in 1919, with the reorganisation of the Ipswich Engineering Society, of which he was elected President in the same year. He was also largely instrumental in the formation in 1917 of the East Anglian Employers' Association, and had served on the Board of Management of the Engineering and Allied Employers' National Federation for over 20 years prior to his retirement.

"Cement-Mortar Lining of Water Mains.": Addendum.—Since publication of our article, with the above title, on the "Centriline" system of lining water mains with cement, which appeared in our issue of October 5, on page 432, *ante*, we have been informed that, though the demonstration that we witnessed was arranged by Messrs. John Mowlem & Co., Ltd., as was stated in the article, the 75-in. tunnel main referred to was constructed by Messrs. Kinnear Moodie & Co., Ltd. London, S.E.13, with Sir William Halcrow and Partners acting as consulting engineers to the Metropolitan Water Board.

The Junior Institution of Engineers' Exhibition.—As we mentioned on page 403, *ante*, the Junior Institution of Engineers are arranging an exhibition to be held in their rooms at 39, Victoria-street, Westminster, S.W.1, from Wednesday to Friday, October 24 to 26. It will be open from 9.30 a.m. each day, and will close at 7.30 p.m. on October 24 and 25, and at 8.30 p.m. on October 26. The exhibits will cover items of historic interest to the Institution, models and apparatus made by members, etc., and a special section dealing with Henry Maudslay (1771-1831), the inventor of the screw-cutting lathe, in whose works the Junior Institution began in 1884 as an association of apprentices, and in whose memory was founded the Maudslay Scholarship, which is awarded annually by the Institution in collaboration with the Maudslay Society, who established it.

THE PARIS MOTOR SHOW.

A brief report of the Paris Motor Show, which closed on Sunday, October 14, after having been open from October 4, was given in Engineering on page 467, *ante*. This show was probably the largest of its type to be held, as it covered not only cars but commercial vehicles, motor cycles and bicycles as well, the cars together with some commercial vehicles being exhibited at the Grand Palais, Avenue de Champs Elysées and the remainder of the commercial vehicles, the motor cycles and cycles at the Parc des Expositions, Porte de Versailles. As pointed out in our earlier review, it is doubtful whether such a comprehensive show is quite desirable, as the effect on those interested in all sections was, to say the least, wearisome. Matters were not improved by showing some of the commercial vehicles in the Grand Palais as it must have proved irksome for the commercial operators to have had to visit both places. Be that as it may, there can be no doubt that the Grand Palais presented a colourful spectacle particularly at night when the neon lighting installed for the occasion was switched on. Perhaps the outstanding impression gained was the international character of the show, since exhibitors from France, America, Germany, Italy, Czechoslovakia and Great Britain had stands in all three sections of the salon.

Broadly speaking, there was little in the way of startling innovations and it would appear that the continental motor industry generally, like ours, is going through a period of consolidation, placing faith in well tried and proven designs. Probably the extensive rearmament programme has had a damping effect on the production of new designs but, whatever the cause, the phase can do no harm as before the last war there was too much striving after novelty for novelty's sake and new designs were introduced, largely at the behest of salesmen, before their predecessors were fully developed. Inevitably it added to the cost and with the present need for economy there is much to be said for concentrating on existing designs. It should not be assumed however, that the European motor industry has reached a position of stalemate, as the Grand Palais contained many cars of outstanding design. Any novelties present were to be found in the collection of miniature cars, for in France, as in most European countries, there is at present a great demand for economical personal transport. As a consequence, a considerable number of ultra-light cars has been evolved, some of which are powered with engines having a capacity as low as 125 c.c. They are a heterogeneous lot, some very good and others not so good and it is doubtful whether many of them will withstand the competition from the manufacturers of conventional vehicles once the need for desperate measures of economy has passed. Quite a few provide transport in a most inconvenient form, comfort being at a minimum and no real attempt being made to give protection from the elements. Although there are one or two single-seat machines, the majority are of the two-seat type. One of these ultra-light vehicles seats the two occupants in tandem, the upper part of the vehicle body being hinged along one side so that it can be folded back to permit entry, this being gained by stepping over the side of the body. As can well be imagined, entry is accomplished with a certain amount of difficulty, coming within the realms of gymnastics; how it is accomplished in an emergency does not bear contemplation. Nevertheless, it does provide more comfort and certainly more weather protection than a motor cycle and may prove popular with those who prefer four wheels to two.

In some cases, the finish of the ultra-light cars left much to be desired; on one chassis, for example, it was noticed that the Bowden cables to the brakes, accelerator, etc., were loose and if this happens on machines prepared, presumably, specially for the show, then anything may happen on production models. This criticism, however, can only be levelled at a few and at the opposite end of the scale there were several fine examples of really light cars. Régie Nationale des Usines Renault, for instance, were exhibiting a small car, with the engine in the rear, which accommodates four passengers in comfort and has a performance and road-holding qualities comparable in every way with its larger contemporaries. It is, in fact, as near to perfection as a miniature car is likely to reach, being provided with a four-cylinder water-cooled engine of 4 h.p., French rating. A conventional three-speed gearbox is used and a notable feature is the employment of independent suspension for all four wheels. The coachwork has not been skimped in any way and four doors allow easy entry to its comfortable interior. Panhard and Levassor also were showing a full four-seater miniature saloon car combining comfort with high performance. Known as the Dyna, it is powered by a flat-twin air-cooled engine situated forward and arranged to drive the front wheels through a four-speed gearbox. Here again independent suspension is employed all round and comfort, performance and road holding are equal to, if not better, than some of its larger brethren.

What might well be termed an austerity car was being shown by Société Anonyme André Citroën; slightly larger than those just referred to, it has a full four-seater saloon body from which frills have been entirely eliminated. In fact, almost everything has been sacrificed to cheapness and the result is an austerity vehicle *ne plus ultra* which makes no pretence towards good looks. Canvas seats similar in form to deck chairs are provided for the driver and three passengers, and all luxuries such as interior trimmings and unessential instruments have been disregarded. It is powered by a two-cylinder air-cooled engine of 2 h.p., French rating, and, in common with other Citroen models, employs front-wheel drive and independent suspension. By modern standards it is cheap both to buy and operate, the petrol consumption being in the neighbourhood of 60 miles per gallon and although austere from all viewpoints it fulfils a long-felt need for cheap utilitarian transport. British manufacturers might well ponder over its design and see if something similar could be done to help the car-hungry populace here.

In what might well be termed the medium field, there were several excellent examples of French cars on view. Fortunately, Continental designers have largely resisted American trends in body design and have kept a sturdy individualism. As a consequence, their cars are not covered with useless masses of chromium and do not bulge in the most unexpected places but have modern and pleasing appearances. An outstanding vehicle in this class is the Salmson Randonnée, a comfortable four-seater saloon car with most attractive lines. It has a four-cylinder engine with a bore and stroke of 82 mm. and 108 mm., respectively, employing overhead valves operated by twin overhead camshafts. These are driven through skew gearing by a vertical shaft situated at the forward end of the engine, the gears fitted to the camshafts being of the silent type. This form of construction permits the use of a hemispherical combustion chamber and centrally located plugs, a design much favoured by the manufacturers of high-performance cars and one that gives a high output. The front wheels are independently-sprung by means of torsion bars and associated linkages but conventional cantilever springs are fitted at the rear, a system long favoured by Salmson. The Peugot 203 is another medium-size four-seater saloon car having attractive lines. It differs considerably from the Salmson in that the body and chassis are of unit construction while the suspension system employs a leaf spring at the front and coiled springs at the rear. It has a four-cylinder overhead-valve engine having a bore and stroke of 75 mm. and 73 mm., respectively, and the transmission assembly comprises a four-speed over-drive gearbox and a conventional transmission, the gearbox being designed to form a single unit with the engine.

One of the most popular cars at the show proved to be the Simca Aronde, a family saloon which already is being produced in quantities of the order of 200 a day. It is a full four seater of unit construction employing independent suspension through coil springs and swinging links at the front and conventional springing with leaf springs at the rear. The engine is a four-cylinder unit having a bore and stroke of 72 mm. and 75 mm., respectively, and developing nearly 45 h.p. at 4,500 r.p.m. Overhead valves are fitted and these are operated in the normal manner by push rods and rocking levers. Transmission is by means of a single-plate clutch to a four-speed gearbox and then by an open propeller shaft to a conventional rear axle. The car is, in fact, of straightforward design and yet the performance is quite outstanding, a speed of over 70 miles an hour being well within its capabilities while the average petrol consumption is approximately 30 miles a gallon. This undoubtedly is a good performance and one obtained largely by attention to detail; it seems fairly certain that a great deal will be heard of the Aronde in the near future. Before turning to the larger cars, mention should be made of the four- and six-cylinder Citroën standard models. These cars, of course, are familiar in this country and it reflects great credit on the designers that, although existing models are virtually the same mechanically as those introduced before the late war, they are in many respects still ahead of their contemporaries.

Most of the larger cars on view, with the exception of such models as the Peugeot family saloon, were of the luxury or semi-luxury class. The Ford V-8 Vedette was another exception; this is a handsome car which is available either in its standard form or as a utility model in which the back lifts to permit the carriage of goods. There is also the Ford Comète which basically is the same as the Vedette but is fitted with a more luxurious body. The more expensive cars included the Type 235 Delahaye, the type 101 Bugatti, the Hotchkiss Anjou and the Lago-Talbot. The Bugatti 101, however, was somewhat disappointing as basically it was the same as the pre-war type, differing only in detail. It has a 3·3 litre straight-eight supercharged engine of outstanding design and finish, being fitted with twin overhead camshafts and reputed to develop more than 180 h.p. But little has been done towards modernising the chassis, which is still fitted with a beam-type front axle connected to the chassis by half-elliptical leaf springs.

As previously mentioned, other Continental countries were well represented. The exhibits from Germany included the Volkswagen, originally introduced under the Hitler régime as the people's car, the Mercedes 300S, the Auto-Union D.K.W. and the Porsche type 356. The Volkswagen has improved in looks but otherwise remains much as it was. The Mercédès 300S is fitted with an overhead-camshaft six-cylinder engine having three carburettors and reported as being capable of developing 150 brake horse-power. It retains the traditional Mercédès form of radiator which, by skilful design, has been blended neatly into the general lines of the car. The Porsche 356 is particularly interesting in that it has a flat four-cylinder air-cooled engine mounted over the rear axle. Two sizes of engine are available, namely, the 1·3 litre and 1·1 litre and these develop 44 h.p. and 40 h.p., respectively, sufficient, it is claimed by the manufacturers, to give speeds exceeding 80 miles an hour. On the Auto-Union D.K.W. a two-cylinder two-stroke water-cooled engine is employed to drive the front wheel through constant-velocity joints. The engine is mounted across the chassis and the drive is transmitted to the road-wheels through a multiple-plate clutch running in oil, a three-speed gearbox and the usual form of differential, the engine, gearbox and differential forming a single assembly. Italy was represented by Lancia, Alfa-Romeo and Ferrari, to mention but three. The Ferrari has done exceptionally well in Grand-Prix racing and one of the cars on view was fitted with a twelve-cylinder engine which, in racing trim, is capable of developing 220 brake horse-power. Alfa-Romeo are another firm who have achieved many successes in Grand-Prix racing but the cars on view were fitted with four-cylinder twin overhead-camshaft engines and not the racing engine. A newcomer to the show which attracted considerable attention was the Pegaso, a high-performance car manufactured by the E.N.A.S.A. Company, Limited, of Madrid. This car is fitted with an eight-cylinder engine in which the cylinders are arranged in two banks of four in V formation, each bank being provided with twin overhead camshafts. The transmission assembly is unusual as the gearbox is located behind the final-drive assembly, an arrangement which increases the weight on the rear wheels and improves the factor of adhesion. There seems to be little doubt that this car has been designed with competition work in view and possibly, at a later date, Grand-Prix racing, although the present design will not be suitable for the new formula shortly to be introduced.

The outstanding exhibit in the commercial-vehicle section of the motor show was, undoubtedly, the Laffly gas-turbine driven 10-ton lorry. Details of the power unit were not readily available but it is understood to comprise a single-stage compressor running at 30,000 r.p.m. and a two-stage turbine operating at between 20,000 r.p.m. to 24,000 r.p.m., the primary turbine driving the compressor and the secondary turbine the road wheels through a conventional transmission assembly. The unit is arranged over the front axle and below the floor of the driving cab, air entering the compressor through a full-width intake situated just forward of the front chassis cross member. The transmission assembly incorporates a two-speed gearbox, the lower ratio of which is used for starting from rest in difficult circumstances, and, to simulate the retarding force of a normal piston-type engine during over-run, a disc brake is incorporated in the transmission line which comes into operation when the accelerator pedal is released. Reduction gearing is, of course, interposed between the power-turbine output shaft and the transmission assembly and the gearbox incorporates a reverse ratio. This vehicle is very much in the prototype stage and as a heat exchanger is not fitted, the fuel consumption is high, being in the neighbourhood of 1 lb. per brake horse-power per hour; considerable improvements will have to be made, therefore, if the vehicle is to compete with existing Diesel-engine designs.

Apart from the Laffly turbine lorry, there was little of an outstanding nature in the commercial-vehicle section of the show. It would seem that French designers have not gone so far as their British and American counterparts in the development of underfloor-engine chassis, and of the few vehicles shown, it was sometimes difficult to obtain technical information, mainly because the vehicles were in the prototype stage and, it appeared, were being shown to ascertain the reactions of the operators. Some firms were showing long-distance coaches with engines mounted in the rear boot; Saurer, for example, were exhibiting such a vehicle with the engine arranged across the chassis and the drive transmitted to the rear axle in much the same way as on the Foden passenger vehicle. Isobloc, on the other hand, were showing a range of rear-engined coaches in which the engines were in line with the chassis, either in the vertical or horizontal position, according to the type of unit fitted. As in this country, most French commercial vehicles of any size are fitted with compression-ignition oil engines, some of which are of advanced design. One of the heaviest vehicles on show, namely, the Willeme six-wheeler, was fitted with an eight-cylinder engine of this type. In general, however, the design of French heavy vehicles does not differ a great deal from their British counterparts, but owing to the freedom from restrictive legislation on size, etc., tend to be of heavier construction. Some of the heavy trailers exhibited at the Parc des Expositions were of an interesting design. One of these, a semi-trailer, was provided with independent torsion-bar springing for the trailing wheels, while an eight-wheel full trailer was designed so that all wheels are steered by means of Ackerman linkages operated by the drawbar. This trailer can be hauled from either end and the wheels, in addition to being steered, are independently sprung on transverse leaf springs.

The exhibits in the bicycle and motor-cycle sections were far too numerous to describe in detail here. So far as the motor cycles are concerned, the emphasis seemed to be on the lighter machines, most of the heavier types being shown by Great Britain, Italy and Germany. The number of bicycles on show was remarkable. Design was of a high standard throughout and careful attention has obviously been paid to details; most brakes, for example, were of the caliper type and some of these are designed so that they are fully compensating. Autocycles have gained great popularity in France and on some of these, dérailleur gears have been incorporated in the drive to give three speeds. In fact, the original conception of the autocycle seems to have been forgotten and they gradually are growing into light motor cycles.

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

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

STIMULATED by the urgency of war demands, engineering progress has disclosed a hitherto unsuspected behaviour of steel under conditions created by the increasing application of welding to shipbuilding. Problems connected with states of toughness or brittleness have been sharply defined, indicating clearly that they are not yet understood. Intensive investigation has disclosed many new facts, and techniques for avoiding serious consequences have been defined for practical use, but we are still ignorant of a fundamental and scientific understanding of the effects that we see. Let me, therefore, review what is known of this subject.

Do not think that disturbing experiences with brittle behaviour are something that has been reserved for this generation alone; similar occurrences were known in the earliest days of steelmaking. Bessemer relates how he established his own steelworks at Sheffield in order to demonstrate to a sceptical world that steel made by his process was ductile and tough in the highest degree. Clients came to see for themselves, and, being convinced, took out licences to operate the process in their own districts. Among the first three to do so was a company still well known in the west of Scotland—Messrs. Wm. Dixon, Limited—who erected a converter at Govanhill. Unfortunately, the results were far different from what they had expected and after many attempts, and even with the assistance of Bessemer himself, they produced nothing but the most brittle and useless material. So their scheme to produce steel was abandoned and Bessemer, to his credit, repaid them their licence fees and the expenses of their fruitless efforts. It was Percy, then Professor of Metallurgy at the School of Mines, who showed that this failure was due to the presence in the steel of phosphorus. Many years later, this embrittling effect was studied in detail by Stead, who drew attention to the influence of phosphorus in promoting large and well-defined crystals in iron, which possessed a strong tendency to fracture along their cleavage faces, this being the main cause of embrittlement.

Contemporaneously Hadfield was examining in the most comprehensive way the properties of a wide range of alloy steels and, in addition to his famous manganese steel, he discovered the improvement in the magnetic properties brought about by silicon when added to the extent of 3 or 4 per cent. to low-carbon steels. Like phosphorus, silicon in such amounts produces exceptionally well developed crystals, and accompanying this growth in crystalline habit is a great increase in brittleness of the cleavage type. Silicon steels also show a very sharp transition from the brittle to the ductile state as the silicon content is increased, and a great increase in the temperature at which this transition takes place. Whereas a very low carbon steel may become brittle below a temperature of − 100 deg. C., a similar steel containing 6 per cent. silicon only loses its brittleness above 400 deg. C., a difference of 500 deg. C. This is an extreme example, but has been chosen to illustrate the fact that the brittleness which certain elements can bring into evidence when they are added to steel is an indirect effect caused by their influence in promoting a more perfect crystalline habit in the iron itself. The more perfect the iron crystals are as crystals, the more orderly are the atoms arranged in rows parallel to the crystal faces and the more readily can these planes be separated in consequence.

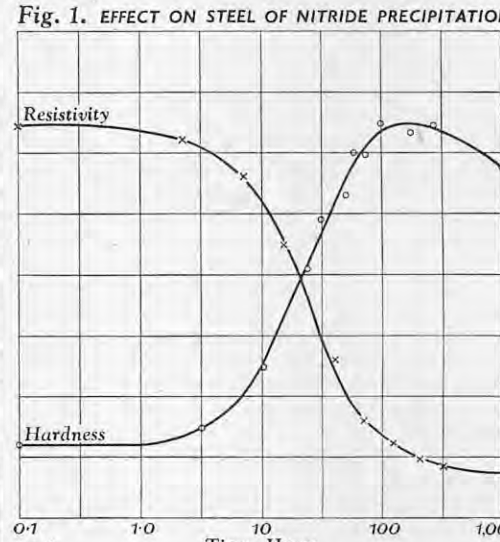
The invention of the basic process by Gilchrist and Thomas enabled deleterious amounts of phosphorus to be removed from steel during the course of manufacture. In consequence, there was no longer any restriction on the use of ores from deposits whose high phosphorus content had hitherto prevented them from having any commercial value, and the development of steel production throughout the world progressed at a rapid rate. On the continent of Europe, particularly where extensive ore fields containing high phosphorus existed, it led to great expansion of steelmaking by the basic Bessemer process, but in this country the continued use of low-phosphorus ores from Spain retarded such a change for some considerable time.

No doubt contemporary metallurgists thought that, with the control of phosphorus, the troublesome failures due to brittleness would disappear, but this did not prove to be so. There grew up a tradition, based on experience, that basic Bessemer steel as made on the Continent was unreliable and that it was sometimes inclined to fracture unexpectedly even when the phosphorus content was well below the limit known to be safe. The result was that, in this country and elsewhere, such steels were debarred from use for shipbuilding and boilermaking, and also from other uses where reliability was essential. For many years this behaviour remained mysterious, and I think the credit for tracking down the cause belongs to Stromeyer, whom many remember as chief engineer of the Manchester Steam Users' Association. From his extensive inspection experience, he surmised that steel was subject to ageing, particularly after shearing and punching operations, and later he associated this ageing property and the brittleness that went with it to the nitrogen content of the steel.

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

With our later knowledge, we can now understand why people were slow to accept nitrogen as the cause, since it is only under specified conditions that brittleness arises from nitrogen. The development and study of age-hardening alloys like duraluminum has enabled the mechanism of what takes place to be understood. Nitrogen exists in steel as a nitride, Fe_4N, which dissolves in ferrite or pure iron, and the amount dissolved increases rapidly with the temperature. The nitride solution reaches its maximum concentration about 590 deg. C. and, since movement is sluggish in solids, the nitrides do not always separate out from the solution when the steel is cooled at all quickly from higher temperatures. In such instances, they are held as an enforced solution at the lower temperature, but, given time and particularly if warmed up, they come out of solution gradually. In doing so, they have to find room for themselves in a space that is already well filled with iron atoms; so they find the space they require by forcing aside those iron atoms, and in this way create centres of intense local strain and hardening. This causes the phenomenon of ageing. It is easier, no doubt, to find room in certain directions than in others, and it has been found that there are certain preferred locations for the nitrogen atoms and that these regions are the cleavage planes of the iron crystal.

Fig. 1. EFFECT ON STEEL OF NITRIDE PRECIPITATION.



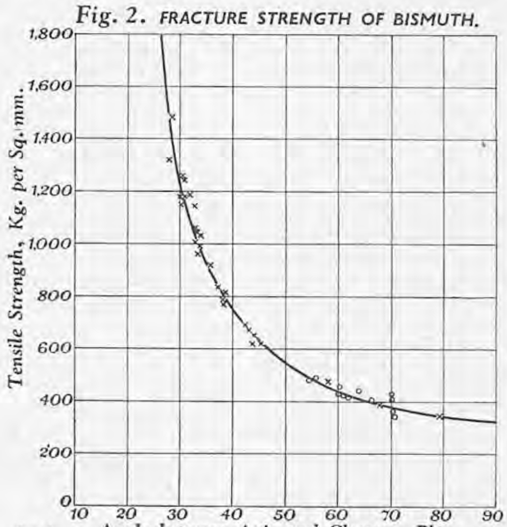
The process has been followed in detail by measuring in the same specimen the electric resistance to determine the amount of nitrogen in solution and also the hardness, and it is clearly shown that the maximum hardness coincides with the condition when all the nitrides have been deposited inside the crystal planes—the condition of maximum dispersion and therefore of distortion (Fig. 1). Thereafter, the minute particles begin to coagulate into larger aggregates with less general distortion of the lattice, and the hardness begins to fall. At the period of maximum distortion, and therefore maximum hardness, the cleavage planes are already forced apart in some degree by these foreign atoms, so that it now takes much less force to complete the process of separating them altogether. In other words, steel containing nitrogen in excess of 0·006 to 0·007 per cent., allowed to cool somewhat rapidly after rolling, will, after the lapse of time, have a strong chance of becoming brittle and of breaking unexpectedly. Unlike phosphorus-bearing steels, steels containing nitrogen are not necessarily brittle. Properly treated, they can be made quite tough, but proper treatment is costly.

Nitrogen merely intensifies the cleavage brittleness of the iron itself and makes it evident. There are many elements that act in a similar manner, but, with the exception perhaps of hydrogen, they are not usually found in steel in amounts likely to cause trouble. Even in the case of hydrogen, the brittleness to which it gives rise is not found in the mild steels used for constructional purposes. It only makes itself evident in high-tensile alloy steels possessing some degree of self-hardening, since it is only in such instances that the conditions for enforced solution with the accompanying lattice distortion in the cleavage planes exist. Normally, the amounts of hydrogen present in commercial steels are very small. Indeed, owing to its very light weight when expressed as a percentage, it is necessary to use units of 10^{-5} and open-hearth steels contain only 5 to 10 such units. To make steel fully brittle, however, requires about 70 units, so it would be quite unusual to find the amounts required to cause brittleness in ordinary practice. In alloy steels possessing self-hardening properties, segregation effects, which are not found in mild steels, come into play, and the hairline cracks which are found in high-strength steels result from this combination of causes.

It will be observed that the effect of these embrittling elements is similar. They facilitate the separation of the crystal cleavage planes, either by helping to grow large crystals or by causing a partial displacement of the planes due to their presence in between.

To answer the next question—in what way final fracture is brought about by an externally applied stress—we have to turn to the work of the metallurgists and physicists who have studied the behaviour of single metal crystals. In such crystals the behaviour under stress can be studied under simplified conditions not possible with a polycrystalline material. A metal possessing some exaggerated characteristic can throw much light on the general behaviour of all materials. For instance, cadmium and zinc crystallise in the hexagonal system, and the plane parallel to the base has a most strongly marked cleavage, peculiarly convenient for study. Bismuth and antimony are inherently brittle, so that single crystals of these metals

Fig. 2. FRACTURE STRENGTH OF BISMUTH.



enable the degree of brittleness pertaining to each crystal plane to be pin-pointed and examined.

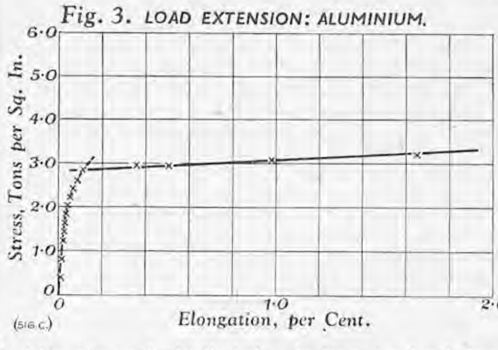
One of the earliest ideas to explain how fracture takes place on cleavage faces was the normal stress law, put forward by Sohncke more than 80 years ago. He arrived at it through studying the fracture of rock salt under stress. It postulates, as its name implies, that when the stress at right angles to any crystalline face exceeds a certain value, separation and fracture take place. Schmid submitted this theory to a most careful test, using single crystals of bismuth. In bismuth the octahedral plane is the determining plane for cleavage and the exact inclination of this plane can readily be found. If θ is the angle which this plane makes with the direction of tension, the resolved normal stress is P sin θ and, since the area of the plane is $\frac{a}{\sin \theta}$, where a is the cross section, the tension required to cause separation, if the normal fracturing stress is constant, will be proportional to $\frac{P}{a \sin^2 \theta}$. The experimental results of Schmid for his bismuth crystals are shown in Fig. 2, together with the full-line curve for a stress based on $\frac{0 \cdot 324}{\sin^2 \theta}$ kg. per square millimetre. There is no doubt that, for brittle materials, this law is obeyed, and it has been found that the normal breaking stress is independent of the temperature at which fracture takes place and that the separation of the cleavage faces is accompanied by practically no extension or contraction of area. It is now fully accepted that brittleness is a condition which is made evident by the separation of a crystalline material across a cleavage face which is parallel to one or other of the crystal faces. The crystalline appearance of a brittle fracture is a necessary consequential characteristic.

If the simple behaviour exhibited by single crystals of the bismuth type had been followed by ordinary materials, which are made up of crystals of many different sizes, there would have been a reasonable hope that the general problem of fracture might by this time have been solved. Unfortunately, in ductile solids under stress, complications arise because plastic extension is an important part of the total extension and the relative proportions of the two modes of extension, plastic and elastic, are not yet known. All that can be said is that, at small stresses, elastic extension predominates almost exclusively, and with large stresses the predominance is practically wholly that of plastic extension.

Ever since the days of Hooke, the elastic behaviour of solids has been an important and extensive problem for engineers and mathematicians. The theory of elasticity, indeed, was one of the main preoccupations of mathematicians during the Nineteenth Century and it may well be that the mathematical theory of plasticity with all its ramifications will become, if it is not already, one of the important occupations of mathematicians during the remainder of this century.

It is usual to recognise two ranges—the elastic and the plastic range—but it would be more correct to split up the elastic range into two stages. In the first, Hooke's law is accurately obeyed until the elastic limit is reached, and the second covers the extension between the elastic limit and the yield point, where Hooke's law is not obeyed. This part of the extension curve is frequently confused with the plasticity curve, but a reference to Fig. 3 shows there is a sharp demarcation between the two. It gives an extension curve for a very pure sample of aluminium, where the stress was allowed to remain until extension was complete. The straight and the curved portions of the elastic extension are clearly shown as merging continuously,

Fig. 3. LOAD EXTENSION: ALUMINIUM.



but there is no doubt that the plastic extension belongs to an entirely independent curve, which is not merely an extension of the elasticity curve, but represents a new set of conditions initiated at the yield point.

To engineers the interesting question has always been, on which of these limits should design stresses be based? Some have advocated the elastic limit, though they are restrained by the doubt that arises from the observation that, the more accurate the instrument used, the lower is the elastic limit found. There have been those who supported a yield-point basis, but it is evident from Fig. 3 that, when this is used, knowledge of the effect of non-linear extension on engineering structures is very necessary. This, of course, is fully realised at the present time and experimental work is being carried out by Professor J. F. Baker at Cambridge for the British Welding Research Association. On the mathematical side, the work of Hill is extending our theoretical ideas on the behaviour of materials under conditions of non-linear extension.

These developments show a disposition to depart from the time-honoured practice of basing design stresses on the tensile strength. As materials become more expensive there is a natural desire to make more efficient use of them and the obvious way is to stress them more highly. Future development will tend more and more to use the yield point as a basis; not the yield point as ordinarily determined, but the yield stress as determined from the intersection of the elasticity and the plasticity curves. For structures involving steady loads it seems the logical and correct basis. This view implies that, under all stresses less than that at the point of intersection, extension ceases, no matter how long the stress is applied. For stresses above this limit, it must be recognised that continued extension by creep is possible. It may be so small at ordinary temperatures as to be quite negligible in itself. On the other hand, if it takes place in one member only of a built-up structure it may throw additional stress on the other members and lead to the development in them of an undesirable stress.

The need for steels which possess high yield points in relation to their maximum tensile strength, in order that proper economy in design can be practised, has led to the development in recent years of many special qualities with the appropriate properties. In ordinary mild steel, the ratio of yield to tensile strength is generally in the neighbourhood of 50 per cent. In the special qualities now available, this ratio has been raised to 75 per cent. without any sacrifice of ductility or toughness; indeed, so far as toughness is concerned there is some added gain, since they are able to retain their tough state at temperatures which are much lower than usual. For fluctuating and live loads, of course, the dependence of the fatigue stress on the tensile strength is so well established that I cannot see existing practice being changed with any degree of justification.

The question why yielding should take place at all has puzzled physicists for some time. Calculations of the inherent strength of metals, based on the interactions of their atoms, have shown that strengths should exist many hundred times greater than those observed. The calculated yield stress required to make a regular array of atoms move by gliding, when each atom nests within the hollows formed by its near neighbours, was much greater than the known tensile strength. To overcome this difficulty, G. I. Taylor suggested that the arrangement of the atoms in a metallic crystal was not as regular as was imagined. Certain rows of the atoms might stop abruptly inside the crystal, the rows on either side closing in on the gap to become a regular lattice again further on. Such gaps were called "dislocations" and the suggestion was regarded somewhat doubtfully, until Bragg showed that small bubbles, formed on the surface of a liquid, imitated most successfully in two dimensions the behaviour of a three-dimensional lattice, and that bubble dislocations of the nature postulated by Taylor were very definitely formed. This gave new life to the conception and much work has been devoted to studying the changes in properties to be expected from the presence of such dislocations in crystalline materials.

The hypothesis gave a simple explanation of the relatively low yield stress found in practice compared with theoretical calculations. The forces between atoms fall off very rapidly with their distance apart and, the binding forces across the wider dislocation gap being much less than normal, give a start to the shearing glide at correspondingly reduced external stresses. Once started, it is, of course, easier to maintain the glide movements which together make up the effects visible as plastic flow. This problem of plastic flow is not only an intriguing one in itself, but it is also of great practical importance. In the manipulation of metals into their finished form, almost every known process makes use of plastic deformation.

It is nearly 50 years since Ewing and Rosenbaum found that polished specimens of metals showed, under the microscope, very definite lines or striations on their surfaces when strained beyond the yield point. These slip lines or slip bands were identified with the translational movement or glide which followed the shearing stresses accompanying the yield point tension. A cross-section showed them as minute steps or serrations on the surface. These slip bands have been studied extensively since then, but still little is known about them. Measured in millionths of an inch, they are two to four units broad and their glide movements are 20 to 30 units long, and that just about sums up our knowledge to date. In many instances, plastic glide movement takes place in jerks, so that a closer examination of the plastic strain-extension curve shows it up as a series of steps and not as a continuous movement. This is particularly the case in hexagonal metals like zinc and cadmium, but it is by no means unknown in steel and it gives rise to a characteristic "orange peel" type of roughness on the surface of sheets used for deep stamping—for example, those used for motor-car bodies—if steps to correct it are not taken. What is occurring is that gliding takes place first on the most favourably situated planes and then, when the ability to glide in these planes is exhausted, the task is handed over to the second-best planes and so the process goes on in a series of steps.

In pure metals, the gliding planes are so closely spaced that the steps are imperceptible. When discontinuous gliding occurs, some of the normal glide planes have been put out of action, so that the spacing of the planes increases and a correspondingly greater increase in effort is required to progress from one plane to the next. When it occurs in steel, this locking or immobilising of the glide planes is due to small quantities of carbon or nitrogen dissolved in the pure ferrite. Other elements may also cause the same effect, but these two at least are known. To counteract their influence, small amounts of vanadium or titanium are added to the composition—generally to the extent of 0·03 to 0·05 per cent. By combining to form insoluble carbides or nitrides, they remove the offending elements from solution and restore the ability of the sheets to make smooth and satisfactory pressings.

Very small quantities of other elements sometimes have the most profound effect on the properties of the parent metal. Damping capacity is a case in point. When a steel bar is set vibrating, the amplitude of movement slowly dies down owing to the energy absorbed by a lack of elasticity in the steel. The ratio of the movement in successive swings is constant, and the logarithm of this ratio is the damping capacity. Puzzling differences occurred in the behaviour of different samples of steel and these have now been traced to small quantities (0·005 to 0·02 per cent.) of carbon and nitrogen. When in solution in iron at ordinary temperatures, the atoms of these elements find a resting place in the lattice between the iron atoms. There are two alternative spaces available—

one of which has plenty of room to hold them but which they do not seem to like, and another which they prefer but which has not sufficient room. When the lattice starts vibrating, it stretches and the second space widens. The carbon and nitrogen atoms immediately slip into their favourite spots, only to be squeezed out again on the return swing. Atoms cannot move about in this way without absorbing energy and it is this energy absorption which is the cause of damping. The energy variation with temperature has been calculated by Snoek and Dijkstra and the course of this curve follows exactly the variations in damping capacity with temperature found experimentally. These variations are quite large and they can be used to calculate the percentage of carbon and nitrogen present in the state of solution in any given specimen. The development of exact physical methods of this nature is bringing to our knowledge most useful and practical information concerning peculiarities in the properties of metals which for long have been a puzzle.

In test pieces under experimental conditions, there is nothing to prevent the free movement of the large displacements involved in plastic deformation. In large structures, where the incidence of stress is far from being uniform, very different conditions often arise. In the hull of a large vessel moving through the sea, the stresses are varying rapidly with time and also varying in their distribution. A peak stress in some part may well attain a value above the plastic limit. But if the material on either side of the peak is well below this value, deformation will be constrained by the rigidity on either side. A condition of enforced elasticity then exists. An insight into such conditions is given by considering a test-piece to which, in addition to a longitudinal tensile stress, side stresses are applied. This is equivalent to a constraint which prevents side movement and has the advantage that the degree of constraint is under control. A stress can be applied to opposite pairs of faces of a square bar which will just keep the cross-sectional area unchanged. When the bar is extended along the axis by x the sides contract by an amount σx, Poisson's ratio being σ. They can be pulled back to the original size by a side stress of $\frac{\sigma}{1-\sigma}$ times the longitudinal stress. In this way, side movement and shearing glide are prevented and the external stress is balanced against the internal cohesion forces of the atoms without any other complication. These cohesion forces have an extremely short range and it takes little movement to out-range their effect. Separation of the cleavage planes will take place rapidly and without evidence of elongation or toughness. In other words, such fractures will be of the brittle type.

No doubt it was some such action as this that Haigh had in mind when he suggested that brittleness arose from the conditions which gave rise to a triple tensile stress. A triple tensile stress is a volumetric tension under which all the atoms in a sphere would be displaced radially. Haigh's theory is equivalent to postulating a maximum volumetric strain energy as the criterion of fracture, and I am in full sympathy with such a view. It will be recognised, however, from the example given of the square bar, that uniform volumetric stresses are by no means necessary. In steel with a Poisson's ratio of 0·285, the intensity of the side stress for constant cross-section need only be 40 per cent. of the length stress for brittle fracture to result.

The chances of finding the required degree of constraint in practice are much greater in large structures than in small. These chances depend on a lack of uniformity in the stress distribution, so that the reason for this statement will be obvious. For example, at sharp corners, as in hatchway openings, there will be peak stresses which, in the absence of corrective measures, can be two to three times the average for the rest of the plating. The peak stress is severely localised, so that the more lightly stressed material on either side of the peak acts as a constraint which prevents any relieving movement from taking place. The reason why brittle cracks have so often started at such corners is due to this combination of conditions. Make the stress more uniform by suitable thickening at the corners, and the area will be able to withstand successfully stresses which can be actually higher than those which previously started a crack. Looked at from this angle, the question whether internal stresses are dangerous or not may become clearer. The advent of welding, with its intensely localised heat input, has made the consequential effects of such internal stresses a matter of practical importance. It is impossible to weld two pieces of metal together by arc welding without introducing strong temperature gradients in the vicinity of the weld. The thermal expansion creates thermal compressive stresses under which the highly heated metal creeps, always moving in such a way that the heat stresses are reduced. When the arc has passed and the metal cools, the residual stresses are always reversed stresses. If the steel has been subjected to compression, the residual stresses are tensile stresses and vice versa.

(*To be continued.*)

LABOUR NOTES.

Outspoken comments on unofficial strikes, especially the recent strike at Manchester docks, are contained in the October issue of *Man and Metal*, the journal of the Iron and Steel Trades Confederation, which was published on Monday last. The journal refers to the issue of the official report on the strike, which lasted from April 25 to June 7, and states that that report provides clear evidence that there was an organisation in existence, long before the strike occurred, ready to take whatever opportunity was offered to it of making trouble. The chance came when two men defied an agreement freely negotiated by the joint negotiating committee for the dock industry and refused to work overtime. The strike which resulted " was due to no spontaneous outburst of feeling on the part of the dockers when these two men were suspended, and there is no record of bad feeling between the management and men at the Manchester docks such as might have accounted for the dockers taking such strong, though misguided, action in a mood of discontent and irritation."

The dockers " were plainly duped " into coming out on strike, the journal considers, by an organisation which had not the slightest interest in them or in the two individuals whom the dockers imagined that they were supporting by the stoppage. The strike leaders " were concerned only with disrupting the work of the docks for their own purposes," proof of which lay in the fact that long after the original cause of the strike had ceased to be a real issue, the strike was prolonged by demands that could not possibly be met without undermining trade-union authority, invalidating the joint agreement on overtime, and repudiating the appeal machinery of the dock labour scheme. When the dockers " belatedly began to show that they were not completely devoid of common sense," and became increasingly reluctant to continue the strike, the journal states, pressure and even intimidation were brought to bear upon them.

Nothing was gained from the strike by the dockers, who lost 150,000*l*. in wages and, in spite of their eventual repudiation of their unofficial leaders, the fact that " some 2,500 dockers should have allowed themselves to be led like sheep for so long by a group of irresponsible *saboteurs* is a matter for grave concern," the journal comments. Unofficial strike action of this kind deals a blow at the very foundation of the trade-union movement and could, if allowed to spread, weaken the whole movement or even destroy its influence completely. The journal feels that this is exactly what persons who organise unofficial strikes would like to accomplish. They are out to create as much discontent and misery as possible and so to clear a path for the extreme left-wing opinions which thrive in those conditions. " It is fortunate," the journal concludes, " that the great majority of workpeople are not as gullible as some dockers appear to be."

A policy of working to rule and a ban on all overtime were decided upon at a meeting of dock employees at Tilbury on October 4. These restrictions, which have been in force since the following day, have resulted in a steadily increasing degree of congestion. All accommodation for ships at Tilbury has been fully occupied during the past fortnight and the long delays which have taken place in the handling of cargoes has led to some vessels leaving the docks, in order to discharge their freights at continental ports and elsewhere. The trouble has arisen as part of a protest by the dockers against the engagement of additional men on a permanent basis by one of the leading firms of master stevedores. In the early days of the dispute numbers of men refused to report for work, but there has since been some improvement in the situation in this connection. Members of the Watermen, Lightermen, Tugmen and Bargemen's Union in the London area agreed at a meeting early this week that their working-to-rule arrangements should remain in force.

The total working population of Great Britain increased during August by 84,000, of whom 47,000 were men and 37,000 were women. According to Ministry of Labour statistics, made available on Monday last, the increase reflects the large intake of young persons leaving school, which is usual in that month. The estimated total number of persons in Great Britain aged 15 and over who work for pay or gain, or who register themselves as available for such work, was 23,449,000 at the end of August, and comprised 16,012,000 men and 7,437,000 women. This total compares with one of 23,180,000 (15,891,000 men and 7,289,000 women) at the end of December, 1950, and with one of 22,904,000 (15,810,000 men and 7,094,000 women) at mid-1948. The working population of Great Britain comprises the Armed Forces, men and women on release leave not yet in employment, the registered unemployed, and all persons—employers, self-employed persons and employees—in civilian employment. Private indoor domestic servants and gainfully-occupied persons over pensionable age are included. Part-time workpeople are counted as full units.

The strength of the Armed Forces was increased by 3,000 during August last to a total of 835,000 persons at the end of that month, of whom 812,000 were men and 23,000 were women. These figures do not include the number of Z-class reservists recalled for 15 days military training. At the end of December, 1950, the armed Forces numbered 752,000, of whom 730,000 were men and 22,000 were women. Some seven thousand ex-Service men and women were on release leave seeking employment at the end of August last. The number of persons registered with the Ministry of Labour as unemployed at the close of that month totalled 205,000, against 195,000 at the end of July, 1951, and represented about 1 per cent. of the number of employees in Great Britain. In comparison, there were altogether 328,000 registered unemployed persons at the close of December, 1950. Persons in the various branches of civil employment numbered 22,402,000 at the end of August last. Some 15,060,000 of these were men and 7,342,000 were women. At the end of December, 1950, there were 22,100,000 persons in civil employment, 14,934,000 men and 7,166,000 women.

Of the 22,402,000 persons in civil employment at the end of August last, 4,194,000 were engaged in the basic industries, an increase of 7,000 on the total for July last. The figures for the end of August comprised 1,790,000 workpeople employed in the transport and communications industries, 1,190,000 persons engaged in agriculture and fishing, 364,000 persons occupied in gas, electricity and water undertakings, 770,000 persons employed in the coal-mining industry, and 80,000 persons engaged in other kinds of mining and in quarrying. The number of wage earners on colliery books, included in the total of 770,000 for the coal-mining industry, mentioned above, was 697,000. In the same month, 8,725,000 workpeople were engaged in the manufacturing industries, including no fewer than 4,130,000 in the engineering, metals and vehicles group. The textile industry employed 1,032,000 persons and the food, drink and tobacco trades a total of 828,000 persons.

Miscellaneous industries and services were responsible for the employment of a total of 9,483,000 persons during August. Of this total, 3,962,000 persons were engaged in professional, financial and similar services, 2,661,000 workpeople were employed in the distributive trades, and another 1,453,000 men and women were employed on building and contracting work. Public administration claimed the services of the remaining 1,407,000 persons; 770,000 being engaged on local government service and 637,000 being employed in the various Departments and agencies of the national Government. The number of persons employed in Government Departments, given above, does not include individuals in the service of the various nationalised undertakings, the numbers of these employees having been included in the totals of the respective industries and services. Altogether, employment in the basic industries increased by 7,000 persons and, in the manufacturing industries, by 42,000 persons, during the month of August. Employment in the professional and financial services, distributive trades, building and contracting work, and in public administration, rose by 21,000 persons during the month.

The supplementary pension scheme for employees in the coal-mining industry, which was developed jointly by the National Union of Mineworkers and the National Coal Board, has now been accepted by an overwhelming majority of the union's branches and is due to come into operation on January 1 next. It was announced at the close of a delegate conference of the Scottish area of the N.U.M., which met in Edinburgh on Monday last, that the area representatives had decided to reverse a former decision and accept the scheme. Mr. Abe Moffat, the President of the Scottish area, stated that the N.C.B. had expressed its willingness to pay a contribution on behalf of miners who were ill, up to a maximum period of three months.

Another concession granted by the Board dealt with deferred retirement. In view of the fact that the present scheme made no provision for a pension payment to miners who had retired since vesting day, the Scottish area delegate conference authorised the executive committee for the Scottish area to ascertain how many miners had retired to date since the mines were taken over by the State. In this connection, Mr. Moffat reported that the Scottish executive had been empowered to consider the possibility of granting small pensions or gratuities to retired miners who were not covered by the scheme.

FUEL RESEARCH.

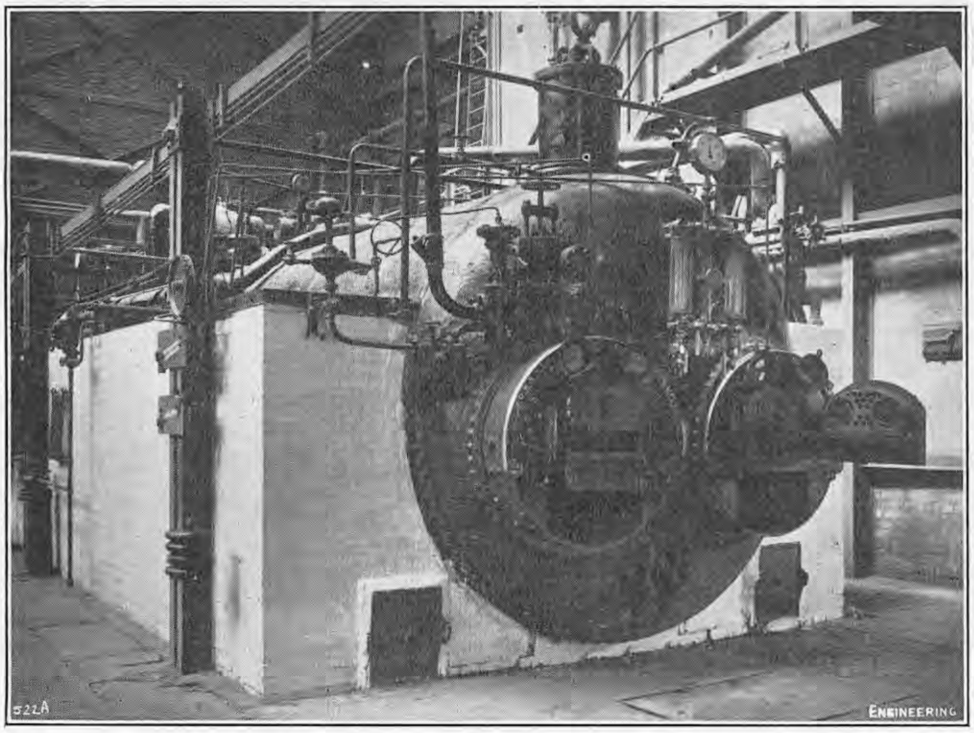


FIG. 2. LANCASHIRE BOILER WITH SMOKE-ELIMINATOR DOORS.

BRITAIN'S FUEL PROBLEMS AND THE WORK OF THE FUEL RESEARCH STATION.*

By A. PARKER, C.B.E., D.Sc.

(Concluded from page 477.)

WITH large industrial boiler installations, such as those at electricity generating stations, there should be no great difficulty in burning bituminous coal efficiently and with the emission of little or no smoke, provided that the equipment is kept in order and properly operated. If arrangements can be made for regular supplies of coal of the type and size-grading to suit the installation, conditions can soon be found to give the maximum efficiency and the minimum quantity of smoke; but, if the fuel varies in quality and size from day to day, frequent adjustment of conditions is necessary, and maximum efficiency cannot be expected.

Though there has been experience over a long period of years with the main types of hand-fired boilers in use in industry and on merchant ships, the problem of firing them efficiently and without the discharge of large quantities of smoke still provides great scope for the fuel technologist. The difficulties have been due partly to inadequate arrangements for controlling the amount of secondary air admitted to burn the combustible gases and vapours, and partly to inadequate training of the boiler operatives. Far too many of these boilers are inadequately equipped with such instruments as draught gauges and CO_2 recorders, and many of the instruments that have been installed are not maintained in full working order. As a result, there are in every large industrial area numerous factory chimneys periodically emitting great quantities of smoke and boldly advertising waste of fuel.

During the recent war, smoke from coal-fired merchant ships disclosed their position to enemy aircraft even well beyond the horizon. In consequence, ships and their crews were unnecessarily lost. The Research Station was accordingly asked by the Admiralty to investigate the possibilities of eliminating or greatly reducing the emission of smoke from hand-fired marine boilers. The problem was studied under the conditions on merchant ships, and series of experiments were undertaken with the Scotch marine boiler at the Station. It was important that any equipment devised should be simple to make and to fit to ships' boilers, and easy to operate. Equipment meeting these requirements was developed and was fitted to the boilers of more than 1,000 ships with satisfactory results. It provides at the right time and in the right way the extra air required for the necessary period after firing to burn the smoky volatile matter evolved from the fresh charge of coal. Designs were introduced for both natural-draught and forced-draught marine boilers. Tests on the full-scale marine boiler at the Research Station, and tests by the research staff on the boilers of a merchant ship during a voyage of several weeks, have shown that not only is smoke almost eliminated, but the quantity of coal consumed for the same amount of steam is reduced with average bunker coal by 5 or 6 per cent. With some coals the saving of fuel is as high as 10 per cent.

The work was then extended with the object of applying the same general principles in controlling the supply of secondary air to natural-draught hand-fired boilers of the shell type (e.g., Lancashire), thousands of which are in use in industry. As a result of a long series of experiments and trials with the full-scale Lancashire boiler at the Research Station, a new type of fire-door has been introduced. This smoke-eliminator door, shown in Fig. 2, is simple to construct and to fit in place of the usual doors, and its operation is easy and calls for no special skill on the part of the fireman. It is just as effective as the device for marine boilers in reducing smoke emission and saving fuel. In the tests to determine the effect of the smoke-eliminator door under different operating conditions, data were obtained on the effects of smoke, excess air, and load on efficiency. With increasing smoke there was little change in the percentage of carbon dioxide in the flue gas, but there was a steady rise in the percentages of the combustible gases—carbon monoxide, hydrogen, and methane. This caused a drop in thermal efficiency roughly proportional to the optical density of the smoke. The reduction in efficiency caused by the invisible combustible gases was many times greater than that due to the visible suspended matter or smoke.

Smoke eliminators of F.R.S. design are being manufactured commercially by several firms, and are now in use on several hundred boilers. Further work is in progress with the object of applying the same principles to vertical boilers. There is no doubt that, on average, the efficiency of hand-fired boilers in industry could be improved without great difficulty to raise the same amount of steam with a reduction of 5 per cent. in the quantity of fuel now consumed. As these boilers use at least 20 million tons of coal a year, the saving could be at least 1 million tons a year. In addition, by cutting down waste, there could be economies in many instances in the quantity of steam required for various processes. Better insulation of buildings and equipment would also lead to a saving of fuel.

The thermal efficiency of the large water-tube boilers at modern power stations is now very high—over 80 per cent.—so that there is not great scope for improvement in this respect. With many of these boilers raising steam at high pressures and temperatures, however, there has been serious trouble from the deposition of solid matter on the external side of the heating surfaces and from corrosion of the equipment for preheating the air supplied for the combustion of the coal. With some boilers, the amount of solid matter deposited has been so great that the boilers have had to be shut down for extensive cleaning after having been in continuous operation for only a few weeks. Without this difficulty, it should be practicable, if needed, to keep the boilers in continuous operation for a year—say 8,000 hours—before shutting them down for annual inspection and cleaning. Operation for 8,000 hours in the year is considered to be 100 per cent. "availability." The effect of this trouble with deposits on heating surfaces has been particularly important during the last few years, with the great increase in the demand for electricity and the shortage of generating plant.

At the request of the boiler-makers and the electricity-supply industry, through their Boiler Availability Committee which was set up some years ago, the Fuel Research Station and the British Coal Utilisation Research Association are co-operating with the industry in investigating the problem. The task allotted to the Station has been to ascertain the effect of the type and composition of the coal used in relation to the design and method of operation of the boiler installation. It has already been proved that there is a relationship between the severity of the trouble, the nature and amount of the inorganic substances in the coal, and the conditions of operation. For example, coals containing relatively high amounts of alkali chlorides, sulphur, or of phosphorus, give marked trouble when fired with mechanical stokers of the coking type. Though coals considered to be rich in phosphorus contain only about 0·05 per cent., equivalent to less than 1 per cent. of the ash of the coal, deposits collected have contained as much as 10 per cent. of phosphorus. There has been relatively little trouble of this kind with boilers fired with pulverised coal. Much work lies ahead, but the results so far have shown how the difficulties can be greatly reduced by modificati n in the allocation of coals and by changes in conditions of operation. Improvement in the availability of the boilers at generating stations has already been achieved. Work is also being carried out on the effects of conditions of combustion and on the amounts of sodium chloride, sulphur, vanadium, and other constituents of fuel oil on the formation and character of external deposits in boilers fired with oil.

Within the past 30 years there has been steady development in the use of pulverised coal for firing boilers and furnaces, and the proportion of coal used in pulverised form at power stations is increasing rapidly as new power stations are brought into operation. One reason for this development is that, when burned under suitable conditions, pulverised coal gives to the coal-fired furnace some of the advantages of flexibility usually associated with oil firing. Another reason is that small coal, which is necessarily produced in considerable quantity, particularly with mechanised mining, has been sold at a much lower price than coal of larger size. The Fuel Research Station has always taken a prominent part in work on pulverised-fuel firing; the first Fuel Research Special Report, published in 1919, was on this subject. Experiments have covered methods of pulverising, so-called "grindability" of different coals, and conditions and mechanism of combustion, from individual particles in laboratory equipment to burners of special design, each using several hundred pounds of coal per hour. F.R.S. "grid" and "multi-jet" burners have been developed and are in use in a variety of furnaces in industry.

A special "vortex" combustion chamber, shown in Fig. 3, page 506, was designed before the war and was used in experiments, burning up to 500 lb. of pulverised coal per hour, with the high heat release at atmospheric pressure of 500,000 B.Th.U. per hour per cubic foot of combustion space. In this system, the aerodynamic conditions are so arranged that the particles of coal move in a balanced vortex, with the air passing around and across the particles. As the particles burn to ash and become smaller in size, they move towards the centre of the vortex and away with the gaseous products of combustion. The initial object was to develop a new type of combustion chamber for boilers and other furnaces.

Tests have been carried out continuously over a period of six months on six representative types of CO_2 recorders (Fig. 4, page 506), under conditions similar to those to be expected in the boiler-house of a small works. The recorders were given no more skilled attention than could be made available in such works, and 10 to 20 minutes were spent daily in adjusting and servicing each instrument. With this amount of attention, all six recorders were satisfactory and consistently gave readings within 1 per cent. of the correct value. If a recorder is required for special conditions, some care is necessary in selecting the most suitable type, particularly if a quick response to rapid fluctuations in gas composition is required. At the start of the tests, condensation and dust deposition caused blockages in the pipe-line leading from the boiler flue to the instruments, demonstrating the importance of a correct layout of the pipe-work and filters.

Before the last war progress had been made in

* Paper presented at the autumn general meeting of the Institution of Heating and Ventilating Engineers, held in London on October 10, 1951. Abridged.

experiments on the use of powdered coal in place of oil for Diesel engines. Five or six years ago it was decided not to continue this work, but to investigate the more promising possibilities of using powdered coal, and producer gas from coal and coke, to provide the energy for gas turbines. Considerable progress has been made in developing combustion chambers based on the F.R.S. vortex chamber and on the grid and multi-jet burners for pulverised fuel. Each chamber of the two experimental units at the Research Station has been designed to burn up to 500 lb. of coal per hour at atmospheric pressure, and includes cooling air to protect the equipment from overheating and for mixing with the product gases to give a mixture at a temperature (about 700 deg. C.) suitable for gas turbines. Combustion efficiencies of 92 to 95 per cent. have so far been achieved. When a suitable stage has been reached in these experiments at atmospheric pressure, the work will be extended to the combustion of coal at a pressure of several atmospheres. It is hoped that in equipment of about the same size it will be possible under pressure to burn about 2,000 lb. of coal per hour to give a heat release of the order of 2 million B.Th.U. per hour per cubic foot of combustion space. This should be sufficient for a turbine of about 2,000 kW. In both systems, the ash is carried as particles of solid matter in the product gases. There is the problem, therefore, of removing these solid particles to an extent sufficient to avoid damage to the turbine. This problem is being investigated. There is also required a really satisfactory method of feeding the coal under pressure to the combustion chamber. A third combustion chamber of the cyclone type is being developed by the British Coal Utilisation Research Association for the Fuel Research Station. In this chamber, designed for operation with granular fuel, a large proportion of the ash is fused and leaves as molten slag, thereby reducing the quantity of solid particles carried forward with the gaseous products.

Close co-operation is maintained with the Ministry of Fuel and Power and with the various industrial firms working under contract to the Ministry on the use of solid fuel for gas turbines. Design data for combustion chambers have been provided and assistance has been given in dealing with some of the associated problems, such as grinding and feeding the fuel. In addition, various fuels, including peat, have been tested in the combustion chambers at the Research Station; and experiments have been made on the influence of dust in the combustion products on the performance of heat exchangers for turbine equipment. It is worthy of mention that the only open-cycle gas turbines that have been run on coal have used burners based on F.R.S. design; though much work lies ahead before entirely satisfactory systems will be developed for coal and other solid fuels.

Another branch of this programme includes experiments on the production of producer gas under conditions suitable for providing the energy for gas turbines. In addition, the Station is participating in an investigation on the damage to turbine blades by the products of combustion of heavy fuel oils, which usually contain alkali chloride, sulphur, vanadium, and nickel.

Extensive explorations have failed to reveal any appreciable reserves of natural oil in Great Britain. World reserves of oil may be large, but it is fairly certain that they are equivalent to not more than a few per cent. of world reserves of coal. That is why several countries are interested in processes of obtaining oils as main products from coal. The Fuel Research Station has been interested for a long time. Coal carbonisation is one way of obtaining tar oils and benzole as by-products, with coke and gas as the main products. In this way, up to 20 gallons per ton of coal can be obtained. Other by-products include ammonia and sulphur.

There are two types of process, however, in which oils are the major products. In the first, coal is treated with hydrogen at temperatures in the region of 450 deg. C. and at pressures from 200 to 700 atmospheres. This process was introduced in Germany, where the first commercial plant was started at Leuna in 1927. By 1944 there were 18 large plants in Germany producing oil at a combined rate of 3·5 million tons a year. At that time most of the German aviation spirit was made by hydrogenation of coal or coal-tar oils. Experiments on this type of process were begun at the Fuel Research Station in 1923, using British coals, and they were continued for about 15 years from fundamental work in the laboratory to the stage of treating one or two tons of coal or tar per day. Experiments were also undertaken by Imperial Chemical Industries, Limited, who have had a commercial plant in operation since 1935 producing between 75,000 and 150,000 tons of oil a year, mainly from coal-tar creosote. There has also been much experimental work at the Fuel Research Station on the hydrogenation of coals from other parts of the Commonwealth.

In the second main type of oil-from-coal process, known as the Fischer-Tropsch process, coal is converted by various methods into a mixture of the two gases, carbon monoxide and hydrogen. The mixture is purified to remove sulphur compounds and is then passed over catalysts containing cobalt or iron at a temperature of 200 deg. to 300 deg. C. to synthesise hydrocarbon oils and waxes. In the synthesis reaction a considerable amount of heat is generated, and one of the main chemical engineering problems is to carry away this heat rapidly, otherwise the temperature of the catalyst rises unduly and the main product is methane. The process, with cobalt catalysts, was developed in Germany to the scale of production in 1944 at a rate of about 600,000 tons of product a year. Since 1934 the process and various modifications of it have been under continuous investigation at the Station in laboratory equipment and on a somewhat larger scale (Fig. 5), using both cobalt and iron catalysts. Much useful information has been obtained on the mechanism of the synthesis reactions and on various techniques. Recently, the work has been extended to include two small pilot plants each of a size to produce 30 to 50 gallons of product per day. In one plant the "fluidised-solids" technique is employed, whereby the synthesis gas is passed upwards through a bed of small particles of catalyst at such a rate as to keep the bed in motion and give it properties resembling those of a liquid. This has the effect of greatly increasing the rate of heat transfer and thus of simplifying the equipment. In the other pilot plant the catalyst is suspended in high-boiling oil from the process and the suspension is kept in motion by the synthesis gas.

In 1943 the U.S. Bureau of Mines became interested in the possibilities of obtaining oil from coal and were provided with all the information available at the Fuel Research Station. Since that time, the processes of hydrogenation and hydrocarbon synthesis have been investigated on a considerable scale by the U.S. Bureau and by commercial undertakings in the United States, and there has been regular exchange of information with the Fuel Research Station.

There is no doubt that the technique adopted in the commercial plants in Germany for the synthesis of oil from carbon monoxide and hydrogen could be greatly improved. No commercial plant for hydrocarbon synthesis has been erected in Great Britain. Under conditions in Germany before the war, the cost of producing oils by either hydrogenation or hydrocarbon synthesis was greater than the price of petroleum oils, but Germany used the processes on a commercial scale largely with the object of being less dependent on imported petroleum. With coal at its present price in Great Britain, the oils from these processes, as so far developed, would cost 2*s.* to 2*s.* 6*d.* a gallon at the plant. The major part of the cost, at least 70 per cent., is incurred in the production of the synthesis gas from coal. There are parts of the Commonwealth, however, where coal of certain types can be produced at a price as low as 5*s.* to 10*s.* per ton; and a decision has recently been reached, for example, to erect a commercial plant in South Africa for synthesis of oil from cheap coal. It may be that in the not far distant future there will be a serious shortage of petroleum oils in some areas. It is for this and other reasons that it has been decided to extend and intensify the work at the Station.

On average, British coals contain approximately 1·5 per cent. of sulphur, with a range from somewhat less than 1 per cent. to 4 per cent. or more in a few instances. Part of the sulphur as brought up with the coal from underground is in the form of pyrites, which

FUEL RESEARCH.

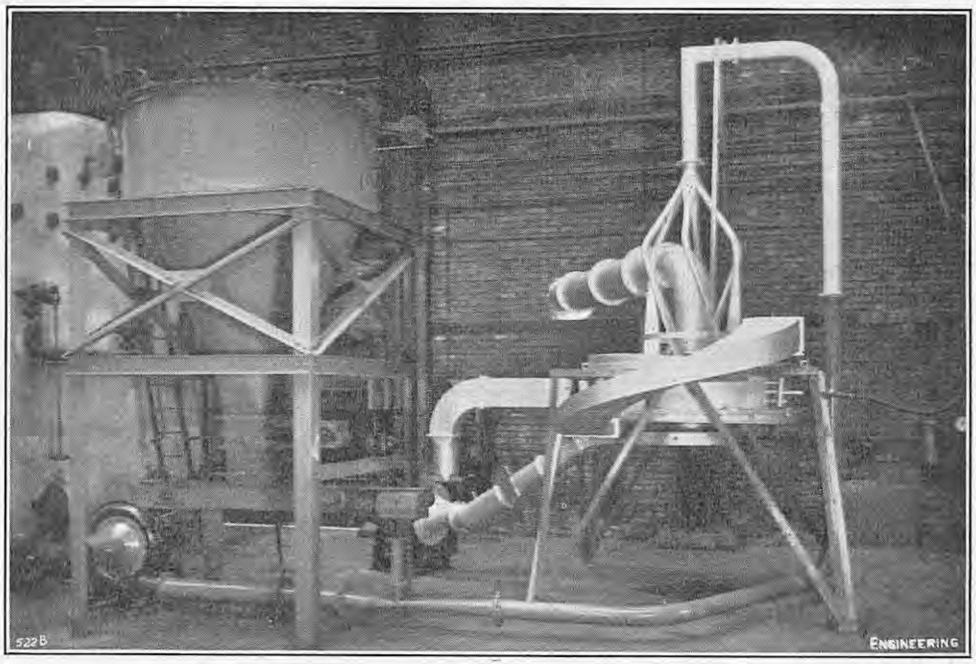


Fig. 3. Vortex Combustion Chamber Burning Coal for Gas Turbines.

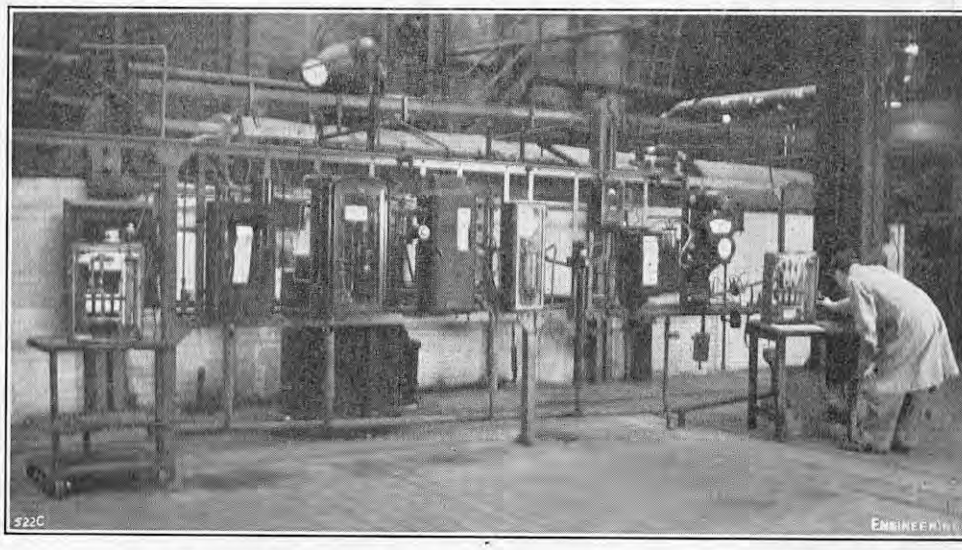


Fig. 4. Testing CO_2 Recorders on Boiler Flue Gases.

FUEL RESEARCH.

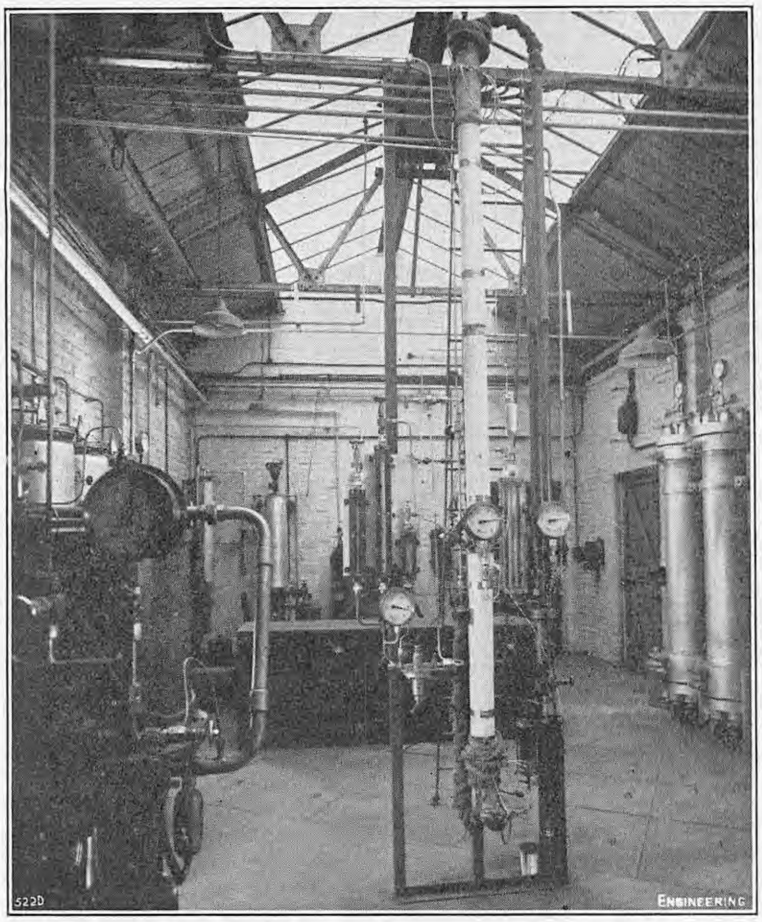


FIG. 5. EXPERIMENTAL PLANT FOR SYNTHESIS OF OIL.

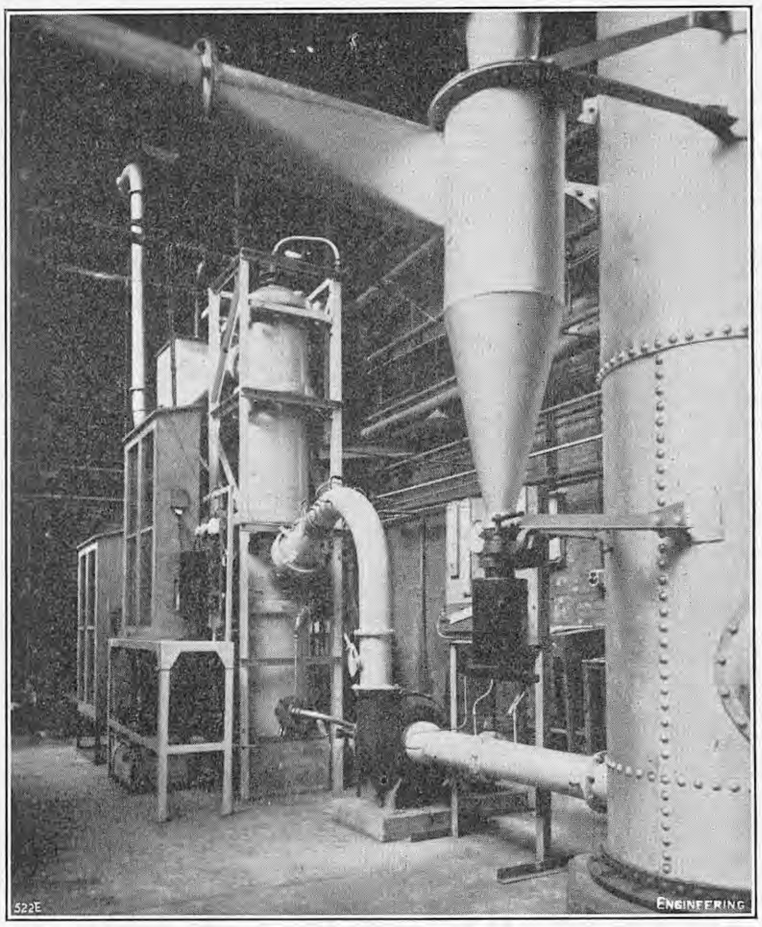


FIG. 6. PILOT PLANT FOR RECOVERY OF SULPHUR FROM BOILER FLUE GASES.

can be separated to some extent by coal-cleaning processes. During the last war the Station co-operated in work on the recovery from coal of pyrites for the manufacture of sulphuric acid, thus reducing the quantity of pyrites that had to be imported. As a result of these efforts, the quantity of pyrites recovered reached 50,000 tons per annum.

When coal is carbonised for the manufacture of coke and gas, some of the sulphur from the coal appears in the gas as hydrogen sulphide, which is removed before the gas is distributed for town supply. By the usual system of purification the gas is passed through iron oxide, which is eventually converted to "spent oxide" containing 50 per cent. of sulphur by weight. This spent oxide can then be used for making sulphuric acid. At the present time more than 200,000 tons of spent oxide are produced annually. In the past, the price obtained for the spent oxide, on the basis of the sulphur content, has been less than the cost of producing it, but the gas industry is under legal obligation to purify the gas before distribution. It would be preferable to recover the sulphur in elemental form of fairly high purity, if this could be achieved efficiently at reasonable cost. Several processes with this object have been suggested and some have been tried. In view of the acute shortage of sulphur at the present time, the Research Station is studying these processes and advising the Government Departments interested.

Coke usually contains about the same proportion of sulphur as the coal from which it is made. On combustion of coal or coke, most of the sulphur is converted to sulphur dioxide to be discharged with the chimney gases. With the object of reducing atmospheric pollution, there have been efforts to devise satisfactory methods of removing the sulphur from the flue gases of installations, such as power stations, burning large quantities of coal. Two processes have been used on a large scale, one at Battersea and the other at Fulham. In the Battersea process, the sulphur is removed as a solution of calcium sulphate, which is discharged as a waste liquid into the River Thames. In the Fulham process, the sulphur is removed as a wet sludge of calcium sulphate, which has been of no value. At present prices, the overall cost of these processes is equivalent to adding 7*s*. to 10*s*. to the cost of each ton of coal burned under the boilers. The problem is a difficult one to solve economically, because each ton of coal gives rise to about 400,000 cub. ft. of flue gas containing only about 0·1 per cent. of sulphur dioxide by volume. During the past two or three years, pilot-plant experiments have been carried out at the Research Station on a Fulham-Simon Carves process designed to recover the sulphur mainly as ammonium sulphate and partly as elemental sulphur. The pilot plant is illustrated in Fig. 6. Technically, the experiments have been successful, though further work is necessary to bring the process to full-scale operation; but the net cost, after allowing for the value of the products, is very high. Other possible processes have also been considered.

FIG. 7. DEPOSIT GAUGE FOR MEASURING ATMOSPHERIC POLLUTION.

Under the guidance of the Atmospheric Pollution Research Committee, which is now a committee of the Fuel Research Board, methods of measuring different forms of atmospheric pollution have been improved and new methods devised. Fig. 7 shows a deposit gauge used in the City of London for measuring atmospheric pollution. Systematic records of the extent of pollution in many parts of the country have been obtained over a long period of years, with the assistance of local authorities and others interested. The number of organisations co-operating by making regular observations in their areas is now more than 100; and since the work came under the Fuel Research Station five or six years ago, the total number of instruments in regular use has increased from about 200 to about 900.

In addition, there are special investigations by the research staff. For example, over a period of three years, there was an intensive survey of pollution in a selected area. Leicester was chosen for this work, which provided valuable information on the factors affecting the movement and dispersal of pollution. At the present time, there are in progress intensive surveys of pollution by sulphur in several areas with the objects of finding the effects of discharges from the high chimneys of installations, such as power stations, burning large quantities of coal. A beginning is also being made in a fundamental investigation of the effects of various factors on the dispersion of polluting substances from a single source, such as a high chimney in an area some distance from other sources of pollution. All these activities on measurement and dispersion of pollution are closely linked with other work at the Station on methods of improving fuel efficiency and of reducing the emission of polluting substances.

There have been numerous miscellaneous investigations, some on an extensive scale, to meet the needs not only of this country but also of Commonwealth countries overseas. They have included work on the winning and utilisation of peat; production of oil from shale; extraction of special waxes from lignite and peat; use of waste materials such as sawdust and waste wood, flax shives, and ground-nut shells as fuels; orchard heating to prevent damage by frost; and many other items.

There is a comprehensive information and library service at the Research Station to assist all who are interested in fuel problems. The service includes the preparation of bibliographies and summaries of the literature on topics of special interest, and the publication of the monthly periodical *Fuel Abstracts*, which includes 8,000 or 9,000 abstracts a year and covers every significant paper in the field of fuel science and technology. In the preparation of *Fuel Abstracts* the Station works in close co-operation with the fuel industries and their research associations.

Unless there are great advances towards the better utilisation of our fuel resources, it will be difficult for this country to maintain her position in world affairs, and industry and to keep up the standard of living of the people. Our estimated reserves of coal are no more than 6 per cent. of the coal reserves in the U.S.A. We have practically no indigenous petroleum and relatively very little oil shale and potential water power. Even our peat resources are equivalent to only about 5 per cent. of our coal reserves, and so far the utilisation of this peat has not been economic. It is of the very greatest importance to Great Britain, therefore, that improvements in the utilisation of fuels should be pressed forward as rapidly as possible.

THE WORK OF THE ELECTRICITY SUPPLY INDUSTRY.*

By Sir John Hacking.

The first object of an electricity-supply industry is to supply electrical energy. Table I has been prepared to indicate how the consumer in Great Britain has fared in this respect in comparison with consumers in other countries. It shows the energy supplied to consumers from the public systems in a number of countries in 1939 and in 1949, and the increases during this decade.

Table I.—*Energy Supplied to Consumers from Public Systems,* 1939 *and* 1949.

Country.	Amount, kWh.		Increase.	
	1939.	1949.	kWh.	Percentage.
	× 10^9	× 10^9	× 10^9	
United States ..	105·8	248·5	142·7	135
Sweden	5·2	10·9	5·7	110
Switzerland ..	3·3	6·4	3·1	94
Great Britain ..	22·6	41·4	18·8	83
Norway	4·1	7·5	3·4	83
Netherlands ..	2·4	4·2	1·8	75
Belgium	2·5	4·3	1·8	72
France	13·2	20·2	7·0	53
Western Germany ..	Not available	20·8		
Italy	Not available	13·5		

It will be seen from this table that the growth in public supply in Britain during the ten-year period 1939-49 represented an increase of 83 per cent., a figure exceeded only by Switzerland, Sweden and the United States. The figures refer only to the public supply, but in many countries a considerable proportion of the national electricity supply is provided from private industrial power stations directly to the works which they serve. A better picture of the rate of growth in the various countries is therefore given by Table II, which shows the total energy supplied from both public and private systems.

Table II.—*Energy Supplied to Consumers from Public and Private Systems,* 1939 *and* 1949.

Country.	Amount, kWh.		Increase.	
	1939.	1949.	kWh.	Percentage.
	× 10^9	× 10^9	× 10^9	
United States ..	139·5	302·7	163·2	117
Sweden	7·9	13·9	6·0	76
Great Britain ..	29·0*	47·6†	18·6	64
Switzerland	5·0	8·0	3·0	60
France	17·6	26·6	9·0	51
Netherlands ..	3·6	5·4	1·8	50
Belgium	5·3	7·7	2·4	45
Norway	9·6	13·7	4·1	43
Italy	15·8	17·2	1·4	9
Western Germany ..	Not available	32·3		

* Includes an estimate of 6·4 × 10^9 kWh from private generation.
† Includes an estimate of 6·2 × 10^9 kWh from private generation.

From this second table it will be seen that the true growth in total electricity supply in Britain between 1939 and 1949 was about 64 per cent., a figure similar to that for Switzerland and not much greater than the figures of 45 to 50 per cent. for the Netherlands, France, Norway and Belgium, though substantially greater than those for Italy and Western Germany. The British 64 per cent. was, however, rather less than Sweden's 76 per cent., and considerably less than the figure of 117 per cent. for the United States. In order to indicate the relative growth of requirements of different classes of consumer, Table III has been prepared and it will be seen that there has been a marked increase in most countries in the proportion of the total consumption attributable to the group "agriculture, shops and offices, domestic, public lighting and small power." The proportional consumption in 1949 of this group in Britain at 40·0 per cent. of the total was, for that year, among the highest in any of the countries listed and was similar to the figure of 40·2 per cent. for the United States, though lower than that of 44·1 per cent. for Switzerland. It was very much greater than the figures of 23·6 per cent. for Western Germany, 20·0 per cent. for France, 19·7 per cent. for Italy, and 14·6 per cent. for Belgium. While the figures which have been quoted give a picture of the rate of growth of energy supply in Britain as compared with other countries, there still remains the question of the relative absolute rates of energy supply in the different countries. This is shown for 1949 in Table IV.

* Presidential address delivered to the Institution of Electrical Engineers on Thursday, October 11, 1951. Abridged.

Fig. 1. AVERAGE WEEKDAY PLANT-LOAD CONDITIONS DURING DAILY PEAK.

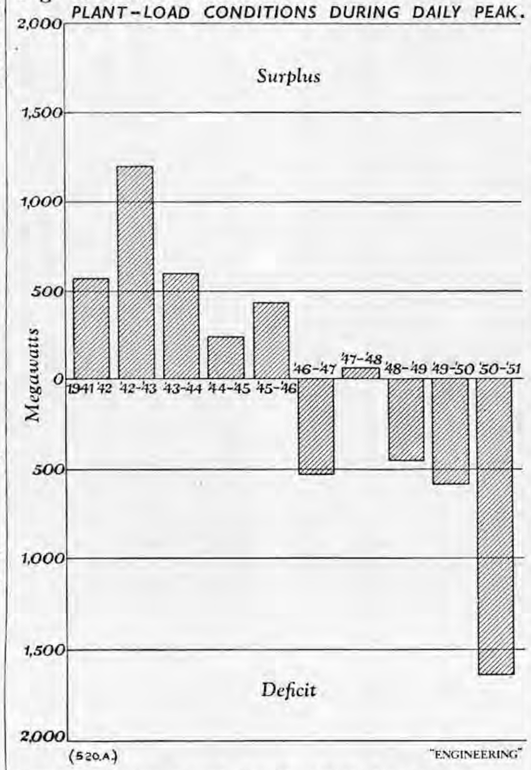


Table III.—*Proportion of Tota l Supply from Public and Private Systems Taken by the Various Consumer Groups in* 1939 *and* 1949.*

Country.	Year.	Traction.	Industry.	Agriculture, Shops and Offices, Domestic, Public Lighting and Small Power.	Total consumption, kWh.
		Per cent.	Per cent.	Per cent.	× 10^6
Belgium ..	1939	4·4	83·3	12·3	5,327
	1949	4·0	81·4	14·6	7,714
France ..	1939	5·3	77·6	17·1	17,588
	1949	6·3	73·7	20·0	26,565
Great Britain	1939	4·3	64·9	30·8	29,001
	1949	3·0	57·0	40·0	47,574
Italy ..	1939	Not available			
	1949	8·5	71·8	19·7	17,207
Netherlands	1939	6·8	67·5	25·7	3,580
	1949	4·2	64·9	30·9	5,437
Norway ..	1939	1·1	74·7	24·2	9,588
	1949	1·3	63·9	34·8	13,695
Sweden ..	1939	9·0	75·6	15·4	7,861
	1949	9·1	62·7	28·2	13,918
Switzerland ..	1939	6·0	57·6	36·4	4,951
	1949	6·3	49·6	44·1	8,017
United States	1939	4·1	60·8	35·1	139,468
	1949	2·0	57·8	40·2	302,664
Western Germany	1939	Not available			
	1949	3·3	73·1	23·6	32,271

* Only in the case of the 1949 figures for Norway and Sweden is any analysis of the total supplies from private systems available. In all other cases it has been assumed that the whole of such supplies is given to "industry."

In this country it is, however, the supply of power at time of peak load rather than the supply of energy over the year which has been, in recent times, the most serious problem. Here the position of Britain is not so favourable as that of other European countries. Shortly after the end of the Second World War several of the Western European countries such as Italy, France and Western Germany, as well as Britain, had serious power deficits, amounting to as much as 500 to 1,500 MW at time of peak load. By the winter of 1950-51, however, it appears that in all parts of the mainland of Western Europe—except South Holland—these deficits had been eliminated or reduced to negligible proportions. Meanwhile, in Britain the position has grown worse instead of better, despite the efforts which have been made both to commission more plant and to reduce the peak load. This is illustrated by Fig. 1, which shows the average weekday surplus or deficit of generating plant available at time of daily peak demand during the months of December and January for the winters 1941-42 to 1950-51. The reason for this deficit appears to be that at rate of construction after the end of the war lagged in Britain, as compared with other countries, until about 1948, although since then it has accelerated until it is now level with what is being achieved elsewhere. Britain's slow start is perhaps not unexpected in view of the restrictions on new generating plant which had necessarily to be imposed after Dunkirk and which produced its full effect only some years later. Furthermore, there is one factor which has undoubtedly been of assistance to some Continental countries. This is the use which they have made of Marshall Aid funds to purchase American power plant. Thus, for instance, in France an American 100-MW set was installed at the Gennevilliers power station in Paris, and the expansion of the industrial power plants was also to some extent aided from this source; an example of the latter is the installation of two 60-MW American generating sets at the Déchy station of the French coal mines. Similarly, a proportion of the Marshall Aid allocated to Italy was used to increase the sources of electricity production in that country. The purchase in the United States of 12 thermal and hydro turbo-generators with a total capacity of 600 MW, together with boiler plant of a capacity of 120 MW, was financed from these funds between 1948 and 1951, and it is expected that further similar purchases will be made. No part of the dollar funds made available under the Marshall Plan to the United Kingdom was used to assist in overcoming our serious power shortage.

Table IV.—*Energy Supplied to Consumers from Public and Private Systems per Head of Population,* 1949.

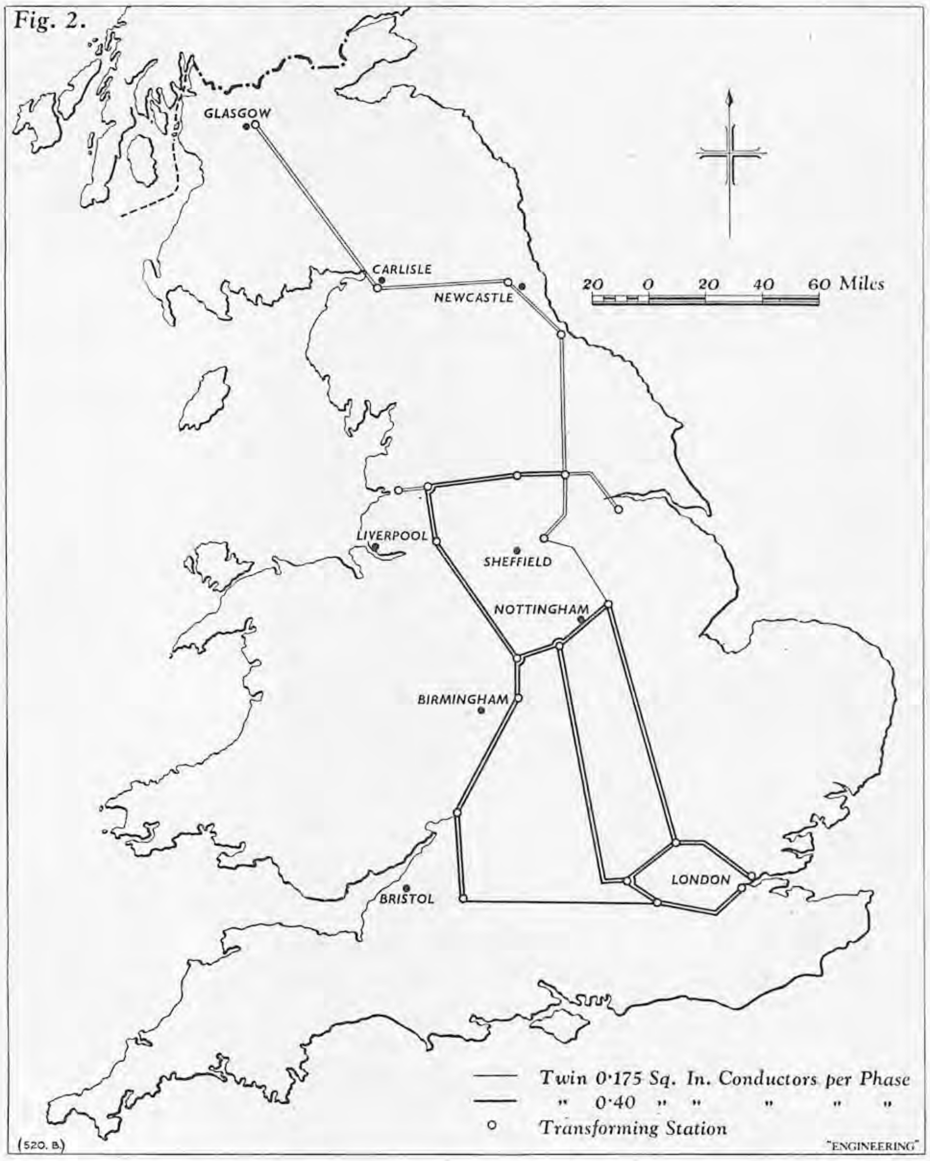
Country.	Supplied from the Public System.	Supplied from Public and Private Systems.
	kWh.	kWh.
Norway	2,340	4,280
United States ..	1,670	2,030
Sweden	1,500*	1,910
Switzerland ..	1,350	1,710
Great Britain ..	811	933†
Belgium	502	897
Western Germany ..	439	681
France	488	643
Netherlands ..	415	544
Italy	291	372

* Excludes an estimate of 3·0 × 10^9 kWh from private generation.
† Includes an estimate of 6·2 × 10^9 kWh from private generation.

It is not the only object of the supply industry to make available adequate supplies of energy and peak-load power. It is also necessary to do this with maximum economy and efficiency. In this respect a comparison of British and oversea achievements is not easy, as many of the data required are not available and the operating conditions in the different countries vary greatly. For instance, many of the European countries depend to a large extent—in some cases almost entirely—on water power, the thermal stations being used only at certain seasons of the year or for peak-load operation. Thus it is not surprising to find that the thermal efficiency of the coal-fired stations of Electricité de France—which derives about half its supplies from water-power plant—was only 17·3 per cent. in 1948 and 17·7 per cent. in 1949, as against corresponding figures of 21·0 per cent. and 21·3 per cent. for the stations of the British Electricity Authority. A comparison with the United States, where only about one-quarter of the total output is from water power, would be more useful; but overall figures of thermal efficiency are not available, as the published national statistics refer only to fuel consumption per kilowatt-hour sent out from power stations, and the average calorific value of the coal burned in these stations is not known. However, more complete data are available for a group of 200 base-load stations located fairly representatively over the whole of the United States. In 1947—the latest year for

ELECTRICITY SUPPLY IN GREAT BRITAIN.

Fig. 2.



which information is available—the coal burned by this group represented 72 per cent. of the total tonnage consumed in public-utility stations in the United States, and had a weighted average calorific value of 11,980 B.Th.U. per pound. If this figure is applied to the national average coal consumption in public-utility stations in the United States in 1947 of 1·31 lb. per kilowatt-hour sent out, the resulting thermal efficiency is 21·7 per cent. For the same year the British figure was 20·7 per cent. Alternatively, a comparison can be made between the thermal efficiency of this group of 200 American base-load stations and a roughly corresponding group of 60 British stations. This comparison shows that in 1947 the thermal efficiency of the American group was 23·3 per cent., and of the British group 22·4 per cent. In comparing these figures the appreciably higher load factor of the American systems should be borne in mind. This is indicated by the number of kilowatt-hours sent out per kilowatt of installed capacity, which in 1947 amounted to 5,379 kWh for the American group of base-load stations as compared with 3,815 kWh for the British group.

In 1950, the national average coal consumption in the United States had fallen to 1·19 lb. per kilowatt-hour sent out. In the absence of other information it may perhaps be permissible, for the purpose of a rough estimate, to apply the same figure for calorific value as in 1947. The resulting thermal efficiency in 1950 would then be 23·9 per cent., which may be compared with the corresponding British figure of 21·5 per cent. It thus appears that between 1947 and 1950 the improvement in thermal efficiency in America was much greater than in Britain. It is not hard to find a reason for this difference: in Britain, owing to the enforced retention in service of old plant and to the long running hours required from that plant because of the virtual removal by load shedding of the shorter-term peaks, the average thermal efficiency of generation of a quarter of the total output in the year ended March 31, 1951, was as low as 16·3 per cent. It is estimated that, had it been possible to commission new plant according to programme and so to be in a position to meet demands in full, the output of the lower-efficiency plant would have been substantially reduced and the overall average thermal efficiency increased from 21·5 per cent. to 22·5 per cent., thus saving about 1½ million tons of coal in the year. Had it been possible, in addition, to replace by new plant 1,000 MW of the old plant of lowest efficiency, the average thermal efficiency would have been increased to 23·0 per cent., with a further saving of some 800,000 tons of coal in the year.

During the war, the programming of new generating plant in this country was brought practically to a standstill. Since 1945, however, the total installed capacity of new plant released has been about 13,000 MW. This includes the installation of 9,700 MW in no less than 53 new generating stations, which, when fully developed, will accommodate plant with a total capacity of 12,500 MW. Of the plant programmed for the five years 1946-50, only some 47 per cent. had been commissioned by the end of the period. The reasons for the failure to achieve a greater proportion of the programme, or the measures which have been and are being taken to improve the rate of commissioning will not be discussed, but it is suggested that with the increasing capacity of units, the overall effort on the part of all concerned in carrying out the generating-plant programmes is not necessarily proportional to the size of the programmes. Provided the necessary materials and labour can be made available, the programmes which are now in hand, and even larger future programmes, are, therefore, well within the capacity of the manufacturers and of the design staffs of the Authority and the consulting engineers; but the rearmament programme is at present seriously increasing the difficulties in obtaining materials. It is essential that these difficulties should be removed if the generating plant programmes are to be achieved.

Although the early programmes sanctioned after the war included a proportion of plants which were repetitions of existing designs, discussions with manufacturers indicated that there would be no difficulty in building straight condensing sets up to 60 MW at 3,000 r.p.m., and that this was economically desirable. The position was not so clear with regard to boilers, and at first it was deemed necessary to limit capacities to some 360,000 lb. per hour, for which rating either fusion-welded or forged drums could be used for designs involving only one or two drums. A number of stations were therefore planned with 60-MW turbo-alternators each associated with two 360,000-lb. boilers. With the installation of several fusion-welding plants of increased size and the associated heavy plate-bending presses, larger capacities became practicable, thus permitting adoption of the desirable unit layout—one boiler, one set—for capacities up to 60 MW, and later even up to 100 MW. More than one-third of the total 13,000-MW programme is being installed with the unit boiler arrangement. This comprises a total of 97 individual sets and boilers, including 50 of 60-MW capacity and five of 100-MW capacity. Over 70 per cent. of the total programme will employ pulverised-fuel firing. This is at present the only practicable method of firing the large boilers required in the unit arrangement.

Three general standard steam cycles have been adopted and the development of the gas turbine is being encouraged. Its future may, however, depend on the possibility of using coal and much research is taking place at various manufacturers' works on methods of doing this. In a variation of the normal closed gas cycle, it has been proposed to use steam as the working fluid with a large proportion working over about the same pressure ratio as in the closed gas cycle; and to obtain about the same temperature ratio by diverting the balance of the steam, after it has been passed through the gas turbine and exhaust heat-exchanger, to a low-pressure condensing turbine driving an additional generator. The condensate from the condensing turbine would be reintroduced in spray form to the main turbine and compressor circuit, either ahead of a number of compressors working in series or at their individual suction branches. The efficiency of the cycle will be influenced to a considerable extent by that of the steam compressor, and separate experiments are taking place on this item of equipment before proceeding with further development. Great interest is also being taken in the possibility of combining the gas and steam cycles. The air passed through an open-cycle gas turbine is much in excess of that required for the combustion of the fuel, with the result that most of the oxygen is left in the exhaust gases. It has been proposed that the exhaust flow from the turbine should be used as the combustion air supply to a steam boiler, which in turn would supply a normal turbine. Many combinations have been developed, in some of which the exhaust flow from the gas turbine is also used for inter-stage reheating of the steam turbine and for feed-water heating. Other schemes envisage using the open-cycle gas turbo-compressor system as a means of obtaining pressurised combustion in the boiler furnace, as originally exemplified by the Velox boiler. With pressurised combustion, the heat-transmission rates through the boiler surfaces are materially increased, so enabling the dimensions of the boiler to be reduced. Overall efficiencies of around 40 per cent. might be obtained with these methods, but the practical development depends on correctly proportioning the gas-turbine and boiler components.

The water-power resources in the northern half of Scotland have been developed to the extent of 165 MW, but it is expected that they will ultimately reach some 500 MW. The only other major hydro-electric possibilities of an orthodox kind are in North Wales. Other hydro-electric possibilities lie in the direction of pumped storage schemes, and several possible sites are being examined. The Severn barrage scheme is being critically examined and research is also being undertaken on wind power. The possibility of ultimately using the heat from atomic piles is being kept in mind.

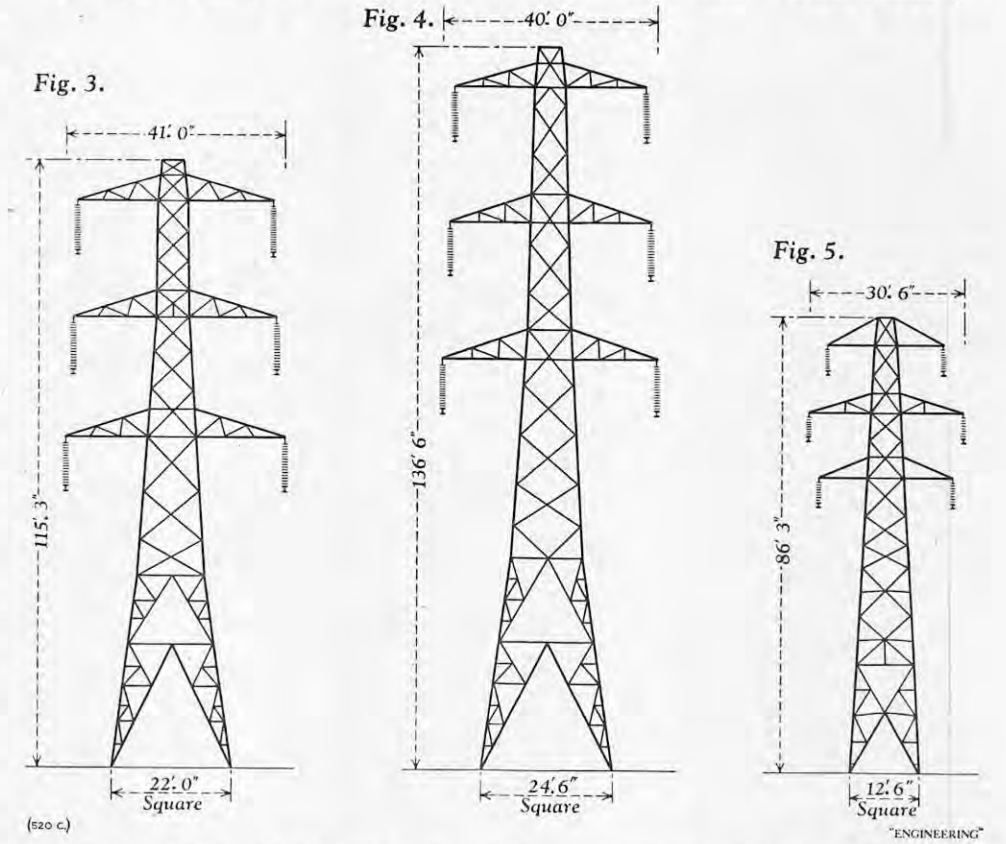
As regards transmission developments, a matter of major importance is the co-ordination of the 132-kV grid and the main distribution systems, which has become possible since nationalisation. Many of the former undertakings obtained a financial advantage by restricting the number of points at which they took supply from the Central Electricity Board. It is now possible to consider the best method of meeting requirements from the point of view of overall economy, irrespective of which party has to bear the capital expenditure involved. More than 40 new 132-kV supply points have therefore been established or agreed since April 1, 1948, compared with only seven—one of which was a temporary supply—during the previous five years. In all these cases the relative merits of extending the distribution system and of establishing a new 132-kV supply point have been compared, and, on technical and financial grounds, the new supply point has been preferred.

The main object of the original 132-kV grid was the pooling of generating plant within defined areas. It was intended that each area would normally operate independently; the few circuits linking adjacent areas were intended only for occasional use, to facilitate maintenance or in emergencies. However, owing to the impossibility of accurately predicting the varying rates of load growth in the different areas and of matching local plant resources to local requirements, there arose a situation in which, although there was in total enough plant to meet the national load, its distribution was such that there was a deficit in some areas and a surplus in others. Interconnected operation of all areas was therefore tried experimentally in 1938; it proved successful and has since continued as the normal arrangement. Thus, for nearly 13 years the grid has been performing a function for which it was not designed, that is, national pooling—as distinct from regional pooling—of generating plant. The value of this during the war is already well appreciated; but it is probably not so generally realised that, as the subsequent plant shortage has gradually developed, so the grid has been called upon to deal with increasing transfers of power from one part of the country to another in order to relieve areas where the shortage is greatest, and thus to spread the burden of load shedding as evenly as possible. To-day the grid is far more heavily stressed than during the war.

Although a number of 132-kV lines have been added since the initial scheme was completed, the grid still retains its original character with relatively weak interconnection between the various areas. For example, only two circuits connect the north and south of the country, so that the power which can be safely transferred is limited to 90 MW in either direction. To make the maximum use of all available plant on every occasion and so to minimise load shedding, at least four times that capacity would be needed. Although many of our present difficulties in grid operation would not have arisen if new generating plant had been installed according to programme, it has long been realised that, for the continuance of operation as an integrated national system, there must ultimately be very substantial reinforcement of transmission capacity between the different parts of the country. To determine the form which the reinforcement should take, a comprehensive investigation was initiated by the Central Electricity Board and carried to a conclusion by the Authority. For this purpose, a study was made of the probable conditions when meeting a national load of 30,000 MW, which it was expected would be reached by 1965 or thereabouts, and an assessment was made of the transmission capacity likely to be required for interconnection of areas for the purpose of national pooling of generating plant. It was found that the only way to provide the required capacity was by superimposing an entirely new system which normally would form the sole means of connection between the various regional systems. Although the superimposed system could possibly consist of 132-kV circuits of higher capacity than those of the original grid, it was concluded that a system consisting of fewer circuits operating at a higher voltage would be more satisfactory and no more costly. A further advantage of the higher voltage was that it would enable provision to be made for bulk transmission of energy from the coalfields to the load centres, for which it appeared that there would be considerable scope in the future. Consideration was given to the alternative of ultimately abandoning national operation and reverting to the original conception of a number of areas operating independently. To provide the same security of supply in each area, however, it was estimated that at least 5 per cent. more generating plant would have to be installed and that the capital cost of this would be much greater than that of the superimposed system.

The higher voltage to be used required very careful consideration. On the Continent, 220 kV has been extensively developed during the last decade. At the upper extreme it seemed possible that 380 kV, the highest voltage at present being developed anywhere on a commercial scale, might be economically justified for future bulk transmission. With the difficult atmospheric conditions in this country, however, much research and development on insulation problems would be needed before a system could be designed for that voltage. For similar reasons it was considered that high-voltage direct-current was not practicable for the immediate requirements. It was decided finally to design the new system for initial operation at 275 to 300 kV. This voltage is one of the proposed international standards and was considered the highest practicable for immediate adoption. Fig. 2, opposite, shows the 275-kV scheme proposed to meet requirements up to 1960. The main features comprise a central ring embracing the East Midlands, the Midlands, Lancashire and the West Riding of Yorkshire, with a connection to Scotland, via the North-East Coast and Carlisle, and two lines direct to the London area. These connect to a horse-shoe round London, terminating at Tilbury on the north bank of the River Thames and Littlebrook on the south. A third connection between the Midlands and London is formed by a line via the Severn Valley. Altogether, about 1,100 miles of new

ELECTRICITY SUPPLY IN GREAT BRITAIN.



line construction will be required, the total estimated cost of the scheme being some 52*l*. million at the prices ruling at the time of its adoption a year ago. A substantial part has been approved for completion by 1955, and work is actively in progress. As with the existing grid, the new system will operate with solidly-earthed neutral at each transforming point. All the equipment will be designed for continuous operation initially at voltages up to 300 kV and an impulse test level of 1,050 kV.

An experimental 40-mile section of line between Staythorpe and Sheffield is now nearing completion. This comprises single-circuit towers equipped with twin conductors of steel-cored aluminium on each phase, each conductor being of 0·175 sq. in. equivalent copper section. For the remainder of the scheme, double-circuit construction will be used, partly on account of the inherent economy in capital cost per kilovolt-ampere of transmission capacity and partly to make the best use of wayleaves. Experience with the existing 132-kV system has proved the validity of both these reasons. Two sizes of conductor will be used: twin 0·175 sq. in. per phase, having a thermal rating of about 375 MVA per circuit; and twin 0·4 sq. in. per phase, having a thermal rating of about 570 MVA per circuit, i.e., 1,140 MVA gross capacity per line of towers. Comparison of these figures with the 90-MVA rating of the original 132-kV single-circuit grid lines reflects the development in thought and practice in the field of electrical transmission over the past 20 years. The smaller conductor will provide sufficient capacity for interconnection purposes only, and will be used for the connection from Yorkshire to Scotland. For the remainder of the scheme the larger conductor will be used, and the circuits proposed will provide for a total export of nearly 3,000 MW from Yorkshire, the East Midlands and Midlands to Lancashire, Merseyside, London and the southern counties; of the total export capacity about half will be available for planned exports, the other half being required for interconnection purposes, i.e., for the pooling of spare plant in the exporting and importing zones.

Two ranges of tower design will be used, one for the twin 0·175-sq. in. conductors and the other for the twin 0·4-sq. in. conductors. The normal spans will be 1,000 ft. and 1,200 ft., respectively. Both designs will follow the same general outline as the existing 132-kV towers and will carry a single earth-wire. Figs. 3 and 4 show the towers for the 275-kV smaller and larger conductors, respectively, while Fig. 5 shows a standard 132-kV tower for comparison. An important feature in the new tower design is the use of high-tensile steel. By using 60 per cent. of such steel the total weight of the smaller double-circuit tower will be about the same as that of the single-circuit tower which is employed on the Staythorpe-Sheffield experimental section, which is built wholly of mild steel. Extra clearances are being provided on the towers carrying the larger conductors in order to permit the voltage to be increased possibly to 380 kV or 400 kV in the future, should developments show this to be a practicable and economic method of providing further transmission capacity. The lines will be equipped initially with suspension insulator strings of the conventional cap-and-pin type, and accommodation of all the additional units required for operation at 380 kV to 400 kV would, according to the present state of knowledge, necessitate lower cross-arm spacing than that shown. It is hoped, however, that by the time the need for a higher voltage is reached, advances in insulation technique will have led to an appreciable shortening of the string. Research on insulators of the rod type, and in the use of semi-conducting glaze, offers some promise of early progress in this direction.

The switching and transforming stations, broadly, will follow present practice on the existing grid system, most stations being laid out on conventional double 'bus-bar lines. Owing to the greater spacing and clearances needed, and in order to keep structure heights within the economic range of reinforced-concrete construction, the ground area required is very large. For instance, a station containing ten 275-kV bays, with transformers and associated 132-kV equipment, requires an area of about 12 acres. The 275-kV switchgear will have a short-circuit rating of 7,500 MVA and current ratings of 800 amperes and 1,200 amperes. Both air-blast and bulk-oil circuit breakers will be used, and provision will be made for high-speed automatic reclosing. The transformers to be installed initially will be 120-MVA three-phase units of the star-connected auto-transformer type, stepping up from 132 kV to 275 kV. Voltage control will be provided by means of on-load tap-changing gear. The choice of 120-MVA three-phase units was governed largely by transport limitations, and the requirements of the scheme will involve double banking of these units at numerous points. For instance, it is envisaged that, in each of the main connecting stations for the London area, there will be six transformers in three banks to provide a gross transformer capacity of 720 MVA.

Before the war there was little scope for bulk electrical transmission in this country, because London and the towns on the eastern and southern coasts could obtain coal cheaply by sea from the North-East Coast and South Wales, while most of the other major load centres could be supplied by rail from relatively nearby coalfields. Since 1939, however, the coal consumption of the electricity supply industry has more than doubled and the combined contribution of the East Midlands and Yorkshire coalfields has increased from 30 per cent. to 39 per cent. of the total; this trend is expected to continue. Because of the relatively long initial rail haul from pithead to port, transport costs for coal from these sources delivered at coastal and estuary stations are considerably greater than for coal from the North-East Coast and South Wales, where the initial

660-VOLT AIR-BREAK SWITCHGEAR.

GENERAL ELECTRIC COMPANY, LIMITED, LONDON.

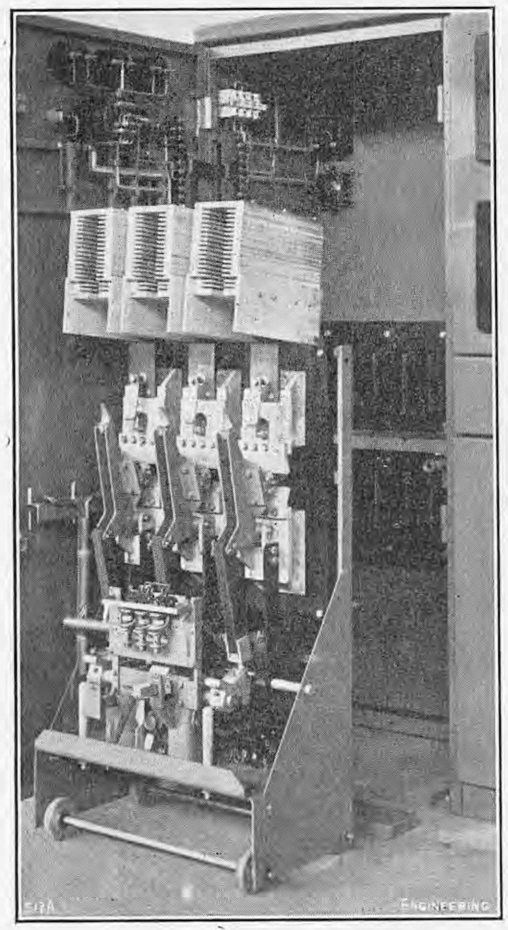


FIG. 1. 2,000-AMPERE CIRCUIT BREAKER WITHDRAWN FROM CUBICLE.

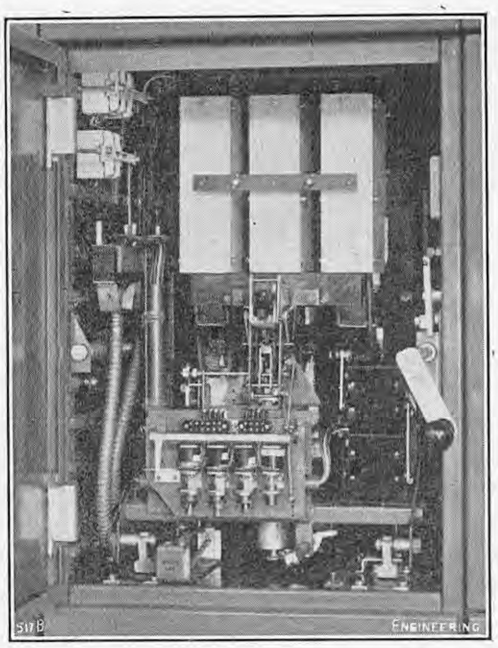


FIG. 2. 800-AMPERE CIRCUIT BREAKER.

rail haul is short. It was found that, by augmenting the capacity of a transmission system suitable for interconnection purposes only, and thus enabling these transfers of energy to be made electrically, considerable net savings could be made as compared with transporting the coal.

At a range of some 10 years ahead, a forecast must of necessity be speculative, but it is estimated that by then some 70 per cent. of the total energy exported from the Mid-East and Central zones will be handled electrically.

Looking back 24 years to the presidential address of the late Sir Archibald Page,* we were then on the threshold of one of the major developments in the supply industry, namely, the establishment of the 132-kV grid. In 1926, the year before his presidency, some 5,750 million kWh were sold by public-supply undertakings in Great Britain, excluding the North of Scotland district, and Sir Archibald mentioned that output during the last five years had increased by 54 per cent. It is of interest to compare those figures with our latest figures. In the year ended March 31, last, over 46,500 million kWh were sold, an increase of 50 per cent. during the last five years and eight times the 1926 figure. We are now passing another milestone with the establishment of the 275-kV grid, and further milestones are dimly in sight. These include the possibility of interconnection with the Continent and, on the horizon, the prospect of a revolution in electricity generation in the shape of gas turbines and nuclear stations. No end can yet be seen to the development of our methods of supplying electricity or to its ever-increasing part in the life of the community.

CONFERENCE OF ENGINEERING LIBRARIANS.—The Library Association is holding an informal conference of librarians working in the field of engineering, on Friday, November 23, at 11 a.m., at Chaucer House, Malet-place, London, W.C.1. The conference will discuss the interim report of a working party on the "Co-operative Provision of Books, Periodicals, and Related Material in Libraries." Copies of the report, and further particulars of the conference—to which all interested librarians are invited—may be obtained from the secretary.

* See ENGINEERING, vol. 124 page 531 (1927).

660-VOLT AIR-BREAK SWITCHGEAR.

A RANGE of air-break switchgear recently produced by the General Electric Company, Limited, Magnet House, Kingsway, London, W.C.2, is designed for service at alternating voltages up to 660. It is available in single-tier form for currents up to 3,000 amperes, and a typical unit of this kind is illustrated in Fig. 1, in which the arc chutes are shown raised and the 2,000-ampere circuit breaker is withdrawn from the cubicle. It is also manufactured in double-tier form for circuit breakers with capacities up to 800 amperes and isolators of all ratings, as illustrated in Fig. 2; and in four-tier form for fused-switches and for contactors. In all cases, the sheet-steel cubicles, which are designed to afford easy access to any part of the equipment, are of standard height and depth. The instrument panels are of corresponding dimensions, so that the various units may be assembled to form a complete switchboard.

The circuit breakers are of the horizontal draw-out type with rupturing capacities of from 15 to 30 MVA at 400 volts and with max'mum current ratings of 800, 2,000 and 3,000 amperes. They can be arranged for either electrical or manual operation and emergency hand closing is available on the former. Operation is effected by a lever which is attached to a shaft. This shaft projects through the door of the cubicle and is fitted with a pointer to show whether the breaker is "on" or "off." The breaker is isolated by a screw and nut racking mechanism, which is operated by a loose handle. This moves it forward in the cubicle thus operating the isolating contacts. As the breaker advances, the shaft moves with it and projects farther through the cubicle door until, when the fully withdrawn position has been reached, the fact that isolation has been effected is indicated by a mark. This arrangement enables enclosure to be preserved during isolation. Easy access to the 'bus bars, cable terminals and current transformers, which are housed in the rear section of the unit, is provided through a sheet-steel door at the back of the cubicle.

INSTITUTION OF BRITISH AGRICULTURAL ENGINEERS.—Eight candidates have been successful in passing the final examination for the National Diploma in Agricultural Engineering recently established by the Institution of British Agricultural Engineers, 24, Portland-place, London, W.1. Three candidates obtained a pass with distinction, namely, Mr. R. T. Stirling, of Lennoxtown; Mr. C. J. Swan, of Campbeltown, Argyll; and Mr. W. C. Wilson, of Glasgow. The remaining five candidates secured a pass; they are Mr. C. Cowley, of Coventry; Mr. P. King, of Danbury, near Chelmsford; Mr. K. E. Morgan, of Lichfield; Mr. J. A. Patterson, of Mid-Calder, Midlothian; and Mr. R. R. Robertson, of Newport, Salop. All the above are entitled to use the term N.D.Agr.E. as a professional qualification.

LAUNCHES AND TRIAL TRIPS.

M.S. "WESTERN COAST."—Single-screw cargo vessel, built by the Goole Shipbuilding and Repairing Co., Ltd., Goole, for the Coast Lines, Ltd., Liverpool. Main dimensions: 220 ft. between perpendiculars by 35 ft. by 21 ft. to shelter deck; deadweight capacity, about 1,235 tons on a mean draught of 13 ft. 11 in. British Polar seven-cylinder two-stroke Diesel engine, developing 1,140 b.h.p. at 250 r.p.m., constructed by British Polar Engines, Ltd., Glasgow. Speed, 12 knots. Trial trip, September 25.

M.S. "NOTRE-DAME DE LA GARDE."—Single-screw trawler, built and engined by Chantiers et Ateliers Augustin Normand, Le Havre, France, for Mr. Engelhardt, Lorient, France. Main dimensions: 105 ft. between perpendiculars by 23 ft. by 13 ft. 3 in.; fishroom capacity, 4,450 cub. ft. M.A.N. six-cylinder four-stroke single-acting Diesel engine, developing 450 h.p. at 207 r.p.m. and a speed of 10½ knots. Launch, October 2.

M.S. "ATLANTIC DUKE."—Single-screw oil tanker, built by Smith's Dock Co., Ltd., South Bank-on-Tees, for Mr. Stavros G. Livanos, Piræus, Greece. Main dimensions: 500 ft. between perpendiculars by 69 ft. 6 in. by 38 ft.; deadweight capacity, 16,500 tons on a draught of about 29 ft. 9 in. Hawthorn-Doxford five-cylinder opposed-piston two-stroke airless-injection oil engine, developing 5,500 b.h.p. at 112 r.p.m., constructed by R. and W. Hawthorn, Leslie & Co., Ltd., Newcastle-upon-Tyne. Speed in service, 13½ knots. Launch, October 3.

M.S. "TJIBANTJET."—Single-screw cargo vessel, with accommodation for four passengers, built by Bartram & Sons, Ltd., Sunderland, for Koninklijke Java-China-Paketvaartlijnen, N.V., Amsterdam, Holland. Main dimensions: 440 ft. between perpendiculars by 61 ft. 3 in. by 38 ft. 3 in. to shelter deck; deadweight capacity, 8,900 tons on a draught of 26 ft. 2 in. N.E.M.-Doxford six-cylinder opposed-piston airless-injection oil engine, developing 6,800 b.h.p. at 116 r.p.m. in service, constructed by the North Eastern Marine Engineering Co. (1938), Ltd., Wallsend-on-Tyne. Loaded speed, 16½ knots. Launch, October 3.

M.S. "TABOR."—Single-screw cargo vessel, built by the Caledon Shipbuilding and Engineering Co., Ltd., Dundee, for the Moss Hutchison Line, Ltd., Liverpool, 2. Main dimensions: 360 ft. between perpendiculars by 55 ft. by 32 ft. 6 in. to shelter deck; deadweight capacity, 4,800 tons on a draught of 21 ft. 6 in. Hawthorn-Doxford four-cylinder opposed-piston oil engine, developing 4,400 b.h.p., constructed by R. and W. Hawthorn, Leslie & Co., Ltd., Newcastle-upon-Tyne. Speed, 15 knots. Launch, October 3.

S.S. "SAXONGLADE."—Single-screw oil tanker, built and engined by Vickers-Armstrongs Ltd., Walker-on-Tyne, for the North American Shipping and Trading Co. (London), Ltd. (Mr. Stavros S. Niarchos), London. First of a series of ten vessels. Main dimensions: 528 ft. between perpendiculars by 75 ft. by 40 ft.; deadweight capacity, about 20,000 tons on a draught of about 30 ft. 6 in. Double-reduction geared turbines, developing 8,300 s.h.p., and two Babcock and Wilcox boilers. Speed, 14½ knots, fully loaded. Launch, October 3.

CONTRACTS.

THE ENGLISH ELECTRIC EXPORT AND TRADING CO., LTD., and METROPOLITAN-VICKERS ELECTRICAL CO., LTD., have successfully negotiated a contract, valued at 1,000,000*l*., for the hydraulic, mechanical and electrical equipment for a new power station to be built by the Hidro-Electrica do Zezere, S.A.R.L., at Cabril, on the River Zezere, about 120 miles north-east of Lisbon. The power station will be equipped with two hydro-electric generating units, each of 73,000 maximum h.p., together with ancillary switchgear and transformer equipment, all of which will be manufactured in Great Britain.

BRITISH TIMKEN LTD., Duston, Northampton, announce that British Timken S.A. (Pty.), Ltd., have received a contract from the South African Railways and Harbours Administration for tapered roller bearings for sixty 4-8-4 steam locomotives ordered by the Administration from the NORTH BRITISH LOCOMOTIVE CO., LTD., Glasgow. The roller bearings which will be manufactured at the Aston, Birmingham, works of British Timken Ltd. will comprise tapered roller-bearing cannon boxes for the leading bogie and all coupled wheel axles, tapered roller-bearing axleboxes for the trailing bogies and tapered roller-bearing crankpin equipment.

THE EXPRESS LIFT CO., LTD., 9, Greycoat-street, London, S.W.1, have received orders from the London County Council for a total of 100 lifts for various housing estates in the London area. This brings the total number of lifts of this type ordered from the Express Lift Co. by housing authorities throughout the country to over 670.

BOOKS RECEIVED.

National Building Studies. Research Paper No. 11. *A Study of the Voussoir Arch.* By PROFESSOR A. J. SUTTON PIPPARD and LETITIA CHITTY. H.M. Stationery Office, Kingsway, London, W.C.2. [Price 2s. 6d. net.]

The Teaching of Statistics in Schools. A Report of the Council of the Royal Statistical Society. Offices of the Society, 4, Portugal-street, London, W.C.2. [Price 1s.]

The Craft of the Metalworker. By R. S. DUDDLE. The Technical Press Limited, Gloucester-road, Kingston Hill, Surrey. [Price 17s. 6d. net.]

Atomic Physics. By PROFESSOR MAX BORN. Fifth edition. Blackie and Son Limited, 16-18, William IV-street, London, W.C.2. [Price 35s. net.]

The Fundamental Principles of Reinforced Concrete Design. By PROFESSOR W. T. MARSHALL. Blackie and Son, Limited, 16-18, William IV-street, London, W.C.2. [Price 20s. net.]

Theory and Design of Valve Oscillators for Radio and Other Frequencies. By DR. H. A. THOMAS. Second revised and enlarged edition. Chapman and Hall, Limited, 37, Essex-street, Strand, London, W.C.2. [Price 36s. net.]

Carburation. By CHARLES H. FISHER. Third revised edition. Volume One. *Applied Carburation and Petrol Injection.* Chapman and Hall, Limited, 37, Essex-street, Strand, London, W.C.2. [Price 36s. net.]

Magnetic and Electrical Methods of Non-Destructive Testing. By D. M. LEWIS. Report prepared for the Magnetic and Electrical Methods Sub-Committee of the British Iron and Steel Research Association. George Allen and Unwin, Limited, Ruskin House, 40, Museum-street, London, W.C.1. [Price 35s. net.]

Electroplating and the Engineer. By ALAN WHITTAKER. Mechanical World Monographs No. 64. Emmott and Company, Limited, 31, King-street West, Manchester, 3. [Price 4s. net.]

Untergrundbahnen und ihre Einsatzgrenzen. By DR.-ING. RUDOLF BERGER. Wilhelm Ernst und Sohn, Hohenzollerndamm 169, Berlin-Wilmersdorf, Germany. [Price 9·50 D.M.]; and Lange, Maxwell and Springer, Limited, 41-45, Neal-street, London, W.C.2. [Price 16s. 8d.]

Die zweiseitig gelagerte Platte. By DR.-ING. HUGO OLSEN and PROFESSOR FRITZ REINITZHUBER. Volume 2. *Anwendungen und Folgerungen.* Wilhelm Ernst und Sohn, Hohenzollerndamm 169, Berlin-Wilmersdorf, Germany. [Price 29 D.M. in paper covers; 32 D.M. bound]; and Lange, Maxwell and Springer, Limited, 41-45, Neal-street, London, W.C.2. [Price 50s. 9d. in paper covers; 56s. bound.]

Jahrbuch der Schiffbautechnischen Gesellschaft. 1950. Springer-Verlag, Reichpietschufer 20, Berlin W.35, Germany. [Price 30 D.M.]

Oxford Junior Encyclopaedia. Edited by LAURA E. SALT and ROBERT SINCLAIR. Volume VII. *Industry and Commerce.* Oxford University Press (Geoffrey Cumberlege), Amen House, 12, Warwick-square, London, E.C.4. [Price 30s. net.]

The Birmingham Exchange. Directory of Members, Subscribers and Representatives. 1951. The Secretary, Birmingham Exchange, Stephenson-place, Birmingham 2. [Gratis.]

Year Book of the Heating and Ventilating Industry. Technitrade Journals Limited, 8, Southampton-row, London, W.C.1. [Price 8s., post free.]

Fuel Oil Manual. By PAUL F. SCHMIDT. The Industrial Press, 148, Lafayette-street, New York 13, U.S.A. [Price 3·50 dols.]; and Bailey Brothers and Swinfen, Limited, 26-27, Hatton-garden, London, E.C.1. [Price 30s.]

Physical Chemistry of Lubricating Oils. By A. BONDI. Reinhold Publishing Corporation, 330, West 42nd-street, New York 18, U.S.A. [Price 10 dols.]; and Chapman and Hall, Limited, 37, Essex-street, Strand, London, W.C.2. [Price 80s. net.]

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

Positive-Displacement Pumps and Fluid Motors. By WARREN E. WILSON. Sir Isaac Pitman and Sons, Limited, Pitman House, Parker-street, Kingsway, London, W.C.2. [Price 40s. net.]

Electro-Plating. A Survey of Modern Practice. By SAMUEL FIELD and A. DUDLEY WEILL. Sixth revised and enlarged edition. Sir Isaac Pitman and Sons, Limited, Pitman House, Parker-street, Kingsway, London, W.C.2. [Price 20s. net.]

The Measurement and Control of Temperatures in Industry. By R. ROYDS. Constable and Company, Limited, 10-12, Orange-street, London, W.C.2. [Price 25s. net.]

Vorausbestimmungen im Wirtschaftsleben. By DR.-ING. KARL DAEVES. Verlag W. Girardet, Gerswidastrasse 2, Essen, Germany. [Price 9.60 D.M., or 16s. 4d., bound; 8.40 D.M., or 14s. 4d., in cardboard covers.]

ALL-WEATHER FIGHTER AIRCRAFT.

DE HAVILLAND AIRCRAFT COMPANY, LIMITED, HATFIELD.

ALL-WEATHER FIGHTER AIRCRAFT.

THE illustration above shows a new twin-engine swept-wing fighter aircraft, the D.H.110, designed and constructed by the de Havilland Aircraft Company, Limited, Hatfield, Hertfordshire. It is propelled by two Rolls-Royce Avon axial-flow jet engines and is equipped with electronic navigation and combat aids for day and night operation in weather that would render an aircraft not so equipped ineffective. Further details are secret.

BRITISH STANDARD SPECIFICATIONS.

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

Galvanised-Steel Cisterns, Tanks and Cylinders.—A fourth revision of B.S. No. 417, covering galvanised mild-steel cisterns, tanks and cylinders, for domestic use for the storage of water supplies, has been issued. In the present edition consideration has been given to the sizes now in demand as the result of post-war conditions and some amendments have been made to meet these requirements. Twenty-one sizes of cisterns, having an actual capacity ranging from 4 to 740 gallons; eight sizes of tanks, varying from 17 to 53 gallons in actual capacity, and eleven sizes of cylinders, ranging in actual capacity from 16 to 97 gallons, are now provided for in the specification. [Price 2s. 6d., postage included.]

Hose Couplings.—A new specification, B.S. No. 1782, covers couplings for suction and delivery hose of nominal sizes from $1\frac{1}{2}$ in. to 8 in., other than fire-hose couplings. Two types are specified, namely, the screw type and the swivelling-ring swing-bolt type. The design of the couplings differs from those previously used in that they have ribbed instead of serrated tail ends. The screw type of couplings have a thread of coarser pitch. This more robust thread, coupled with the more substantial outer horns given to the couplings, confer ability to withstand rough usage and also lead to easier coupling of hoses. For any particular nominal size of coupling two diameters of tail end, namely, full bore and reduced bore, are provided. The full-bore coupling has a waterway equal to its nominal size and also equal to the outside diameter of the appropriate standard pipe for attaching to hose with enlarged ends. The reduced-bore coupling is interchangeable with the full-bore coupling, but has a tail end of outside diameter to suit canvas or other non-elastic hose of nominal bore. The couplings covered by the specification are intended for working pressures not exceeding 100 lb. per square inch. They have been designed primarily for use with water, but they may be utilised for other suitable liquids. The screw-type are also suitable for use with compressed air. [Price 5s., postage included.]

Arc-Welded Construction.—The Council for Codes of Practice for Buildings, Construction and Engineering Services, working under the ægis of the Ministry of Works has now issued, in final form, Sub-Code CP No. 113.102, covering arc-welded construction. It is intended, at some future date, to amalgamate this sub-code with the head code, No. 113, relating to "The Structural Use of Steel in Buildings." The present publication, however, has been arranged to be complete in itself, as far as possible. The Code contains recommendations for the design, fabrication and erection of metal-arc welded structural steelwork used in any part of a building but excluding the welding of steel tubes which will be dealt with in Sub-Code No. 113.201, now in preparation. It includes recommendations for the design of welded joints and also for the design of connections, plate girders, compression members and stanchion bases embodying arc-welded construction. Points of special interest include some recommendations for the qualification and testing of welding operators and examples of "virtually flexible" welded joints. [Price 4s., postage included.]

Wrought Aluminium-Alloy Forgings and Plate.—The series of specifications for wrought aluminium and aluminium alloys has now been completed by the issue of B.S. No. 1472, covering forgings, and including hot pressings, hot stampings, drop stampings and drop forgings, and B.S. No. 1477, which is concerned with plate. The forgings specification takes account of seven alloys and provides both for the forgings themselves and for the bar material for the forgings. The specification for plate covers three purities of aluminium and six alloys. Both specifications include clauses on mechanical composition, condition and mechanical properties, as well as general clauses covering freedom from defects, tolerances, the provision of test-pieces and mechanical tests, and an appendix on heat treatments. [Price of B.S. No. 1472, 4s., and of B.S. No. 1477, 5s., both postage included.]

Steam Turbines.—A revision of B.S. No. 132, covering steam turbines and originally issued in 1930, has now been published. Although intended mainly for steam turbines for use in electric power stations, many of its provisions apply to steam turbines for other service. In view of the progress made during the last 20 years, particularly as regards size and advanced steam conditions, new material has been added to the specification. This refers chiefly to the provision of supervisory instruments, to operational requirements in respect of high steam pressure and temperature and to precautions to be taken with larger turbines in respect of falling vacuum. A table of recommended ratings (covering the range from 10,000 kW to 100,000 kW) together with steam pressures and temperatures, maximum feed-water temperatures, and number of extractions points, has also been added, the object being to create a small number of standard turbines which, in the long run, will reduce production costs and increase reliability and interchangeability to the benefit of the manufacturer as well as the purchaser. In view of the very great variations in output and operating conditions of the smaller turbines, particularly those used for industrial purposes, it has been found inexpedient to extend the range of "recommended standards" below the 10,000 kW rating. The user of the smaller turbines, however, will find ample information covering his particular requirements. It is intended to continue to watch further progress and, whenever advisable, to issue additional information in the form of a supplement to the specification. [Price 2s., postage included.]