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The Acid Bessemer Process of Steel-Making.

READ

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On Tuesday, March 14th, 1939, at 6 p.m.

CHAIRMAN: MR. R. RAINIE, M.C. (Chairman of Council).

Synopsis.

HISTORICAL INTRODUCTION: *Including some notes on the early use of the process in three works with which the authors have been associated.*

STATISTICS OF PRODUCTION: *Data are provided in the form of Appendices showing the production of acid Bessemer steel in the important steel-making countries and the relation of acid Bessemer to other steel-making processes. The reason for the reduced proportion of acid Bessemer steel is dealt with.*

THE ACID BESSEMER PROCESS AS PRACTISED BY THE WORKINGTON IRON AND STEEL CO.: *The plant and process are described in detail, with particular reference to the improvements embodied in the new plant which commenced operations at Workington in 1934.*

THE USES AND PROPERTIES OF ACID BESSEMER STEEL: *Attention is directed to the principal uses to which acid Bessemer steel has been put and to certain outstanding characteristics, such as wear resistance, machinability, weldability, work hardening characteristics, age hardening, corrosion, creep resistance, etc. New data are included in this section, including some relating to the gas content of acid Bessemer steel as compared with that of other steels.*

The paper endeavours to give an indication of the growth in the production of acid Bessemer steel since its inception and the reasons for its comparatively decreased use at the present time, and concludes with a summary of the present position.

Although the title submitted to the authors demands a description of the *process,* it is inferred that the properties of the resulting *product* will perhaps provide greater interest for the members of The Institute. The acid Bessemer process has been long established but, for reasons to be referred to later, its activities have fluctuated and it is probable that many of the younger generation of steel-makers have never had an opportunity of seeing it practised. Therefore, the authors will record in some detail the *process* as practised to-day by their Company at Workington, in amplification of the descriptions to be found in most standard text books on steel-making.

May it be emphasized at the outset that the authors are dealing with the *acid* process, whereby pure Hematite iron is refined in a vessel having an acid lining. It is not the purpose of this paper to attempt to make comparison with the basic Bessemer process, in which phosphoric pig iron is refined in a basic lining, but it is important to realise that the two processes have this fundamental difference. Also might it be added that the authors are dealing essentially with the acid Bessemer process as normally employed for producing steel ingots, *i.e.* bottom-blown, and it is not proposed to discuss side-blown, surface-blown or "stock" converter steel, which is principally used in the manufacture of steel castings. It is, however, to be remembered that these processes are well established and have a wide field of application.

Historical Introduction.

Henry Bessemer first published in 1856 (in a paper to the British Association, August 11th, 1856, "The Manufacture of Malleable Iron and Steel without Fuel"), his discovery that, by the simple process of blowing air through liquid pig iron, the carbon, manganese and silicon were removed and the metal made malleable; and when Mushet, by his patent, September 22nd, 1856, showed how Bessemer's early troubles of red shortness could be overcome by an addition of manganese, the foundation was laid for the first process by which reliable steel could be produced in bulk at a reasonable price. Since that time, millions of tons of steel have been made without any essential modifications of the principles then propounded. The open hearth or Siemens process, by which the bulk of to-day's tonnage is produced in this country, was developed some ten years later.

Contemporaneously with Bessemer, the process was pioneered in America by Holley and others—it is even claimed that the process was originated in America by Kelly, who was experimenting on the same lines as early as 1851—and soon became of great importance. Also in Sweden, through the work of Goransson, the process was found to be particularly applicable to certain grades of Swedish iron and Swedish Bessemer steel has held a great name for high quality. Through lack of suitable raw material, the acid Bessemer process has never made bulk production in other countries.

Until about 1920 there was a considerable number of plants operating the process in this country, and it so happens that three of the works now constituent parts of The United Steel Companies Ltd. operated the acid Bessemer process, namely: Messrs. Samuel Fox & Co. Ltd. at Stocksbridge, Messrs. Steel, Peech & Tozer at Rotherham (both near Sheffield) and The Workington Iron & Steel Company in Cumberland.

It is perhaps not without interest to record something of the early experiences of these plants:

Samuel Fox & Co., Ltd.

Messrs. Samuel Fox were amongst the first (we believe actually the second) to take out a licence for the manufacture of Bessemer steel. Steel-making was commenced in the first shop in 1863 and continued regularly in this shop until 1872. The plant consisted of two small converters of 3-tons capacity and three air furnaces for melting the iron. Ingots of 5/6 cwts. each were cast, these being hammer cogged prior to rolling. In this early plant, normal production was one blow about every 6 hours.

In 1870 two cupolas replaced the air furnaces and the output was increased from about 5 to 12 tons per shift. Soon afterwards a new shop was built containing two converters of 5-tons capacity and the output was raised to about 30 tons per shift. It must be remembered that there were no such things as detachable bottoms in those days, the lining and bottom being rammed *in situ,* and numerous troubles attended the early developments.

In 1876 a fourth move was made, a shop being built essentially on the same lines as before, except that a new horizontal blowing engine was installed.

Developments from that time until after the War consisted of a closer study of the composition of the charge and attention to casting details, with the result that the output was increased, the plant producing in the year 1917 nearly 39,000 tons of steel. The record weekly output was 1,126 tons and shift output 121 tons. The authors are obliged to Mr. G. Elsam, who was associated with this shop from 1874 until his retirement some 50 years later, for these notes.

So far as shops using cupola melted iron are concerned, the above is probably representative of many.

It is commonplace to say that "necessity is the mother of invention" and this was very much the case in the experience of one of the authors (Dr. Swinden) during 1914-18. It is well known that during this period there arose a large demand and comparative scarcity of pig iron while, on the other hand, steel scrap was plentiful and comparatively cheap. It was necessary, therefore, to concentrate on the use of a maximum amount of steel scrap through the cupola and, in these days when this subject has raised such attention in the foundry world, it may be worth while to record the actual achievements in this direction towards the end of the War. Pre-War, the cupola charge contained normally about 85 per cent. of pig iron and the blowing time for an 8½-ton charge was about 22 minutes. Towards the end of 1918, we were using only 57 per cent. of pig iron through the cupola, blowing a charge in about 14 minutes and, by judicious control of the silicon content, obtaining extremely regular and satisfactory steel, a very large proportion of which had to pass inspection by one or other of the Service inspection departments. The cost of production was very considerably reduced by this practice, which may be of interest to anyone who is still operating Bessemer steel-making from cupola melted iron.

STEEL, PEECH & TOZER.

The acid Bessemer plant at the Ickles Works was started up in 1872, there being two shops each with two 8-ton vessels, and a small shop with two 30-cwt. vessels. After about 1882 the work was concentrated in one shop, in which were two 10-ton vessels—enlarged later to 12½ tons—and capable of producing about 2,000 tons of ingots per week. Steels of all kinds were made ranging from 0·08 to 1·25 per cent. carbon, in the form of billets, rails, tyres, straight- and crank-axles and forging ingots.

Until 1891, the Bessemer was the only steel-making process at the Ickles Works. It closed down in 1924.

WORKINGTON IRON & STEEL COMPANY.

The first Bessemer steel-making plant in the Workington district was the old West Cumberland Works. now dismantled, which commenced operations in 1875.

The early difficulties of producing acid Bessemer steel there received the close attention of Bessemer himself and it was he who, in a personal investigation, seized on the fact that certain high phosphorus "cinders" were being used in the blast furnace, which accounted for the resulting steel being much higher in phosphorus than had been anticipated from the blast furnace charge.

West Cumberland, as the source of pure Hematite pig iron in this country, was naturally seized upon for the development of the acid Bessemer process and the same fact explains why that same district is the last stronghold for this process in the country at the present day.

There have, however, been many changes at Workington since those early days. The present Moss Bay Works had their origin in 1871 and commenced with one blast furnace, which was built in refractory stone encircled with iron bands. Steel-making commenced in 1876. The Derwent blast furnace plant commenced operations in 1874; Messrs. Charles Cammell took over the furnace in 1883 and erected a steelworks.

The Moss Bay Bessemer plant was the only survivor, a fact due, no doubt, to its compact lay-out resulting in speedy and economical working. Commenced originally with three 8-ton converters, it was increased in capacity by enlarging the units up to 15 tons each, the latter operating up to 1934, when (by further modifying the design of the vessels) they were blowing up to 18 ton heats and producing well over 5,000 tons per week.

In 1934 an entirely new acid Bessemer steel-making shop was built, the reconstruction being based on a study of conditions in America, where acid Bessemer steel-making had developed on large tonnage lines.

Before describing in some detail the present Moss Bay plant, it would be of interest to record some statistics of World production.

Statistics of Production.

By courtesy of Sir William J. Larke, K.B.E., Mr. R. M. Shone of the Statistical Department of the British Iron & Steel Federation has very kindly prepared a table, reproduced in APPENDIX I, showing the production of acid Bessemer steel in the United Kingdom, United States, France, Germany and Sweden, so far as such data are available from 1868 to 1937.* APPENDIX II shows the production of steel ingots and castings from 1871 to 1937 by *processes* in Great Britain, as published by the Federation. APPENDIX III shows the steel production of Great Britain by process and district for 1937.

The world production figures by all processes may be interesting in putting the above data in its right perspective and these, as published recently in the *"Foundry Trades Journal"*, are given in APPENDIX IV for 1936, 37 and 38. Let us consider these figures very briefly for the lessons they tell concerning the *acid Bessemer process.*

SWEDEN continues to make acid Bessemer at a fairly steady rate corresponding to about 1·6 per cent. of her total steel output, all for special purposes.

GERMANY declined rapidly after the War and since, say, 1926 has made no appreciable quantity of acid Bessemer steel.

FRANCE has maintained a fairly steady production, but note that from 1913 the figures include castings. So far as the authors are aware, there is no serious production of acid Bessemer *ingots* in France.

AMERICA. Note the rapid rise in the early years and progressive development reaching the huge figure of over 12 million tons in 1906. Following this period, apart from trade fluctuations, the figure tends to decline. In 1937, approximately 3½ million tons were produced by this process, representing something like 7 per cent. of the total steel production and about 54 per cent. of the production capacity of Bessemer steel. Comparing 1929 (the peak year) with 1937, the production of acid Bessemer steel is down by about 50 per cent., although the difference in the total weight of steel ingots produced was only about 10 per cent. in the two periods.

* The data are incomplete for the years earlier than those for which figures are given; the blanks do not mean absence of production.

BRITAIN. It will be seen that there was progressive and continuous development for some 20 years. Separate figures for acid and basic Bessemer steel are not available for 1880-1888 inclusive, but in 1889, the production of acid steel is recorded as 1,719,292 tons or nearly 50 per cent. of the total production. About that time (see APPENDIX II), the open hearth process began to overhaul the Bessemer process in tonnage production, but acid Bessemer maintained an average annual output of well over a million tons a year in this country until 1914, but with a declining percentage of the total. During the War years, the output declined further, but still represented some 10 per cent. of the country's total production of steel. Since then, it has declined in both tonnage and percentage, being fairly steady for the past few years at 200/250,000 tons output and about 2 per cent. of the total.

Since about 1930, the output figures for acid Bessemer steel represent virtually the production at our Workington plant, so far as ingots for rolling are concerned.

It is reasonable to enquire what led to a reduction in the production of acid Bessemer steel relative to total production during 1914-1918 and subsequently. In referring to our experience at Stocksbridge, it has already been stated that, during the War, pig iron was scarce and scrap plentiful. Moreover, we have reproduced, in APPENDIX V, relative prices of Hematite pig iron ("mixed numbers") and heavy steel scrap—as extracted from the "*Iron & Coal Trades Review*". It will be seen that, whereas in, say, 1908 pig iron could be bought at a price only a few shillings above that of heavy steel scrap, during the War the differential increased considerably and, in the "boom" of 1919-1920, the *difference* grew to some £7 per ton. Then came the slump of 1921 and the differential was still over £5 per ton.

Meantime, open hearth plant capacity had been increased during the War, and as the acid Bessemer process must use a large proportion of pig iron, the position was such that all the plants using cupola re-melted iron for this process became uneconomical in production costs and were. one by one, closed down and eventually dismantled. It is important to point out that the closing down was not on account of any question of quality for the purposes for which it was so largely used—on the contrary, for many purposes, *e.g.* rails, springs, engineers' tools, case-hardening steels, etc., its decline was viewed with the gravest apprehension. It is natural that the process should survive in a plant where suitable pig iron is produced alongside the Bessemer plant, thereby reducing costs and ensuring a control which will be described shortly when dealing with the modern Workington plant.

The Acid Bessemer Process as Practised at Workington.

The present plant consists of a 400-ton mixer, two 25-ton converters and a casting shop, with the necessary auxiliary handling equipment.

The present-day Bessemer plant is very different from that of years ago. In the early days, the iron was re-melted in a cupola, from which it passed down a runner into the converter. The only weighing possible was before charging into the cupola. The iron is now stored in a molten condition in the mixer, from which it is poured as required into a ladle standing on a weighing machine, and afterwards taken by an electric overhead crane

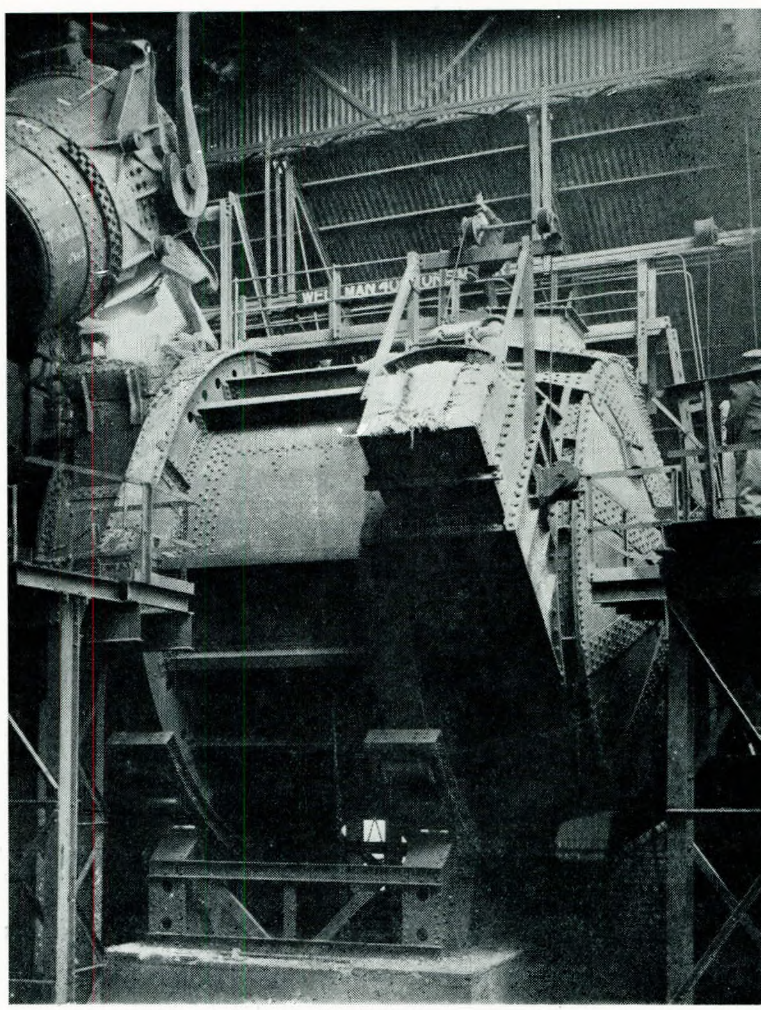


FIG. 1.—400-ton mixer.

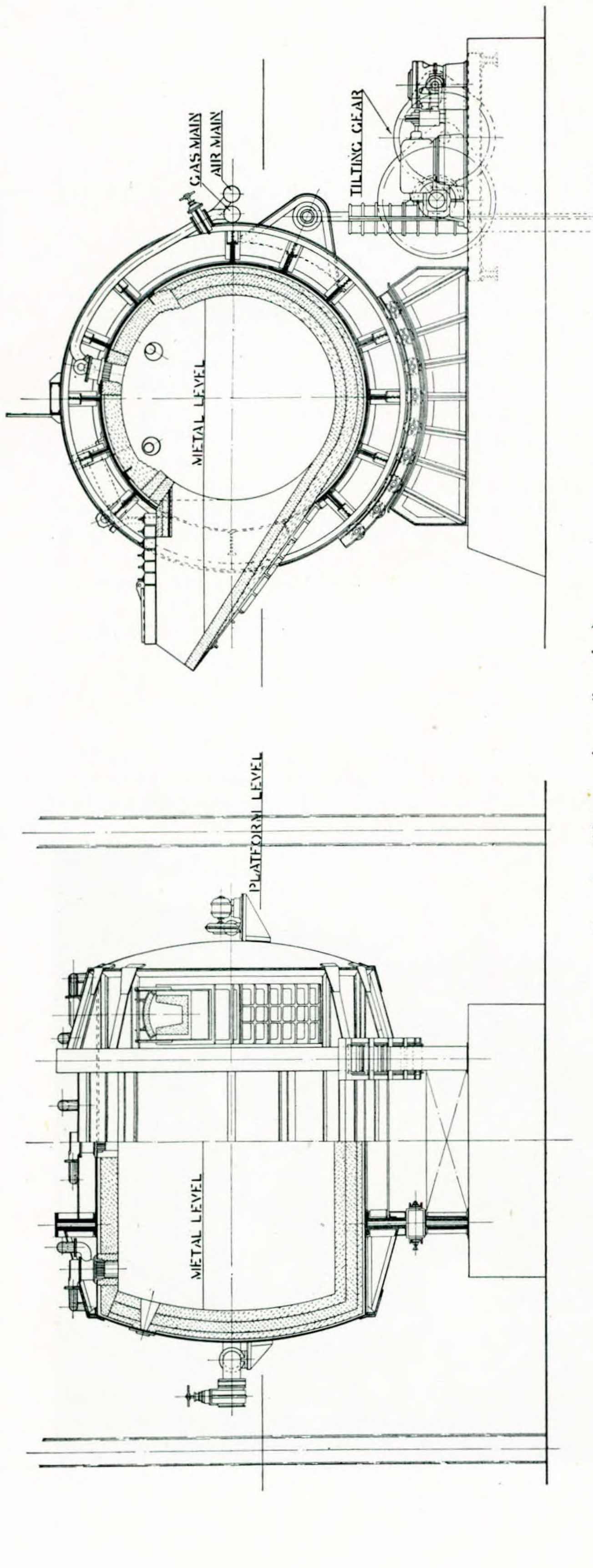


Fig. 2.—400-ton mixer (inactive).

to the electrically-driven converters. Where originally the finished steel was poured into a ladle supported by a jib carried on a hydraulic ram, and revolved over the moulds in the semi-circular casting pit by man power, the steel ladle is now handled by an electric overhead crane which gives much greater freedom of movement and control. The old ingot handling cranes, a simple jib attached to a hydraulic ram, the rack being hand-operated, have given place to an overhead electric stripping machine, which strips the mould from the ingot, or, if the mould sticks, forces the ingot out by means of an electrically driven ram, transfers the mould to a cooling bench and also re-loads the casting cars with cool moulds. The ingots pass on to an overhead electric charging crane, which picks them off the cars and places them in the soaking pits to prepare for rolling. The casting cars referred to replace the old semi-circular casting pit sunk in the ground, which gave no flexibility at all.

The process as carried out at Workington will now be described.

Mixer.

The molten pig-iron is brought direct from the blast furnaces in 50-ton ladles, and is poured into the mixer by a 100-ton overhead crane.

The mixer is a cylindrical steel shell, lined with silica brick, and mounted on heavy rollers, which permit it to be rotated by an electrically driven rack, in order to pour out the metal as required. Fig. 1 is a photograph of the mixer showing the 50-ton ladle in position for pouring in. Fig. 2 shows longitudinal and cross sections of the 400-ton mixer. Heat is supplied by means of a blast furnace gas fed through four burners, three in the roof and one in the pouring-out spout. The burners in the roof are not used during active operation, as the flame temperature developed by unrecuperated blast furnace gas is lower than that of the molten metal poured into the mixer. It is possible, therefore, to attain a higher temperature in the mixer by keeping radiation and convection losses down to a minimum by closing all openings and shutting off the gas. These burners are only used for heating up from cold and for maintaining the heat during the week-end whilst the mixer is empty, preparatory to refilling for the next week's work. The burner in the pouring-out spout is in constant use, as this opening cannot be effectively closed on account of the frequency of pouring out. It is necessary to counteract the chilling effect of the outside atmosphere in order to keep the passage sufficiently hot to avoid excessive chilling of the metal on its way out, with consequent blocking of the opening by the formation of skull.

The movement of a container carrying several hundred tons of molten metal calls for some safeguards. If, for example, the power were to fail whilst a heat was being poured, many tons of metal would over-run the lip of the ladle before the level of the metal fell sufficiently for the stream to cease flowing, unless provision were made for returning the mixer independently of the normal power supply. Accordingly, an auxiliary steam-driven unit is coupled through a clutch to the same shaft as the electric tilting motor.

The mixer performs several functions. In the first place, it provides a buffer between the blast furnaces and the converters. With increasing size of cast from the individual blast furnace (over 100 tons now, compared with 20 tons not so many years ago), serious difficulties would arise without an adequate storage reservoir in which the metal could be held with little loss of heat until it was possible for the steelworks to deal with it. In this capacity of storage reservoir, the mixer enables advantage to be taken of one of the features of Bessemer operation not possessed by the open-hearth. The steel production can be synchronised with the rolling mill requirements; the Bessemer may be scheduled to deliver blows to the mill quickly or slowly according to the section being rolled, without any interference with the normal blast furnace routine. So it is possible to avoid having considerable tonnages of ingots delayed by some hold-up in the mill, with consequent increased risk of damage by holding at rolling temperature for an unnecessarily long period, or losing heat through lack of accommodation in the soaking pits. In this way, regular heating of the ingots in the soaking pits is facilitated with advantage to the maintenance of a uniform rolled product.

The second function performed by the mixer, as the name implies, is that of mixing the various grades of iron delivered to the Bessemer plant, and thus providing a more uniform supply of hot metal for the conversion process. As the securing of uniformity in both raw materials and operating conditions is a most important feature of Bessemer control, the mixer must be regarded as a very necessary means to this end.

Another advantage offered by a fairly large mixer is that the steelworks production may be augmented by the amount of week-end iron which it will hold before the Bessemer commences blowing.

The iron supplied by the blast furnaces normally varies within the following limits:—

Carbon.	*Silicon.*	*Sulphur.*	*Phosphorus.*	*Manganese.*
4·0/4·3%	1·5/2·5%	·025/·045%	·035/·045%	·75/1·00%

CONVERTERS.

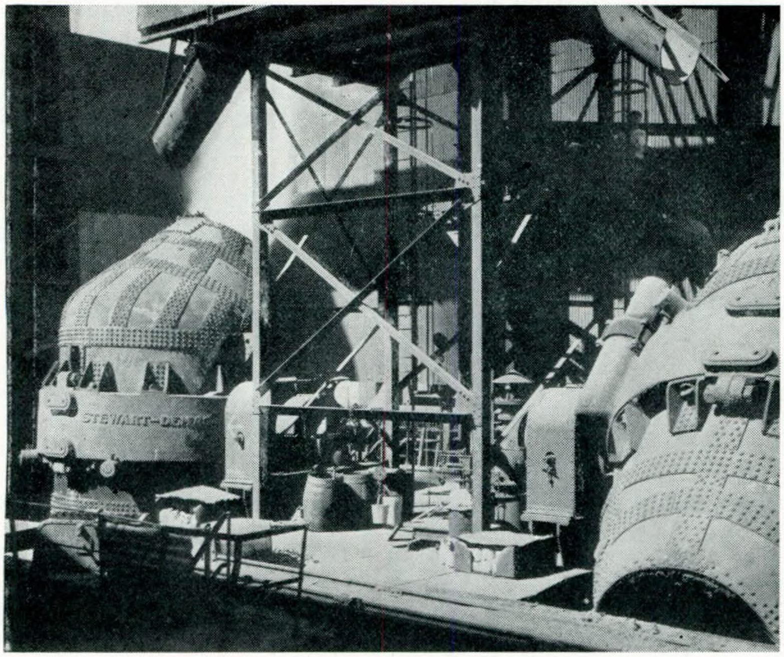
Fig. 3 illustrates the old converters and Fig. 4 the new, while Fig. 5 compares the sections of the two vessels and Fig. 6 is a more complete drawing of the new 25-ton converter vessel.

The iron is transferred to the converters by the same crane as handles the iron from the blast furnaces. The converter is a steel shell mounted in a trunnion belt which can be rotated through gearing by two 125-h.p. mill-type electric motors. The shell may be lifted out of the trunnion belt for relining, and a spare shell is kept ready lined for quick replacement. The lining is silica brick which, except for certain parts subject to abnormal wear, lasts for several months. Repairs to the weak portions are carried out each week-end.

The bottom section of the converter is attached to the body by means of cotters to facilitate replacement, as the refractory portion is subject to rapid wear. This necessitates renewal after about 20 blows. A jack-car fitted with a hydraulic ram runs underneath the converter, lowers off the old bottom, which weighs approximately 30 tons, conveys to the bottom-making shop and returns with the new bottom, which is pushed up against the body and re-cottered. The joint is made with ganister.

The bottoms are made up with 30 tuyeres, cylindrical firebricks 34in. long, perforated longitudinally with ten ½in. holes. The spaces between the

FIG. 3.—Old converters.



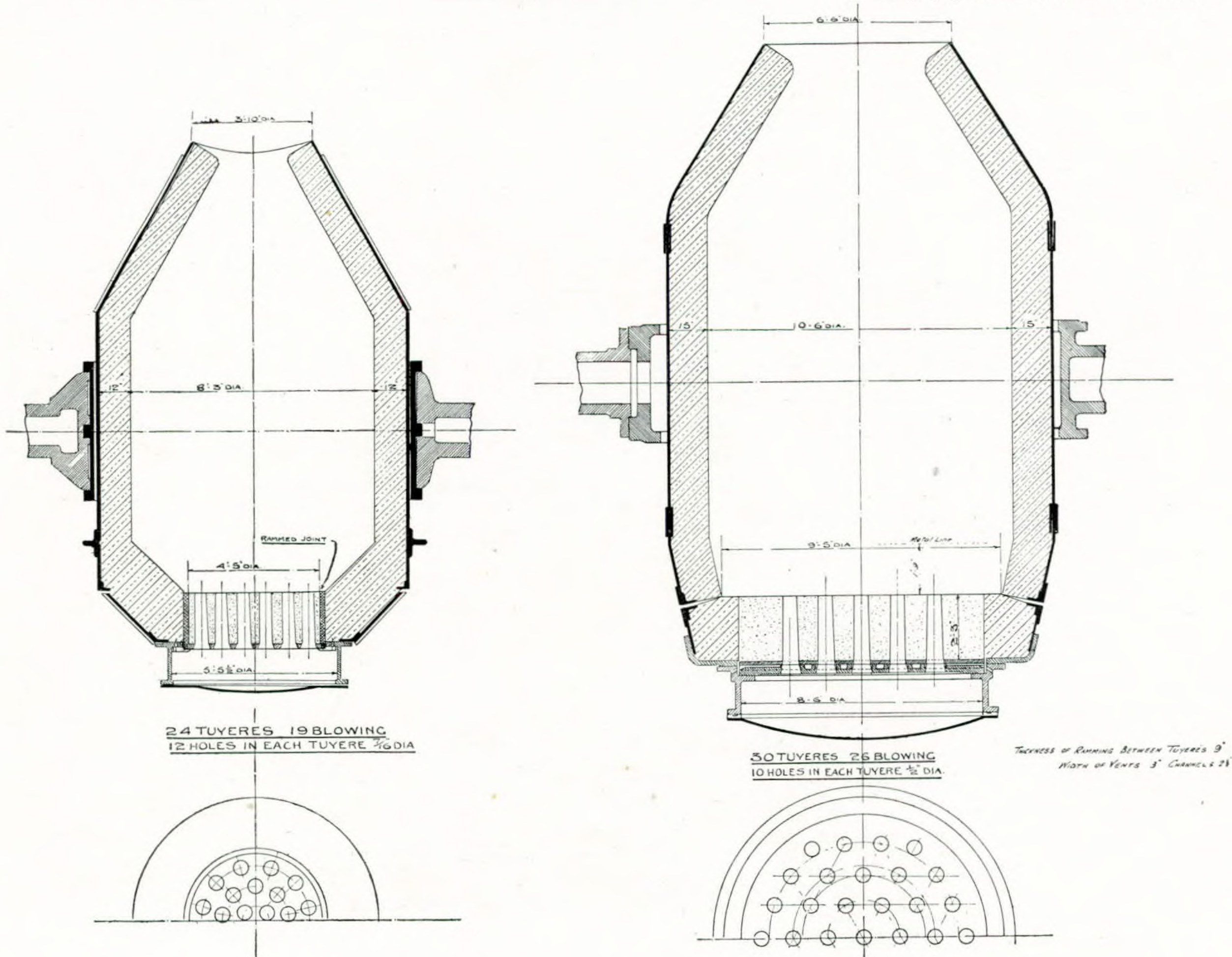
tuyeres are filled with firebricks and a mixture of crushed firebrick and fireclay rammed hard with pneumatic rammers. After ramming, they are put into stoves heated by coke-oven gas for a sufficient time to ensure that they are thoroughly dry before being put on the converters.

The blast for the converters is provided by a twin compound vertical steam engine at a pressure of around 25lb. per square inch.

The molten pig iron is poured into the converter whilst the latter is in the horizontal position. The blast is then turned on and the vessel rotated to the vertical position, so causing the metal to submerge the tuyeres, and the air passing through the bath com-

FIG. 4 (left).—New converters.

FIG. 5 (below).—(L) Old 18-tons converter; (R) New 25-tons converter.



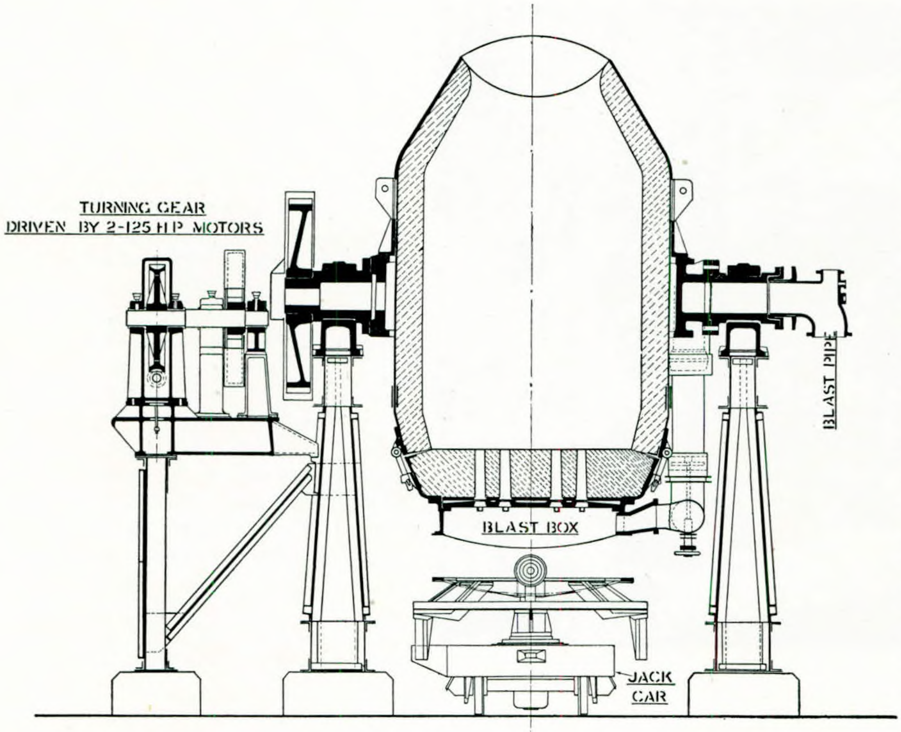


Fig. 6.—25-ton converter.

mences its work of oxidising the unrequired elements in the iron.

Control of the Blow.

The control of the blow is based almost entirely on judgment of the indications of the flame issuing from the nose of the converter. In no other steel-making process are there such clear and instantaneously available indications of the progress of the operation. The phenomena which are reflected in the visual appearance of the flame are interpretable at once, and no records or indications from such instruments as pyrometers, spectroscopes, etc., have yet been successful in providing a satisfactory substitute for the experienced human eye.

The two main factors over which the "blower", *i.e.* the man who is immediately responsible for the steel-making, exercises his control, are the temperature and the end-point of the blow. Normally, the heat developed during the blow is more than sufficient to raise the temperature of the bath from the original 1,250° C. to the temperature necessary for successfully casting steel ingots, say 1,650° C. The surplus heat must be dealt with, otherwise it will have a very detrimental effect on the ingots, besides causing manipulation troubles during casting. It is turned to good account by adding cold steel scrap to the blow, thus providing a ready means of disposing of the bulk of the scrap produced in the mill in the shape of discards, at no cost for fuel.

The indications of the progress of the reactions in the converter reflected in the flame are sufficiently sensitive to enable the blower to adjust his additions of cold scrap very closely, and he can normally keep the finishing temperatures of a series of blows within a range of 20° C. This is necessary as, in addition to the penalties indicated above for blows which are too hot, at the lower end of the permissible range of temperature, difficulties arise in getting the steel to run into the moulds cleanly, and at the worst, it will not run at all.

The end-point of the blow can be judged very closely, and thus the analysis of the steel desired can readily be obtained.

Figs. 7 and 8, plotted from the data in Tables 1 and 2, show the course of the reactions during a blow. These graphs show that the silicon and manganese oxidise rapidly during the early part of the blow, whilst the carbon only drops very slowly until the silicon is fairly low, when the carbon removal accelerates rapidly and proceeds steadily towards practically complete elimination during the second half of the blow. Some iron is oxidised during the blow, giving the characteristic reddish fume which

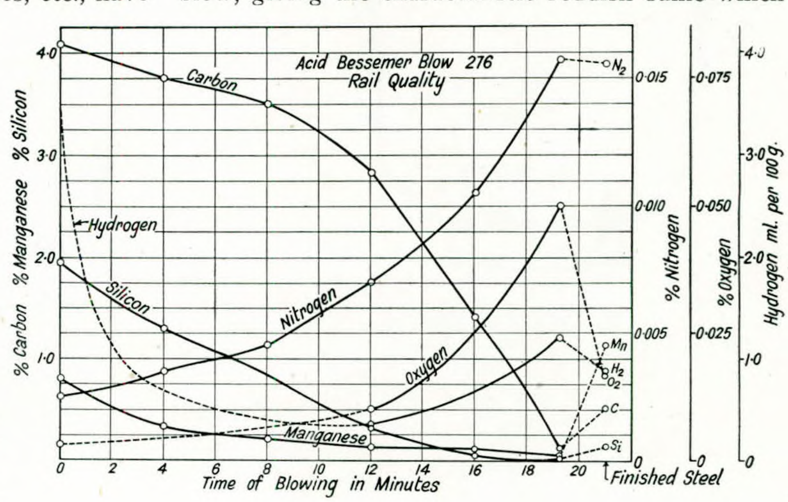


Fig. 7. (See Table 1).

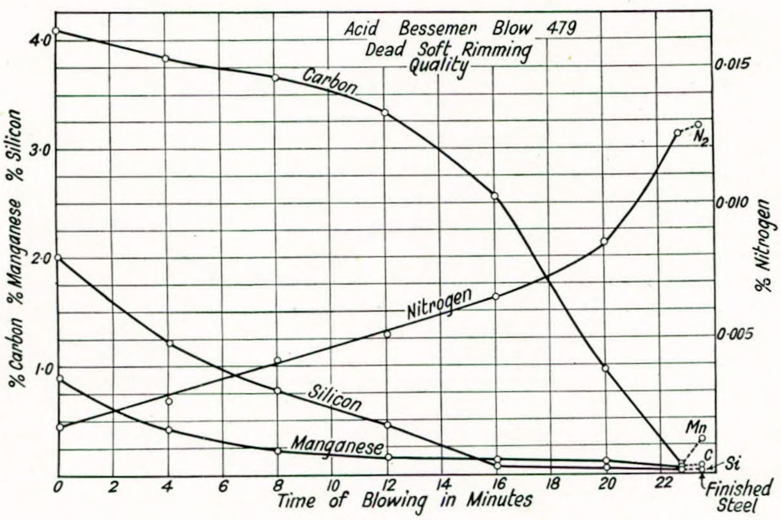


FIG. 8. (See Table 2).

TABLE 1.
BLOW 276.
CHANGES IN COMPOSITION DURING THE PROCESS OF MAKING A "RAIL" CAST.

Time of blowing.	*Chemical analysis.*				*Vacuum fusion analysis.*		
	Carbon.	*Manganese.*	*Silicon.*	*Nitrogen.*	*Nitrogen.*	*Hydrogen*.*	*Oxygen.*
	%	%	%	%	%	*mls./100g.*	%
Mixer metal	4·08	0·80	1·96	0·0025	0·003	3·3	0·003
Blown 4 mins.	3·76	0·33	1·30	0·0035			
8 "	3·52	0·21	0·84	0·0045			
12 "	2·82	0·12	0·326	0·007	0·0055 } 0·0065 }	0·4 } 0·3 }	0·011 } 0·0095 }
16 "	1·40	0·10	0·037	0·0105			
19¼ "	0·095	0·05	Trace	0·0155	0·0165	1·2	0·050
Finished steel, rail quality	0·50	1·15	0·128	0·0155	0·0165	0·85	0·0165

*1 ml. per 100g. = 0·00009% H_2.

TABLE 2.
BLOW 479.
CHANGES IN COMPOSITION IN THE PROCESS OF MAKING A "SOFT" CAST (RIMMING QUALITY).

Time of blowing.	*Chemical analysis.*			*Nitrogen.*
	Carbon.	*Manganese.*	*Silicon.*	
	%	%	%	%
Pig iron	4·10	0·89	2·00	0·0018
Blown 4 mins.	3·84	0·42	1·21	0·0027
8 "	3·65	0·22	0·77	0·0042
12 "	3·32	0·15	0·44	0·0051
16 "	2·54	0·12	0·07	0·0065
20 "	0·96	0·09	0·04	0·0085
22¾ "	0·06	0·03	trace	0·0126
Finished steel "soft" billet	0·055	0·30	trace	0·0127

is ejected into the atmosphere. As the quantity is such a small proportion of the total iron present, it is not possible to give a graphical representation of the extent of this oxidation but, though representing only a small weight of metal, the appearance of the oxide in the flame is rather important from the point of view of control. The temperature affects the course of the reactions in the following way. With higher temperatures, the oxidation of carbon and iron tends to accelerate, and that of silicon and manganese to slow up. The presence of silicon and carbon tends to prevent the oxidation of iron. The flame affords evidence of these tendencies sufficiently clearly to enable the blower to decide on his course of action to keep the rate of temperature increase within the desired limits.

Advantage is taken of this effect of temperature in the manufacture of refined iron, sold under the trade name of "Uco". Various brands of this iron are made to specifications ranging from 2·0/3·0 per cent. carbon, 0·25/2·50 per cent. silicon and 0·20/1·20 per cent. manganese. It is possible, by suitably controlling the temperature of the blow, to produce a refined iron of a given carbon content, say 3·0 per cent., with silicon varying from 0·20 per cent. to 1·20 per cent. as desired. Anything over 1·20 per cent., of course, requires an addition of a silicon alloy.

The products of the oxidation of the silicon, manganese and iron during the early part of the blow, give the slag a refractory silicate of iron and manganese which is normally not sufficiently fluid to play an active part in the process. In this respect the Bessemer contrasts sharply with the open-hearth, in which the slag plays a major part in the progress of operations. During this early period of the blow, the flame issuing from the nose of the converter is short and of a dull reddish colour. As the carbon begins to oxidise, the flame lengthens and brightens until finally it is some 25 feet long and of intense brilliance. This flame is the carbon monoxide generated by the oxidation of the carbon in the bath burning to carbon dioxide on coming in contact with atmospheric oxygen at the nose of the converter.

At the end of the blow, the clearing of the carbon is marked by a shortening of the flame, accompanied by an increase in the fume due to the oxidation of iron, which proceeds rapidly when the carbon has gone. This is the signal to turn the converter down once again to the horizontal position, thus immediately checking further oxidation, and the blast is shut off.

The spectroscope has been used to detect the end-point of the blow. The application has not been sufficiently successful to secure the establishment of the use of the instrument. The changes in the spectrum are not as clearly defined as those seen by direct observation of the flame, and to stand with one's eyes glued to an instrument of this nature for several minutes whilst waiting for the clearing of the carbon, makes a much more severe demand on one's powers of concentration than the direct observation of the flame. More important still, the spectroscope affords no help in the control of temperature, a matter making even greater demands on the judgment of the blower than the finishing of the blow.

The application of pyrometric control to a process of this nature is not at present a practical proposition. As previously emphasized, the more regular the conditions under which the blowers work, the less need is there for any help in this respect.

Some time ago, an attempt was made in America* to improve the control of the blow by supplying the blast at constant volume per unit of time rather than at constant pressure, which is the usual practice. A modern converter plant was equipped with flow-meters to indicate the volume of air being supplied. The blower was able, by means of a push-button control panel, to speed up or slow down the electrically driven rotary blowing machine, whilst recorders provided him with a continuous record of the blast pressure and volume. With a blowing engine of the type in use at Workington, the more positive delivery of the blast enables the engine speed to be taken as representing the blast volume. Fig. 9 is a record of a blow showing engine speed and blast pressure. It will be observed that during the earlier part of the blow the pressure is high and the engine speed low, indicating difficulty in forcing the blast through the

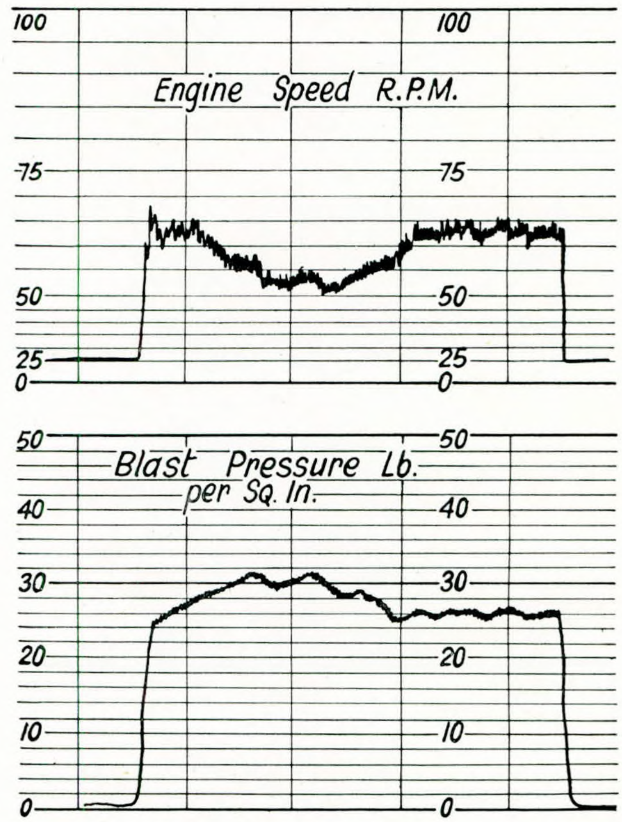


FIG. 9.—Engine Speed and Blast Pressure during a blow.

metal. Later, the pressure falls and there is a very considerable increase in the speed of the engine. The theory behind the attempt to blow at constant volume is that during the later period of the blow, if full pressure is maintained, the oxidation proceeds too fast, with detrimental results to the steel quality. It is not easy to demonstrate any difference in results by the two methods, and opinion in America was by no means unanimous on the benefits to be obtained by limiting the delivery of air towards the end of a blow.

It would undoubtedly be an advantage if the blowing area could be varied during the course of a blow. The area adopted has to be a compromise between the extremes necessary to get sufficient air through the bath during the "sticky" stage and afterwards to maintain sufficient pressure to keep the metal off the tuyeres during the later period when the blowing engine may be running at full capacity.

At the conclusion of the blow, the analysis of the metal is as follows : Carbon ·04 per cent., silicon trace, manganese trace, the sulphur and phosphorus unchanged to any appreciable extent. In some circumstances there may be a slight drop in sulphur, whilst the phosphorus may be a shade higher, due to concentration.

To obtain the required grade of steel, a suitable "finishing" addition is made to the blown metal.

* See R. S. McCaffery, "The Bessemer Process and its Products", American Iron and Steel Institute, New York, Oct. 23rd, 1931.

The addition has the two-fold object of deoxidising the bath and providing the desired composition. For low carbon steels, ferro-manganese is added either in the converter or in the steel ladle. Ferro-manganese contains about 6·75 per cent. carbon and 78 per cent. manganese. A straight addition of this alloy will add, say, ·06 per cent. carbon and ·50 per cent. manganese, thus giving a ·10 per cent. carbon steel. For higher carbon steels, an addition of iron from the mixer may be made to give the carbon required over and above that added by the ferro-manganese. Alternatively, an alloy of lower manganese content, spiegeleisen, may be used. Spiegel, as it is usually called, is really a manganiferous pig-iron containing about 4 per cent. carbon, the manganese content being anything up to 30 per cent. in a series of standard grades. The percentage of manganese is chosen to give the proportion of carbon to manganese required in the finished steel, making allowance, of course, for the manganese lost in deoxidising the blown metal. The quantity of spiegel usually required necessitates the pre-melting of suitably blended alloys in a cupola before adding to the steel.

It may be said that it is preferable to pre-melt *all* finishing additions, but the rapidity with which skulling occurs with such small quantities of ferro-manganese as are necessary for the making of soft steel, brings a grave danger of error in the quantity added, so that it is preferred to make these small additions in the solid form. Naturally, suitable precautions require to be taken to ensure that the whole of the additions enter the liquid steel and are properly assimilated.

Particular attention is paid to the sampling of the finished steel for analysis, test samples corresponding to the first and last ingots being taken.

One of the details which is much more satisfactory in the modern Bessemer than in the old, is the provision of weighing facilities. The weighing of molten metal is not always quite straightforward but, when it is considered that working to close specifications is absolutely dependent on the accurate weighing of materials, it is obviously necessary to be quite sure that the methods adopted can be depended on to work satisfactorily in any eventuality which can reasonably be expected. For example, in weighing spiegel, it is necessary to tap a predetermined weight from the cupola. This necessitates the ladle standing on a weighing machine whilst the spiegel is actually running in. A machine in such a position is exposed to the risk of a break-out from the cupola tapping hole, or an over-run through failure to stop the tapping-hole when desired. Adequate measures must be taken to ensure that such mishaps are not likely to put the machine out of action or affect its accuracy. A similar problem has to be met at the mixer, where a power failure just as a ladle is almost full results in an over-run before the auxiliary engine can be brought into action. Scrap additions, spiegel charged into the cupola (necessary on account of the mixing of various grades), alloy additions and ingots, have all to be weighed, and considerable improvements have been made at these points, with resulting benefits in the direction of regularity of product.

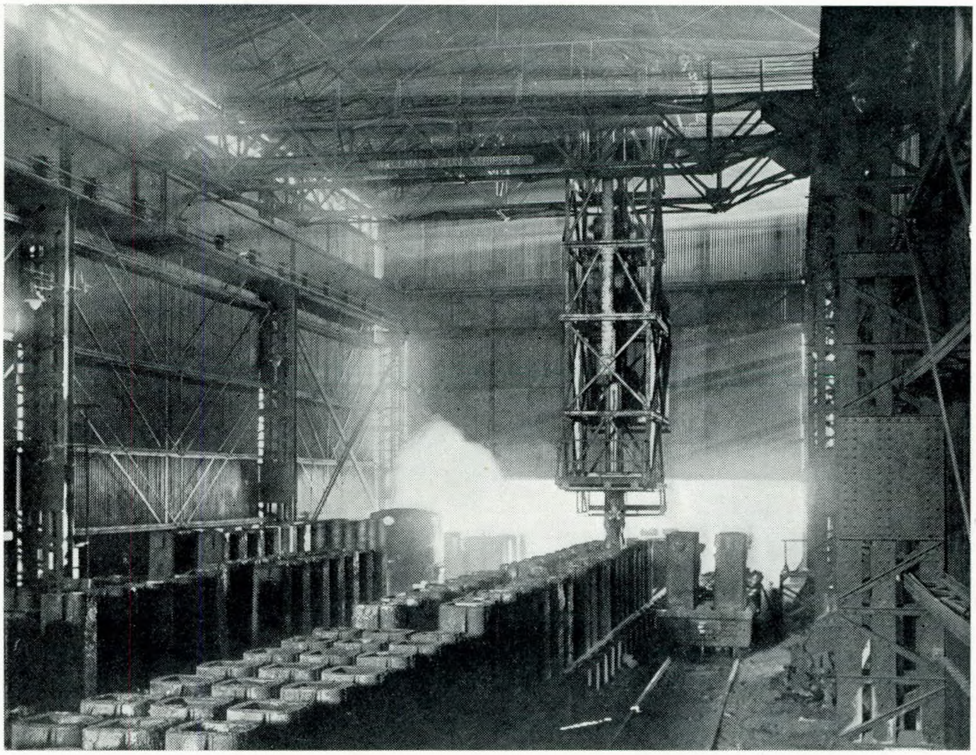


Fig. 10.—Ingot stripper.

Casting.

The facilities for the further handling of the steel after it has been poured from the converter are a great advance on those of the old Bessemer casting pit. This is in line with modern tendencies throughout the steel-making industry, more attention being given to ensuring that good steel is not spoilt by faulty casting technique. Uphill casting was a practical impossibility under the old conditions. It is now a perfectly straightforward proposition and full advantage can be taken of new methods of mould preparation. In spite of the high rate of output, the casting technique is capable of a control equal to that in any modern open hearth plant.

The steel ladle is picked up from a transfer car by an overhead crane, which conveys it to a casting platform alongside which the moulds stand on cars. Under the same roof is a large mould stocking area in which a considerable variety of moulds is kept, so that the type most suitable for the required product may be selected. The moulds are loaded on to the cars by the stripper crane, which also strips the moulds from the ingots after casting. See Fig. 10. The ingots are then run under the soaking pit cranes, which put them in the pits to be prepared for rolling.

The story cannot be considered complete without a brief reference to the soaking pits in which the ingots are placed prior to rolling. The old type of soaking pits were coal-fired and non-reversing. With these, absolute dependence was placed on the regular transfer of ingots from the casting pit at sufficient speed to ensure that sufficient heat for rolling was self-contained in the ingot, which then only required "soaking" to equalise the temperature throughout, assistance from the coal-fire being kept to a minimum. Immediately anything disturbed the normal transfer routine, and the heating, as distinct from the "soaking" capacity of the furnace, was brought into play, the weakness was evident. The ingots near the fire were liable to be overheated, whilst difficulty was experienced in getting those furthest from the fire sufficiently hot for rolling. In fact, this was only accomplished by transferring the ingots from the back to the front, a procedure which is very unsatisfactory and makes the maintenance of an even flow of material through the various processes impossible. It was only the peculiar advantages of the Bessemer process for the quick transfer of ingots from the casting pit which enabled such furnaces to exist as long as they did.

The new regenerative gas-fired soaking pits, illustrated in Fig. 11, are capable of heating up a cast of ingots perfectly uniformly from cold, whilst they can still take advantage of the heat content of a cast of hot ingots direct from the Bessemer. They are built above the ground level, and this offers much better facilities for slagging than the old type, which were sunk below the ground level. In view of the amount of damage which can be done to ingots by soaking pit slag, this is a point of some importance.

A few general notes on Bessemer practice may not be out of place.

The most striking feature of Bessemer operation is the enormous output which may be secured from a comparatively small and compact plant. In America, where markets can be found for such quantities of steel, full advantage is taken of this. As an illustration, one plant, consisting of two 10-ton converters, can produce 10,000/12,000 tons per week. This is comparable with the largest open-hearth shops in this country. In this connection, the contrast between the old and the new types of converter as regards freedom from splashing or "spitting" from the nose during blowing, is noteworthy. The photographs (Figs. 3 and 4) show the accumulations of metal on the old type blowing at the rate of 50 tons per hour, as compared with the new blowing at the rate of 85/90 tons per hour. The latter could be driven much

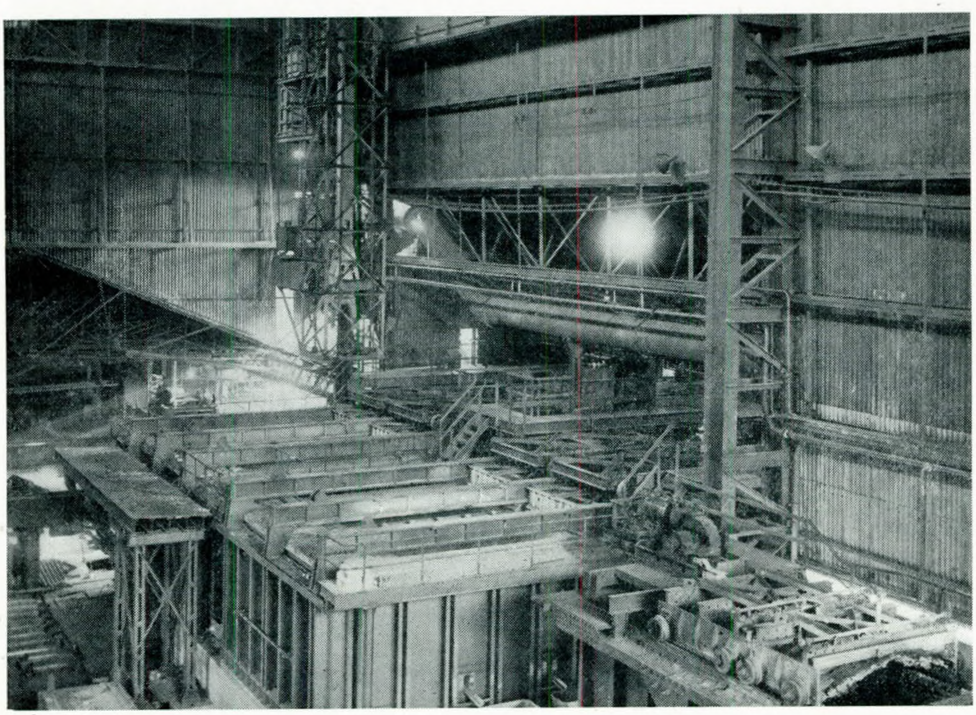


FIG. 11.—Ingot soakers.

faster even than this without meeting with serious trouble from splashing. It is a larger converter, of course, but this by no means fully accounts for the difference.

Two new large Bessemer plants have been erected fairly recently in America, each with three 25-ton converters. They were rated at between 700,000 and 800,000 tons per annum. It should not be too readily assumed that such outputs are obtained by slap-dash methods which disregard quality of product if it competes with quantity. No-one can read American technical journals and believe that quality is not given serious consideration. The acid Bessemer process lends itself to speed, and all the available evidence points to the fact that no sacrifice of quality is necessarily incurred in attaining that speed of operation.

The Properties and Uses of Acid Bessemer Steel.

The authors have already indicated that very large tonnages of this type of steel have been—and in fact are being—used, and they have suggested that the decline in production is largely a question of economics. Incidentally, however, when America's largest steel-making combine, having all processes at its command, chooses to erect two new large Bessemer plants, there is some evidence that the acid Bessemer process is not without virtue.

One of the earliest uses to which Bessemer steel was put was for rails, and to-day it is still pre-eminently suitable for this purpose. Meantime, its use has been extended to railway axles, tyres, springs, sleepers, wire, edge tools, saws, screws, tubes, case-hardened parts, etc. Its use is permitted in a large number of British Standard Specifications.

In America, a very large proportion of the production goes into screw stock and skelp for the manufacture of butt-welded tube. In this country also, Bessemer steel is still used very largely for these purposes.

The reasons for the *particular* suitability for certain purposes will perhaps best be revealed by a study of its characteristics. It is specially urged that the data be considered without prejudice and that members having knowledge of cases of unsuitability of *acid* Bessemer steel based on real fact will give the authors an opportunity of considering these in the discussion.

Gases in Acid Bessemer Steel.

In so far as this subject will be referred to as affecting the properties, it is considered desirable to interpose a short section on gases in steel. Time will not permit a full discussion of the subject which, incidentally, will be to the forefront at the meeting of the Iron and Steel Institute in May. It can, however, be stated that the determination of total oxygen, hydrogen and nitrogen can now be made with extreme accuracy.

Oxygen.

Total oxygen is determined by the vacuum fusion method. By this is meant the oxygen existing as FeO in solid solution—if any—or as non-metallic inclusions, *i.e.* MnO, SiO_2, Al_2O_3, etc. It must be admitted that the accurate determination of the oxygen existing in the several oxides is not quite so definite, although the work has progressed a long way and extensive research is still being pursued, with particular reference to the FeO fraction. One considers that this is the most important one, as affecting the physical properties of the steel. The other oxides exist, of course, in the form of non-metallic inclusions with or without FeO in combination.

It is an entirely erroneous view to hold that acid Bessemer steel is abnormally high in oxygen. In Table 1, and graphically in Fig. 7, the values for total oxygen are recorded for samples representing the complete process on cast 276.

The oxygen in the original iron is extremely

TABLE 3.

A series of mild steels. Analytical data.

Identification letter.	*Cast No.*	*Method of manufacture.*	*Type of steel.*	*Analyses.* C.	*Mn.*	*Si.*	*S.*	*P.*	*Ni.*	*Cr.*	*Cu.*	*Oxygen.* %	*Nitrogen.* %
A	699	Acid Bessemer	Solid	0·16	0·59	0·06	0·038	0·035	Nil	Tr.	Tr.	0·015	0·014
G	220	Acid Bessemer	Solid	0·12	0·48	0·055	0·046	0·040	Nil	Nil	Tr.	0·031	0·014
B	450	Acid Bessemer	Rimming	0·09	0·37	Tr.	0·040	0·033	Nil	Nil	Tr.	0·018	0·011
H	201	Acid Bessemer	Rimming	0·12	0·44	Tr.	0·047	0·048	Nil	Nil	Tr.	0·014	0·013
D	32/4489	Basic open hearth	Solid	0·11	0·42	0·085	0·031	0·017	0·09	0·03	0·10	0·032	0·005
K	23/5770	Basic open hearth	Solid	0·16	0·53	0·20	0·030	0·022	0·11	0·018	0·19	0·031	0·005
M	34/7676	Basic open hearth	Rimming	0·135	0·47	Tr.	0·050	0·022	0·11	0·04	0·12	0·019	0·004
C	17/617	Acid open hearth	Solid	0·10	0·47	0·11	0·029	0·026	0·027	Tr.	Tr.	0·026	0·004
L	21/1776	Acid open hearth	Solid	0·12	0·53	0·095	0·034	0·037	0·03	Tr.	0·075	0·017	0·005

low. It increases towards the end of the blow and, in this case, the finished steel is reported to have a total oxygen content of ·0165 per cent. This, bear in mind, is the total oxygen from all sources. Other casts of rail steel have given values of ·0075, ·012, ·008 and ·017 per cent. Such values are *not* high compared with open hearth steel. Even rimming steel, produced by the acid Bessemer process, does not show a high oxygen content, typical values being in the region of ·015 per cent., although here a word of warning must be given that it is well recognised that the distribution of impurities in rimming steel is not uniform throughout the section. A further paper on this particular subject is being presented to the Iron and Steel Institute in May.

Those interested would note, possibly with surprise, the experiment reported in the Fourth Report of the Heterogeneity of Steel Ingots Committee to the Iron and Steel Institute in 1932. Example 49 and plate XXXI in that Report illustrated a case where acid Bessemer steel was deliberately overblown and then finished in the usual way, the resulting ingot being remarkably sound and free from objectionable characteristics.

Finally, by way of comparison, Table 3 sets out a series of mild steels made by different processes, recording the total oxygen (and, incidentally, the nitrogen) content of these respective steels.

These results confirm that acid Bessemer steel *per se* does not carry a higher content of total oxygen than open hearth steel.

Hydrogen.

One cannot speak with quite the same certainty concerning the determination of hydrogen, as for oxygen. The accuracy of the method is at least equal, but it is found that the hydrogen content can vary, the evidence being that the content tends to fall with the passing of time after manufacture.

Numerous samples of acid Bessemer steel have been tested and the results fall between 0·2 and 0·8 c.c. per 100 gms. This is equal to 0·000018 and 0·000072 per cent. by weight. These are certainly minute values, but it is probable that the hydrogen content is not without significance.

While the oxygen (and nitrogen) are very low in the original iron and increase progressively during the period of the blow, note that the hydrogen is comparatively high in the original iron, is almost eliminated during the boil, and slightly increased in the finishing stages.

Looking through the records of tests of many other steels, these values are almost identical with those normally obtained for open hearth steels.

Nitrogen.

The nitrogen content of Bessemer steel is almost invariably higher than that of open hearth steel. It will be noted from Tables 1 and 2 how the nitrogen content increases during the blow from about ·002 in the original iron to about ·015 in the finished steel. The normal range for Bessemer steel is ·011/·018 and this range is common to all types of Bessemer steel, including Swedish. On the other hand, open hearth steel usually contains ·004/·007 per cent. with an average of say ·005 per cent. The values given in Table 3 may be taken as typical.

It is worth adding that as a result of very extensive testing, it can be stated definitely that, at least for plain carbon steels, the nitrogen content, as determined by the chemical method and by the vacuum fusion method, is the same. As in the former only nitride nitrogen is determined, this may be accepted as definite proof that the whole of the nitrogen exists in the form of nitride in the steels. There is no doubt that the nitrogen content has an important bearing on the mechanical properties.

MECHANICAL PROPERTIES.

It is, the authors feel, unnecessary to cite masses of tests of the conventional type. When,

TABLE 4.

APPROXIMATE COMPARISON OF ANALYSES FOR SIMILAR TENSILE STRENGTH.

	Manganese 0·25/0·35.			*Manganese 0·45/0·55.*			*Manganese 0·70/0·80.*			*Manganese 1·00/1·10.*		
	Carbon.			*Carbon.*			*Carbon.*			*Carbon.*		
Tensile tons/ sq. in.	*Acid Bessemer.*	*Acid open hearth.*	*Basic open hearth.*	*Acid Bessemer.*	*Acid open hearth.*	*Basic open hearth.*	*Acid Bessemer.*	*Acid open hearth.*	*Basic open hearth.*	*Acid Bessemer.*	*Acid open hearth.*	*Basic open hearth.*
23			0·07									
24	0·04	0·075	0·09			0·07						
25	0·06	0·09	0·11		0·07	0·09						
26	0·08	0·115	0·135	0·07	0·09	0·115						
27	0·095	0·13	0·15	0·09	0·115	0·135			0·11			
28	0·12	0·15	0·175	0·105	0·13	0·15		0·105	0·125			
30	0·16	0·19	0·215	0·15	0·175	0·195	0·12	0·15	0·17			0·13
33			0·28	0·25	0·275	0·29	0·22	0·24	0·26	0·18	0·20	0·22
36			0·34	0·30	0·325	0·34	0·27	0·29	0·31	0·23	0·25	0·27
40				0·395	0·425	0·44	0·36	0·38	0·40	0·32	0·34	0·36
45				0·51	0·54	0·56	0·46	0·48	0·50	0·41	0·42	0·43
50					0·65	0·67	0·53	0·55	0·58	0·47	0·49	0·50
55							0·61	0·63	0·66	0·55	0·58	0·59
60							0·75	0·78	0·82	0·69	0·73	0·74

TABLE 5.
TESTS ON ACID BESSEMER STEEL RAILS.
100lb. M.R.

Item.	*Date and firm.*	*Analyses.*					*Tensile.*		
		C.	*Si.*	*S.*	*P.*	*Mn.*	*Max. stress, tons/ sq. in.*	*Elong.* %	*Redn. of area* %
1	1903 S.F.	0·47	0·065	0·076	0·045	1·16	49·52	15·5	31·60
2	1904	0·41	0·052	0·054	0·058	1·05	42·6	18·0	24·14
	S.P.T.	0·42	0·042	0·055	0·060	1·13	44·55	19·5	28·44
3	1905	0·43	0·068	0·052	0·046	1·22	47·05	21·5	31·60
	C.L.	0·44	0·065	0·058	0·046	1·28	47·5	17·0	25·40
4	1906 S.P.T.	0·42	0·093	0·054	0·061	1·05	50·44	18·5	27·36
5	*95lb.* L.N.E.R. Workington	0·48	0·119	0·043	0·054	1·10	51·65	18·4	29·9
6	*95lb.* Workington As rolled	0·47	0·129	0·038	0·043	1·02	49·6	19·4	30·5
	Sandberg "regulated" process.	,,				,,	59·8	15·1	28·3

for certain purposes, particularly in connection with shipbuilding and marine engineering, the use of acid Bessemer steel has been debated, it has usually been agreed that the tensile, bend and other orthodox tests can be met without difficulty. Reliability, as a matter of routine production, has been questioned and, to be perfectly frank, rather mysterious cases of failure attributed to some form of brittleness have occasionally been quoted. As to regularity, it is hoped that the description of the process as now practised will have indicated that, notwithstanding the speed of operation, there are adequate safeguards as regards both composition and quality. It is manifestly impossible to deal with cases of failure unless full details are available.

It is important, however, to realise that acid Bessemer steel differs in certain characteristics from open hearth steel—as, for example, greater tensility or stiffness with similar carbon content; stronger work-hardening tendencies, etc., which will be dealt with shortly; and some of these differences have been attributed to nitrogen content which, as before mentioned, is higher in Bessemer than in open hearth steel.

Table 4, extracted from data prepared by Mr. J. H. Warlow, Jnr., may serve as an *approximate* guide to the carbon content required for equivalent tensile in acid Bessemer, acid open hearth and basic open hearth respectively. The tensile figures correspond to steel in 2 to 4in. square section in the "as rolled" condition.

C. C. Henning* indicates a rough ratio of 100 to 85 for the respective stiffness of Bessemer and equivalent open hearth steel.

Reverting to rails, Table 5, items 1-4, shows a group of analyses and tests of 100lb. M. R. rails quoted from a paper read in 1928.†

Only the analyses and tensile tests are given in this table, but it may be taken that the falling weight tests were entirely satisfactory.

Item 5 represents the average of 33 recent casts of 95lb. L. & N.E.R. rails tested without any treatment subsequent to rolling. Item 6 is a test representing the average of 30 rails treated by the Sandberg regulated process alongside the tests of similar rails untreated. The advantage of the Sandberg process is not fully revealed in these tests, as space precludes a full description of the hardness distribution and increased toughness under the drop test.

The subject has recently been dealt with in a very interesting manner by Cecil J. Allen in a paper entitled "The Exceptional Wearing Properties of Early Steel Rails" read before the Fourth International Rail Congress held in Düsseldorf. In this paper, the author again testifies to the excellent results obtained from acid Bessemer steel in the form of rails, from the point of view of reliability and the combination of hardness with toughness.

At the same conference Mandel gave an analysis of twenty-five years' statistics of curved track obtained on the Hamburg elevated railway. Bessemer rails with a tensile strength of 38/45 tons per square inch provided better wear resistance than ordinary open hearth rails with a tensile strength of 48/54 tons per square inch. So much for rails.

* Amer. Inst. Min & Met. Engrs., Sept., 1935.

† "Chromium Steel Rails", by T. Swinden and P. H. Johnson, Jnl. I.S.I., No. I, 1928, p. 637. The same paper compares Bessemer and open hearth steel rails and, incidentally, introduced the chromium steel rail, which has found extended use. This was first produced in the acid Bessemer plant at Stocksbridge and some remarkable examples of its satisfactory wear resistance are contained in the paper.

TABLE 6.

TYPICAL ANALYSES AND TESTS OF ACID BESSEMER STEEL.

Quality.	*Analyses.* C.	Mn.	*Max. stress, tons/ sq. in.*	*Elong. % on 8in.*	*Redn. of area %*
Sheet bar ...	0·08	0·34	26·6	29·5	—
Sleepers (1)	0·10	0·50	28·6	31·0	—
.. (2)	0·34	0·81	39·4	31·0	—
				on 2in.	
Fishplates (1)	0·23	0·77	33·6	32·5	56·0
„ (2)	0·36	0·79	40·4	26·0	40·4
Billets (1) *2/2½in. sq.*	0·09	0·36	26·0	37·0	63·0
(2)	0·12	0·57	28·4	32·5	50·8
(3)	0·16	0·59	30·8	30·0	48·0
(4)	0·20	0·70	31·8	27·0	43·4
(5)	0·23	0·85	34·0	27·0	38·6

Table 6 shows a few analyses and tests of acid Bessemer steel selected as typical from every-day production.

Tyres and axles are not at present manufactured in plants making acid Bessemer steel, but as before mentioned, huge quantities of both straight and crank axles, as well as carriage and wagon tyres, have been produced and many no doubt are still in service. Also, although it is not considered desirable to quote tests, immense quantities of shell steel of various types have been produced by this process.

Probably it will be of more interest to the Members of this Institute to have a direct comparison of a series of acid Bessemer and open hearth mild steels. In Table 3 are listed the analyses of such a series in illustrating the oxygen and nitrogen contents. Table 7 compares the tensile tests obtained on ⅝in. bars in the normalised condition.

The authors now proceed to comment on certain special aspects in regard to acid Bessemer steel.

WEAR RESISTANCE.

Although certain laboratory tests have been made using the Humfrey wear-testing machine, the position of laboratory tests for wear is still such that one hesitates to quote actual values. Fortunately, however, there is sufficient evidence of a practical character, particularly in the case of rails, as already quoted, to indicate that acid Bessemer steel of similar tensile strength has equal or superior wear-resisting properties to open hearth steel.

MACHINABILITY.

Bessemer steel has gained a high reputation in the United States and in this country, particularly in the manufacture of screws. In this country, it is still used in large tonnages of the normal sulphur type, because of the fine finish obtained. It is in this direction, rather than in laboratory tests by the Losenhausen or other apparatus, that the machinability of acid Bessemer steel shows to the greatest advantage.

C. C. Henning, in his position with the Jones & Laughlin Steel Corporation, is particularly well qualified to speak on the subject of machinability and, quoting from his paper (loc. cit.), he says: "There is no grade yet developed that even closely approaches the potential high speed cutting quality of the Bessemer screw steels and, for this reason, it is to-day one of the major tonnage outlets for the Bessemer".

WELDABILITY.

As previously mentioned, a large outlet for Bessemer steel has been in the supply of skelp for the manufacture of butt-welded tubes. For many years it was considered impossible to produce an

TABLE 7.

COMPARATIVE TENSILE TESTS OF A SERIES OF MILD STEELS.

⅝in. bars in the normalised condition.

Identi-fication letter	*Quality.*	*Type.*	*Tensile range, tons/ sq. in.*	*Analysis*.* C.	Mn.	Si.	*Yield point, tons/ sq. in.*	*Max. stress, tons/ sq. in.*	*Elong. % on 2in.*	*Redn. of area %*	*Izod impact ft.-lb. avge.*	*Bend.*
G	Acid Bessemer	Solid	24/28	0·12	0·48	0·055	18·2	27·8	38	68	89	180°
B	Acid Bessemer	Rimming	„	0·09	0·37	Tr.	17·1	25·1	42	72	89	180°
C	Acid open hearth	Solid	„	0·10	0·47	0·110	15·6	25·5	43	70	93	180°
D	Basic open hearth	„	„	0·11	0·42	0·085	15·0	25·4	43	72	92	180°
M	Basic open hearth	Rimming	„	0·135	0·47	Tr.	16·5	25·8	40	61	75	180°
A	Acid Bessemer	Solid	28/32	0·16	0·59	0·06	19·3	30·5	38	66	77	180°
P	Basic open hearth	„	„	0·18	0·59	0·187	22·6	30·7	38	66	88	180°

**See* Table 3 for full analysis.

TABLE 8.

COMPARISON OF THE EFFECT OF COLD WORK ON BESSEMER *v.* OPEN HEARTH STEEL (HENNING).

	Bessemer steel.		*Open hearth steel.*	
	Hot rolled.	*Cold drawn.*	*Hot rolled.*	*Cold drawn.*
Yield point, lb. per sq. in. ...	42,780	75,040	39,040	63,220
Tensile strength, lb. per sq. in.	64,900	88,170	65,000	77,880
Elongation, per cent. in 2in. ...	38·0	19·5	36·5	19·0
Reduction, per cent.	65·2	53·3	61·8	57·0

open hearth grade which would suit this purpose as satisfactorily as Bessemer steel. Both acid and basic Bessemer have been proved to be highly suitable for this purpose. There are two probable reasons for this, namely, the low carbon which it is possible to produce and the comparative freedom from small contents of "residual elements", which are averted in the case of Bessemer steel, as it is, in every sense of the word, virgin material.

Welding tests were, in fact, carried out on the series of steels, G, B, C, D and M, for which the analyses and mechanical properties have already been listed in Tables 3 and 7. These were examined as butt-welded specimens prepared by arc welding, oxy-acetylene welding, flash butt welding and forge welding. As a result of these tests, it can be stated with complete certainty that the Bessemer steels were in every way satisfactory and, in fact, one rather disappointing feature of this piece of research was that no significant differences were revealed between the types of steel examined.

REACTION TO COLD WORK OR WORK-HARDENING FACTOR.

This is an important feature because, in addition to the higher initial hardness for equivalent carbon content, the reaction to cold work is greater in acid Bessemer steel than in open hearth steel. It is probable that the excellent machinability of the Bessemer steel is contributed to by this factor and it is most probably a potent factor in respect of resistance to wear.

On the other hand, due regard must be paid to this fact when using acid Bessemer steel for deep-drawing purposes, and it is necessary to adjust the analysis and pay particular attention to the finishing operations in steel-making, if the increased tendency to work-harden of acid Bessemer steel is likely to be detrimental.

Henning (loc. cit.) quotes the data in Table 8, comparing the effect of cold work on acid Bessemer and open hearth steel, pointing out that while the tensile strength is about the same in the hot rolled condition, cold drawing increases the yield point about 19 per cent. and the tensile 13 per cent. more than in the open hearth steel.

The authors have also done considerable work in this direction, examining the effect both by increase of tensile during progressive cold rolling and by using the Herbert Pendulum Hardness Tester.

TABLE 9.

COLD WORKING FACTORS AS SHOWN BY COLD ROLLING.

	Tensile Test.				
	Max. stress tons/ sq. in.	*Elongation % on 2″*	*Thickness.*	*% Reduction in thickness.*	*Cold working factor.*
Acid Bessemer.	46·7	17·0	·064″	—	—
Hot rolled	67·8	2·5	·039″	39·0	·540
(normalised).	73·6	2·0	·032″	50·0	·538
	78·8	1·5	·0255″	60·1	·533
	82·7	1·5	·019″	70·3	·514
Basic Open	46·9	17·0	·064″	—	—
Hearth.	66·3	4·0	·038″	40·6	·477
Hot rolled	71·7	3·0	·031″	51·5	·481
(normalised).	74·3	2·5	·0255″	60·1	·455
	79·1	2·0	·020″	68·7	·468

TABLE 10.

WORK-HARDENING TESTS BY THE HERBERT PENDULUM HARDNESS TESTER.

Acid Bessemer.

Average time hardness 21·44

Work-hardening tests.

Passes of ball ...	0	2	4	6	8	10	12
Time hardness ...	21·4	30·6	31·7	32·4	32·5	<u>32·7</u>	32·4
	21·3	30·2	31·6	32·2	32·3	<u>32·7</u>	32·0

Basic Open Hearth.

Average time hardness 20·96

Work-hardening tests.

Passes of ball ...	0	2	4	6	8	10	12
Time hardness ...	21·0	27·6	28·5	28·7	<u>29·5</u>	28·8	
	20·7	27·1	27·9	29·2	<u>29·2</u>	29·3	28·7

An example on rail steel is as follows:

	ANALYSIS.						
	C.	*Mn.*	*Si.*	*S.*	*P.*	*Ni.*	*Cr.*
Acid Bessemer ...	·52	·88	·105	·032	·042	Tr.	Nil.
Basic Open Hearth	·59	·72	·105	·022	·026	·118	·064

Hot rolled strips, ·064in. thick, were normalised and samples taken after progressive degrees of cold rolling, the cold working factor representing the increase in tensile strength divided by the percentage reduction in thickness, being shown in Table 9.

Tests by the Herbert Pendulum Hardness Tester, using the Standard 4 Kg. Pendulum and 1 mm. bright steel ball, are also interesting, and are shown in Table 10.

In making these tests, the selected spot is rolled repeatedly by tilting the Pendulum, the hardness being measured after each second pass until it reaches a maximum (underlined) and shows a decline. In both sets of tests, the appreciably greater work-hardening ability of acid Bessemer steel is clearly indicated.

Similar tests have been carried out on dead soft steel strip and also on free-cutting (high sulphur) wire. Without repeating all the tests, it may be said in the case of the strip that, whereas the work-hardening factor for dead soft open hearth steel was approximately ·35, that for acid Bessemer steel ranged from ·45 to ·50. Similarly, in the case of the free-cutting wire, two different makes of open hearth quality had a work-hardening factor of ·36 and ·37 respectively, whereas the Bessemer had a factor of ·45. In summary, therefore, it may be said that the reaction to cold work is definitely greater in the case of Bessemer steel than in open hearth steel and it is indicated that the effect is more pronounced in the case of the lower carbon steel.

EMBRITTLEMENT.

It is possibly in this direction that a certain amount of apprehension exists in some quarters concerning Bessemer steel. The various types of embrittlement which can be developed in mild steel have been dealt with* elsewhere, but it is necessary to refer again to this phenomenon in some detail.

Strain-Age-Embrittlement.

By this is meant a reduction in the impact value when mild steel is strained and particularly when it is subsequently reheated to a temperature, say, not exceeding 400° C. and preferably in the region of 200/250° C. to produce the maximum effect.

The authors' standard procedure for this test is to strain the sample by extending it 15 per cent. followed by reheating for 30 minutes at 250° C.

An extensive series of tests of various steels subjected to this treatment was reported by G. R. Bolsover (Jnl. I.S.I., No. 1, 1929). It was shown there that phosphorus is a very important factor and it has subsequently been shown that the degree and method of deoxidation has a predominating influence. One way of correlating the method of deoxidation with the properties of the resulting steel is by determination of the McQuaid-Ehn grain size and this has been dealt with at length in a paper by T. Swinden and G. R. Bolsover.* It is necessary to emphasize this because the authors have shown that mild steel with inherent fine grain size is strongly resistant to strain-age-embrittlement, whereas steel with inherent coarse grain is more highly susceptible, and we have ample evidence that this statement holds irrespective of the method by which the steel is produced.

Data are contained in the papers referred to on this point, but it can be amplified by further new data for the purpose of this paper. The results are in every way similar.

Table 11 gives strain-age-embrittlement tests for steels G, B, C, D, M, fuller details of which have been given in previous tables. It will be noted that these steels were selected having practically uniform McQuaid-Ehn grain size.

The Bessemer steel shows a greater reduction in impact on straining than the open hearth steels, but it will be noted that after straining and reheating, all the impact values are reduced to comparatively low figures.

Supplementing what has been said on the inhibiting effect of fine grain on strain-age-embrittlement, a further pair of acid Bessemer steels having different grain size has been tested in addition to the example quoted in the paper to the North East Coast Institution (loc. cit.). Details are as follows :

Acid Bessemer Steel.

	Cast No. 220	Cast No. 717
Analysis :		
Carbon	0·12	0·12
Manganese	0·48	0·55
Silicon	0·055	0·078
Sulphur	0·046	0·040
Phosphorus	0·040	0·049
	Coarse.	*Fine.*
McQuaid-Ehn grain size... ...	3	8
Heat Treatment.		
All samples were normalised at 910° C.		
Tensile and Izod Impact Figures.		
Max. stress, tons/sq. in. ...	28·1	29·9
Yield point „ ...	18·2	20·0
Elong. % on 2 inches	39·0	40·0
Redn. of area %	66·0	70·0
Izod impact figures. ... Ft. lb.	79, 78, 77	88, 85, 86
Avge.	78	86

* T. Swinden : "Special Steels and their Application to Engineering and Shipbuilding". North East Coast Institution of Engineers and Shipbuilders, February, 1938.

* "Controlled Grain Size in Steel", Jnl. I.S.I., No. II, 1936.

TABLE 11.
STRAIN-AGE-EMBRITTLEMENT TESTS.*

Steel.	*Quality.*	*McQuaid-Ehn grain size.*	*Izod impact figures—ft.-lb.* *Normalised 920° C.*		*Normalised 920° C., strained 15%.*			*Normalised 920° C., strained 15%, reheated 250° C.*		
				Avge.		*Avge.*	*% Decrease*		*Avge.*	*% Decrease*
G	Bessemer. Solid.	3	91, 86, 90	89	6, 7, 10	8	91	4, 3, 4	4	95
B	Bessemer. Rimming.	2	91, 89, 87	89	5, 5, 4	5	94	2½, 2½, 2½	2½	97
C	Acid O.H. Solid.	3	100, 90, 90	93	61, 60, 31	51	45	13, 9, 8	10	89
D	Basic O.H. Solid.	3	98, 88, 89	92	66, 21, 13	33	64	13, 7, 6	9	90
M	Basic O.H. Rimming	3	73, 78, 75	75	52, 52, 52	52	31	19, 13, 16	16	79

* See Table 3 for full analysis.

TABLE 12.

ANALYSIS OF AN EXPERIMENTAL SERIES OF STEELS.

Steel	1	2	3	4	5	6	7	8
S.G. No. ...	2715	2754	2753	2755	2745	2746	2906	2907
Type of grain ...	Coarse	Fine	Coarse	Fine	Coarse	Fine	Coarse	Fine
Carbon % ...	0·16	0·15	0·19	0·18	0·16	0·16	0·19	0·19
Manganese % ...	0·62	0·59	0·60	0·66	0·60	0·62	0·69	0·69
Silicon % ...	0·17	0·19	0·18	0·19	0·17	0·18	0·13	0·13
Sulphur % ...	0·042	0·042	0·039	0·041	0·035	0·036	0·049	0·048
Phosphorus %...	0·049	0·047	0·048	0·048	0·046	0·047	0·048	0·049
Nitrogen % ...	0·005	0·005	0·010	0·008	0·012	0·013	0·018	0·018
McQuaid-Ehn ... Grain size ...	1 to 5 mainly 2	7 to 8	2 to 4 mainly 2	8	1 to 4 mainly 3	7 to 8	2 to 4	8

Strain-age-embrittlement Tests.

	Izod Impact Figure.	*Avge.*	*Ft. lb.*	*Avge.*
Normalised 910° C. ...	79, 78, 77	78	88, 85, 86	86
„ stretched 15%	8, 9, 6	8	72, 72, 72	72
„ „ +250° C. ½ hr.	9, 5, 3	6	73, 72, 70	72

It is again shown that the loss of impact in the fine grain steel is comparatively negligible and, as indicated elsewhere, the same applies to open hearth steel.

It is not the authors' purpose in this paper to enter into a theoretical consideration of the phenomenon of strain-age-embrittlement. However, in so far as the possible effect of oxygen and nitrogen is concerned, a further piece of work has been done which is worth recording:

The Influence of Nitrogen on Strain-Age-Embrittlement.

A series of fine and coarse grain steels containing 0·15/0·20 per cent. carbon has been made in the small high frequency furnace, respectively coarse and fine grain and respectively containing progressively increasing contents of nitrogen (see Table 12).

Mechanical Tests.

Samples of $\frac{11}{16}$in. diam. bars forged from the ingots were normalised at 900° C., tested for tensile and notched-bar impact figures, and also by the authors' standard method for susceptibility to strain-age-embrittlement. (See Tables 13 and 14.)

The very marked superiority of fine grain over coarse grain steel in resistance to strain-age-embrittlement is confirmed in this series of tests.

Increase in nitrogen content from 0·005 to 0·010 per cent. in the *coarse* grain steel increases the susceptibility of the steels to strain-age-embrittlement, but beyond this content any further effect is comparatively slight.

Increase of nitrogen content from 0·005 to 0·013 per cent. appears to have little effect on the susceptibility to strain-age-embrittlement of the *fine* grain steels, but when the nitrogen content is further increased to 0·018, there is a definite increase in susceptibility to embrittlement, though, even at this content, the degree of embrittlement is only small compared with that found in the coarse grain steels.

In so far as it may be considered that the fine grain steel will presumably have a lower FeO content than the coarse grain steel, the indications are that this factor is of primary importance as regards strain-age-embrittlement.

The term "embrittlement" has been used to indicate types other than strain-age-embrittlement, but it is felt that it is in regard to strain-age-embrittlement that the marine engineer is usually primarily concerned. A few words can be added, however, concerning two other types of embrittlement.

Quench-Ageing.

It is well-known that if mild steel is quenched, preferably from a temperature of about 650° C. and then allowed to rest, or is reheated to a low temperature, the tensile strength increases and, generally speaking, the impact value is reduced. It has been shown elsewhere* how this applies equally well to open hearth and acid Bessemer steel and how the embrittlement, as illustrated by the impact test, is almost completely eliminated notwithstanding the increase in hardness and tensile strength, if the steel is made under special deoxidising conditions resulting in the production of inherent fine grain. Complete details of this data can be supplied later if desired.

* Paper (*loc. cit.*) to the North East Coast Institution of Engineers and Shipbuilders, p. 187.

TABLE 13.

TENSILE AND NOTCHED-BAR IMPACT TESTS. (See Table 12).

Steel.	*Max. stress tons/sq. in.*	*Yield point tons/sq. in.*	*Elong. % on 2in.*	*Redn. of area %*	*Izod impact figure, ft.-lb.*	*Avge.*
1	31·4	23·1	39·0	63·6	80, 77, 81	79
2	29·4	22·6	40·0	66·0	81, 83, 81	82
3	32·8	23·6	38·0	63·6	70, 65, 80	72
4	31·6	23·3	39·5	68·0	81, 80, 81	81
5	31·6	22·0	38·5	63·6	71, 71, 74	72
6	31·4	23·3	40·0	68·0	81, 82, 81	81
7	34·8	25·3	35·0	59·2	56, 64, 73	64
8	32·6	24·8	35·0	59·2	71, 75, 75	74

TABLE 14.
STRAIN-AGE EMBRITTLEMENT TESTS. (See Tables 12 and 13).

Steel.	*Treatment.*	*Izod impact fig. ft.-lb.*	*Avge.*	*Percentage redn. in Izod fig.*
1	Normalised	80, 77, 81	79	—
	„ strained 15%	59, 59, 58	59	25
	„ „ +250° C. for ½hr.	22, 10, 21	18	77
2	Normalised	81, 83, 81	82	—
	„ strained 15%	67, 66, 68	67	18
	„ „ +250° C. for ½hr.	67, 67, 67	67	18
3	Normalised	70, 65, 80	72	—
	„ strained 15%	11, 18, 13	14	81
	„ „ +250° C. for ½hr.	8, 6, 4	6	92
4	Normalised	81, 80, 81	81	—
	„ strained 15%	65, 67, 68	67	17
	„ „ +250° C. for ½hr.	66, 66, 65	66	19
5	Normalised	71, 71, 74	72	—
	„ strained 15%	8, 11, 9	9	87
	„ „ +250° C. for ½hr.	6, 6, 7	6	92
6	Normalised	81, 82, 81	81	—
	„ strained 15%	67, 66, 67	67	17
	„ „ +250° C. for ½hr.	65, 66, 64	65	20
7	Normalised	56, 64, 73	64	—
	„ strained 15%	11, 7, 12	10	84
	„ „ +250° C. for ½hr.	3, 5, 2	3	95
8	Normalised	71, 75, 75	74	—
	„ strained 15%	54, 54, 53	54	27
	„ „ +250° C. for ½hr.	50, 51, 48	50	32

In the authors' view this confirms the theory that quench-ageing is essentially a function of some form of precipitation hardening, the carbon and nitrogen content being predominantly influential. This subject has recently been examined exhaustively by Andrew and Trent.†

Quench-age-hardening is taken advantage of in the production of hard drawn spring wire, etc.

Blue-Brittleness.

It is known that when mild steel is deformed at a temperature corresponding to the "blue heat", it exhibits a certain lack of ductility and this is often referred to as "blue-brittleness". The question may be asked as to how acid Bessemer steel compares with open hearth steel in this respect. A preliminary series of tensile tests have been made at temperatures ranging from 100 to 300° C., following which careful tests were made at 150 and 200° C. as indicating the range where the ductility may be affected most.

Table 15 compares two acid Bessemer and two basic open hearth steels, full details of which appear in previous tables. These tests are interesting, as showing the increase in tensile strength and decrease in ductility (particularly as indicated by reduction of area) when the test is pulled at 200° C., but that as between acid Bessemer and basic open hearth, there is no significant difference.

† Jnl. I.S.I., II, 1938.

CASE-HARDENING.

Acid Bessemer steel has been used very extensively as a case-hardening quality on account of the high surface hardness that can be obtained (probably assisted by the nitrogen content), together with excellent core properties. A typical set of tests of material complying with the well-known Air Board Specification 2 S 14, is as follows:—

Analysis:
- Carbon ·14%
- Manganese ·76%
- Silicon ·131%

Depth of carburisation on 1⅛in. diameter bars for 4, 8 and 12 hours respectively at 920° C. in Kasenit, was ·047, ·064 and ·085in. The surface hardness after the usual double quench from 900° C. and 780° C. in water, was 820 on the Vickers' scale. Core tests on specimens of ⅝in. and 1⅛in. diameter are shown in Table 16. Incidentally, duplicate tests,

TABLE 15.
BLUE-BRITTLENESS.
TENSILE TESTS AT 150° C. AND 200° C.
Rate of straining—1/24-in. per minute.

Steel.†	*Temperature.*	*Max. stress, tons/sq. in.*	*Yield point, tons/sq. in.*	*Elong. % on 1·5in.*	*Redn. of area %*	*Decrease in percentage elongation. %*
G Acid Bessemer	Room	28·2	19·2	*39	68	
	150° C.	39·3	21·8	25	50	36
	200° C.	40·8	20·6	28	50	28
D Basic open hearth	Room	25·4	15·0	*43	72	
	150° C.	32·3	18·1	25	60	42
	200° C.	33·2	20·3	25	62	42
A Acid Bessemer	Room	30·5	19·3	*38	66	
	150° C.	41·8	22·0	25	47	34
	200° C.	42·8	21·9	31	53	18
P Basic open hearth	Room	30·7	22·6	*38	66	
	150° C	35·5	23·3	25	53	34
	200° C.	36·5	20·1	24	53	37

* Gauge length 2in. † See earlier tables for details.

TABLE 16.
CORE TESTS OF CASE HARDENING STEEL.

Process of manufacture.	*Size of bar diam.*	*Resting period.*	*Max. stress, tons/ sq. in.*	*Yield point, tons/ sq. in.*	*Elong. % on 2in.*	*Redn. of area %*	*Izod impact figure, ft.-lb.*	*Avge.*
Acid Bessemer	⅝in.	6 hrs.	41·7	24·4	32·5	59·2	65, 67, 70	67
		1 week	44·0	28·3	34·0	59·2	66, 68, 71	68
	1⅛in.	6 hrs.	36·6	23·6	37·5	66·0	79, 79, 79	79
		1 week	36·7	23·5	35·5	66·0	81, 83, 83	82

after resting the pieces for 6 hours and 1 week after treatment, are included, showing no adverse effect on the impact test as a result of ageing.

The above tests readily comply with 2 S 14 specification, and for many important purposes, acid Bessemer case-hardening steel is preferred to that made by other processes.

RESISTANCE TO CORROSION.

Corrosion tests have been carried out on the series of mild steels referred to in Table 3, as well as subjected to exposure in an industrial atmosphere both in the "as rolled" and surface ground conditions for a period of 2 years.

The difference in loss after de-rusting is not very marked between the various specimens, the actual values being reported in Table 17.

It is very important to note in considering these results, that the steels are not strictly comparable. Attention is directed to the carbon and particularly the copper content. It is well proven that a small content of copper assists resistance to atmospheric corrosion and this undoubtedly accounts for the *slight* apparent superiority of the open hearth steels.

There is considerable evidence, particularly in the States, that acid Bessemer steel with a similar copper content, is at least equal, and according to Henning (loc. cit.) definitely superior, to basic open hearth steel.

CREEP PROPERTIES.

By "creep", of course, is meant the behaviour of steel at elevated temperatures whereby, under a sustained load at a given temperature, the material continues to extend or creep. The subject is, of course, of vital importance in connection with high temperature steam service and similar purposes.

The question has been asked as to how acid Bessemer steel compares with open hearth steel in this direction. From a general knowledge of the subject, one could say that there is no reason to believe that acid Bessemer steel has any inherent properties detrimental as regards resistance to creep. To provide a definite answer, a small series of tests has been carried out.

The two casts of acid Bessemer steel, Nos. 220 and 717, referred to in the section on embrittlement, have been checked by the Barr-Bardgett method,* and the "zero" creep stress at a temperature of 450° C. is respectively 2·2 and 2·0 tons per sq. in. on the coarse and fine grain steel.

After examining our records very thoroughly, it can be stated that basic open hearth steel of equivalent tensile strength would have Barr-Bardgett creep values of 2·1 and 1·9 respectively with similar grain size. It can be stated with certainty that acid Bessemer steel is at least equal to basic open hearth steel in respect of creep properties.

SUMMARY AND CONCLUSIONS.

The introductory section contains a brief historical survey of the development of the acid Bessemer process, including some notes on experiences in the authors' own works.

Statistics of production trace the rapid development of the acid Bessemer process, particularly in America and Great Britain, and show the gradual

* See Proc. Inst. Mech. Engrs., 1932.

TABLE 17.
CORROSION TESTS.
LOSS OF WEIGHT, AFTER DE-RUSTING, IN GRMS. PER UNIT AREA OF 4in×2·25in.

Identification letter.	*Method of manufacture.*	*Type of steel.*	*Period of exposure: 2 years.* As rolled (1)	As rolled (2)	Ground (1)	Ground (2)	Ground Mean.	Merit.
A	Acid Bessemer	Solid	19·3	18·6	18·2	17·6	17·9	8
G	Acid Bessemer	Solid	18·2	17·9	17·6	17·1	17·35	7
H	Acid Bessemer	Rimming	18·6	18·8	17·3	17·1	17·2	6
D	Basic open hearth	Solid	16·5	16·0	15·3	15·4	15·35	4
K	Basic open hearth	Solid	14·4	14·5	14·0	13·9	13·95	1
M	Basic open hearth	Rimming	15·0	15·3	14·1	14·0	14·05	3
P	Basic open hearth	Solid	14·1	13·8	13·9	14·0	13·95	1
L	Acid open hearth	Solid	16·7	16·8	15·7	15·3	15·5	5

For analyses—*see* Table 3.

decline (as a percentage of the total steel production), until to-day it only represents approximately 2 per cent. in Great Britain. This decline is a result of shortage of essential iron ores and of the economic situation, particularly as regards the relative availability and price of pig iron and scrap.

The acid Bessemer plant at the Workington Iron & Steel Company was rebuilt in 1934. It is described in detail, as is also the process itself, illustrated by data showing the rate of removal of carbon, manganese and silicon, and also, the authors believe for the first time, introducing values for the oxygen, hydrogen and nitrogen contents during the blow.

The properties and uses of acid Bessemer steel are dealt with at some length, attention being devoted to features on which new data are available. For example, the subject of gases is now very live and data are included respecting acid Bessemer steel.

A table is included giving an approximate guide as to the carbon content required for equivalent tensile in acid Bessemer, acid open hearth and basic open hearth steel respectively, but it is not felt necessary to deal with the orthodox tests at any length.

Some data is included concerning rails, these representing, as they do, such an important outlet at the present time for acid Bessemer steel.

Notes are included concerning machinability and weldability and considerable data given concerning reaction to cold work.

It is shown that acid Bessemer steel has a higher work-hardening factor than open hearth steel, this no doubt being of importance in regard to wear-resistance and free-cutting properties.

Strain-age-embrittlement, quench-age-embrittlement and blue-brittleness are dealt with, comparing acid Bessemer and open hearth steel.

It is shown that inherent grain size has a far greater influence on the tendency to embrittlement than has the method of steel manufacture. It is shown that Bessemer steel with coarse grain has a lower notched bar impact value on straining than open hearth steel of similar grain size, but both are reduced to a low value after straining and ageing.

The influence of nitrogen on the series of comparable laboratory-made steels confirms that with fine grain the resistance to strain-age-embrittlement is excellent up to ·018 per cent. nitrogen.

Acid Bessemer steel is well suited to quench-ageing, where advantage is taken of the increase in tensile strength resulting from this process. The embrittlement which may accompany quench-ageing is almost eliminated in both Bessemer and open hearth steel by control of the inherent grain size.

There is no significant difference in response of the two types of steel to blue brittleness.

Typical data of the case-hardening properties of Bessemer steel are given and also some comparative data on the resistance to corrosion.

Creep tests by the Barr-Bardgett method show acid Bessemer steel to have a slightly superior creep strength to equivalent open hearth steel.

It is submitted that nothing is revealed in the course of this work to support the view that acid Bessemer steel is in any way an unreliable material. It differs from open hearth steel in its degree of response to cold working, but adjustment of composition and special control of the finishing operations can be adopted to minimize the difference, where such is necessary. In other directions, this is regarded as an advantageous characteristic and full use is made of it.

It is hoped that as a result of the full description of the process, those not hitherto familiar with it will have benefited and that any who have entertained fears concerning the possibility of producing regular reliable steel by this process, will have had those fears completely dispelled.

Finally, the authors record their thanks to The United Steel Companies, Ltd. for permission to draw freely upon the data available for use in the preparation of this paper.

APPENDIX I.

PRODUCTION OF ACID BESSEMER STEEL IN THE UNITED KINGDOM, UNITED STATES, FRANCE, GERMANY AND SWEDEN.

Year.	*U.K. production (ingots only).*	*U.S.A. production (ingots and castings).*	*France production (ingots and castings).*	*Germany production (ingots only).*	*Sweden production (ingots and castings).*
	Long tons.	*Long tons.*	*Metric tons.*	*Metric tons.*	*Metric tons.*
1868	110,000	7,600			
1869	160,000	10,700			
1870	220,000	35,700			
1871	329,000	40,200			
1872	410,000	107,239			
1873	495,828	152,368			
1874	539,813	171,368			
1875	619,785	335,283			
1876	699,758	469,639			
1877	749,741	500,524			
1878	806,248	653,773			
1879	834,222	829,430			
1880	1,044,020*	1,074,262		678,953	
1881	1,440,122*	1,374,247		509,400	
1882	1,673,070*	1,514,687		687,324	
1883	1,552,843*	1,477,345		396,745	
1884	1,299,227*	1,375,531		388,876	
1885	1,303,676*	1,519,430		378,814	
1886	1,569,970*	2,269,190		341,142	
1887	2,063,689*	2,936,033		345,672	
1888	2,012,098*	2,511,161	403,350*	316,702	
1889	1,719,292	2,930,204	393,741*	324,392	
1890	1,612,730	3,688,871	431,748*	350,862	
1891	1,306,229	3,247,417	471,789*	307,357	
1892	1,202,000	4,168,435	515,640*	251,055	
1893	1,230,992	3,215,686	493,011*	280,992	
1894	1,139,611	3,571,313	489,157*	327,700	
1895	1,093,675	4,909,128	499,732*	315,600	
1896	1,357,580	3,919,906	726,463*	351,500	
1897	1,374,339	5,475,315	802,326*	391,850	
1898	1,255,252	6,609,017	883,601*	383,232	
1899	1,307,696	7,586,354	879,181*	371,620	62,949
1900	1,253,903	6,684,770	919,283*	223,063	61,385
1901	1,115,985	8,713,302	816,677*	299,816	?
1902	1,157,380	9,138,363	959,097*	341,885	53,968
1903	1,316,915	8,592,829	1,161,954*	435,327	48,352
1904	1,129,224	7,859,140	130,294	423,742	43,063
1905	1,396,233	10,941,375	132,896	424,196	46,311
1906	1,307,149	12,275,830	107,978	407,688	42,492
1907	1,280,315	11,667,549	78,771	387,120	39,634
1908	906,466	6,116,755	89,393	374,100	38.331
1909	1,111,042	9,330,783	103,238	151,148	29,026
1910	1,138,103	9,412,772	105,582	171,108	44,150
1911	887,767	7,947,854	110,923	187,359	41,116
1912	980,662	10,327,901	124,663	187,179	43,317
1913	1,048,772	9,545,706	252,704†	155,138	45,069
1914	797,072	6,220,846	74,767	100,617	32,053
1915	821,408	8,287,213	29,827	164,570	25,921
1916	914,346	11,059,039	583,323*	175,109	26,897
1917	916,348	10,479,960	638,780*	173,430	21,398
1918	754,899	9,376,236	294,637*	148,980	11,761
1919	493,000	7,271,562	48,682	51,174	16,834
1920	547,600	8,883,087	60,188	45,102	17,260
1921	183,300	4,015,938	45,094	20,371	12,272
1922	272,300	5,919,298	43,612	46,624	16,214
1923	357,800	8,484,088	70,957	6,626	14,592
1924	405,500	5,899,590	91,709	26,848	19,900
1925	447,200	6,723,962	78,903	22,448	20,098
1926	151,700	6,934,568	60,699	133	19,003
1927	445,100	6,191,727	70,559	354	15,699
1928	475,600	6,620,195	80,588	28	16,848
1929	527,600	7,122,509	98,811	—	13,471
1930	255,100	5,035,459	116,910	—	9,255
1931	113,000	3,023,446	85,964	15	5,635
1932	111,600	1,532,076	55,404	3	7,619
1933	189,400	2,428,791	48,069	—	5,939
1934	222,900	2,162,357	42,691	—	11,784
1935	199,200	2,835,031	46,218	—	20,886
1936	238,600	3,458,457	40,471	—	15,942
1937	254,600	3,449,927	47,799	—	16,390

* Includes basic Bessemer steel.

† Castings are included from 1913.

APPENDIX II.

PRODUCTION OF STEEL INGOTS AND CASTINGS BY PROCESS, 1871-1937 (GREAT BRITAIN).

Year.	*Converter ingots.*		*Open hearth ingots.*		*Electric.*		*All other steel castings.*	*Total.*	*% of acid Bessemer to total production.*
	Acid.	*Basic.*	*Acid.*	*Basic.*	*Ingots.*	*Castings.*			
	Tons.		Tons.		Tons	Tons	Tons	Tons	
1871	329,000		—		—	—	—	329,000	
1875	619,785		87,969		—	—	—	707,754	
1880	1,044,020		250,913		—	—	—	1,294,933	
1881	1,440,122		337,882		—	—	—	1,778,004	
1882	1,673,070		435,849		—	—	—	2,108,919	
1883	1,552,843		455,342		—	—	—	2,008,185	
1884	1,299,227		475,085		—	—	—	1,774,312	
1885	1,303,676		583,710		—	—	—	1,887,386	
1886	1,569,970		693,910		—	—	—	2,263,880	
1887	2,063,689		980,764		—	—	—	3,044,453	
1888	2,012,098		1,292,295		—	—	—	3,304,393	
1889	1,719,292	422,211	1,429,169		—	—	—	3,570,672	48·1
1890	1,612,730	402,133	1,564,200		—	—	—	3,579,063	45·0
1891	1,306,229	335,776	1,514,538		—	—	—	3,156,543	41·4
1892	1,202,000	298,783	1,418,830		—	—	—	2,919,613	41·2
1893	1,230,992	262,362	1,456,309		—	—	—	2,949,663	41·7
1894	1,139,611	395,753	1,575,318		—	—	—	3,110,682	36·6
1895	1,093,675	441,550	1,724,737		—	—	—	3,259,962	33·5
1896	1,357,580	457,262	2,317,555		—	—	—	4,132,397	32·8
1897	1,374,339	509,816	2,602,006		—	—	—	4,486,161	30·6
1898	1,255,252	504,134	2,806,600		—	—	—	4,565,986	27·5
1899	1,307,696	517,378	3,030,251		—	—	—	4,855,325	26·9
1900	1,253,903	491,107	3,156,050		—	—	—	4,901,060	25·6
1901	1,115,985	490,628	2,946,614	351,177	—	—	—	4,904,404	22·7
1902	1,157,380	668,399	2,676,508	406,780	—	—	—	4,909,067	23·6
1903	1,316,915	593,103	2,613,274	510,809	—	—	—	5,034,101	26·1
1904	1,129,224	652,309	2,583,282	662,064	—	—	—	5,026,879	22·5
1905	1,396,233	577,977	3,042,834	795,238	—	—	—	5,812,282	24·0
1906	1,307,149	600,189	3,378,691	1,176,245	—	—	—	6,462,274	20·2
1907	1,280,315	578,944	3,384,780	1,278,709	—	—	—	6,522,748	19·6
1908	906,466	572,073	2,578,840	1,238,263	—	—	—	5,295,642	17·1
1909	1,111,042	622,178	2,763,158	1,385,250	—	—	—	5,881,628	18·9
1910	1,138,103	641,012	3,016,830	1,578,536	—	—	—	6,374,481	17·9
1911	887,767	573,373	3,131,118	1,869,354	—	—	—	6,461,612	13·7
1912	980,662	541,825	3,365,570	1,908,087	—	—	—	6,796,144	14·4
1913	1,048,772	551,929	3,811,382	2,251,793	—	—	—	7,663,876	13·7
1914	797,072	482,444	3,680,848	2,874,749	—	—	—	7,835,113	10·2
1915	821,408	479,816	4,090,752	2,958,968	20,000	2,000	177,071	8,550,015	9·6
1916	914,346	542,119	4,355,845	2,978,885	42,734	3,975	153,825	8,991,729	10·2
1917	916,348	584,816	4,545,196	3,355,571	84,586	14,006	216,021	9,716,544	9·4
1918	754,899	550,500	3,880,949	3,986,269	78,791	46,657	241,374	9,539,439	7·9
1919	493,000	296,200	2,960,000	3,934,800	47,000	30,000	133,000	7,894,000	6·2
1920	552,500	268,400	3,302,100	4,682,000	55,200	33,900	173,200	9,067,300	6·1
1921	184,500	54,000	1,136,900	2,214,100	10,600	15,900	87,400	3,703,400	5·0
1922	272,500	196,000	1,680,400	3,624,300	21,300	18,100	68,000	5,880,600	4·6
1923	357,800	137,500	2,515,700	5,278,100	40,900	23,300	128,500	8,481,800	4·2
1924	405,800	109,700	2,358,800	5,117,500	41,800	22,700	144,900	8,201,200	4·9
1925	447,200	28,300	1,968,600	4,744,000	39,700	24,400	133,200	7,385,400	6·1
1926	152,500	—	1,027,000	2,260,400	38,800	22,000	95,400	3,596,100	4·2
1927	445,200	—	2,519,100	5,920,900	48,600	25,800	137,500	9,097,100	4·9
1928	475,900	—	2,170,500	5,660,800	49,900	28,500	134,100	8,519,700	5·6
1929	527,600	100	2,403,800	6,480,200	56,600	30,200	137,700	9,636,200	5·5
1930	255,300	—	1,761,000	5,091,100	40,400	35,600	142,300	7,325,700	3·5
1931	113,000	—	1,155,100	3,777,400	27,800	25,500	103,800	5,202,600	2·2
1932	111,600	—	1,096,700	3,905,200	32,200	23,000	92,700	5,261,400	2·1
1933	189,400	—	1,523,700	5,132,200	51,400	23,500	103,800	7,024,000	2·7
1934	222,900	—	1,708,400	6,667,100	65,600	30,800	154,900	8,849,700	2·5
1935	199,200	223,800	1,812,000	7,346,500	77,400	29,400	170,400	9,858,700	2·0
1936	238,600	323,600	2,111,800	8,760,600	108,100	44,500	197,400	11,784,600	2·0
1937	254,600	417,600	2,215,000	9,660,000	154,600	60,800	221,400	12,984,000	2·0

APPENDIX III.

PRODUCTION OF STEEL INGOTS AND CASTINGS BY PROCESS AND DISTRICT, 1937.

(In thousands of tons).

District.	*Open hearth.* *Ingots.*	*Open hearth.* *Castings.*	*Open hearth.* *Ingots.*	*Open hearth.* *Castings.*	*Bessemer ingots.*	*All other ingots and castings.*	*Total.*	*Total castings (included in previous column).*
1. Derby, Leicester, Notts and Northants. 2. Lancs. (other than 10), Denbigh, Flint and Cheshire. 3. Yorkshire (other than 5 and 9).	69·9	10·2	973·5	0·5	Basic 417·6	39·0	1,510·7	49·7
4. Lincolnshire.	—	—	1,288·5	—	—	10·7	1,299·2	10·7
5. North-East Coast.	206·7	9·3	2,576·5	0·4	—	31·9	2,824·8	41·6
6. Scotland.	440·1	26·2	1,391·3	0·8	—	36·7	1,895·1	62·3
7. Staffs., Shrops., Worcester and Warwick.	15·2	—	659·0	8·5	—	19·2	701·9	27·7
8. South Wales and Mon.	819·0	3·0	1,798·6	1·5	—	6·7	2,628·8	8·3
9. Sheffield.	588·4	7·0	927·4	1·3	—	214·6	1,738·7	72·6
10. North-West Coast.	75·7	5·6	45·2	—	Acid 254·6	3·7	384·8	9·3
Total 1937 ...	2,215·0	61·3	9,660·0	13·0	672·2	362·5	12,984·0	282·2
„ 1936 ...	2,111·8	47·4	8,760·6	11·7	562·2	290·9	11,784·6	241·9
„ 1929 ...	2,403·8	46·8	6,480·2	8·0	527·7	169·7	9,636·2	166·9

Appendix IV.

ESTIMATED WORLD OUTPUT OF STEEL IN 1938 COMPARED WITH 1936 AND 1937.

(In 1,000 tons of 2,240lb.).

Countries.	Steel ingots and castings.		
	1936 (Estimated).	1937	1938 (Estimated).
EUROPEAN.			
Great Britain	11,785	12,984	10,570
Germany ...	18,910	19,535	22,700
Austria ...	412	639	
France ...	6,602	7,795	5,991
Belgium ...	3,123	3,808	2,220
Luxemburg ...	1,950	2,471	1,428
Czecho-Slovakia ...	1,514	2,281	1,700
Iceland ...	1,123	1,430	1,450
U.S.S.R. ...	16,080	17,543	18,100
Italy ...	1,920	2,054	2,300
Sweden ...	962	1,088	950
Spain ...	464	170	280*
OTHER COUNTRIES.			
United States	47,768	50,569	28,100
Canada ...	1,078	1,352	1,150
Australia ...	750	900	940
British India	866	895	956
South Africa	298	322	345
Japan, including Korea and Manchukuo	5,283	5,720	5,280*
World total, including other countries ...	122,100	133,280	107,000

*Very doubtful.

Appendix V.

AVERAGE PRICES OF HEMATITE PIG IRON AND HEAVY STEEL SCRAP.

(Extracted from the "Iron & Coal Trades Review").

Year.	Hematite pig iron.						Heavy steel scrap.		
	*W. Coast mixed Nos. at Sheffield.			†E. Coast mixed Nos. at Middlesbrough.			North of England.		
	£	s.	d.	£	s.	d.	£	s.	d.
1908	2	19	7¼‡	2	17	3	2	12	0
1909	2	18	1¼‡	2	17	2	2	12	3½
1910	3	5	4¼‡	3	4	2	2	16	3½
1911	3	3	1‡	3	2	9	2	14	3¾
1912	3	15	9¼	No quotation			2	13	9½
1913	3	18	4½	"			2	14	5
1914	3	6	10¼	"			2	7	10¾
1915	5	13	3	5	6	11½	3	8	1¼
1916	6	9	2½	6	8	1½	4	16	5¾
1917	6	7	6	6	2	6	5	5	0
1918	6	7	6	6	2	6	5	5	0
1919	8	14	7	8	11	4	5 6	5 15	0 0
1920	14	4	11½	12	11	8	6 8	10 0	0 0
1921	8	7	9½	8	2	2	3	3	7
1922	5	12	2	4	14	5½	3	5	6
1923	5	19	5½	5	7	10¾	4	3	9
1924	5	10	3¼	4	15	2½	4	0	0
1925	4	14	3¼	3	19	5¼	3	2	8
1926	4	11	0	4	1	7½	3	2	10
1927	4	13	1½	3	19	2½	2	17	8
1928	4	4	4	3	9	9¼	2	15	11
1929	4	6	11	3	14	11¼	3	4	0
1930	4	8	6¼	3	13	3¾	2	12	9
1931	4	3	7	3	5	6	2	0	8
1932	4	3	6	3	1	10	1	15	10
1933	4	3	6	2	19	9	2	3	5
1934	4	3	6	3	7	2	2	10	4½
1935	4	4	8½	3	9	11½	2	12	5
1936	4	6	7½	4	0	7¼	2	18	5½
1937	6	0	2	5	14	2	3	7	4

*Subject to rebate of 5s. per ton since July, 1936.

†F.o.t. furnaces prior to 1933; delivered Middlesbrough subsequently.

‡F.o.b. Cumberland Ports.

Discussion.

Mr. W. Dennis Heck, B.Sc. (Member of Council), opening the discussion, thanked the authors for extending the scope of the paper beyond that implied in the title. Not only had they described the acid Bessemer process of steel-making, but they had dwelt at length with the product.

The authors had probably asked themselves why marine engineers should take a special interest in acid Bessemer steel—sufficient interest to invite this paper. The reason was that marine engineers had observed that acid Bessemer steel was creeping into many British Standard Specifications. The authors had alluded to that. Marine engineers had hitherto adopted an unfavourable attitude towards Bessemer steel in general, *i.e.* both the acid and the basic processes. Apparently the authors' endeavour was to convince marine engineers that whatever the basic process might give, the acid process gave something entirely different and provided a thoroughly reliable material.

Reliability was of paramount importance in marine work. On shore, if anything went wrong with a plant, everyone could go home until the millwrights put it right. At sea the circumstances were quite different since, while repairs were in progress, the vessel might be subjected to the risk of falling into the trough of the seas or being blown on to a lee shore.

The paper had indicated the difference between acid and basic Bessemer steel, and had shown that in the acid process better materials were employed. The authors' Company had at their disposal a very pure ore, and advantage was taken of that when employing the acid process. In passing one might comment, however, that they must use some scrap, and it had not been shown that the scrap used was of better quality than that employed in other processes. The other great advantage claimed for the acid process over the basic process was the absence of the dangerous after-blow, which was necessary in the basic process to remove phosphorus. While speaking of the blow, he would comment on the very interesting colour film with which the authors had supplemented the lecture. The speaker had been a little disappointed that the film did not include the crucial, 18th, 19th—or was it 20th minute?—that very short space of time when the blower had to decide whether to go on or stop.

Summarizing, it appeared the case for the acid process was that it employed a superior raw material and there was no after-blow. The paper supplied, in addition, the results of many tests, and so far as the engineer could judge these results did not favour one class of material or the other, *i.e.* acid Bessemer or open hearth steel, although the majority of comparisons were drawn between the acid Bessemer and the basic open hearth processes, whereas for boiler materials the marine engineer appeared to favour acid open hearth.

The authors, in putting the facts embodied in the paper before them, suggested that they should have complete confidence in this material. Reviewing the merits of the case, it could be said of the process that it was just as rapid, or slightly more rapid, than the basic process and it still possessed the fundamental feature that it was judged by the eye—"the human element" was the phrase used when talking of things of this nature. In considering the results of the laboratory tests, it was necessary to note that these were not always confirmed in practice. There had been cases where, inadvertently he supposed, Bessemer steel, presumably tested in the normal way, had found its way into the shipyard and had failed in service. The authors had invited precise details of these cases, but the speaker was bound to explain that in such cases a number of parties were involved and he did not feel at liberty to give full details.

There was another point. In Appendix I figures were given for the production of acid Bessemer steel, and it would be noted that on the average, over a number of years, production in the United States was roughly 12 to 14 times that of this country. One might reason therefore that if any progress should be made in the application of acid Bessemer steel to shipping and marine engineering, it should occur in the United States. The leading classification society in that country, however, did not accept this material for ships, boilers or steam pipes.

He did not wish the authors to think that marine engineers were entirely conservative. They all knew that acid Bessemer steel could be used on ships, in the form of cast steel anchor heads. In a recent case Bessemer steel, basic he thought, had been worked into the welded bedplate of an oil engine made by one of the leading firms. Again, every engineer recognised that a great deal of Bessemer steel, acid or basic, was usefully employed, particularly for rails. Any engineer who, standing on a platform waiting for a train, had seen a heavy goods train passing over an imperfect joint in the line and had noticed the repeated flexing, would remark that the material must be good to stand that.

One wished to be entirely fair, so that while mention should be made of the recent failure of the Hasselt Bridge, which was made of Bessemer steel, the failure of the Quebec Bridge in 1907, which was made of open hearth steel, would also be recalled. In regard to routine testing, all engineers were aware that open hearth steel was tested in a very simple and economic manner. The speaker wondered if a similar system were applied to acid Bessemer steel whether the same good results would be obtained as in the case of open hearth material. It did appear to him that some test was required in the case of any Bessemer steel to indicate the presence of oxidised or over blown material, and so far it seemed that a simple test of this nature had not been devised. A laboratory test was necessary, and this was not suitable for routine commercial testing.

He would suggest to the authors a method whereby they could convince the marine engineer of the reliability of acid Bessemer steel. The authors should put themselves in the position of the marine engineer and assume the responsibilities which many of the Members of The Institute had to bear. Having such faith in their material, let the authors build a boiler and a set of steam pipes of acid Bessemer steel, install them in their own works and run them under normal conditions. If after five or six years service the boiler was in safe, sound and satisfactory condition, then they would have gone some distance in convincing the marine engineer. Of course, the first difficulty encountered would be that no insurance company would insure the plant. If an accident occurred there would be an inquiry, and the authors would be called upon to show that they had taken every reasonable precaution to secure the safety of human life and property.

Mr. C. P. Sandberg, C.B.E. (Visitor) said that as a consulting engineer for railways he had had the opportunity over a very long period of years, and his father before him in the same firm, of intimately knowing the steel works of this country, the Continent and America. The last speaker referred to the reduction in the use of acid Bessemer steel in America. Dr. Swinden had not given the true explanation why there was this enormous reduction. There was acid Bessemer steel and acid Bessemer steel. In America their native ores used for acid Bessemer resulted in the steel containing 0·1 per cent. of phosphorus, which with segregation resulted sometimes in the content being as high as 0·12 per cent., and the effect on the railways of broken rails was so serious that as soon as there was the possibility of applying commercially the basic open hearth process this was adopted.

There seemed to be some confusion in referring to Bessemer steel. This title should be reserved for acid Bessemer steel, while basic Bessemer should be known, as it was on the Continent, as Thomas steel.

The production of acid Bessemer steel had been reduced largely because of the lack of pure ores, and he did not think the authors had "blown the trumpet" they were entitled to by reason of the fact that at Workington they possessed one of the very few sources of pure Hæmatite ore, by means of which they were able to make a very high quality steel.

On the proposal of **Mr. T. A. Bennett, B.Sc.** (Member of Council) a very hearty vote of thanks was accorded to the authors.

The Authors' Reply to the Discussion.

Dr. Swinden, replying on behalf of his co-author and himself, stated that he naturally had had in mind the fact, to which Mr. Heck pointedly called attention, that Bessemer steel, acid or basic, was not viewed with favour by the marine engineer. Mr. Heck had rather put words into the authors' mouths in comparing acid and basic Bessemer steel. He (Dr. Swinden) had stated definitely that they were not attempting to compare the two. The paper was simply a description of the process and they had taken readers of the paper fully into their confidence by including laboratory tests and tests of a type which were not normally asked for by engineers, with the object of disclosing the properties of the material and comparing it with open hearth steel. It was compared in certain characteristics with acid and basic open hearth steel in cases where both these qualities were normally used. He would prefer not to be drawn into a discussion of the merits of acid and basic Bessemer steel. He would much rather the paper be taken on its merits and the material judged on its merits.

Mr. Heck suggested that one way to convince the marine engineer would be to build a boiler, but he admitted that there were practical difficulties in doing that. He (Dr. Swinden) would rather suggest that as engineers they should find it possible to devise some test which would indicate whether this material was satisfactory or not. It would be foolish to press for the use of a material in which one had not confidence, and he was fully alive to the importance of complete reliability in the case of the shipbuilding industry. He would stress that the data given was intended to serve in a much more thorough way than the usual tensile and bend tests in comparing these respective processes.

Mr. Heck had referred to the speed of production—the speed with which iron was converted into steel—compared with the lengthier time of the open hearth process. It was obviously not the authors' business to deprecate open hearth steel as they made far more of it than Bessemer. Speed, however, did not mean inferior quality. Mr. Heck raised the old criticism that the end point was judged by eye. He (Dr. Swinden) sometimes felt that if they had a lot of instruments and produced a lot of figures, it would seem more convincing. The blow could in fact be judged with extreme accuracy. Without wishing to deprecate open hearth steel, a good deal still depended on the melter in that process. He could only leave it that the tests put forward were honest tests, they were representative tests and they did not attempt to get below the surface of the question.

He hesitated to comment on the reference to the failure of the Hasselt Bridge, of which he had some samples under investigation in his laboratory. It would be accepting the challenge to discuss the relative merits of the acid and basic Bessemer processes were he to comment on this; but it was unwise to assume that this failure had anything whatever to do with acid Bessemer steel.

He was obliged to Mr. Sandberg for his explanation of the position in America and of the well-known fact that large quantities of rails were made very satisfactorily by this process.

Mr. Heck referred to the use of scrap. There was a comparatively small proportion used in the acid Bessemer process and it was its own virgin scrap. The question as to how far steel deteriorated by repeated melting was one on which some people held strong views and which certainly merited further investigation.

In conclusion he would again urge that acid Bessemer steel should be considered on its merits and that, in view of its proved reliability for so many purposes, its acceptance should be reconsidered at least for certain purposes in shipbuilding.

In a supplementary written reply, the authors emphasized the paragraph at the top of page 111, reading :—

> "It is specially urged that the data be considered without prejudice and that members having knowledge of cases of unsuitability of acid Bessemer steel based on real fact give the authors an opportunity of considering these in the discussion".

While the difficulties explained by Mr. Heck in the way of disclosing full details of service failures were realised, it was very disappointing, from the authors' point of view, that they were still without authentic details of such failures to which a reasoned reply might be given. As already explained there was a difficulty in accepting Mr. Heck's suggestion of building and installing a boiler, but it would have been useful had Mr. Heck indicated in what way he considered that such a boiler would fail. If this were stated, then surely laboratory tests could be undertaken to compare acid Bessemer steel with the steel normally accepted for such purposes, in the hope of either confirming or dismissing the fears which presumably prompted this suggestion. In point of actual fact; the Workington Company, at whose works the acid Bessemer steel was made, did not possess plate mills and therefore, from a commercial angle, the acceptance or otherwise of acid Bessemer steel for boiler plates was not at issue. The United Steel Companies, Ltd. had ample facilities for supplying both boiler and ship plates in open hearth steel from their Appleby-Frodingham plant.

It was, however, the broader issue which one would like to have cleared up, namely, why the marine engineer and shipbuilder still viewed with apprehension the use of acid Bessemer steel in connection with marine engineering and shipbuilding.

ELECTION OF MEMBERS.

List of those elected at Council Meeting held on Monday, 27th March, 1939.

Members.

Robert Loudon Aitken, 16, Rafford Way, Bromley, Kent.

Geoffrey Edward Justice Benn, 13, Stratford Place, W.1.

Joseph Emmerson Black, 2051, Great Western Road, Glasgow, W.3.

Edward Blechynden, 295, Grey Street, Hamilton, N.Z.

George Chalmers, 256, 10th Street, North Vancouver, B.C.

Wilfrid Coates, Craig-Lea, Timothy Lane, Batley, Yorks.

Alverdo Arie Corwin, Com'r., U.S.N., 97, Inwood Road, Bridgeport, Conn., U.S.A.

Thomas Arkle Crowe, Highlaws, Bearsden, Dumbartonshire.

Alexander Elliott Davidson, Major-General, 11, The Pryors, Hampstead, N.W.3.

John Dick, 9, Ventry Street, Belfast.

Thomas Martin Gilray, 32, Groathill Avenue, Blackhall, Edinburgh.

William John Stevenson Glass, P.O. Box 35, Port Tewfik, Egypt.

Ernest George Gummer, 105, Upney Lane, New Barking, Essex.

Frederick Edward Hall, 30, Lenmore Avenue, Grays, Essex.

William Henry Macfarlane, 11, The Terrace, Grosvenor Street, St. Helier, Jersey, C.I.

George Alexander McGregor, c/o New Zealand Shipping Co., Ltd., 138, Leadenhall Street, E.C.3.

Edward Duncan MacPherson Nimmo, 4, Widecombe Court, Lyttelton Road, N.2.

Archibald Orr, China Nav. Co., Shanghai, China.

Charles Samuel Arthur Pring, 10, Empress Avenue, Ilford, Essex.

John Quayle, 68, North Park Avenue, Roundhay, Leeds, 8.

Percy Scorer, 37, Green Lane, Purley, Surrey.

Alfred Edgar Spurrier, 432, Winchester Road, Bassett, Southampton.

Garret Wellesley Walker, Ard-na-Greine, Ardeevin Road, Dalkey, Co. Dublin.

John Somers Walter, 35, St. Andrews Road, Cranbrook Park, Ilford, Essex.

John Warren, Martindale, New Forest Lane, Chigwell, Essex.

Associates.

Marcel Bollengier, 70, Rue Emile Lemaitre, Boulogne-sur-Mer, France.

James Bowman, Mountview Cottage, Methil, Fife.

Richard Henry Brown, 34, Stanley Street West, North Shields.

Triloki Nath Kochhar, 20, St. David's Road, Southsea, Hants.

George Victor Lawson, 12, Wellesley Road, Grove Hill, Middlesbrough.

Aubrey Frazier Mills, 7, Rookfield Close, N.10.

Rees Whitney Price, 11, Redbrook Road, Newport, Mon.

Transfer from Associate to Member.

James Smith, Dockyard Supt., Irrawaddy Flotilla Co., Ltd., Mandalay West, Burma.

Transfer from Student to Associate Member.

Edward Clark Cowper, 44, Harton Lane, South Shields.

ADDITIONS TO THE LIBRARY.

Purchased.

The Use of Derrick Cranes. (Home Office Safety Pamphlet, No. 15). H.M. Stationery Office, 6d. net.

Notes on the Grants to Research Workers and Students. H.M. Stationery Office, 2d. net.

Symposium on Propellers. North-East Coast Institution of Engineers and Shipbuilders, 21s. net.

Universities Yearbook, 1939. G. Bell & Sons, 15s. net.

The "Shipping World" Year Book, 1939. The Shipping World, Ltd., 25s. net post free.

Presented by the Publisher.

Handbook for Constructional Engineers. Dorman, Long & Co., Ltd.

Special Steels and Their Application to Engineering and Shipbuilding. (Reprint of a paper by Dr. T. Swinden).

Some Notes on the Melting and Pouring of White Metals. The Eyre Smelting Co., Ltd.

White Anti-friction Metals. The Eyre Smelting Co., Ltd.

Hugo Hammar, 1864-1939. Issued by the Maritime Museum at Gothenburg as a Memorial Volume to commemorate the 75th birthday of Dr. Hugo Hammar.

Report of the National Physical Laboratory for 1938. H.M. Stationery Office, 2s. 6d. net.

The Nomogram. By H. J. Allcock, B.Sc. and J. R. Jones, M.A., F.G.S. Sir Isaac Pitman & Sons, Ltd., 224 pp., 77 illus., 10s. 6d. net.

This is a new and revised edition of a standard work on alignment charts. Most of the book is unchanged, but some important additions have been made.

A new worked example (xix A) is included for grid nomograms of the first class. This deals with a more complex case, and is a valuable addition, as it was difficult to see the application of the method from the existing very simple example. The addition of the method for transforming nomograms with set-square index materially increases the usefulness of the book for those types of problem in which it is impossible to make a double alignment chart for the same limiting values of the variables. It would have been an improvement here if a clearer indication had been given of when these cases occur, as the set-square index is on the whole an unhandy form to use compared with double-alignment. The new section on the unusual circular nomogram is interesting, but it is a pity that both the examples given consist of circular functions only, and no indication is given as to when and how the form is of use in dealing with equations which involve, but do not consist entirely of, circular functions. The addition to the appendix of the method of multiplying determinants saves some searching through the book.

The new edition is certainly a most useful and handy book, slightly improving what was already one of the best available references to a useful subject with scanty literature. There appears to be practically no published information on the construction of charts from empirical data which are not immediately reducible to simple equation form. In another edition, the authors might consider adding a short section to give guidance on this class of problem.

Practical Hints on Commercial Refrigeration. By J. H. Robinson. Technical Press, Ltd., 64 pp., 3s. 6d. net.

The author, in this little book written mainly for salesmen, has endeavoured to describe the basic principles of automatic refrigeration and their application in non-technical language. Consequently, the book will be useful to the young salesman looking for further applications and outlets for his products. This applies particularly to dealer salesmen, who far too frequently are sent on the road with but a hazy idea of their product.

Beginning with an elementary description of heat, the book goes on to describe the refrigeration cycle, the various accessories employed and some definitions. The definition of the American Ton of Refrigeration on page 13 appears to be a little involved.

The method of assessing the plant capacity required for a butcher's cold room described on pages 32-35 is quite clear and should be of value to the executive responsible for the purchase of these plants. Various applications are briefly described and the part dealing with dairy refrigeration should be of interest to all persons engaged in this type of work in view of the gradual tightening of regulations controlling the sale of milk. But the reviewer is of the opinion that an important subject like air conditioning is worth more than three brief paragraphs as given in pages 58 and 59. To discuss this subject effectively one must have a little knowledge of humidity and its control. This book, consisting mainly of superficial descriptions, is not likely to be of great interest to engineering students.

Advanced Mathematics for Engineers. By Professors H. W. Reddick and F. H. Miller. New York: John Wiley and Sons, Inc. London: Chapman and Hall, Ltd., 473 pp., 130 illus., 20s. net.

It would be difficult to improve on the title of this book, having regard to the needs of engineers, since the work as a whole contains a mass of useful information that is not frequently given in courses on applied mathematics. The text covers the usual treatment of ordinary and partial differential equations, and there are equally good chapters on vectors, series, and elliptic functions. Thus, the requirements of average courses on the subject are fulfilled.

Many advanced students in all branches of mechanical science and in naval architecture will attach a special value to Chapter X, devoted as it is to functions of a complex variable, a knowledge of which can scarcely be dispensed with in investigations into the flow of fluids, heat, and electricity. There is, for electrical engineers in particular, an instructive chapter on Heaviside's operational calculus, and attention may be drawn in this direction to the section on Bromwich's line integrals, as being a noteworthy addition to Heaviside's method.

It will be gathered from these remarks that the authors have prepared a course of study that can be utilized in several fields of engineering activity. The fact may be further illustrated by reference to the chapter on gamma and Bessel functions, certain parts of which enter in the solution of questions connected with vibrations, and with aerodynamical interference, to mention but two important applications.

A high standard of workmanship is maintained throughout the eleven chapters, and the exercises with answers greatly enhance the value of the discussion on the related theory, which is explained in a manner that makes for easy reading.

Heat Engines. By A. C. Walshaw, M.Sc. D.I.C., A.C.G.I. Longmans, Green & Co., 413 pp., 251 illus., 7s. 6d. net.

The author has very ably produced a book which more than gives an introduction to the subject of heat engines and applied thermodynamics. The scope of the work covers the Ordinary National Certificate and Part I of the Final B.Sc. Examination.

The contents are arranged to give an early introduction to the functions and essentials of heat engines. The numerous illustrations and photographs of engines and engine gear tend to put a practical aspect on the volume and to create an early conception of the connection between heat energy and its various practical applications. The first part of the book finishes with a very useful chapter on engine testing with an appropriate number of exercises on engine trials. Part II of the book, which occupies a little more than the middle third of the work, is entirely devoted to steam and steam engine plant. Much of this is the sound information on steam which is to be found in any standard work on heat engines. Part III is devoted to thermodynamics and internal-combustion engines and includes a number of reports of engine trials.

A feature of this book is the representing of plant diagrammatically by means of line diagrams together with energy stream diagrams, report sheets with graphical representation of results and conclusions. There is a supplementary chapter at the end on entropy, the applications being mainly steam problems. The volume concludes with a copy of abridged Callendar steam tables in the foot pound centigrade units.

The author has produced a book suitable for the purpose for which it is intended, and has presented it in such a manner that an early interest in the subject is created, an interest which should be maintained throughout the volume.

The Modern Diesel. Iliffe & Sons Ltd., 5th edn., 248 pp., 169 illus., 3s. 6d. net, postage 3d.

This handbook, which deals with the high-speed compression-ignition oil engine in its applications to road and rail transport, aircraft and marine work, has now passed through four editions. This the fifth edition has been brought up to date to cover the not inconsiderable progress made in the short period which has elapsed since the book first appeared. The advance in power efficiency, and working economy of Diesel power units and their auxiliary equipment are dealt with. New fuel pumps and new American and Continental engines are described, and the Kadenacy principle of operation is illustrated and explained in detail. The chapter headings give some idea of the scope of the work, viz.:—The term "Diesel", a general survey, the compression-ignition cycle, fuel injection systems, cylinder head design, heavy-oil fuel, road transport, transport engines, high-speed Diesels in service, Diesels and railway service, aircraft engines, marine service, marine engines reviewed. The book also contains tables showing principal characteristics of c.i. engines for road transport, aircraft and marine work, and a detailed index. The chapters devoted entirely to marine engines occupy 30 pages.

JUNIOR SECTION.

Electricity Applied to Marine Engineering (Section 3).

By W. LAWS, M.Sc., A.M.I.E.E.

The Generation of Electromotive Force.

Whenever a conductor of electricity moves across a magnetic field so that it can be visualized as cutting through the lines of force, an electromotive force or voltage is induced in the conductor. The same thing happens if the conductor remains stationary and the field moves so that the lines of force cut across the conductor. The size of the voltage induced depends upon *the rate of relative movement* of the conductor and the field, and can be expressed thus:—

$$\text{Volts induced per conductor} = \frac{\text{lines cut per second}}{100{,}000{,}000} = \frac{\text{lines cut per second}}{10^8}$$

The mutual directions of motion, field and voltage (or current if the conductor forms part of a closed circuit) are given by Fleming's Right Hand Rule, which states that if the thumb and first two fingers of the *right hand* are held mutually at right angles, then if the thumb points in the direction of the relative motion of the conductor. and the first finger in the direction of the magnetic field, then the second finger gives the direction of the voltage or current. It is worth emphasizing here that the thumb points in the direction of relative motion of the conductor, because in certain types of electrical apparatus the conductor remains stationary and the field moves, so that the relative motion of the conductor is in the opposite direction to the actual motion of the field. One of the simplest practical applications of this principle is obtained from the rotation of a rectangular coil having its ends connected to two rings, called slip-rings, in the uniform field between two magnet poles of unlike polarity. The slip-rings can be connected to an external circuit by carbon brushes resting on them. Consider an arrangement such as that sketched in perspective in Fig. 24 and diagrammatically in Fig. 25 and suppose the coil *ABCD* is being rotated at constant speed about the axis *OO′*. At the instant shown in Fig. 25(a) the two sides of the coil *AB* and *CD* are momentarily moving in the same direction as the direction of the field.

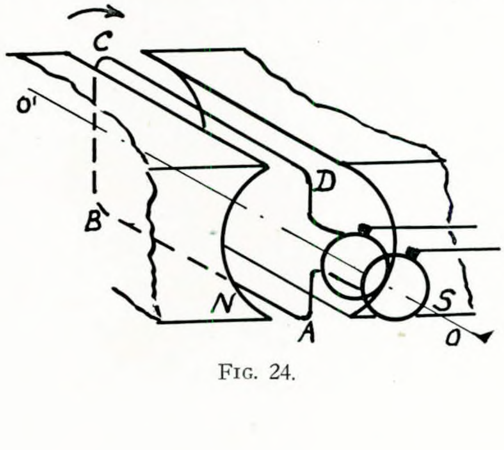


FIG. 24.

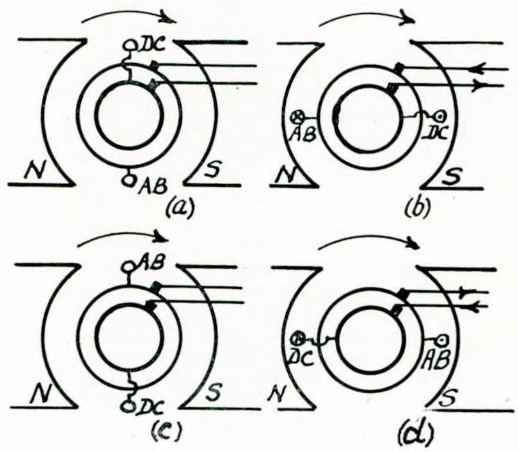


FIG. 25.

There is therefore no cutting of lines of force and no voltage induced. When, however, the coil has turned through a quarter of a revolution, Fig. 25(b), both *AB* and *CD* are cutting across the field at the maximum possible rate and the maximum voltage will be induced in the coil which, by an application of the Right Hand Rule is found to be in the direction indicated. When the coil has turned through another quarter revolution to position Fig. 25(c) there is again no voltage induced because once again the momentary direction of movement of the conductors is the same as the direction of the field and there is no cutting of lines of force. When the conductors get round to position Fig. 25(d), maximum voltage is again induced but this time in the opposite direction to what it was before both in the coil itself and also in the external circuit. If the voltage were plotted against a time or a pole pitch base, having first decided quite arbitrarily that a voltage in one direction through the coil should be called positive, and in the opposite direction, negative, a graph of the form shown in Fig. 26 would be obtained. Such a voltage (or current) is called alternating because it keeps on reversing its direction at regular and equal intervals of

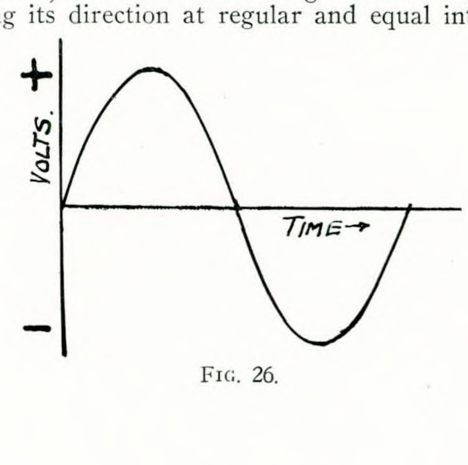


FIG. 26.

time. If the coil is connected to an external circuit by means of "brushes" lying on the slip-rings, then a current will flow in the coil and in the external circuit which will also be alternating. One complete alternation of the current as shown in Fig. 26 is called a period or cycle, and the number of complete cycles per second is called the frequency. It should be especially noted that the production of one complete wave does not depend on the fact—except in this special instance—that the coil has made one complete revolution, but on the fact that each of the coil sides has moved across two poles. If a generator has more than two poles, then in each revolution there will be as many cycles as there are pairs of poles, so that:—

$$\text{Frequency in cycles per second} = \frac{\text{pole pairs} \times \text{r.p.m.}}{60}$$

Although electricity supply on shore has been standardized with alternating current, there are not as yet many ships which have alternating current supply, so that, for the present, we are concerned mainly with direct current, *i.e.* current which flows continuously in

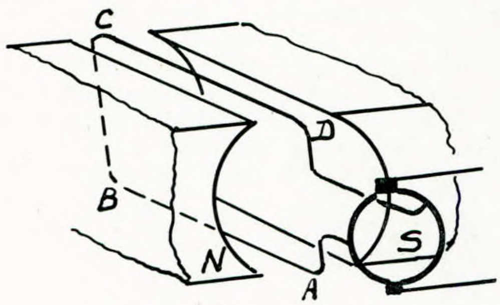


Fig. 27.

the same direction through a conductor. It is therefore now necessary to consider how the alternating current in the coil can be converted into direct current in the external circuit. This is accomplished by a device called a commutator which, in its simplest form, is shown in Fig. 27. In this elementary form it consists of a ring split on a diameter, the two halves being insulated from each other, and being connected to the two ends of the coil.

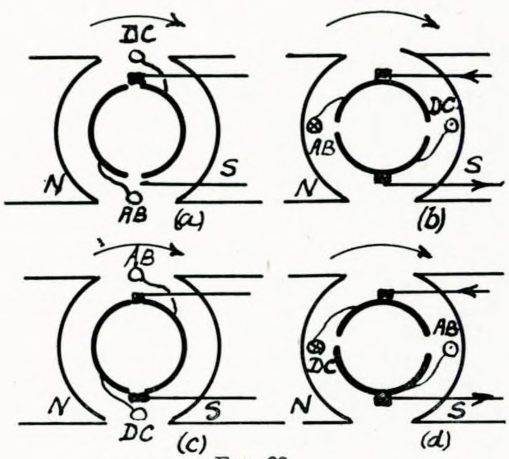


Fig. 28.

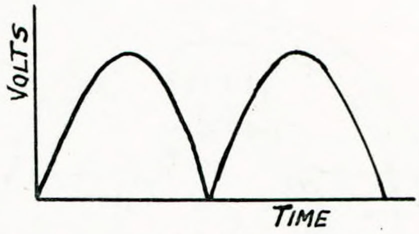


Fig. 29.

If Fig. 28 is examined, it will be observed that as between positions (b) and (d) whereas the current in the coil itself has been reversed, it is still in the same direction in the external circuit. If the current in the external circuit were plotted against a time base a graph in the form shown in Fig. 29 would be obtained. This shows that the current is unidirectional, but pulsating. In an actual generator, in order to approximate to a steady unidirectional current such as would be obtained from a battery, many coils would be used and many commutator segments. Fig. 30 shows diagrammatically how this is accomplished although the type of armature illustrated is now obsolete. "Comm." is the commutator made up of many copper segments insulated from each

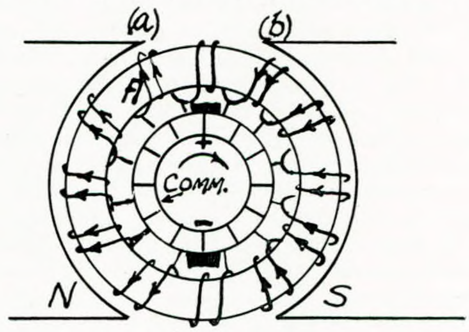


Fig. 30.

other by pure mica. There is a steady flow of current up each side of the armature, the current joining and leaving the armature at the positive brush for the external circuit, from which the current re-enters at the negative brush at which it divides to flow through the armature. In short, there are two circuits in parallel in the armature. If there were more than two poles, then there would be as many circuits in parallel as there were poles with this particular type of armature winding.

Essential Parts of a D.C. Generator.

As we have already seen, an E.M.F. is induced in a conductor when it moves across a magnetic field. The essential parts of a d.c. generator are therefore a magnetic field, a system of connected conductors which can be moved across that field, a means of converting the alternating current which will be induced in those conductors into direct current in the external circuit, a means of conveying the current from the rotating armature to the stationary external circuit, and of course a bedplate for the generator and bearings for the armature.

The Magnetic Circuit. The magnetic circuit or "field" consists of a cast steel yoke to which are fixed a

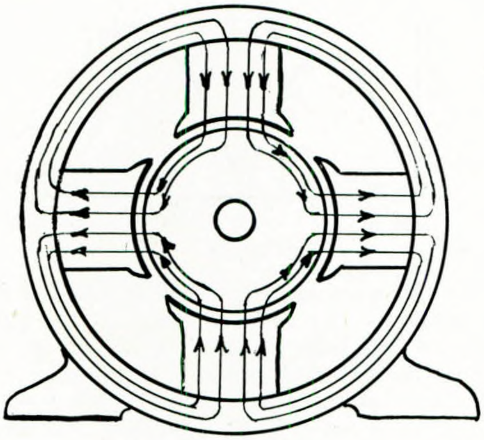


Fig. 31.

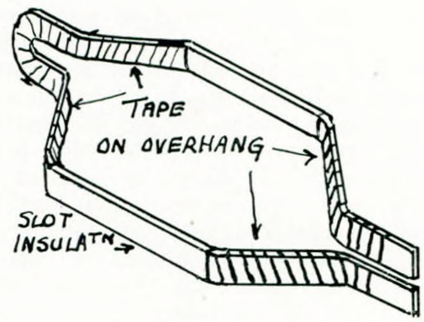
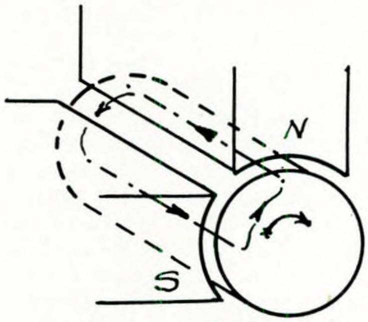


Fig. 33.

number of poles, always an even number. On the majority of machines of any size the poles are laminated, that is built up of very many thin sheets of core-plate steel. This is done in order to limit eddy currents. The poles are excited by current flowing in field coils fitted over the poles. The source of this field current will be dealt with under methods of excitation. The magnetic circuit is completed across the air gap left for mechanical clearance and through the armature core which is also laminated. The general direction of the magnetic path for a four-pole machine is shown in Fig. 31, the direction of the lines of force being indicated by arrow heads.

The Armature. The armature core is built up of laminations of about 0·02in. thickness, insulated from each other either by thin sheets of paper of the nature of tissue paper or by some sort of insulating varnish. The necessity for this will be realised from Fig. 32. If the armature core were solid, then because steel is a conductor, even if not such a good conductor as copper, currents would be induced in it which would flow the whole length of the core under one pole and return through the part of the core lying under the next pole. These currents while serving no useful purpose whatever would produce considerable heat losses which would not only impair the efficiency of the machine, but might also seriously damage the insulation of the armature coils. The effect of laminating the core is materially to increase the length of the path along which such currents must flow and so increase the resistance of the path relative to the voltage induced in the core by its movement past the poles. Such currents are called eddy currents. The outer periphery of the armature core is slotted to receive the armature coils and hold them securely. The coils are held down in the slots against the action of centrifugal force by fibre or hard wood wedges, the parts of the coil which project beyond the ends of the core being held down by bands of steel wire of high tensile strength put on under tension over strips of presspahn (a fibrous insulating material not unlike cardboard to look at) or micanite. The armature coils are usually formed to the correct shape, and insulated, away from the machine. They are generally of "diamond" shape as illustrated in Fig. 33.



PATH OF EDDY CURRENT SHOWN CHAIN DOTTED.

Fig. 32.

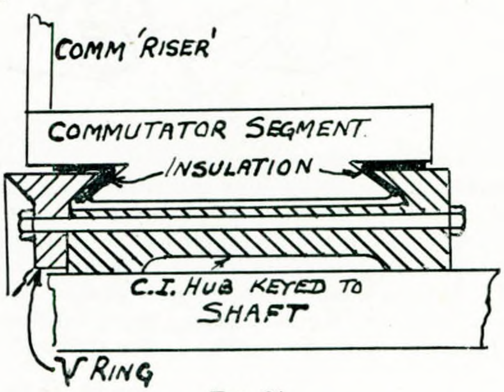


Fig. 34.

The commutator is built up of as many copper bars as there are armature coils (not necessarily slots, because one slot may hold several coil sides). Sometimes the armature has dummy coils, but that is an exceptional condition into which we need not enter here. The commutator segments are approximately of the shape shown and are insulated from each other by sheets of pure mica, and from the V rings between which they are clamped by moulded micanite. The construction is illustrated roughly in Fig. 34. The armature coils can be connected to the commutator in many ways but only the simplest forms of the two main types of winding will be considered here. They may either be connected as shown in Fig. 35 which is called a lap winding, or as in Fig. 36 which is known as a wave winding. The principal differences between them from the point of

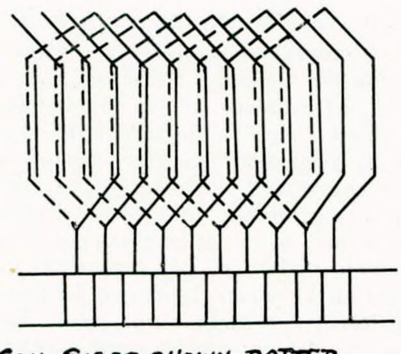


FIG. 35.

view of the working of the machine are as follows :—

A lap winding has as many circuits in parallel as there are poles; has as many brush arms as there are poles; and is usually employed on a low voltage heavy current machine.

A wave winding has only two circuits in parallel, however many poles there are, need have only two brush arms but may have more, and is usually employed on a higher voltage lighter current machine. The majority of 4-pole d.c. generators are wave wound and have four brush arms. Having the additional brush arms beyond the bare two which are necessary reduces the current density in the brushes.

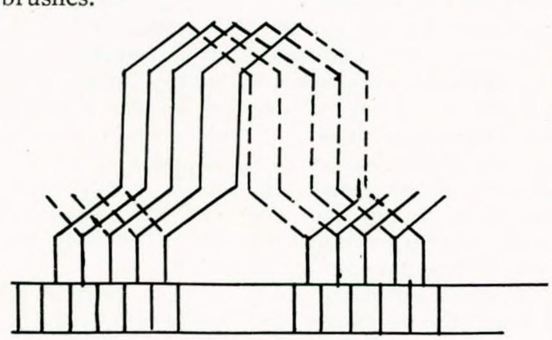


FIG. 36.

Brush Gear. The current is collected from the commutator by means of carbon brushes, that is, rectangular blocks of carbon or copper carbon held in suitable boxes mounted on axial spindles which are fixed to a brush rocker. On many machines the brush rocker can be moved round so that the brushes can be shifted circumferentially. The brushes are held down on the commutator by a spring pulling on a lever the end of which rests on the top of the brush. The tension of the spring can usually be adjusted to suit the grade or hardness of the brush. An average figure is about 2lb. per sq. inch. The bedplate and bearings require no special description. The lubrication is generally derived from oil rings dipping in a reservoir of oil in the pedestals. The armature core plates, if not keyed directly to the shaft, are mounted on a cast-iron spider which is keyed to the shaft. The best way to find out how a d.c. machine is put together is to examine one when it is not working.

Excitation of D.C. Machines.

The magnetic field essential for the production of voltage can be obtained in several ways.

(1) Permanent magnets. This would apply only on very small machines, *e.g.* a magneto, though a magneto actually produces alternating current.

(2) Electro-magnets, which may be

(*a*) separately excited

(*b*) self-excited.

A generator which has separate excitation may derive its excitation current either from the ship's mains, assuming of course more than one generator on the ship, or from a small auxiliary generator called an exciter the whole purpose and function of which is to supply the exciting current for its bigger brother. It may be away from the main machine, or may be mounted on a pedestal at the end of the bedplate of the main machine. having its armature mounted on the shaft extension of the main machine.

Self Excitation. Since the function of a generator is to provide current, the question at once arises—cannot we use its own current to excite itself? It sounds rather like getting something for nothing, an idea which an engineer promptly and unhesitatingly rejects. But one must not forget that all the energy associated with the generator, both its useful output and its losses, whether in the armature, field, iron, bearings, or anywhere else must ultimately be supplied by the prime mover driving the generator so that there is no question of getting anything for nothing. Admitting the general principle of the possibility of self-excitation, the next question that arises is—are there any special conditions that must be fulfilled before the machine can be self-exciting? There are. They are as follows :—Firstly, there must be some residual magnetism. When a d.c. generator has been working and is shut down, the field system retains some magnetic flux even when the field current has ceased to flow. This magnetism can persist in the poles for quite a long time and is called residual magnetism, or sometimes "remanence". When the generator is started up again the armature conductors cut through this weak magnetism and therefore have a small voltage induced in them. This causes a small current to flow round the field windings which strengthens the flux, causing more volts, more field current, more flux and so on, on a sort of compound interest principle until the armature voltage has built up to the maximum which is possible for the particular values of speed and field circuit resistance which are obtaining at the moment. Were there no residual magnetism, it would be impossible for the machine to be self-exciting.

The second condition which must be fulfilled is that the total resistance of the complete field circuit including the field coils, the brushes, the armature, the field regulator (if there is one), all the necessary cable connections, and, in the case of a series generator, the resistance of the external circuit, must not be more than a certain maximum known as the "critical resistance". The reason for this is that the voltage required to send a current through a resistance varies directly as that resistance. If the field circuit resistance is too high more voltage may be required to send a small current through the field circuit than would be induced by that small current when flowing in the field coils, so that it is impossible for the machine voltage to "build up".

The third condition to be met is that for a given value of field circuit resistance the speed must not be less than a certain minimum, otherwise an insufficient amount of volts will be induced to send sufficient current through the field circuit.

The Connection of the Field Circuit.

The field coils may be connected to the armature in three ways as follows :—

The Series Generator. As the name might suggest, in the series generator the armature, field, and external

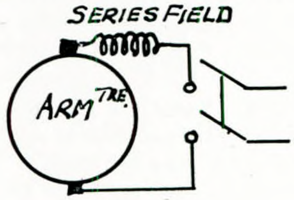


FIG. 37.

circuit are all connected in series together as shown in Fig. 37.

The Shunt Generator. In this arrangement the field coils are connected directly across the brushes so that

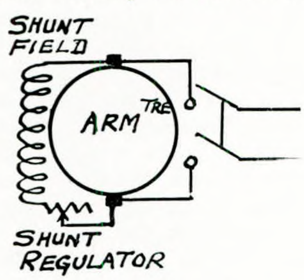


FIG. 38.

the armature and field form an independent circuit irrespective of the external circuit. See Fig. 38.

The Compound Generator. This has both a series and a shunt field as illustrated in Fig. 39.

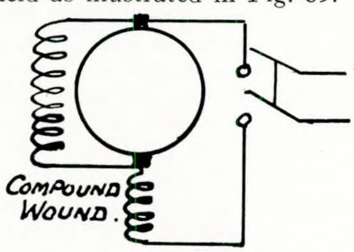


FIG. 39.

External Characteristics of the Various Types.

By the "external characteristic" is meant a graph drawn between the terminal volts and the load current. This is most informative as to the behaviour of the machine on load. Before dealing with these it would be advisable to consider the behaviour of iron when it is gradually magnetised by means of a coil carrying a current which is gradually increased. Suppose a specimen of iron in the form of a ring has a coil wound round it which is connected to supply mains via an adjustable resistance and an ammeter as shown in Fig. 40. If the iron is previously un-magnetised, and the current is gradually increased from zero to some maximum in steps,

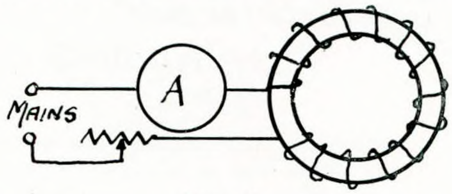


FIG. 40.

and for each successive value of current the number of lines of force in the iron is measured by means which are available but which need not be dealt with here, then if a graph be plotted of magnetism against exciting current, it will be of the general shape shown in Fig. 41. It should be pointed out that the number of lines of magnetic force depends upon the product of amperes multitplied by turns, *i.e.* ampere-turns per cm. length of iron. Four amperes flowing through 25 turns would have the same effect as two amperes flowing through 50 turns or one ampere flowing through 100 turns. If, as is very often the case, the number of turns remains constant, then the amount of magnetism varies directly as the exciting current. An examination of the graph shows that the magnetism increases rapidly and uniformly at first for an increasing current, but that after a while this increase slows down, the curve bends over, and afterwards the magnetism does not increase nearly so rapidly for corresponding increases of exciting current. The iron is then said to be *saturated.*

If a series generator were to have its field disconnected from the armature and connected to the supply mains through an adjustable resistance and an ammeter, and the field current were gradually increased, while at

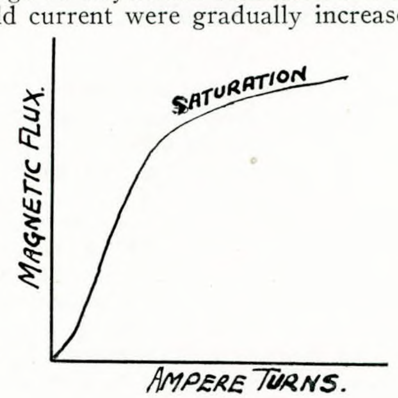


FIG. 41.

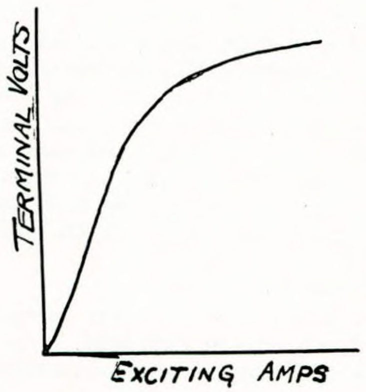


FIG. 42.

the same time, for each value of exciting amperes, the voltage across the brushes of the machine was measured, the machine being driven at constant speed, then if a graph were drawn of terminal voltage against exciting current it would be of the general shape shown in Fig. 42, that is, of identical shape as the magnetisation graph of the iron. This must follow from the fact that the voltage induced depends on the rate of cutting magnetic lines, and for a given mechanical speed of rotation the rate of cutting will depend on how many lines there are to be cut, which in turn depends on the exciting current.

If a series generator were self-excited and a series of increasing currents passed through it, and the terminal voltage for increasing values of current were measured, then the graph drawn between terminal volts

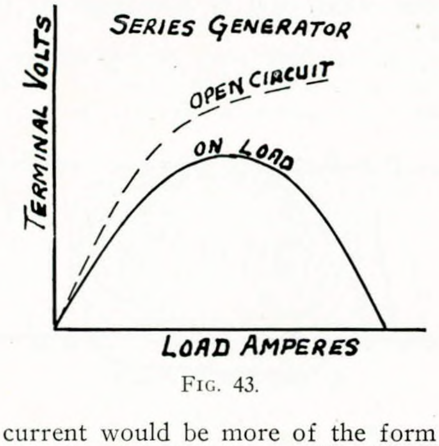


FIG. 43.

and load current would be more of the form shown in Fig. 43, thick line labelled "on load". The reason for the falling off of voltage is because part of the voltage induced is used up in forcing the current through the resistance of the armature and field, and partly because of an effect known as armature reaction which will be explained more fully presently. The chief thing to notice for the moment is that the terminal voltage is by no means constant, or anything like constant for variations in load current, so that a series generator is quite useless for a constant voltage supply service such as is required for lighting, heating, motors, etc. The series generator has a very useful function which will be dealt with under distribution.

The Shunt Generator.

This has its field coils connected directly across the brushes, so that even when the main switch is open there is still a complete field circuit. If the terminal voltage is plotted against the load amperes for a self-excited shunt generator, a graph of the general shape shown in Fig. 44 will be obtained. The voltage has its

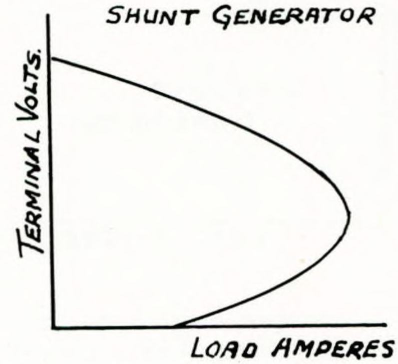


FIG. 44.

maximum value when the load current is zero. As the load current is gradually increased the terminal volts gradually decrease until eventually a point is reached where the graph bends back on itself as shown. This means that the terminal volts are falling away even more rapidly than the resistance of the external circuit is lowered, so that the current itself begins to decrease. This falling away of voltage is due to the voltage drop in the armature and also to the effect of armature reaction, just as for the series generator. It is of course assumed in the above that the machine is being driven at constant speed. The terminal volts on a shunt generator can be maintained approximately constant by hand by means of a shunt regulator in the field circuit. The machine can be designed so that it gives its full nominal voltage at full speed with most of the field regulator resistance in the field circuit. As the load increases and the terminal volts decrease, the shunt regulator resistance is gradually cut out, permitting more current to flow through the field coils, which induces more magnetism in the poles, which causes more volts to be induced in the armature to make up for the increased "voltage drop". Also, the armature reaction mentioned above has a demagnetising effect so that the extra magnetism counteracts this. A shunt generator would therefore be suitable for any service where the load is not subject to frequent and violent fluctuations, and the voltage can be kept adjusted to the correct value by hand.

On certain types of power loads where heavy current appliances, *e.g.* motors, are frequently started and stopped, it would not be feasible to follow the voltage fluctuations by hand. What is required is some means by which the terminal voltage will remain constant despite the load fluctuations. This is accomplished by means of a compound generator.

The Compound Generator.

This is essentially a shunt generator to which a few series turns have been put on the poles. As the load on the generator increases the series coils automatically get more current, so that the field is strengthened to com-

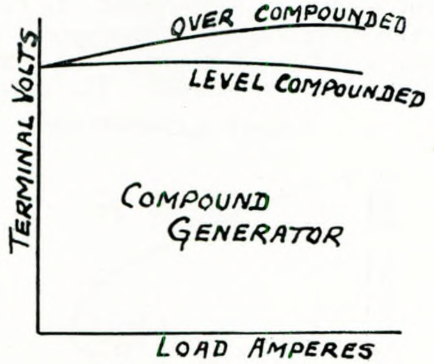


FIG. 45.

pensate for the armature reaction and the voltage drop. The suitable proportioning of the shunt and series field windings is a job for the machine designer, and need not concern us here. A generator in which the terminal voltage is the same at full-load as at no-load is said to be "level-compounded". By adding a few more series turns the voltage can be caused to rise slightly on load. The machine is then said to be over-compounded (see Fig. 45). (Most generators on ships are over-compounded). The reason for over-compounding is to compensate automatically for voltage drop in the supply mains. A simple numerical example will explain this. In Fig. 46, suppose the generator is supplying a power load M, taking say 490 amperes, and also a lighting load L taking 10 amperes. The total load is then 500 amperes. The motors and lamps are both designed for a 200-volt supply at their terminals. If, then, the two supply cables each have a resistance of 0·02 ohms, that is 0·04 ohms, there and back, a voltage of $500 \times 0{\cdot}04 = 20$ volts will be required to force the 500 amperes through the supply cables, so that if the terminal voltage at the load is to be 200 volts, the

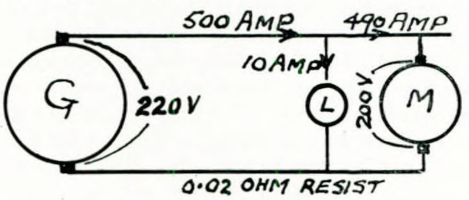


FIG. 46.

terminal voltage of the generator must be $200 + 20 = 220$ volts. Suppose now that the motor or motors are being frequently switched off and on. When they are switched off, the load current falls to 10 amperes, *i.e.* the current for the lamps, so that the drop in the mains will be only $10 \times 0{\cdot}04 = 0{\cdot}4$ volts and the voltage on the lamp terminals will therefore rise to $220 - 0{\cdot}4 = 219{\cdot}6$ volts. This would not burn them out immediately, but would certainly shorten their life. If, however, the generator is over-compounded by an amount which causes the terminal voltage to rise from 200 volts at no load to 220 volts at a load of 500 amperes, and by proportionate amounts at intermediate loads, then the voltage at the load end of the supply cables will remain approximately constant whatever the load is doing. A series field winding has a few turns of thick copper because it carries the full load current of the machine. A shunt field winding has many turns of fine wire because it has the full voltage of the machine applied to it and must therefore have a high resistance to limit the power loss.

Armature Reaction.

This has been mentioned in the foregoing and what is meant by it will now be explained. Any coil carrying a current has a tendency to produce a magnetic field. If two coils carrying current act on the same magnetic circuit in opposite directions, or at right angles to each

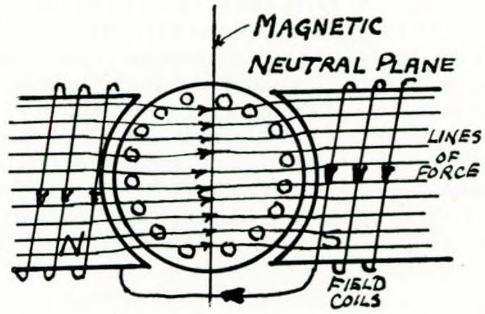


FIG. 47.

other, they will not produce two separate magnetic fields but only one which will be the result of their joint resultant effect.

In Fig. 47, if there were current in the field coils as shown but no current in the armature windings, then the lines of force would be roughly as indicated. On

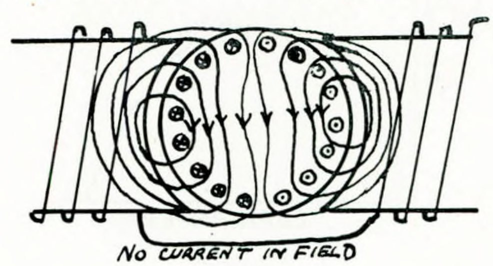


FIG. 48.

the other hand, if there were current in the armature windings, but no current in the field coils, the lines of force would follow a path as indicated in Fig. 48. When there is current in both field coils and in armature windings, which is the state of things when the machine is working under normal conditions, the two sets of lines of force do not both exist at once, crossing each other, but a resultant distorted field is produced of a shape similar to that shown in Fig. 49; the greater the armature current, the more will the field be distorted. It will be observed that the density of the lines of force is increased at what are called the trailing pole tips and diminished at the leading pole tips. If the increase were

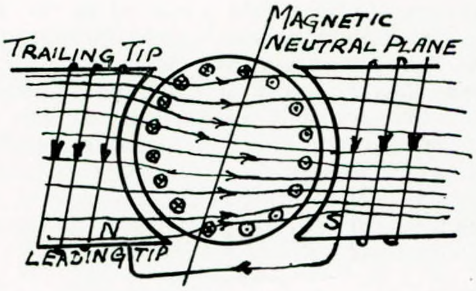


FIG. 49.

exactly as much as the decrease, then the total flux leaving or entering each pole would be unaltered, and the average voltage induced would be unchanged. Owing, however, to magnetic saturation, the increase is not as much as the decrease for the following reason. Suppose in Fig. 50 on open circuit the field ampere turns are OB giving a flux of OP; when the load comes on, the nett ampere turns acting on the trailing pole tip are increased to OC, giving an increase of flux at that point of PQ while the nett ampere turns acting on the leading pole tip are reduced to OA $(AB=BC)$ causing the flux to be reduced to OM, MP being obviously greater than PQ, *i.e.* the nett decrease is greater than the increase, with the result that on the whole the total flux is reduced and consequently the induced voltage is reduced.

There is an additional and important reason why in the shunt generator the terminal volts decrease on load. When the terminal volts do decrease there is less voltage acting on the shunt field, so that less current flows through it, so that less magnetic flux is produced and

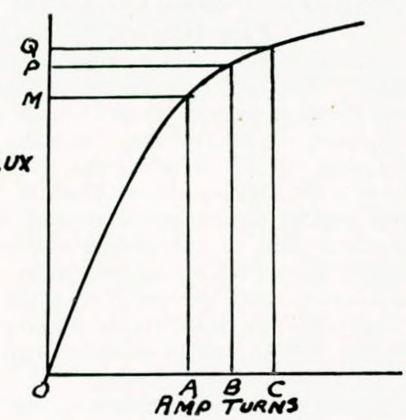


FIG. 50.

consequently less voltage is induced in the armature. One of the purposes of the series coils on the compound machine is to maintain the voltage across the brushes so that the shunt field current does not become weakened. There is another point to be considered. The region where the magnetic field is weakest, known as the magnetic neutral plane, would be, on a 2-pole generator not carrying any armature current, on a line at right angles to the main axis of the poles. Owing to the distortion of the field by armature reaction described above, the magnetic neutral plane is shifted forward in the direction of rotation when the armature is carrying current, the amount of shift depending upon the amount of current.

Position of Brushes. Referring to Fig. 30 it will be noticed that the coil whose two commutator segments are lying under the brush is, for the time being, short circuited by the brush. Now an armature coil has a very low resistance indeed, so that it is desirable that there shall be no material voltage induced in the coil at that instant, otherwise a heavy current would flow in the coil and across the brush, causing sparking. It is necessary therefore that the brush should lie on two commutator segments to which are attached the ends of a coil which is lying in the magnetic neutral plane, so that there will be very little voltage induced in that coil. But we have seen that on load the magnetic neutral plane is shifted forward in the direction. The brushes therefore must also be shifted forward in the direction of rotation by varying amounts depending on the load. This applies only to a generator without interpoles. The action of interpoles or commutating poles will be described under commutation.

Commutation.

Referring to Fig. 30 it will be observed that coil A has current flowing in it in one direction while in the position illustrated at (a), but when it has moved over to the position illustrated in (b) the current is flowing in the coil in the opposite direction. That is, between the position (a) and (b) the current must be reduced from some value to zero, and then built up to its original value but in the opposite direction. Suppose the machine is running at 1,200 r.p.m., *i.e.* 20 r.p.s., and that it has 100 commutator segments. It will make one revolution in $\frac{1}{20}$th second. For the coil to move from position (a) to (b) the periphery of the commutator must move a distance of two commutator segments, i.e. $\frac{1}{50}$th of a revolution which will take $\frac{1}{1000}$th second. Yet in that time it is necessary to carry out a complete reversal of current in the coil. There is a property of an electric circuit called inductance which, in its effects, is very closely analogous to inertia in mechanics. Inertia always *opposes* any sudden change of rate of movement, whether from rest to movement, from movement to rest, or from movement at one velocity to movement at some other velocity, either higher or lower. (A wise person does not step off a moving vehicle on the near side facing sideways, right foot first. Why?—Inertia). In the same way the inductance of an electric circuit always opposes any change of current either upwards or downwards. The inductance of the armature coil therefore opposes the rapid reversal of the current and tends to slow it up. If the current has not attained its full value in the new direction in the coil when the leading commutator segment to which the coil is attached parts company with the brush there will be sparking at the trailing tip of the brush. It is desirable therefore to speed up the reversal of current if possible. Before the days of interpoles this was done by shifting the brushes forward in the direction of rotation in a generator, so that the short-circuited coil lay in the

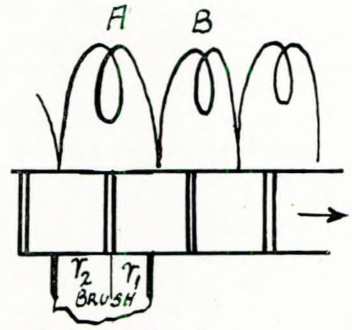


FIG. 51.

fringe of the flux of the next pole. Such a flux induces a slight voltage in the new reversed direction, which helps to speed up the reversal.

Improved commutation can also be obtained by the use of carbon, or copper-carbon brushes. Carbon has a much higher resistance than copper. As the commutator moves past the brush the current has two alternative paths offered to it from coil *B* (see Fig. 51) into the brush, either straight across the narrow strip r_1 or round coil *A* and across the strip r_2. As the commutator moves to the right in the diagram r_1 is getting narrower and narrower and consequently its resistance is getting greater and greater while r_2 is getting wider and wider and its resistance getting less and less so that the current flowing into the brush has more inducement to take the lower resistance path, via coil *A*, which is desirable.

Use of Commutating Poles.

Supposing that auxiliary poles are fixed as in Fig. 52 midway between the main poles, having their field coils consisting of a few turns of thick conductor excited by the main armature current or some definite fraction of it; then there will be a reversing field fixed in space, the strength of which will adjust itself automatically to the strength of the armature current to be reversed. Moreover the direction of the field produced by these poles will be directly opposite to the

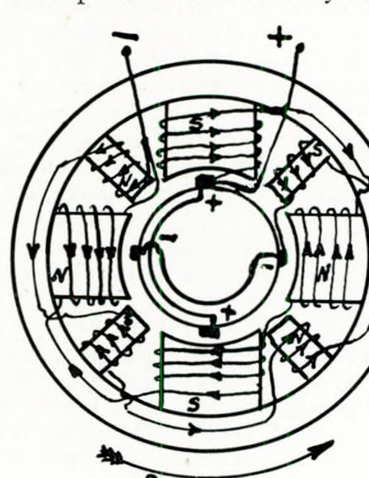


FIG. 52.

general direction of the field produced by the armature current. These poles, known as commutating poles, or interpoles, therefore serve two purposes; they provide a reversing field to assist in obtaining sparkless commutation at all loads with fixed brush position, and also tend to neutralize the effect of armature reaction. In generators, they are of the same magnetic polarity as the next main pole forward in the direction of rotation. In motors they are of the opposite polarity, but this will be dealt with more fully under motors.

The Development, Uses and Characteristics of Ferrous Alloys in Marine, Constructional and Power Engineering.

A most informative lecture under the above comprehensive title was delivered by Dr. W. H. Hatfield, F.R.S., to a large audience at a joint meeting of the Junior Section and the students of the Chelsea Polytechnic on Thursday evening, March 16th, 1939. Dr. F. J. Harlow, M.B.E., Principal of the College, occupied the Chair.

Dr. Hatfield preceded the lecture by displaying an excellent colour film illustrating the activities of the research laboratories and works of the Company with which he is associated. This formed a most appropriate introduction to the discourse, illustrated by lantern slides, which followed. The lecturer's replies to the numerous questions which followed the lecture concluded a very successful meeting.

On the proposal of Mr. B. C. Curling (Secretary), seconded by Dr. A. Abbott, C.B.E., Dr. Hatfield was accorded a very enthusiastic vote of thanks.

It is hoped to publish a full account of the lecture in a later issue of the TRANSACTIONS.

Film Display.

In the Lecture Hall of The Institute on Thursday evening, March 30th, 1939, a largely attended meeting of the Junior Section was privileged to see a programme of technical films of outstanding interest. Mr. E. F. Spanner, R.C.N.C. (ret.) occupied the Chair.

By courtesy of Messrs. Thos. Firth & John Brown, Ltd., the first part of the programme consisted of a most instructive colour film of the production of large steel ingots followed by a film on making alloy steels in the electric arc furnace and the production of carbon and alloy steel bars. Mr. J. Hopcraft of Messrs. Thos. Firth & John Brown, Ltd., greatly enhanced the interest of these films by a running commentary.

The second part of the programme comprised a film depicting the construction of the s.s. "Queen Elizabeth" and a film of the launching of the s.s. "Mauretania", both films being kindly lent by the Cunard White Star Line.

On the proposal of Mr. H. R. Tyrrell, B.Sc., Mr. Hopcraft and both the Companies concerned were warmly thanked for their contributions to a very successful meeting. On the proposal of Mr. J. H. Graves (Associate Member), Mr. F. A. Everard (Student) was accorded a hearty vote of thanks for his efficient operation of the projector, which he had kindly loaned for the meeting.

Abstracts of the Technical Press

Measuring Metal-plate Thickness.

A method of electrically measuring the thickness of a metal plate of which only one side is accessible is used in the research department of Woolwich Arsenal, and is described by A. G. Warren in the *I.E.E. Journal* for January. The method consists in applying about 4 A (constant) and picking off the potential difference between two specified points, for which purpose "contact squares" are used, the defining size being the side of the square. For example, those of less than 1in. square side have four gramophone needles sliding in parallel cylindrical holes in an insulating disc. In plan the axes of the holes are in perfect square and the disc is capable of a limited sliding motion within a hollow cylindrical holder. The butt ends of the needles, to which lead-out wires are soldered, bear upon a pile of rubber discs. When the point rests upon a metal surface and pressure is applied to the holder, they are forced into good electrical contact, even if the surface is painted or moderately rusty. Two adjacent needles are used as current contacts and the remaining pair as potential contacts. Thermal EMF in the potential-measuring circuit is usually small, but can be taken into account by readings taken with reversed current. Using two successive contact squares of sizes definitely greater than the plate thickness to be gauged, the potential difference obtained will be slightly greater for the smaller square, while the ratio between the PD will increase rapidly as the size of the larger square is reduced towards the plate thickness. Thus the PD ratio establishes a relation between the sides of the contact square and the thickness of the plate. This method is used for detecting corrosion pits, near which a considerable increase in PD occurs, and has enabled extraordinarily accurate estimates of thickness to be made, errors as great as 3 per cent. being uncommon. The Thornton method of metal-plate measurement differs from the one described above in that it depends on a comparison of the electrical resistance through the specimen with that of a known sample of similar shape.—*"The Electrical Review", Vol. CXXIV, No. 3194, 10th February, 1939, p. 197.*

New Swedish Experimental Tank for Testing Ships' Models.

The Chalmers Technical High School in Gothenburg is to have a model tank for the purpose of conducting scientific experiments and tests with models of ships. The tank, which will be partly cut out of solid rock, is, in the first instance, to be about 510ft. long, 33ft. wide and 16½ft. deep, but provision will be made for extending the length to over 820ft. at a later period, if required. The tank is to be completed by the end of the present year.—*"Schiffbau", Vol. 40, No. 2, 15th January, 1939, p. 36.*

Some Contributions of Chemistry and Chemical Engineering to Steam Generation.

The paper is presented from the point of view of the large generating stations and many of the features discussed in it are not yet applicable to smaller plant. Among these is the theory of coal sampling, which is briefly described. The problem of burning coal efficiently on large mechanical stokers is discussed in general terms and illustrated by the results of a boiler-trial. Closer attention is given to the various sources of loss of heat, especially the loss that arises from the escape of unburnt gases from the furnace, which is particularly important when a boiler-efficiency of 90 per cent. or over is desired. A means of assessing this loss with some precision is described, but not the analytical technique involved. Owing to the fact that present-day knowledge of feed-water and boiler-water treatment is too confusing for ordinary discussion, it has been summarised in the form of a table which contains many references to the original literature, a study of which is essential for a proper understanding of the subject. The more recent researches receive particular attention, especially those dealing with silicate scale, caustic embrittlement and carry-over. The very real advantages of pure feed-water are discussed entirely from the point of view of the authors' own experiences. The paper concludes by a review of those methods of removing oxides of sulphur from flue-gases that have at least reached the stage of pilot-plant operation, with special reference to recent advances in theory and to the process with which the authors themselves are most familiar. The paper contains four tables and seven diagrams to illustrate the text.—*Paper read by G. W. Hewson and R. Ll. Rees, M.A., before a meeting of the Institution of Chemical Engineers, on the 17th February, 1939.*

Novel Application of Voith-Schneider Propulsion.

A number of new motor launches have just been put in commission at Venice for the maintenance of the passenger service between that city and the Lido. The boats were built by the Cantieri Breda at Porto Marghera near Venice, and have all-welded steel hulls. They have an overall length of about 60ft. 6in., an extreme breadth of about 11ft. 6in., and a mean draught of 4ft. 2in. with accommodation for 46 passengers. Propulsion is by means of Voith-Schneider propellers driven by Fiat engines of a similar type to those used in the new Italian streamlined railway trains.—*"Journal de la Marine Marchande", Vol. 21, No. 1038, 23rd February, 1939, p. 269.*

American Marine Power Practice.

The specifications of the propelling machinery of the U.S. Maritime Commission's new C.3 type ships indicate that these vessels may be either turbine steamers or motorships. Each type of machinery is to develop 8,500 s.h.p. with a propeller speed of 85 r.p.m. Compound turbines for a steam pressure of 440lb./in.^{2}, with double-reduction gears, are specified. The astern turbines need only develop 40 per cent. of the power of the ahead turbines and the temperature of the steam at the turbine throttles is to be 750° F. The propelling machinery in the motorships is to consist of four engines coupled to a single-screw shaft through reduction gears and hydraulic couplings, with two engines coupled to each of two pinions. Two-stroke, single-acting engines are called for, with crankshaft-driven scavenging pumps. Fresh-water cooling of the cylinders is specified, and oil-cooling from the lubricating system, for the pistons. In both steamers and motorships the deck machinery and engine-room auxiliaries are to be driven by electric motors.—*"Shipping", Vol. XXVIII, No. 319, February, 1939, p. 46.*

A Portable Magnetic Crack Detector.

A new portable crack detector introduced by one of the greatest electrical manufacturing firms in this country, is in the form of a hollow disc-shaped container, filled with a specially reduced iron dust, carried in almost colloidal suspension in dry oil and with one or both sides transparent, so that concentrations of the iron dust can be seen. The detector is, of course, only intended for use on flat surfaces and other articles must be immersed in a bath of the fluid. The surface to be examined is first magnetised and the detector is then placed on it, preferably in a horizontal position, and gently tapped or rocked. Within 15 to 20 seconds any crack in the surface is clearly indicated by a black line formed by the fine iron particles which are attracted to the magnetic poles created at the edges of the crack. As with larger applications using the concentration method of detection, the indication is sensitive and unmistakable, and even hair cracks which could scarcely be detected by ordinary microscopic examination are shown. After the indication has been noted, the indicator is shaken to redistribute the iron dust ready for the next test. and routine tests or elaborate explorations can be made very rapidly. The detector is said to be proving very useful for the industrial inspection of ferrous materials, and also for instruction in schools and colleges. Apart from the detection of flaws, it can be used for the study of leakage paths in magnetic systems, the magnetic fields associated with current-carrying conductors, the effects of work hardening of steels, and many other magnetic and metallurgical problems. It can even be used to indicate the presence of electrostatic fields. While for most purposes the residual flux in a magnetised specimen is sufficient to give clear indications in the detector, a large increase in sensitivity can be obtained by increasing the field strength by means of magnetising coils. With a high degree of magnetisation, it is possible to locate sub-surface faults. The sensitivity to magnetic discontinuity makes it possible to detect invisible magnetic markings, such as can be made by drawing lines with a magnetic point on a hardened steel surface. — *"The Engineer", Vol. CLXVII, No. 4,337, 24th February, 1939, p. 258.*

Supercharging for Oil Engines of Volga Motorships.

In order to improve the efficiency of the propelling machinery and service speed of certain oil-engined river craft on the Volga, superchargers have been fitted for the purpose of increasing the effective power developed. The article gives particulars of the performance of a four-cycle engine of a large motorship, with and without supercharging, and quotes four equations for the calculation of the effect of supercharging on engine efficiency. Details are given of the increase of power and speed achieved by the application of supercharging to the engines of a twin-screw passenger vessel of 1,430 h.p., making due allowance for hull resistance and the mechanical efficiency of the engines, propellers and blowers. A number of diagrams and equations are furnished for this purpose. The net result of the application of supercharging to this vessel was an increase in engine power from 1,430 to 2,220 h.p., and in revolutions per minute from 216 to 257, corresponding to an increase in speed from 11·0 to 12·13 knots. This increased speed would probably have been still higher, had a new propeller, suitable for the increased power, been fitted. — *"Soudostroienie" No. 6, 1938.*

The Combustion Gas Turbine.

In the course of a paper on this subject read by Dr. Adolf Meyer before the Institution of Mechanical Engineers on the 24th February, 1939, the author made a reference to the application of the combustion turbine to the propulsion of ships. He stated that the adoption of such turbines of from 2,000 to 4,000 h.p. instead of reciprocating engines in oil-fired ships, merits a thorough investigation, since efficiencies of over 20 per cent. can be obtained with a combustion-turbine plant by utilising the heat of the exhaust gases for preheating the air. This would be equivalent to an increase of about 20 per cent. on the efficiency of present-day reciprocating engines. As regards merchant vessels, each case must be examined individually, but with warships, and, in particular, torpedo craft, the position is different. Such vessels are usually driven by steam turbines, the drive being a compromise, since the top speed entails outputs up to 20 times that required at normal cruising speed. The steam and oil consumptions at both the top and cruising speeds differ, therefore, from those customary in the case of stationary plants. The efficiency of such a marine turbine plant at full power is about 14 to 18 per cent., *i.e.,* of the order of that which can be obtained with a gas-turbine plant without pre-heating the combustion air. At cruising speed the efficiency may even be as low as 11 to 14 per cent. A simple form of gas turbine for the propulsion of such vessels would, therefore, be deserving of consideration, since the average oil consumption over the whole speed range of the ship would be equal to the average of a steam drive. If, however, the many advantages offered by the gas turbine are taken into account, even a slightly higher fuel consumption should be acceptable. A further appreciable improvement is obtained if Diesel engine drive is resorted to for the cruising speed. This should be practicable due to the fact that the gas turbine is much lighter and requires less space, so that the complete plant—turbine plus Diesel engine—is still more compact and lighter than a steam turbine plant. In the course of the discussion that followed, Commander W. G. Cowlland, R.N., commented on the high efficiency of 84 per cent. that the author had obtained for the gas turbine, which compared well with the best overall efficiency of a steam turbine of about 78 per cent. An analysis of the curves given in the paper indicated that the gas turbine possessed an advantage of about 5 per cent., due to the neglect of certain losses, one of which was pressure drop. The good effect of a heat interchanger, for example, would be largely affected by unwanted pressure drops in getting the gases round corners. The size of a 5,000 sq. ft. heat interchanger for a 2,000-kW. output turbine was about equal to the cooling surface of a condenser for an 8,000 h.p. steam turbine, so that it was a big thing. Another speaker, Mr. A. J. H. Fitt, remarked that much had been made of blade cooling, but there were other parts of the gas turbine which would probably give rise to trouble through distortion, etc. The combustion of the gas turbine would have to be very good, or trouble might arise from carbon formation on such working parts as governor valves. The gas, moreover, was presumably noxious and precautions would therefore be needed on board ship.—*"Engineering", Vol. CXLVII, No. 3,816, 3rd March, 1939 pp. 247-250 and 256.*

New Sand-blasting Apparatus.

A well-known British shipbuilding firm have patented a sand-blasting apparatus primarily intended to remove paint and incrustations from ships' plates. The apparatus is so arranged that the abrasive substance employed is confined to an enclosed circuit, which may be described as a casing, with an opening which is placed over the surface to be treated, the sand being projected on the surface tangentially and then deflected by baffle plates back to the compressed-air nozzles, the process being continuous. Rubber strips are fitted round the opening to prevent dissipation of the blast, and rollers and handles are provided for moving the apparatus, which may be compared, as regards general outlines, to a lawn mower or a vacuum cleaner.—*"Fairplay", Vol. CL., No. 2912, 2nd March, 1939, p. 435.*

New Motorboats for Destroyers.

Nearly two dozen 25ft. destroyer launches have been built by John I. Thornycroft & Co., Ltd., at their Hampton works, for the Royal Navy, in addition to a number for various foreign governments. These boats are equipped with a 23-69 h.p. Thornycroft engine, based on the Ford V8, and are capable of a maximum speed of 20 knots at 3,200 r.p.m. The normal running speed is 2,800 r.p.m. The boats are of the hard-chine type, with a beam of 7ft., and are strongly built of double-skin mahogany on sawn timbers, intermediate steamed and bent timbers being fitted. Accommodation for officers is arranged in the forward cabin, the after cabin being intended for the crew. A hinged hatch at the forward end allows communication with the helmsman, whose cockpit is located in the bow and is equipped with a tip-up cushioned seat. A feature of the instrument board is a tachometer, which records the number of revolutions which have been made by the engine during any particular trip. The boats possess good manœuvring qualities and acceleration, and are said to be very easy to handle.—*"The Motor Boat", Vol. LXX, No. 1805, 24th February, 1939, p. 189.*

Cargo Ships of the Future.

In a lecture delivered before members of the Technical Society of Gothenburg, entitled "Suggestions for High-speed Medium Sized Cargo Motorships", Dr. H. Blache, a former director of Burmeister & Wain, and now with Harland & Wolff, Ltd., expressed the view that speed would play an all-important part in the sea transport of the future. For this reason he believed that construction should be based on the power unit and that the conventional practice of designing hulls and putting engines into them, was wrong. He suggested that, on the contrary, designers should concentrate on the construction of suitable propelling plants, around which the hulls would subsequently be built up. The introduction of more powerful engines would necessitate stronger hull construction, and care should be taken to design such hulls to offer a minimum resistance to wind and water. Dr. Blache thought that the possibilities of the modern oil engine were, at the present time, inadequately exploited, and that the present trend in motorship construction was in the wrong direction. He considered that British shipowners in particular, were mistaken in displaying a predilection for 10-12 knot cargo motorships in the 9,000-10,000 deadweight class, as medium-sized vessels of 6,000-7,000 tons, fitted with powerful engines for high speed, would be much more successful. That type, he believed, would be the cargo carrier of the future.—*"The Journal of Commerce", (Shipbuilding and Engineering Edition), No. 34,633, 23rd February, 1939.*

New French Cross-Channel Steamers.

A contract for the building of two steamers to replace the "Rouen" and "Newhaven", which are now reaching the end of their term of service between Dieppe and Newhaven, has been placed by the National Railway Company with the Forges et Chantiers de la Méditerranée. The new ships will have the same dimensions as those they are to replace, viz., a length of 308ft., a beam of 39·7ft., and a load draught of 10·3ft. on a displacement of 2,000 tons, with provision for carrying about 1,450 passengers. The twin propellers will be driven by Parsons turbines of 20,000 h.p. supplied with steam at 384lb./in.^{2} by two Penhoët oil-fired small-tube boilers. All the auxiliary machinery will be electrically driven. The contract speed on trials is to be 25 knots. One of the cargo steamers of the Dieppe-Newhaven service is also to be replaced by a new vessel, to be built by the Chantiers de Normandie at Rouen, with two M.A.N. engines of 500 h.p. each and with two decks arranged for the transport of 58 motor-cars. British tenders for all three ships were from 20 to 23 per cent. below the French ones and in order to secure the work for the French shipyards the difference in cost is being met by the funds of the State Crédit Maritime.—*"The Engineer", Vol. CLXVII, No. 4, 337, 24th February, 1939, p. 265.*

The New Götaverken Diesel Engine.

The first of the new Diesel engines developed by the Götaverken shipyard was installed in the motorship "Dicto", in January. The builders (who are also one of the Burmeister & Wain's licensees and are still building B. & W. engines) have developed this new design to meet the demand for a 2-stroke crosshead engine of a heavy type, and it is also claimed that this engine is easy to dismantle for refit and repair. The engine installed in the "Dicto" is designed to develop 5,200 i.h.h., or 4,300 b.h.p., in six cylinders of 680mm. diameter and 1,500mm. stroke, the mean indicated pressure being 92·45lb./in.^{2}. On the trial trip at full load, the exhaust temperature was about 460° F. The uniflow system of scavenging is employed, with a poppet exhaust valve in the cylinder head. The valves are operated by rods connected to levers in the crankcase actuated by means of crankshaft cams. There is no separate camshaft for the valve gear. The cylinder covers are circular, and attached to the cylinder blocks with heavy studs. The round covers were adopted for ease of dismantling, thus facilitating examination of the pistons. The fuel pump plungers are actuated from a camshaft driven from the crankshaft by a chain, this camshaft being light, as its work is confined to the operation of the fuel pumps. A tandem piston-type scavenging pump is located at the forward end of the engine and, by the use of large scavenging ports and large-diameter exhaust valves, the scavenging pressure is brought down to about 1·6lb./in.^{2}. The fuel consumption is 0·29lb. per i.h.p./hr., corresponding to 0·355lb. per b.h.p./hr. and the mechanical efficiency is 82 per cent. A single handwheel is employed for starting and manœuvring, with an interlocking device preventing a wrong manœuvre. The "Dicto" is a vessel of 9,500 tons d.w. on a draught of 26ft., with a loaded speed of 13·75 knots.—*"The Motor Ship", Vol. XIX, No. 230, March, 1939, pp. 450-451.*

New German Steamer on Hamburg-London Service.

The s.s. "Cressida", which recently berthed in London Docks on her maiden voyage from Hamburg, was built at the yard of the Lübecker Maschinenbau, of Lübeck, and is a cargo vessel of 1,049 tons gross, with dimensions 222ft. 9in. × 34ft. 4in. × 11-ft. 10in. Cargo capacity of 91,577 cu. ft. grain and 99,442 cu. ft. bale is provided in two holds, in addition to 5,757 cu. ft. of refrigerated cargo space arranged aft, while the cargo-handling equipment comprises five 3-ton swivelling cranes, a 15-ton derrick and a smaller derrick at each hatch. The propelling machinery consists of a double-compound Christiansen & Meyer engine of 850 h.p., taking steam at 215lb./in.^{2} from two coal-fired cylindrical boilers working on the forced-draught system. The engine-room auxiliaries include a steam-driven 16-kW. generator, bilge, ballast, circulating and feed pumps and an evaporator. The service speed of the vessel is 11 knots.—*"Shipbuilding and Shipping Record", Vol. LIII, No. 9, 2nd March, 1939, p. 277.*

Drum Defects in Water Tube Boilers.

The article discusses defects arising from faulty design and construction and points out that seam fractures may take 5 to 10 years to develop, although preliminary warnings in this type of failure are almost invariably given by local leakage. Present-day improvements in plate manufacturing conditions, and the stringent specifications concerning boiler material, have made failures directly traceable to faulty material of rare occurrence, but the application of excessive riveting pressure often forms the starting point for fractures. An undue amount of cold working, or working at a "blue" heat, affects the quality of the metal, while heavy caulking for the purpose of making tight an imperfectly-bedded joint, may result in serious fractures at a later date. Caustic embrittlement and overheating, pitting and internal corrosion, and external corrosion due to dampness, sweating, etc., are all discussed at length, together with various means of prevention.—*S. D. Scorer, "The Power Works Engineer", Vol. XXXIV, No. 393, March, 1939, pp. 105-107.*

The Largest Japanese Trawler.

The biggest trawler ever built in Japan is the "Suruga Maru", which is stated to be one of the largest motor fishing vessels in the world. She was built at the Hikoshima yard of the Mitsubishi concern for the Japanese Fishing Company, has a length b.p. of 203·4ft., a moulded breadth of 34·4ft., and a gross tonnage of 996 tons. The propelling machinery consists of a 2-stroke single-acting engine of Japanese design constructed by the Niigata Ironworks, Tokyo, having seven cylinders with a diameter of 380mm., and piston stroke of 610mm. and designed to develop 1,050 b.h.p. at 200 r.p.m., corresponding to a speed of about 13 knots. The engine is of the trunk-piston type with scavenging through exhaust ports at the bottom of the cylinder. The mechanical efficiency at full load is 83·2 per cent., and on trials the fuel consumption at full power was stated to be 0·38lb. per b.h.p./hr. —*"The Motor Ship", Vol. XIX, No. 230, March, 1939, p. 485.*

New Danish-Norwegian Ferry.

The Motorship "Skagerak I", building at the Aalborg Shipyard, is expected to take up her duties on the ferry service between Hirtshals (Denmark) and Kristiansand (Norway) next April. The vessel has a length of 212ft. b.p., a moulded breadth of 38ft., and a moulded depth to main deck of 16ft. 6in. The main deck is arranged to accommodate about 40 motor cars and there is a rail track aft, with a total length of 74ft. 6in. Forward is a cargo hold, and forward and aft of the engine-room is a 'tween deck for passenger accommodation. This consists of 115 berths, mainly in two- and four-berth cabins, with six *de luxe* cabins on the promenade deck. Smoking and ladies' saloons are also situated on this deck, as well as the dining saloon, bar, office and shop, while the after part of this deck is promenade space for passengers. The machinery installation consists of two B. & W. trunk-piston Diesel engines of the 2-stroke type with 10 cylinders of a diameter of 350mm. The total output of the machinery is 5,000 i.h.p., and is intended to give the ship a service speed of 17 knots. Electric current is provided by two 120-kW. generators driven by two 180 b.h.p. B. & W. engines, and there is also an emergency dynamo on the main deck. The vessel's navigation equipment include W/T and telephone installations, an Echo sounding apparatus and a direction finder. A concert receiver with loud speakers is fitted in the saloon.—*"The Motorship", Vol. XIX, No. 230, March, 1939, pp. 486-487.*

Refrigerating and Air-conditioning Plant of Diesel-electric Liner "Patria".

The Hamburg-American Line m.v. "Patria" has now been in service since August, 1938, and has proved successful in all respects. As the vessel traverses tropical zones, she is well equipped with refrigerating and air-conditioning plant. The former comprises five Borsig NH_3 machines, each of a capacity of 100,000 calories when the evaporator temperature is 14° F., and the sea-water temperature is 86° F. Two units are utilised for the refrigerated-cargo spaces and provision rooms, two machines serve the air-conditioning plant, and the fifth machine is held in reserve. Alfol has been extensively employed for the insulation of the cargo spaces, in the following manner: Between the shell plating and wire netting is an air space, then come 18 layers of crumpled Alfol foil ·007mm. thick, then 4 layers of Alfol ·015mm. thick, a further 4 layers of ·015mm., Alfol in a wooden framework, and finally an outer facing of xylolite. The ship frames are covered in wood. The air-cooling of the insulated hold is assisted by canvas screens to guide the air flow, instead of ducts. It is claimed that this arrangement enables a uniform temperature to be maintained and that, when general cargo is carried, the screens can be removed, and a space unbroken by ducting becomes available. The air-conditioning plant serving the first-class passenger accommodation is designed to maintain a maximum temperature of 82° F., and a relative humidity of 60 per cent., when the ship is in the tropics, the minimum temperature and humidity being 70° F. and 40 per cent., respectively. The capacity of the plant is 950,000 cu. ft. of conditioned air per hour. Making allowance for radiation, heating by lamps, the warming and humidifying effect of persons, etc., the total cooling requirement is assessed at 733,000 B.Th.U./hr., which is met by the refrigerating machinery. The air-conditioning plant also serves to heat the accommodation when necessary, and each set is equipped with electrical heaters in the intake and discharge ducts, the total heating power available being equivalent to 1,470,000 B.Th.U./hr. Each of the 5 similar air-conditioning units consists of a filter chamber, intake heater, cooler, air cleaner, humidifier, outlet heater and fan. A complete system of temperature control is installed, operated by means of controllers in the air ducts, while humidity controllers are used to regulate the amount of cooling of the air.—*"The Shipbuilder", Vol. XLVI, No. 353, March, 1939, pp. 124-125.*

Fires in Ships in November, 1938.

According to the monthly returns of the *Bureau Veritas,* there were, in the month of November, 1938, thirty-five cases of fire on board merchant vessels. Twenty-nine of these fires occurred in steamships, and in two cases led to a total loss of the ship. Five fires took place on board motorships, one of which was completely destroyed.

One fire broke out in a sailing vessel which became a total loss. Thirteen of the fires in steamships were caused by the cargo, four by the fuel and two by attacks of hostile vessels or aircraft. In the remaining ten cases the cause of the fire is unknown. As regards the motorships, one fire was caused by the cargo and one by the main engines, the origin of the remaining three being unknown. Eleven of the thirty-five steamships concerned were British, but no British motorships figure in the list.—*"Journal de la Marine Marchande", Vol. 21, No. 1,039, 2nd March, 1939, p. 307.*

New German Cargo Steamer.

The recently-completed cargo steamer "Klaus Schoke" was built by the Lübeck Flender-Werke for Hamburg owners, and is a single-screw shelter deck vessel of 5,847 tons gross, with dimensions 428ft. × 59ft. 3in. × 36ft. 2in. The vessel has ten 5-ton cargo winches and the steering gear is of the all-electric type. The bunker capacity is 785 tons and the loaded service speed is 11½ knots. Propulsion is by means of a double-compound engine having cylinder diameters of 20in. and 43·3in. for the h.p. and l.p. respectively, with a stroke of 43·3in. The exhaust steam passes into a Bauer-Wach low-pressure turbine, the normal output of the entire installation being 2.600 i.h.p. at 82 r.p.m. Steam at 220lb./in.^{2} and 640° F. is supplied by three coal-fired cylindrical boilers provided with superheaters and working on the forced-draught system.—*"The Marine Engineer", Vol. 62, No. 738, February, 1939, p. 40.*

Auxiliary Steam Plant in the "Dominion Monarch".

Steam on board is used for the boiler-feed pumps, fresh and salt-water calorifiers, evaporator, oily-water separator, oil-fuel heating, and also for steaming out the fuel tanks, etc. There are four Clarkson thimble-tube boilers, two of these being oil-fired and located in the generator room, while the other pair are in the main engine-room casing and fired by means of exhaust gases from the two inboard main engines. Each of these waste-heat units is 8ft. 2in. in diameter and 17ft. high, with a designed output of 5,000lb./hr. of steam at a pressure of 100lb./in.^{2}. The oil-fired boilers have a similar output, the heating surface of each unit being 650ft.^{2}. Fuel is burned on the Wallsend low air-pressure system, oil being drawn from a 3-ton gravity tank. Both steam and electric oil-fuel heaters are fitted. There are two twelve-hundred gallon Weir direct-acting boiler feed-pumps, with a float tank and control gear for the oil-fired boilers, while the waste-heat boilers are fed by a Weir two-throw reciprocating pump driven by an electric motor. Exhaust steam is condensed in a surface condenser served by a Drysdale Upright circulating pump. A vertical Weir evaporator with an output of 50 tons per 24 hours at boiler pressure, is provided to supply make-up feed.—*"The Shipbuilder", Vol. XLVI, No. 353, March, 1939, pp. 159-160.*

Department of Scientific and Industrial Research —Report for the Year 1937-38.

Among the subjects dealt with in the above report, just published by the Stationery Office, is an account of the work carried out by the Department in the field of metallurgical research. The investigations made include the behaviour of materials at high temperatures, aluminimum alloys, magnesium alloys, the cracking of boiler plates, gases in steel, inter-crystalline cracking, surface finish, internal stress and the structure of graphite. —*"Annual Report of the Department of Scientific and Industrial Research for 1937/38, pp. 65-69.*

The Effect of Forced Circulation on Marine Boiler Design.

The purpose of the paper is to formulate the advantages to be gained by the use of forced circulation, to show its effect upon marine boiler design, and to draw a comparison with some natural circulation water tube boilers. The author takes the La Mont forced circulation boiler as an example, and explains the general principle of its construction and operation. Several types of centrifugal circulating pumps for use with the boiler are referred to and illustrated. The design of a typical oil-fired La Mont boiler now being built for a passenger vessel, is discussed in detail and a comparison is made between the characteristics of this boiler and those of a natural circulation boiler of similar capacity. The paper includes two tables giving the leading design particulars of the La Mont boiler and comparative figures of trials results of such a boiler and a natural circulation boiler, respectively. There are also nine illustrations and diagrams.—*Paper read by Capt. R. E. Trevithick at a meeting of the Institution of Engineers and Shipbuilders in Scotland, on 7th March.*

New Range of Ruston Cold-starting Oil Engines.

A new series of oil engines, designed to run at 1,000 r.p.m., has just been introduced by Ruston & Hornsby, Ltd. These engines develop 20 b.h.p. per cylinder at a normal speed of 1,000 r.p.m. B.S.I. rating, and are made in three sizes, *viz.*, four-, five-, and six-cylinder units developing 80, 100 and 120 b.h.p. respectively. A guaranteed consumption of 0·4lb. of fuel per b.h.p./hr. is obtained under service conditions. The engine bedplate is of strong and rigid cast-iron and carries the crankshaft main bearings. Truing-up of the bearing seatings ensures that replace bearings will go into position without hand fitting. The engine housing is a monobloc iron casting with totally encloses the reciprocating parts and carries the cylinder heads and liners, large inspection doors affording easy access to all main and connecting-rod bearings. Separate cast-iron cylinder heads are fitted and these carry the overhead inlet and exhaust valves with rocking levers and brackets, the atomiser and air-starter valve. The cylinder heads are water-jacketed and readily removable. The combustion chamber is of the "open" type and renewable cast-iron liners are fitted. The crankshaft is a solid steel forging, machined, ground and balanced within close limits, the journals and cranks being surface hardened. The main bearings are of steel lined with anti-friction metal and the connecting rods are steel stampings, machined and accurately balanced, the large end bearing being lined with anti-friction metal, while the small end is bushed with chilled phosphor-bronze. Cast-iron pistons, annealed after rough machining and ground to ensure correct clearance at working temperatures, are fitted. Floating gudgeon pins, three pressure rings, and two scraper rings, are fitted to the pistons. The valve-gear camshaft is chain-driven from the crankshaft at the flywheel end of the engine. The inlet, exhaust and air starter valves are actuated by cams and hardened steel tappets. A fuel pump of the monobloc type is fitted, with a separate plunger and guide for each cylinder. Each unit can be adjusted independently to ensure perfect firing balance and a uniformly distributed load. A centrifugal governor, gear-driven from the fuel pump camshaft, is provided, this also having an auxiliary spring, allowing variation in speed. The new type "Mark 37" Ruston Atomiser is used and a mechanically-operated air-starter gives certain and instant starting from cold, all cylinders being fitted with starter valves. The control valve, operated by the camshaft, automatically admits air to the cylinders in the correct sequence. An air receiver. with valves and piping, can be fitted if required. Lubrication is by a submerged gear-type pump, driven from the engine crankshaft, which delivers oil to all wearing surfaces, chain sprockets, and camshaft bearings, all bearings being flooded with oil. A hand oil-priming pump is also provided to ensure initial lubrication. The engine is fitted wth a centrifugal water pump driven directly from the crankshaft by a silent-running chain. The pump comes into operation immediately the engine is started.—*"Gas and Oil Power", Vol. XXXIV, No. 401, February, 1939, pp. 47-48.*

Polish Steamer Capsized in Danzig Harbour.

On the 5th December, 1938, while the Polish steamer "T", was loading cargo alongside one of the quays in Danzig, she capsized. The vessel was of 720 tons gross, with dimensions of about 182ft. × 28ft. × 12ft. 9in.. and a d.w. capacity of 1,020 tons. In addition to a general cargo, the ship was to have loaded 140 tons of iron plates, the total amount of cargo to be carried being 750 tons. with a further 210 tons of bunker coal, feed water, etc. Owing to a delay in loading caused by bad weather, it was found necessary to stow the 140 tons of plates in the 'tween deck, although the metacentric height of the ship would only have been some 7·5in. had it been stowed in the hold. The result of placing this 140 tons of cargo 6ft. 6in. higher than the bottom of the hold, gave the vessel a list of 8° to starboard and to counteract this, a ballast tank on the starboard side of the double bottom was emptied. The effect was to destroy the stability of the ship, which heeled over to port, flooding the double-bottom compartments and coal bunkers. The bridge and both masts fouled the quay and were carried away and the vessel toppled over on her port side, allowing the water to pour down the hatches and finally capsizing and sinking with the loss of two lives. According to the finding of the Marine Court of Enquiry which sat on the 11th January to ascertain the cause of the accident, the master of the vessel was entirely to blame.—*"Schiffbau", Vol. 40, No. 5, 1st March, 1939, p. 83.*

New Rules for Classification and Construction of Steel-built Ocean-going Vessels of German Lloyd.

The revised Rules of the German Lloyd, which came into force on the 1st December, 1938, contain a number of alterations and amendments as compared with the previous (1934) issue. The most important changes concern loss of class for vessels whose freeboard is reduced below that laid down for them. As regards ships built 20 or more years ago, extensions in classification are only to be granted in exceptional cases and subject to satisfactory annual surveys of hatches and steering gear, these surveys being additional to those already prescribed for retention of class. Bi-annual surveys of double bottoms and the lower plating of the outer shell from inside, are also to be carried out. The changes in regard to the Rules for New Construction include revised regulations concerning rudders and steering gear; keels, stern- and stern-posts; double bottoms; frames; outer plating; deck beams; decks, superstructures; raised quarter decks; watertight bulkheads; tanks; hatches; special types of vessels (passenger ships and fishing vessels); tank vessels for the carriage of oil in bulk; separation of engine- and boiler-rooms; masts and rigging; riveting; tests for watertightness; equipment (anchors and cables).—*"Werft* x *Reederei* x *Hafen", Vol. 20, No. 5, 1st March, 1939, pp. 67-68.*

New Glen Liner Launched in Hong Kong.

The twin-screw motorship "Breconshire" recently launched by The Taikoo Dockyard and Engineering Company, Ltd., in Hong Kong, is the largest vessel ever built in a British Colony. She is one of two ships ordered from the same builders for the Glen Line Ltd., and will be of about 10.000 tons gross, with dimensions 475 × 66 × 38ft. The propelling machinery will consist of two sets of 2-stroke double-acting Diesel engines built by Burmeister & Wain, each engine having six cylinders of 620mm. diameter and 1,400mm. stroke. The total power to be developed will be 14,000 i.h.p., giving the vessel a speed of 16 knots.—*"The Shipping World", Vol. C., No. 2, 385, 1st March, 1939, p. 325.*

First Twin-screw Tug with Kort Nozzles Built in India.

Trials of the "Sir Francis Spring", the first twin-screw tug fitted with Kort nozzles to be built in India, were carried out recently at Calcutta, when a mean free speed of 10·9 knots and a steady standing pull of 16¼ tons were obtained with the engines developing 970 i.h.p. and 820 i.h.p., respectively. A further trial carried out after delivery at Madras recorded a standing pull of 17 tons with an assessed i.h.p. of 870. As the designed power was 900 i.h.p., the standing pull to be expected *without* Kort nozzles would be between 11 and 11½ tons, so the effect of the nozzles was to enable a pull of more than 50 per cent. in excess of this figure to be obtained. The tug was built by the Hooghly Docking and Engineering Co., Ltd., of Howrah, Bengal, for the Madras Port Trust, the propelling machinery and Kort nozzles being sent out from England. The displacement on trials was 480 tons, the general dimensions of the vessel being 95 × 30 × 15ft. with a maximum draught (loaded) aft of 12ft. 6in., and a propeller diameter of 7ft. 6in.—*"Shipbuilding and Shipping Record", Vol. LIII, No. 10, 9th March, 1939, pp. 299-302.*

New Insulating Material.

A new material has recently been adopted for insulating magazines and provision chambers in foreign warships building in British yards, and for the insulation of cold chambers in merchant ships. This material, known as Onazote, is a rubber compound, expanded by an inert gas, with a highly cellular form showing a uniform structure of minute cells, each of which is sealed by rubber compound membranes. The material has a density less than half that of cork (4½lb./cu. ft.) and possesses structural strength allied with insulation efficiency. It is claimed to be practically impervious to moisture. N.P.L. tests show that the thermal conductivity amounts to only 0·19 B.Th.U./hr. per sq. ft. per 1in. thickness, and 1° F. difference in temperature. A sample immersed in water for 12 months proved to have an absorption of water equivalent to a film of 2-3mm. on the surface, while a further sample immersed for 235 hours absorbed only 0·6 per cent. by weight, which was restored back to within 0·02 per cent. of the original weight after exposure at room temperature for 48 hours. The material is stated to be hygienic and incapable of absorbing microbes, bacilli and other bacteria-forming organisms, and it is also claimed to be non-inflammable. A further feature is the cleanliness in handling due to the hard moulded outer skin. Despite its strength, Onazote can be cut and shaped with a sharp knife. It is suitable for use as a general insulating medium in all cases where the temperature range is below 200° F.—*"The Journal of Commerce", (Shipbuilding and Engineering Edition) No. 34,665, 9th March, 1939.*

New Vessels for Trade Between Eire and Germany.

The Deschimag Shipyard of Westermünde has just delivered the newly-built cargo steamers "Norderau" and "Süderau" to a Hamburg firm of shipowners engaged in the trade between Eire and Germany. The vessels have been specially designed for the requirements of this trade and are equipped for the carriage of live cattle. The "Norderau", like her sister ship, has a gross tonnage of 1,430 tons and dimensions of about 248ft. × 41ft. 6in. × 14ft. 3in. The machinery and boilers are located aft, as is also the bridge, in order to leave the upper deck clear and to allow of unusually large hatches being provided. There are three of these, one of them having a length of about 42ft. 6in. The covers of the forward hatch are of steel. In addition to the usual cargo-handling equipment, there are special facilities for the embarkation and landing of cattle, the 'tween deck being fitted up for their accommodation with removable cattle stalls. The propelling machinery consists of a simple compound engine with two cranks, in conjunction with an exhaust turbine, the total power developed being 1,500 h.p. at 95 r.p.m., and giving the vessel a speed of 13 knots. Under normal conditions, however, the power developed is usually 1,280 h.p., of which 830 h.p. is provided by the engine and 450 h.p. by the turbine. Steam is supplied by two natural-draught cylindrical boilers. The living accommodation for the officers and crew is exceptionally comfortable the crew being berthed in single- and double-berthed cabins, with a messroom on the upper deck.—*"Werft* x *Reederei* x *Hafen", Vol. 20, No. 5, 1st March, 1939, pp. 71-72.*

Mechanical Stokers in Dover-Dunkirk Ferry Steamer.

A demonstration of mechanical stoking was recently given to representatives of the technical and daily press in the S.R. train ferry steamer "Shepperton Ferry". This vessel has now been in service for three years and the performance of her Taylor mechanical stokers has been satisfactory in every respect. The boiler-room was noticeably clean and the temperature in it was moderate, while the operation of the plant was reasonably silent. A steady steam pressure was maintained by the mechanical stokers throughout a series of manœuvres involving changes from "full speed" to "stop" and *vice versa,* in the course of which very little smoke was observed at the funnel. The coal regularly used for the ship's four Yarrow boilers is slack from the Kent coalfields, such as cannot be burnt economically by hand firing, the vessel's normal consumption being about 24 tons per 24 hours.—*"Fairplay", Vol. CL., No. 2,913, 9th March, 1939, p. 480.*

"Odd" Forms of Diesel Drive.

Speaking at a recent informal luncheon of the Society of Consulting Marine Engineers, Mr. A. C. Hardy referred to the increasing popularity of the electro-magnetic slip coupling as compared to other types of geared Diesel drive. It was estimated that only 2·3 per cent. of a total of 15¼ million tons gross of motor shipping afloat to-day had geared drive, and this low percentage might be attributed to the fact that only special considerations involved the adoption of indirect drive for Diesel engines. Dividing the types of drive into electrical and mechanical, Diesel-electric types were sub-divided again into direct current and alternating current, either of which could be used for electro-magnetic slip couplings. An advantage of Diesel-electric propulsion was that the propelling motors could be situated as far from the main engine or generating room as was practicable, the only physical connection being small cable ducts containing the wires required to convey the current; this enabled greater space to be devoted for cargo-carrying purposes. Diesel mechanically-geared drive could be either through gears—reduction and reverse—or through a clutch, as used in a 2,000-h.p. yacht with a V-type engine; or through a flexible coupling operating with oil, a form found convenient for a single-screw vessel operating in ice, where a low propeller speed, with full engine control, was required. Geared drive employing electro-magnetic couplings was taking the place of hydraulic couplings and had proved adaptable to varied requirements.—*"The Shipping World", Vol. C., No. 2, 385, 1st March, 1939, p. 320.*

The Royal Mail Liner "Andes".

The passenger liner "Andes", launched at Belfast on the 7th March, will be the largest vessel which the Royal Mail Company has so far commissioned, the fastest British liner to sail from the United Kingdom to South America, and the largest merchant vessel to be launched from a British shipyard during the whole of 1939. She will be completed in about six months and is due to sail on her maiden voyage on the 26th September, the centenary anniversary of the Royal Mail Company. The "Andes" will be a two-class ship with accommodation for 403 first-class and 204 second-class passengers. The principal dimensions of the ship are: length overall, 669ft.; breadth moulded, 83ft.; depth moulded, 47ft.; gross tonnage, about 26,000. There are four complete decks in addition to the lower and orlop decks, the hull being divided into 12 watertight compartments, and the continuous double bottom is arranged to hold fresh water, water ballast and oil fuel, the fore peak being a fresh-water tank and the aft peak a tank for oil fuel or water ballast. Deep fresh-water tanks are arranged in No. 1 hold, also between and at the sides of the shaft tunnels. Deep oil fuel tanks of large capacity are arranged right across the vessel forward of the machinery space. There are three cargo holds forward of the latter and two aft. Some of the refrigerated cargo space will be cooled by air coolers, while others will have a system of brine grids. The main propelling machinery will consist of two sets of single-reduction geared turbines of Parsons type, driving twin screws and taking superheated steam at a pressure of 430lb./in.^{2} from Babcock-Johnson water-tube boilers arranged for forced and induced draught. There is also a single-ended Howden-Johnson oil-fired boiler for auxiliary purposes. Electric power will be supplied by three turbo-generators and two Diesel generators, the latter being intended for harbour use. All the cargo and boat winches will be electrically driven, the steering gear having two 120-h.p. motors, while the windlass and two after warping winches are run off 100-h.p. motors.—*"The Shipping World", Vol. C., No. 2, 386, 8th March, 1939, pp. 349-350.*

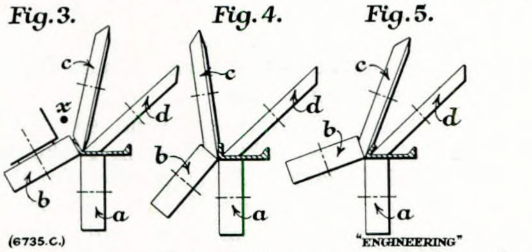
New Turbo-electric German Liner for South American Trade.

The Hamburg-American Line s.s. "Orizaba" launched at the Deutsche Werft in Finkenwärder, on the 11th February, 1939, is intended for the company's service to Cuba and Mexico. She is a single screw vessel of 4,500 tons gross, with dimensions 425ft. × 55ft. 6in. × 34ft. 6in., the d.w. capacity being 6,250 tons and the draught, fully loaded, about 24ft. There are four holds and hatches, with 14 electric winches and derricks, two of the latter each having a lifting capacity of 50 tons. There is accommodation for 12 passengers in five double- and two single-berthed cabins, with a dining-saloon and a smoke-room, while an extensive sun deck affords facilities for exercise. The propelling machinery is turbo electric and consists of two A.E.G. turbo generators supplied with steam by two high-pressure oil-fired La Mont boilers, and providing the current for the propeller motor and all auxiliary purposes. The service speed is 15 knots. Two sister ships of the "Orizaba" are building for the same company.—*"Werft x Reederei x Hafen", Vol. 20, No. 5, 1st March, 1939, p. 72.*

Bevelling Machine for Ship-frame Sections.

A special purpose machine designed for bevelling ship-frame sections has been put on the market by a Düsseldorf engineering firm, and is capable of dealing with angles up to 7¾in. by 7¾in., and bulb angles up to 15in. by 3⅞in. The bevelling operation consists in bending one flange of, say, an angle-iron. so that it makes either an acute or an obtuse angle with the other flange, in place of the original right-angle formed when the section is rolled. The bevelling is carried out by means of four rollers marked *a, b, c* and *d* in the sketch. The cylindrical roller *a* and the coned roller *d* are carried on axles running in fixed bearings, and maintain the position shown under all conditions, while the rollers *b* and *c* are carried on axles mounted in a swinging frame enabling the two rollers to be moved as necessary. The cylindrical rollers *a* and *b* are driven by a reversible electric motor, and serve to propel the section through the machine. The coned rollers run free in their bearings, and are driven only by the friction between their surfaces and the material being bevelled. They serve to maintain the necessary pressure between the work and the driven rollers, and their positions may be adjusted to suit the thickness of the section by means of two large handwheels at the top of the machine. The angular position of the rollers *b* and *c* is adjusted by means of a separate reversible electric motor, either when the machine is stopped or while bevelling, an indicator in front of the operator showing the position of the rollers. For convenience in operation the machine is intended to be mounted adjacent to an oil-fired furnace, the bevelled sections being

Fig. 3. **Fig. 4.** **Fig. 5.**



delivered to a working platform on which bending or other operations may be carried out. It is recommended that the sections should be heated to a temperature of about 1,800° F. before their removal from the furnace by means of a rod clipped to one of the flanges. They are then drawn forward by a wire rope passing over the windlass pulley of the machine, driven by the motor which operates the swinging frame carrying the rollers *b* and *c*. The draw-rod is passed through the machine in the position indicated at *x* in the sketch (Fig. 3). The winch is then started and the section drawn forward until it is gripped by the rollers, being guided in a straight line by means of adjustable guide pulleys at the front and rear of the machine. The positions of the rollers for bevelling the flange to an obtuse or acute angle are shown in Figs. 3 and 5, respectively. The bevelling is completed in a single operation, and no fin is left on the section. An indicator in front of the operator shows the amount of material which has run through the machine, and by observing it he can produce finished sections bevelled at one angle for part of their length, and at another angle for the remainder. The machine is mounted on traversing wheels, driven by the motor which operates the swinging roller-frame and the windlass.—*"Engineering". Vol. CXLVII, No. 3,817, 10th March, 1939, pp. 287-288.*

Cooling Water and Corrosion.

In the cooling systems of Diesel engines corrosion may assume serious proportions unless checked in its early stages. The main causes of such corrosion may be: (1) Air entrapped in the circulating water; (2) Chemical action of rubber joint rings on adjacent metal; (3) Galvanic action between dissimilar metals in contact. Where salt water cooling is employed, corrosion from whatever cause is naturally accelerated. The corrosion of cylinder liners in the upper portion of the entablatures is generally due to air in the cooling water and the fitting of breather cocks in the entablatures immediately below the liner flanges is recommended in the manner shown in Fig. 1. Two cocks at right angles to the inlet connections should suffice for even the largest cylinders. Breather cocks at other points in the system may prove of benefit, but as it is sometimes difficult to maintain control of cooling water outlet temperatures in tropical waters, it should be borne in mind that the tapping of the system by a number of breather cocks causes a loss to that portion of it between the cocks and the final discharge equivalent to the quantity of water issuing from these breather cocks. The design and layout of cooling systems is occasionally defective due to the lack of proper provision for the elimination of cooling water turbulence, the exclusion of

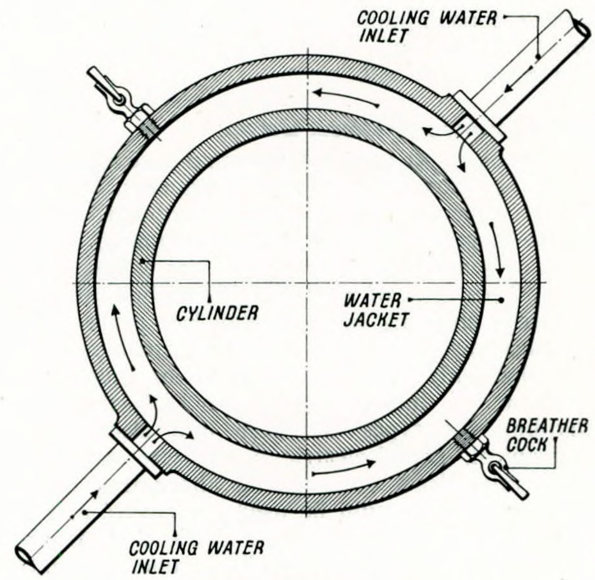


Fig. 1.—Arrangement of breather cocks.

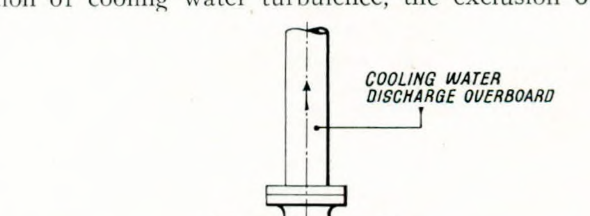


Fig. 2.—Unsatisfactory layout of piping.

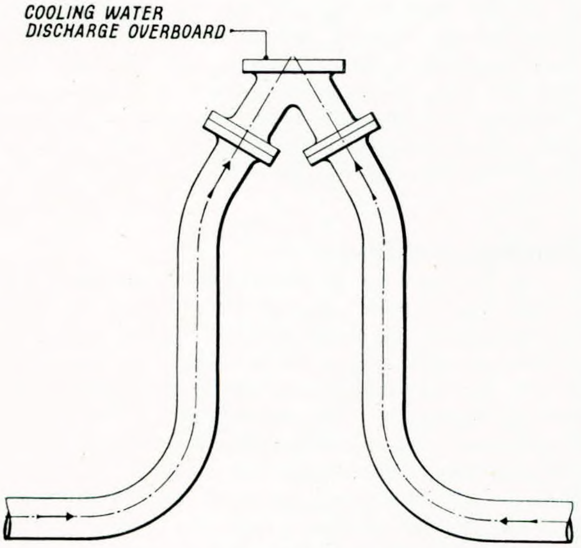


FIG. 3.—Suggested piping arrangement.

air pockets and failure to ensure that minimum power is required to circulate the water through the system. Two examples of bad pipe layout are shown in Figs. 2 and 3. In one case the tee-piece produces unnecessary turbulence and throttles the quantity of water passing, while in the other a more efficient water flow is secured by a somewhat more costly and complicated pipe arrangement. Similarly in Fig. 4, the outlets from the individual cylinder heads should be inclined in the direction of flow, as indicated by dotted lines. Attention to such details would ensure a more efficient circulation and temperature control and would also reduce the load on the circulating pump. The sulphur acquired by rubber during the vulcanising process of manufacture sometimes causes corrosion of the metal adjacent to a joint ring, and for this reason, all such joint rings should be supplied to a specification providing for a guaranteed minimum amount of sulphur. This type of corrosion frequently occurs at the lower joints of cylinder liners, where the cooling water is more or less stagnant, the inlet to the jacket being generally situated much higher up towards the liner flange. Such corrosion may be entirely prevented by covering the rubber rings with a solution made up of red lead, copal varnish, and iron cement. The mixture may be introduced

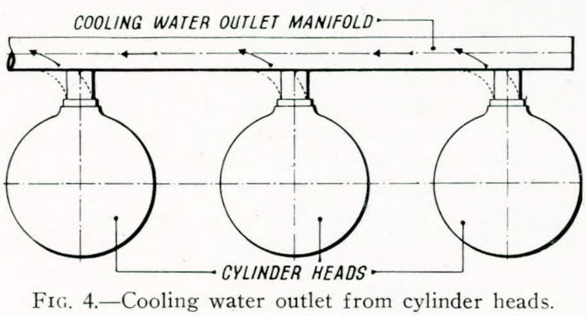


FIG. 4.—Cooling water outlet from cylinder heads.

through the cleaning handholes usually provided in the bottom of the entablature, and should be only just sufficiently fluid to flow around the liner. An added advantage is that leakage of cooling water into the crankcase at this position may be prevented, a common source of trouble due to the expansion and contraction of the liner and consequent "working" of the rubber joints in the extension. It is good practice to keep the by-pass valves which are usually fitted between the cooling water manifold and liner extension, just cracked off the face, in order to prevent the water in the jacket at this position lying stagnant. The valves must not be opened too far after the red lead mixture is introduced, however, as some of the latter might be washed upwards. Corrosion through galvanic action is not necessarily due to dissimilarity of metals, but it sometimes occurs in the oil coolers and compressor intercoolers of motorships, as these usually have a cast iron shell with alloy tube plates and tubes. Zinc plates to check this type of corrosion are generally fitted in such oil coolers. Failure of the sheet Muntz metal bursting discs of compressor intercoolers, is sometimes due to corrosion adjacent to the cast iron shell. This defect may be remedied by tinning the discs on the water side, care being taken to see that the thickness when tinned does not exceed that originally specified. Steel spindles of circulating water pumps also give rise to this form of corrosion, where the body and impellers are of alloy. Such spindles should be turned down and sleeved with bronze to a point just above the gland at the earliest opportunity.—*L. J. Holman, "Shipbuilding and Shipping Record", Vol. LIII, No. 12, 23rd March, 1939, pp. 372-373.*

The Problem of Motion with Submerged Wings.

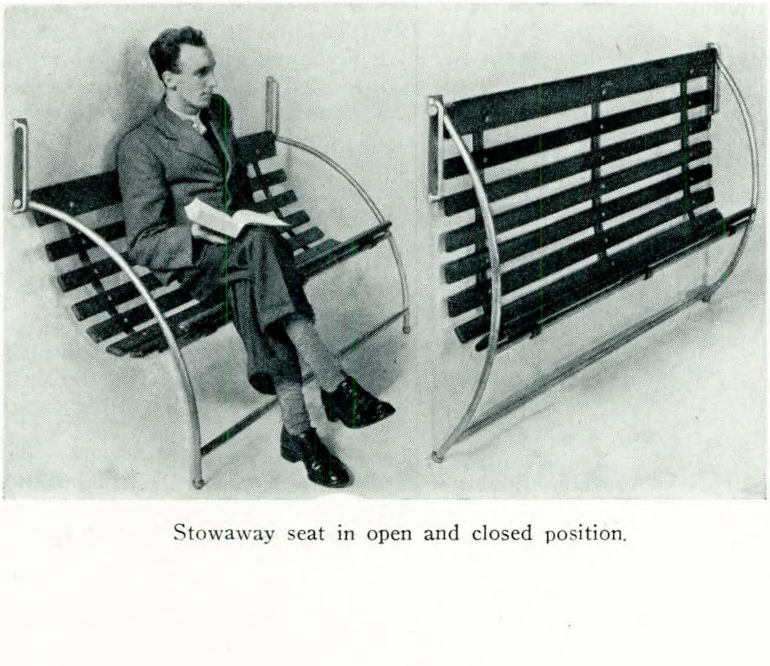
The article is intended to amplify the information contained in one by I. I. Benoit which appeared some months ago (*see abstract on p. 110 in "Transactions of Institute of Marine Engineers", Vol. L., No. 7, August, 1938,*). The first part of the article deals with the hydrodynamic values of submerged wings and their various forms and designs. The hydrodynamic value of an aeroplane wing in water is stated to be about 4 per cent. below that of its aerodynamic value in air. The author then refers to the effect of a gliding plane on a submerged wing and points out that in the case of certain designs of boats equipped with submerged wings, only a partial emersion of the hull from the water is contemplated, whereby the wings would be moving in a disturbed flow caused by the hull while the boat was in motion. In craft in which the entire hull is lifted out of the water by the action of the submerged wings, the effect of the hull on the latter would only be felt prior to complete emersion. The factors which affect the influence of the hull on the submerged wings are discussed in detail, and the position of the submerged wing in relation to the hull is likewise examined. The question of cavitation of submerged wings travelling at high speeds is referred to, as is the fact that a number of experiments for determining the nature of this cavitation have been carried out. The stability of the horizontal motion of submerged wings and the effect of these on propellers, are other points dealt with in the article. The author's conclusions indicate the complexity and difficulties of the problem of motion on the surface of the water by means of submerged wings. The greatest obstacle to a satisfactory solution of this problem is presented by cavitation, and it is considered that this will limit the possibility of utilising submerged wings for gliding boats to speeds of from 55 to 60 miles an hour. Above these speeds it is probable that the usual type of hydroplane will prove more efficient. The article contains a number of formulæ and equations and gives graphs and tables of values in connection with the various points discussed in it, and there are also a number of diagrams and illustrations of various types and sections of submerged wings.—*A. N. Vladimirov, "Soudostroienie", No. 7, 1938.*

A Folding Deck Seat.

The Stowaway deck seat compact is a folding deck seat designed for positions against deckhouses, bulkheads, bulwarks and rails, and is illustrated in the accompanying photograph. When not required the seat can be closed in to the bulkhead, stowing in a space only 8¾in. deep, and giving extra deck room when required. Furthermore, the decks can be more easily hosed and swept with the seat in its closed position. When necessary, the seats can be readily unshipped and stowed below, or warehoused, being so designed that they nest one inside the other, occupying a minimum space. The seat sparring is secured to weather-resisting rubber-fabric straps, which permit the seat to adjust itself to the user and therefore add to comfort, while the frames are of welded steel tubing and, like the necessary bulkhead fittings, heavily galvanised. The seats are made in three standard sizes: 6ft. 4in., 4ft. 10in., and 3ft. 4in., or in special sizes to suit the space available, and are now being adopted in Admiralty and other vessels.—*"Shipbuilding and Shipping Record", Vol. LIII, No. 11, 16th March, 1939, p. 334.*

Distribution of Power.

In the opinion of the well-known Italian naval engineering expert General Rota, based on experiments carried out in the tank of Spezia, higher propulsive results might be obtained by fast liners driven by quadruple screws if the power were divided unequally. He suggests that in vessels having engines of from 120,000 to 160,000 s.h.p., from five-eighths to three-quarters of the total power should be transmitted through the inner screws because of the greater propelling efficiency there prevailing. Some Italian battleships have been powered on this principle which was likewise adopted in the C.P.R. liner "Empress of Britain", where the total power of 60,000 is transmitted through two inner shafts delivering 20,000 s.h.p. each, and two outer shafts 10,000 s.h.p. each. This arrangement was actually adopted not from any consideration of propulsive results, but in order that the two outer screws might be put out of use when the vessel was cruising. The high standard of performance of the ship indicates that General Rota's opinion should be given serious consideration, although in the case of very large and high-powered vessels it would be impracticable to increase the torque on the inner shafts as at the present time the transmission of more than, say, 50,000 s.h.p. through one shaft, would not appear to be advisable.—*"Shipbuilding and Shipping Record", Vol. LIII, No. 12, 23rd March, 1939, p. 355.*



Stowaway seat in open and closed position.

New Motorship for Service on German Rivers.

The motorship "Aken" recently completed by the E. Menzer Shipyard of Geesthacht/Elbe represents the last word in German ship construction to meet the present-day requirements on inland waterways. The "Aken" is a steel-built vessel with an overall length of 188ft., a beam of 24ft., and a moulded depth of 7ft. 3in., flush-decked except for a raised poop. The six cargo holds of the ship have a total capacity of 587 metric tons and are lined with wood throughout. The hatch covers are of corrugated steel. The draught of the vessel when fully loaded is only 6ft. 6in. The officers and crew are berthed forward and in a deckhouse on the poop, above which is the navigating bridge and wheelhouse, the latter being made removable for passage under low bridges. The rudder is of the twin type developed by the shipbuilders. The propelling machinery is located aft and comprises an 8-cylinder single-acting four-stroke Humboldt-Deutz Diesel engine developing 500 b.h.p. at 500 r.p.m. In service, however, the normal power developed will be about 300 b.h.p., at 375 r.p.m., the corresponding fuel consumption being about 0·36lb. per b.h.p./hr. A 5-kW. dynamo is driven off the main engine and supplies current at 24 volts for the ship's lighting system. The compressed air carried in two 7½ cu. ft. bottles suffices for up to 30 manœuvres of the main engine. A Deutz-Diesel engine is also fitted for driving a centrifugal pump and a compressor with a capacity of 565 cu. ft./hr. which enables either of the bottles to be filled to a pressure of 450lb./in.^{2} in under an hour.—*B. Ehrenreich, "Werft* x *Reederei* x *Hafen", Vol. 20, No. 6, 15th March, 1939, pp. 79-80.*

Strength of Marine Engine Shafting.

The paper deals with the strength of marine engine shafting based upon experience and the result of thorough investigation of causes of failure. The contributory factors to failure of crankshafts are considered to come under two headings: (A) Additional loading due to torsional oscillation, malalignment caused by excessive wear-down of bearings, and axial crankshaft vibration. (B) Defective forgings, and bad shrink fits. In addition to these causes, it has been found that shafting is subjected to fatigue loading in rough weather. The author discusses various factors, *viz.,* Material. (Results are given for the fatigue strength of steel taken from large forgings; also for the calculated and measured values of torsional vibration stresses). Torsional vibration. Axial vibration. Alignment of shafting. Shrink fits in built-up crankshafts. Rough-weather stresses. (A method of measuring rough-weather stresses on shafting is described and some results obtained are given). Propeller shafts. Geared systems. The relative importance of gas or steam loading is also discussed. There are nine appendices dealing with: (1) Calculations of natural frequency, determination of torque harmonics in the case of oil engines, triple-expansion and quadruple-expansion reciprocating steam engines. Effect of reciprocating masses on the input energy to the vibration. (2) Determination of axial stiffness of crankshafts. (3) Frequency of axial vibration of crankshaft with thrust as node. (4) Determination of axial vibration of shafting aft of the thrust, with thrust as node. (5) Axial vibration neglecting effect of thrust shaft. (6) Determination of relation between crankshaft alignment indicator readings and stresses induced in crankshaft. (7) Effect of bending moment on the shrink grip of crank webs. (8) Effect of web dimensions on the shrink grip of crank webs. (9) Phasing of engines and geared systems. A number of tables are included in the text of the paper, which is also illustrated by 46 diagrams and plates.—*Paper read by S. F. Dorey, D.Sc., at a meeting of the N.E. Coast Institution of Engineers and Shipbuilders, on the 24th March, 1939.*

Re-building of the m.v. "Stockholm".

An agreement has been reached between the Swedish American Line, the Cantieri Riuniti d'ell Adriactico Monfalcone, and the underwriters of the motor liner "Stockholm", which was destroyed by fire in the autumn of 1938, for the vessel to be rebuilt in accordance with the original building contract of November, 1936. The new "Stockholm" is expected to be completed towards the end of 1940. Although the hull was entirely destroyed, many parts of the vessel which had not yet been brought on board will be used in the new ship, as will also the propelling machinery and much of the engine-room equipment. The new hull is to be built on the same slip.—*"The Scandinavian Shipping Gazette", Vol. XXIII, No. 11, 15th March, 1939, pp. 416-417.*

Improvements in "Allen" Airless Injection Oil Engines.

In the course of the last 12 months a number of improvements have been introduced in the design and construction of the "Allen" S.37 oil engine. This is now termed the S.37-B., and is a 6-cylinder engine developing 480 b.h.p. at 450 r.p.m., of unusually sturdy construction, with crankshaft journals of 9in. diameter, round section hollow-bored connecting-rods, and massive cast steel white metal lined crankhead bearings. The cylinder heads, secured by six bolts, are of deep section, giving improved design of water passages, while the cylinder liners have been made slightly thicker. The "C" frame used for earlier engines has now been discarded in favour of "A" frame construction. Although this has involved the abandonment of the desirable feature of being able to withdraw the crankshaft without dismantling the whole engine, the general accessibility to the main and crankhead bearings is excellent. Among other minor improvements is a new and simplified air starting arrangement with automatic valves in each cylinder head, and a separate control valve for each cylinder operated from the air starting cam. This arrangement enables the engine to be started on any number of cylinders, and in the case of engines with six or more cylinders, starting can be effected without the necessity of barring round to a starting position.—*"The Queen's Engineering Works Magazine", No. 36, 1939, pp. 62-63.*

An Electric Engine-indicator Unit for High Speed Engines.

A well-known firm of electrical accessory manufacturers in the U.S.A. has recently produced an electrically operated engine-indicator device for accurate and reliable measurement of rapidly changing cylinder pressures. It is claimed that the instrument is free from the inaccuracies due to friction and inertia of similar mechanical devices and that it is both sensitive and easy to operate. The apparatus consists of a pressure unit, a cathode-ray oscillograph, an amplifier and a synchronizer unit. The pressure unit, unaffected by temperatures up to 660° F., and designed to withstand pressures of up to 5 000lb./in.^{2}, consists of two quartz crystals mounted in a stainless steel tubular holder which is screwed into a threaded hole in the cylinder head. A piston at the lower end of this holder transmits the cylinder pressures to the crystals, being held in place by a diaphragm which permits pressure variations to reach the crystals. Electrical changes exactly proportional to the pressures are imparted to an electrode between the crystals, and conducted to an output cable, the charges being in exact proportion to the pressures and varying instantly with the latter. It is stated that the apparatus possesses the following characteristics: (1) Easy tracing of pressure curves of any form of dynamic pressure; (2) Simple and accurate location of any point on the diagram in respect of the crank angle; (3) Simple electrical calibration of pressure at any point in the pressure diagram; and (4) Great flexibility, enabling recordings of complete engine-cycles in single curves to be made, or detailed studies of any part of a cycle to be carried out. The instrument is suitable for all engine speeds of over 1,000 r.p.m., but its use is not recommended for speeds under 500 r.p.m.—*"Marine Engineering and Shipping Review", Vol. XLIV, No. 3, March, 1939, pp. 104-105.*

Husun Navigating Equipment.

In order to test the accuracy of the Husun echo-sounding equipment at high speds, the Argentine Naval Commission submitted seven destroyers and a cruiser built by British shipbuilders, to a series of rigorous tests for speed and manœuvrability set by the standard of modern warship performance. Two excerpts from records made by the Admiralty echo-sounders with which these ships were fitted by the makers of this equipment, were taken while one of the destroyers was steaming at 32 knots and 36 knots respectively, the latter being made during the turning trials carried out at that speed. In neither case did the rapid movement through the water and change of direction have any adverse effect on the reception of soundings, which was distinct and consistent throughout.—*"The Syren", Vol. CLXX, No. 2220, 15th March, 1939, p. 539.*

Babcock-Johnson Water-tube Boilers.

When the Royal Mail Company's motor liners "Asturias" and "Alcantara", originally equipped with 4-stroke double-acting Diesel engines of 14,500 b.h.p., were re-engined in 1934 by replacing the internal-combustion engines with Parsons geared turbines and Johnson water-tube boilers working at 450lb./in.^{2}, the speed of the vessels was increased from 16 to 18½ knots, as the turbines developed 24,000 s.h.p. at 140 r.p.m., although the new installation was, in each case, accommodated in the old machinery space. This was only made possible by the utilisation of highly rated boilers, the Johnson type of water-tube boiler being so designed that the furnace is completely surrounded by water tubes, so that the furnace floor and end as well as the sides and roof of the combustion chamber are water-walled. The resultant evaporation of steam per foot of total heating surface is very high without undue forcing of the boiler. In the "Asturias" a rate of about 9lb. of steam per hour was attained, a figure quite 90 per cent. in excess of that usually expected from water-tube boilers of a more orthodox type. Owing to this high rating the Johnson boiler can be made considerably smaller and lighter than a boiler of the ordinary type having the same output. In the case of the "Asturias", the total weight of the boilers, including the water, superheaters and air heaters, is only 250 tons, which is about half the normal weight, while the space occupied by the boilers is approximately two-thirds of that usually required. Babcock-Johnson boilers are being used in the new Royal Mail steamer "Andes", and as the boiler-room arrangement in this vessel is not subjected to similar limitations, an improved performance should result.—*"Fairplay", Vol. CL., No. 2914, 16th March, 1939, p. 531.*

Combined Oil and Gas Engine.

An internal combustion engine which can use gas or oil or both as fuel, is being developed by a British engineering firm in the Midlands. This improved gas-oil engine has cylinder heads differing slightly from those of a normal Diesel engine in having a separate passage for gas as well as for air admission, both being admitted through a common inlet valve. Each inlet valve has separate gas control allowing stratification of the gas charge, by means of a throttle valve in the elbow pipe leading to each cylinder, so that there is individual control to each cylinder. No mixture regulation such as is provided in the normal gas engine is necessary, and when it is desired to change from gas to oil operation, a cock in the gas main is shut off and the output of the Diesel fuel injection pumps is increased. When running on gas, ignition of the charge is effected by oil injection as in a Diesel engine, and for this purpose the fuel injection pumps are regulated down to the minimum injection point, amounting to about 5 per cent. of the normal fuel output. Thus the engine runs as a 95 per cent. gas engine with 5 per cent. of oil fuel to take the place of the magneto and sparking plugs. As ignition is effected by the heat of compression, the engine is of the high compression type, the actual compression ratio being about 14½ to 1. If required, the engine can be run on any ratio of gas and oil fuel, but in practice it is better to run it either as a "straight" Diesel engine or as a gas engine with 5 per cent. fuel oil for ignition. An interesting feature of the engine, apart from the fact that its power output is the same on either fuel, is that the exhaust gas temperature is the same whether it runs on oil or gas, although, normally, the temperature of a gas engine's exhaust is appreciably higher than that of an oil engine of equivalent rating. At the present time such gas-oil engines have only been built in stationary form, but they will doubtless attract considerable attention for marine work.—*"The Shipping World", Vol. C., No. 2,387, 15th March, 1939, p. 378.*

Trials of U.S.S.R. Light Cruiser "Taschen".

The new Soviet light cruiser "Taschen", built at Leghorn by the Orlando Company, recently carried out her acceptance trials between Spezia and Genoa. The cruiser has a length of about 455ft., a beam of about 45ft., and a displacement of 3,000 tons. The propelling machinery consists of two sets of geared turbines, working with high-pressure superheated steam, and developing a total of 110,000 s.h.p. The armament consists of six 5·1-inch guns arranged in three twin turrets, six 1½-inch A.A. guns, six 13mm. heavy machine guns and three 21-inch triple torpedo tubes. In the course of her full power trials the vessel attained a speed of over 45 knots, the average speed being 44·8 knots.—*"Journal de la Marine Marchande", Vol. 21, No. 1041, 16th March, 1939, p. 376.*

Rubber Mountings for Small Marine Diesel Installations.

Anti-vibration mountings with resilient rubber inserts are being increasingly used in connection with the propelling and auxiliary machinery for small motor vessels, Diesel-engined small craft, etc., and flexible couplings in which the use of rubber allows a certain degree of lateral as well as angular movement, have also proved efficacious. Such couplings have now been carried to a stage at which they can even deal with the thrust of a medium-sized propeller. A well-known British firm specialising in this class of equipment, has recently introduced a complete range of marine installation fittings, so that the entire power unit may be insulated from the hull at every point of contact. A flexibly-mounted engine necessitates the provision of allowance for movement between other points of normally rigid attachment, if it is desired to retain the anti-vibration benefits of such mountings. Rubber-bushed propeller A-brackets have already proved successful, but the new equipment enables the tail-shaft to float in the stern tube on ingenious rubber supports which in no way interfere with normal greasing as the lubricant cannot ordinarily come into contact with the rubber, although where such a risk does exist a special grade of rubber, unaffected by grease and oil, is employed. In the case of a lengthy intermediate shaft which requires support by a plummer block, a bonded rubber pad mounting is utilised. The rubber is vulcanized to the metal in such a manner that if great strain is imposed in a testing machine, the rubber will ultimately tear, leaving a considerable portion still adhering to the metal and thus proving that the breaking strain of the rubber is not so great as the adhesion. Where bulkhead glands for propeller shafts are required, these are fitted with grease lubrication in conjunction with a rubber annulus. Apart from the insulation this method affords, a small degree of misalignment does not impose additional strain or wear on the shaft. A choice of several types of fitting is available for pipework. In some instances it is possible to make use of a special corrugated hose of exceptional strength. When this is slipped over the end of an unprepared metal pipe no form of nipple is required for attachment, as the rubber provides a perfect joint which cannot blow off or come adrift, owing to the double recessed nuts which hold the end of the hose rigidly. The corrugated construction affords a very high degree of flexibility to the attachment. Where a pipe has to pass through the ship's side, as in the case of a water inlet, the hull fitting is provided with a specially moulded rubber joint and the securing nut, which is screwed home from inside the hull, beds down on the rubber, so that no metal part is actually in contact with the hull of the vessel or boat. No bolts are required for this form of mounting. The same firm is developing a new marine pump in which the pistons of the horizontally-opposed cylinders do not come into contact with the walls, a seal being provided by a substantial circular rubber ring. The latter is round in section and rolls, but does not rub, with the movement of the piston. The pump valves, including the stems, are of rubber and the object of the design is to avoid wear and enable water, in which there is much sand or other solid matter, to be handled indefinitely without harmful effects or fear of choking. A pump of this type is ideal for bilge water and when driven by a ¼-h.p. motor, its output is 500 gallons per hour against a suction lift of 14ft., and a delivery head of 25ft. Such a unit is compact and light in weight and is likewise suitable for deck washing or fire service purposes.—*"Gas and Oil Power", Vol. XXXIV., No. 402, March, 1939, pp. 78-79.*

Slight Damage to Welded Tanker after Grounding.

After the Norwegian motor tanker "Mylla", a vessel 141ft. b.p. and d.w. tonnage of 500 tons, grounded on rocks at 9 knots some weeks ago, she was drydocked at Oslo for permanent repairs. The ship had previously been surveyed and temporarily repaired immediately after the mishap. The "Mylla" is built on the open frame system, the frames not being directly against the shell plating, but joined to it by means of short connecting pieces. After the tanker had been dry-docked, it was found that the stem had been forced in below the waterline, and that the adjacent shell plating had been buckled, but that none of the welded connections had given way and that the plating only showed longitudinal cracks in the vicinity of the stem. Grounding on rocks at a speed of 9 knots would, it is considered, have caused considerably greater damage to a riveted ship, as the rivets would probably have given way for a distance from the stem. As the welded connections of the "Mylla" resisted the strain of the grounding, which only caused the relatively slight damage referred to above, it is concluded that the welded connections were stronger than they would have been if riveted. The grounding also showed that repair work to welded ships is easier and less expensive. Particularly, it is claimed, does the open framing system simplify the repairing of damaged frames, inasmuch as only the damaged part of the frame need be replaced by welding in a new piece of the same shape. A survey of the "Mylla's" hull indicated that notwithstanding the fact that she has been in service for a year and had frequently experienced stormy weather, the vessel had not been affected, and the welded connections showed no more corrosion than the plating elsewhere.—*"The Journal of Commerce" (Shipbuilding and Engineering Edition), No. 34,671, 16th March, 1939, p. 2.*

New Messageries Maritimes Liner for Far Eastern Service.

The Messageries Maritimes recently placed an order for a new motor liner for the company's service to China and Japan, with the Société Provençale de Constructions Navales. The vessel will have a length of about 597ft., a beam of 75ft. 9in., and a moulded depth of 44ft. 6in., with a mean load draught of 27ft. The propelling machinery will consist of three sets of 2-stroke, single-acting, airless-injection Sulzer Diesel engines, having 11 cylinders each and driving triple propellers, the power developed being 30,000 h.p.—*"Journal de la Marine Marchande", Vol. 21, No. 1,041, 16th March, 1939, p. 376.*

New Elder Dempster Motor Vessel for African Service.

The Elder Dempster passenger and cargo motorship "Seaforth", built by the Caledon Shipbuilding and Engineering Co., Ltd., Dundee, for the West African trade, completed her trials in February, 1939. She is a vessel of the open shelter deck type, with complete main and lower decks, a well-raked rounded-plate stem and cruiser stern. A poop and forecastle are built over the shelter deck, and a large deckhouse is arranged amidships. The ship has an overall length of 388ft., a moulded breadth of 52ft. 6in., and a depth to shelter deck of 33ft. 6in., the deadweight capacity being 6,000 tons and the gross tonnage 4,124 tons. There are four holds for general cargo, and deep tanks amidships at each end of the machinery space for the carriage of palm oil. The cargo-handling appliances comprise three 7-12 ton derricks at each hatch, in addition to a 50-ton derrick at the foremast and a 30-ton derrick at the mainmast. There are 10 electrically-driven winches and an electric windlass, the steering gear being of the electric-hydraulic type, with an Oertz streamlined rudder. Magazines for the carriage of explosives are arranged forward and aft of No. 1 hold on the lower 'tween deck. and there are separate rooms for baggage, bonded cargo and mails. Large refrigerated chambers are also provided. There is accommodation for passengers in 8 single- and 2 double-berthed cabins, with a dining saloon, lounge and veranda, the latter being at the after end of the promenade deck. The ship is also arranged to carry deck passengers along the coast, the forecastle providing shelter, a native galley and conveniences. The propelling machinery consists of a 4-cylinder Doxford opposed-piston balanced oil engine, having cylinders of 560mm. diameter by 2,160mm. combined stroke, developing 3,100 b.h.p. at 120 r.p.m., and giving the ship a service speed of 13 knots in loaded condition. The scavenging-air blower, circulating water and lubricating oil pumps are driven off the main engine, the other engine-room auxiliaries being electrically driven, with current at 220 volts d.c. supplied by three Diesel-driven generators, each developing 82 kW. at 400 r.p.m. A Cochran alternative exhaust-gas or oil-fired boiler, with 510 sq. ft. heating surface, is fitted, the working pressure being 120lb./in.^{2}. The steam-driven auxiliaries and equipment include an air compressor, an evaporator and distiller. On trials, a mean speed of 14·82 knots was attained.—*"Shipbuilding and Shipping Record", Vol. LIII., No. 11, 16th March. 1939, pp. 332-334.*

A Passenger-carrying Oil Tanker.

The tanker "San Jorge", recently completed for the Argentine State Oil Monopoly by Blohm and Voss of Hamburg, is intended to carry oil in bulk from the State-owned oilfields at Comodoro Rivadavia to Buenos Ayres. The design and construction of the vessel involved some difficult problems for the builders owing to the unusual requirements to be fulfilled, as not only did the tanker have to possess a d.w. capacity of 11,500 tons but she had also to provide accommodation for 32 first-class and 28 third-class passengers, a special suite of cabins for the President and his retinue, and exceptionally comfortable accommodation for the 74 officers and men of her crew. Moreover, the trial speed of the tanker was to be 15 knots and the propelling machinery had to be of a simple and robust character suitable for operation by local personnel. The "San Jorge" has an over-all length of 545 ft., a moulded breadth of 62ft., and a moulded depth of

35ft. on a maximum draught of 25ft. 6in., and displacement of 18,200 (metric) tons. The gross tonnage is about 10,000 tons. The hull is all-welded, with 15 watertight bulkheads, extending to the main deck. The 26 cargo tanks have a total capacity of 611,000 cu. ft., and there is also stowage for about 42,500 cu. ft. (bale) of general cargo between the fore peak and the forward cargo tank. The propelling machinery is aft and the double bottom under it is arranged to carry 810 tons of oil fuel, 71 tons of Diesel oil and 145 tons of feed water. The ship's fresh water tanks are right aft and hold 277 tons. The propelling machinery consists of a triple expansion engine of 7,000 i.h.p., with cylinders of 36¼in., 59in. and 98in. diameter, and a stroke of 59in., taking steam at a pressure of 213lb./in.^{2} and temperature of 608° F. from four oil-fired cylindrical boilers, each with a heating surface of about 3,541ft.^{2}, equipped with superheaters and air heaters. In addition to the usual engine-room auxiliaries, there is an electrically-driven air compressor in the well-equipped engineers' workshop. Most of the auxiliary machinery is electrically driven, as are the winches and steering gear, the total number of electric motors in the ship being 72. Electric current at 110 volts d.c. is supplied by two 200-kW. generators driven by two four-cylinder 4-stroke Diesel engines. There is also a 50-kW. emergency dynamo driven by a three-cylinder 4-stroke Diesel on the main deck. The cargo pumping equipment comprises four 200-ton and two 60-ton steam-driven pumps arranged in two compartments. There are extensive refrigerated chambers abaft the main engine-room, the refrigerating machinery being electrically driven. The tanker is fitted with unusually complete steam and CO_2 fire-fighting equipment, two W/T transmitters, two W/T receivers, echo-sounding gear, a W/T direction finder, an electric fire alarm system, electric clocks, loud speakers in the public rooms and a number of other electrical appliances.—A. Keller and J. Hencke, *"Werft x Reederei x Hafen", Vol. 20, No. 5, 1st March, 1939, pp. 58-66.*

Flue Gas Protection for Ships' Tanks.

The paper refers to the need for special precautions for the protection of tankers engaged in the transport of valatile petroleum products, both because of the large investment and of the concentration of risk involved. The manner of formation of explosive mixtures in ships' tanks is reviewed, and it is shown that most of the danger from explosion can be avoided by excluding air from the tanks, supplying in its stead an oxygen-lean flue gas, to take the place of the oil when cargo is discharged. The equipment of a complete flue gas system, and the manner of its operation, are briefly described. Experience has shown that the revised operating routine required in a flue-gas-equipped ship is easily acquired, and that operators are generally appreciative of the greater ease of handling and improved conditions. The pressure made available is a direct aid to getting suction on the ships' cargo pumps, and a virtual necessity when handling casing-head petrol cargoes having a high vapour pressure. The author points out that without special equipment the presence of explosive mixtures in ships' tanks at certain times is the rule rather than the exception, and that it appears unwise to place the full burden of avoiding accidents on the enforcement of safety rules, particularly since some sources of ignition may be beyond the control of the operators. The use of flue gas offers a means of providing additional safety, and in view of the important advantages and the general improvement of conditions presented by the operation of a flue-gas system, the expense involved by its installation is believed to be warranted.—*Paper read by O. W. Johnson, Ph.D. (of the Engineering Dept., Standard Oil Co. of California) at a meeting of the Institute of Petroleum, on the 14th March, 1939.*

Portable Combustible Gas Indicators in the Oil Industry.

Urgent need for new equipment frequently provides the necessary stimulus for the adaptation and perfection of well-known principles, and the Author states that his company's experience in this respect is a case in point, for when research into the manner of formation of explosive gas mixtures in petroleum tanks emphasized the need for an improved method of making analyses in the field, it was found that the application of principles discovered 30 or more years ago and virtually unused since that time, enabled some of the problems involved to be overcome. The development of portable combustible gas indicators is described in the paper, with special reference to the present-day J.-W. Indicator. Some of the more important uses of such indicators are discussed, emphasis being placed on the advantages of continuous sampling and analysis on the spot as an aid to the intelligent direction of various processes where explosive mixtures may be encountered. In connection with tank cleaning, it is pointed out that the presence of men working in or around tanks which are in the explosive condition constitutes a hazard to be avoided as far as possible, and that gas-freeing to make the tank safe from explosion should be the first step in the cleaning process in order to bring about a considerable reduction of the time during which the tank remains subject to possible ignition. The author discounts the prevailing belief that residual sludge may sometimes provide a source of combustion gas and thereby preclude the possibility of effective ventilation. He is of opinion that if the bulk of the liquid oil is drained off or floated off with water and the tank then ventilated down to one-fifth or less of the lower limit concentration, the balance of the cleaning process, including sludge removal, can (with continual ventilation) be carried out without the tank again becoming explosive, provided of course, that the whole process is guided by tests made as often as necessary to establish the conditions actually prevailing in the tank. Examples of the successful use of the above procedure under adverse conditions are given. The author concludes by expressing the hope that an increasing knowledge of the ease and accuracy with which field tests for gas concentration can be made, will serve to further extend the use of these methods to this end, and that increasing economy in operation will be accompanied by an improvement in safety.—*Paper read by O. W. Johnson, Ph.D. (of the Engineering Dept., Standard Oil Co. of California) at a meeting of the Institute of Petroleum, on the 14th March, 1939.*

Problems of Compressors and Compressed Gases in Industry.

The paper is divided into the following sections: (1) General remarks, (2) thermo-dynamics of air and gas compression, (3) classification of air compressors, vacuum pumps and exhausters, (4) problems in the design of compressors and pumps, (5) testing of air compressors, (6) accessories and their design, (7) lay-out of compressed air installations and problems relating thereto, and (8) uses of compressed and some particular cases. Reference is made to the object and work of the British Compressed Air Society and its publication *Compressed Air Terms and Standards.* The paper is illustrated by 34 diagrams, sketches and plates, and a short bibliography is appended.—*Paper read by R. L. Quertier, B.Sc. (Eng.), at a meeting of the Institution of Chemical Engineers, on the 14th March, 1939.*

The Safety of Electrical Apparatus for Use in Inflammable Gases and Vapours.

The paper deals with the design of operation of the various electrically-operated devices which are intrinsically safe for use in atmospheres containing petroleum vapours, the difference between such intrinsically safe electrical apparatus and flame-proof enclosures being indicated. Electrical equipment in industry is divided into three main groups:—

(*a*) Power plant, such as heavy electric motors, switchgear, transformers, etc.;

(*b*) Communications, such as signalling bells, telephones or other light-weight equipment requiring small current; and

(*c*) Lighting, either from power mains or by self-contained portable or semi-portable equipment.

The equipment under each of the above headings is discussed from the aspect of its safety when in contact with inflammable gases and vapours, and reference is made to the machinery which exists at the present time for the official testing and approval of intrinsically safe electrical apparatus for use in industries other than mining. The authority concerned is the Mines Department Testing Station which makes type tests for and on behalf of the Chief Inspector of Factories, Home Office, who on receipt of a satisfactory report from the Testing Station, issues a certificate of approval, accompanied by a schedule of relevant and essential data of design, together with certified drawings. Some of the apparatus for which such Home Office certificates have been issued, is enumerated by the author.—*Paper read by Capt. C. B. Platt, M.B.E., at a meeting of the Institute of Petroleum, on the 14th March, 1939.*

Protection from Dangerous Gases in Oil Tanks.

The paper deals with the dangers of empty tanks, explosive and inflammable limits, the Home Office Regulations concerning the gas-freeing of tanks, cleaning and vapour-freeing, the treatment of various products, testing for inflammable vapour, the taking of samples, electric testing methods, flame testing methods, potential sources of vapour, the removal of water and residues, and the precautions to be taken in vapour testing work. The apparatus for detecting inflammable vapours is briefly described and an illustration of the latest type of Redwood vapour detection apparatus is given.—*Paper read by A. W. Cox at a meeting of the Institute of Petroleum, on the 14th March, 1939.*

Flame Arrestors.

The paper begins by pointing out that the occurrence of explosive mixtures in the storage and manipulation of petroleum products, is frequently unavoidable, and that the possibility of explosives must be reckoned with. The actual purpose of the paper is to describe the working of so-called "flame-arrestors" and their installation, in order to prevent either a flame or an explosion from the outside from entering and igniting a space containing an explosive vapour, and also to ensure that an explosion should not spread between two spaces interconnected by a vapour line. The text is illustrated by four sets of diagrams, two sets of curves, and three plates.—*Paper read by H. H. Radier (of the Bataafsche Petroleum Mj., the Hague) at a meeting of the Petroleum Institute, on the 14th March, 1939.*

Books on Air Conditioning.

Air conditioning may be defined as the simultaneous control, by a mechanical device, of the temperature, humidity, and motion of cleaned air in an enclosed space, such as a room, building, or the like. Industrial and domestic applications of air conditioning have increased to such an extent in recent years that a considerable volume of literature on the subject has been published. Current developments and trends are recorded in the technical press, and many books dealing with the general subject of air conditioning have appeared. To meet a demand for general information regarding such literature, the Canadian National Research Council has compiled *A List of 63 Recent Books on Air Conditioning,* with particulars of their contents, publishers and prices. The list is believed to contain the majority of the books dealing specifically with comfort air conditioning that have appeared in the last two years. Copies may be obtained from the Research Plans and Publications Section of the National Research Council, Ottawa, Canada, at 1s. per copy.—*"Ice and Cold Storage", Vol. XLII, No. 492, March, 1939, p. 34.*

On the Gas Evolution in Petrol Storage-tanks Caused by the Activity of Micro-organisms.

In a series of preliminary investigations it was found that a varied microflora inhabits the water-bottom of oil storage-tanks even where the tanks are used for the storage of purified oils only, including kerosine. It was also found that this microflora includes types which reduce sulphates to hydrogen sulphide and nitrates to nitrogen. The paper discusses the bearing of these observations on the problem of the evolution of gases in oil storage-tanks. The work described by the author was carried out as part of the programme of the Chemistry Research Board, and is published by permission of the Department of Scientific and Industrial Research.—*Paper read by A. C. Thaysen, M.Sc., Ph.D., at a meeting of the Institute of Petroleum, on the 14th March, 1939.*

Fundamental Reflections on the Application of Welding in Mercantile Shipbuilding.

The paper deals with the application of welding to ship construction from the standpoints of financial economy and the improvement of the ship in structure and efficiency, in order to (1) save in weight and costs; (2) secure a higher strength by means of welding in comparison with any riveted connection; and (3) to obtain a reduction in the total costs of shipbuilding. After a detailed consideration of these three points, the author proceeds to define the practical limits for the application of welding in a mercantile shipyard by stating that:

(*a*) Everything that can be welded in the workshop must be welded there.

(*b*) Most detailed working preparation is necessary in the drawing office in arranging for the sub-division of the hull into suitable welding units, the weight of which can be easily handled by the workshop equipment and lifting appliances available for the purpose.

(*c*) Welding should not be attempted where riveting can be done more easily, more quickly, and more cheaply.

(*d*) Welding on the slip must be reduced to a minimum, and confined to work where high strength and tightness are required, or where a simple joint will suffice.

(*e*) Single components must always be welded in the shop in order to reduce the building period.

The paper concludes by a detailed description of the method of welding double bottoms, watertight and oiltight bulkheads, decks and hatches, shell plating and framing. The text is illustrated by 31 plates depicting welding operations in a German shipyard.—*Paper read by Dr. William Scholz (of Hamburg) at a meeting of the N.E. Coast Institution of Engineers and Shipbuilders, on the 10th March, 1939.*

Bearing Metals for High-speed Engines.

The development of high-speed internal combustion engines has taxed very considerably the orthodox white bearing metals, and much research work has been carried out in recent years on bearing alloys of superior properties, capable of withstanding the severe conditions now being imposed. This experimental work has led to the development of the copper-lead, hardened lead, cadmium-base, and silver-bearing alloys, all of which have done much to meet these new conditions. The copper-lead and cadmium-base alloys have been used chiefly in the U.S.A., and the lead-base or hardened lead alloys in Germany. All these alloys are now being used to an increasing extent in this country, not only in the motor-vehicle and aircraft industries, but also to a more limited extent in marine and general engineering. The use of silver for bearing purposes is of more recent development, experimental work on this metal having been carried out in the U.S.A. Copper-lead bearing alloys usually contain from 25 to 45 per cent. of lead, the remainder being copper, sometimes with the addition of small amounts of other elements, such as tin or silver, the most recent addition being 1 per cent. of lithium, in order to reduce segregation tendencies. Copper-lead alloys have excellent bearing properties where very high loads must be sustained, especially at high temperatures, and also where over-stress may occur. Their strength however, is low due to their dendritic structure, and they are subject to failure by fatigue cracking. The addition of tin causes a change in this structure which increases the strength sufficiently to prevent fatigue cracking, but, because of the difference in structure or some other effect of the tin, the alloy is not as good a bearing, and in times of overstress may seize. Tin additions also reduce the anti-score properties, which in any case are well below those obtainable with white bearing alloys. When properly cast, either by ordinary or centrifugal methods or by coating mild steel strip, followed in either case by proper cooling, copper-lead is firmly bonded to the steel with copper only. Cadmium-base alloys consist essentially of cadmium with a small proportion of nickel or of tin and silver or of tin and magnesium. Such alloys have a higher tensile and compressive strength, a greater hardness and a higher fatigue value than tin-base alloys or hardened lead alloys. They give a good bond on steel, the bonding alloy being a eutectic of zinc and cadmium. Cadmium-base alloys are susceptible to corrosive attack by hot oil, but such attack may be retarded by plating iridium on to the finished bearing. The addition of 1 to 2 per cent. of tin and small proportions of other elements such as calcium, cadmium, arsenic, copper, sodium or magnesium, has the effect of hardening lead and rendering it suitable as a bearing metal with properties superior to those obtained in white bearing alloys, except that such alloys are more susceptible to corrosive attack. Lead hardened bearings are being increasingly used for many types of internal-combustion engine bearings. The failure of copper-lead alloys and copper-lead-tin alloys in aircraft engines (in the case of the former due to fatigue cracking, and the latter to seizing in times of over-stress) has led recently to the consideration of the possibilities of silver or silver-rich alloys as bearing materials. Experimental work has shown that silver has a better seizure resistance than either of the alloys mentioned, and that the purer the silver the greater the seizure resistance. Additions of any elements to silver are harmful to the seizure resistance; some elements, such as antimony, calcium and phosphorus, are very undesirable, while others, such as lead, tin, zinc and cadmium, are less harmful. Silver adheres strongly to steel, but is difficult to bond and behaves erratically in engine tests, due, it is believed, to a lack of oiliness. To overcome this lack of oiliness in silver bearings, experiments are being carried out to alloy silver with some element, such as lead or sulphur, which forms a separate phase and does not show oiliness effects or to blend the oil with some additional medium, such as sulphur, which wets the surface of the silver and so promotes oiliness.—*"Foundry Trade Journal", Vol. 60, No. 1,177, 9th March, 1939, p. 209.*

Naval Expenditure on Motor Boats.

Particulars of the expenditure on motor torpedo boats and other naval motor craft—apart from those carried on board warships—are given in the recently-issued Navy Estimates for 1939. The average cost of the nine 60ft. type 18-ton M.T.B.'s Nos. 7, 10-12, 14 and 15-18, all equipped with three Power-Napier engines, was a little over £31 000 per boat, the machinery cost averaging £16,500. Vosper's M.T.B. No. 103 and Nos. 20-30, 70ft. boats, of which four are now under construction, are to cost about £51,400 per boat, the machinery cost averaging £38,000 per boat. The two 70ft. 32-ton Thornycroft M.T.B.'s Nos. 24 and 25, equipped with three Isotta-Fraschini engines, will cost £107,580, the expenditure on the machinery being £83,254. The 67ft. 22-ton M.T.B. under construction by J. S. White & Co., Ltd., will cost £51,190, the machinery costing over £37,000. Provision for another M.T.B.—not yet ordered—is made in the Estimates, to the extent of £50,408, including £35 000 for the machinery. Four motor landing craft—Nos. 14-17, built by Philip & Son, Ltd., and two, Nos. 18 and 19, built by the Rowhedge Ironworks, cost respectively £30,384 and £12,125 in all, whilst another craft of this type, evidently much larger, is provided for to the extent of £20,000, of which £4,000 is for the machinery. Two "motor vessels" built by the British Power Boat Co., Ltd., are stated to have cost £37,263, whilst there are five "motor vessels Nos. 2-6" also by that firm and coming within the financial year 1939 for completion, which are estimated to cost £95,621 in all. The six further M.T.B.'s to be ordered will involve an expenditure of £129,285 in 1939, indicating that they will not be completed this year.—*"The Motor Boat", Vol. LXX, No. 1,807, 10th March, 1939, p. 241.*

Foreign Motor Tankers Purchased by French Firm.

The Société Française de Transports Pétroliers, founded last year, purchased five modern tankers in September, 1938, and have now added two further units to their fleet by the purchase of the Dutch tanker "Loosdrecht" and the Danish tanker "Henning-Maersk". Both vessels were completed by the Odense Shipyard (Denmark) in 1936, and are sister ships of 9,314 gross tons, with a deadweight capacity of 14,500 tons. The approximate dimensions of the tankers are 504ft. × 65ft. 6in. × 36ft., and the propelling machinery, in each case, consists of a supercharged 4-stroke Burmeister & Wain seven-cylinder Diesel engine of 3,500 h.p., the cylinder diameters being 740mm., and the stroke 1,500mm.—*"Journal de la Marine Marchande", Vol. 21, No. 1040, 9th March, 1939, p. 339.*

New Dutch Motor Liner with Asea Couplings.

On the 25th January, 1939, the keelplate of a new motor liner for the Rotterdam Lloyd Company was laid in the Royal De Schelde Company's Shipyard in Flushing. The new ship, which is designated by the number 214, will have a length of about 613ft., a breadth of about 62ft. 4in., and a mean draught of some 29ft., with a gross tonnage of 21,000 tons. The propelling machinery will consist of eight Sulzer Diesel engines each of 4,040 h.p. running at 215 r.p.m. and driving twin screws through reduction gearing and Asea electro-magnetic couplings at 150 r.p.m. At full power the speed of the vessel is to be 22 knots, but the prescribed service speed of 21 knots is to be attained with 27,000 h.p., and this should enable the ship to make the passage from Marseilles to Batavia in 16 days, thereby gaining four days on the present length of the voyage. The new ship is to have accommodation for 750 passengers and will be manned by a crew of 425. She is expected to be ready for service by the spring of 1941.—*"Journal de la Marine Marchande", Vol. 21, No. 1040, 9th March, 1939, p. 339.*

The Detection of Turbulence by Listening.

Many devices have been used to study the flow of streams of fluid in order to find the stream direction and velocity, and particularly to locate regions of irregular motion, eddies, and turbulence. The ear is a ready and very sensitive means of detecting fluctuations of pressure, and so can well be applied in any method of testing depending on small variations of pressure. An ordinary stethoscope can be connected to a device such as an impact tube facing upstream, the open end of the tube being hit by the rush of fluid. As the tube is moved it is found that in regions where there is good reason to know that the flow is steady, the observer hears little or nothing in the stethoscope, but on bringing the exploring head or tube to a solid boundary or other obstruction, a hissing is heard, greater in intensity just where disturbances are known to be greater. If the tube is inclined to the streamlines, a diminution of sound is noticed, which serves to indicate the direction taken locally by the stream, while if the tube is held at right angles to the stream in a disturbed region, the sound does not quite disappear if the tube has a simple end with thin walls. The same method can be used to explore the state of flow at the actual surface of an aerofoil by substituting a series of small holes drilled normally into the surface at various points, for the movable exploring tube. By coupling the stethoscope to these holes in turn, it is possible to detect violent disturbances and thus to analyse conditions closer to the surface than would be possibel with a movable tube of finite dimensions. The aural method is, of course, not intended to replace the impact tube but to supplement it. The latter, as ordinarily used, does not reveal turbulence because the frequency of variation of pressure is too high for any response by the usual type of manometer. The only effect of turbulence is that readings of the dynamic pressure are obtained which are too high by an amount not greater than $\frac{r.q.^2}{2}$, where r is the density and q is the average turbulence velocity, which varies rapidly in magnitude and inclination, and is usually small compared with the velocity of the main stream. The impact tube does not discriminate between the turbulence energy and the kinetic energy due to the main current. Disturbances of extremely high-frequency could doubtless be transmitted effectively to some pressure-sensitive instrument capable of quick response, such as an oscilloscope, but even so, the listening method is particularly useful. The most rapid small-scale turbulence, such as occurs in mid-stream, may indeed escape proper discrimination by the human ear, but the coarser turbulence such as occurs round about the regions where energy loss is taking place will easily be detected. The listening method can also be co-ordinated with other tests. For instance, when the tube is dragged along the surface of, say, an aerofoil, a hissing reveals the onset of turbulence in the boundary layer, before the layer has thickened sufficiently to give general breakaway of the stream. The ear will respond readily to sounds involving a variation of pressure represented by one hundred-millionth of an inch of water, but if ever greater delicacy is required, then the microphone and the thermionic valve will provide almost inconceivable magnification and, of course, greater precision than unaided human senses. The research method arose in the course of tests on forms of blading for steam turbines in one of the laboratories of the Metropolitan-Vickers Electrical Company, Ltd.—*B. Hodkinson, M.Sc., Journal and Proceedings of the Institution of Mechanical Engineers, Vol. 141, No. 1, March, 1939, pp. 27-28.*

High and Low Water Alarm for Water Tube Boilers.

The Yorkshire firm of valve manufacturers who recently placed a new automatic emergency closing valve on the market, are also producers of a high and low water alarm device for water-tube boilers operating at pressures up to 900lb./in.^{2}. The arrangement consists essentially of a vertical cylindrical steel chamber containing a float, and two steam valves, outside the boiler shell, to which it is connected by two small-bore pipes. One of these connects the top of the steel chamber to the steam space of the boiler and the other leads from the bottom to the water space, so that the water in the chamber is always at the same level as that in the boiler. The chamber contains a ball-type float connected to a horizontal spindle actuating two steam valves, so that when the water reaches predetermined levels, too high or too low, a steam valve is opened to admit steam to one or other of the whistles, which are of different tone. The whole device is relatively small in size and extremely sensitive in operation.—*"Industrial Power", Vol. XV., No. 161, February, 1939, pp. 59-60.*

A New Rotary Displacement Pump.

A novel design of rotary vane pump with a constant volumetric discharge, which is claimed to eliminate many of the disadvantages of the vane type of pump, has recently been introduced by a well-known Tyneside engineering firm. The pump is designed to run at high speed for long periods without appreciable wear. The rotor is concentric with the casing bore, causing the vane tips to bear truly across their whole width when forming a seal between the suction and discharge sides of the pump, thereby maintaining a liquid film between the casing wall and the vane tips and ensuring that no actual mechanical contact takes place. Movement of the vanes is mechanically controlled by means of a double cam and rollers at each end of the rotor. The vane is supported for its full radial length when in the outward position by slot extensions in the end flanges of the rotor. When in the outward or loaded position, and functioning as a separating wall between the suction and discharge side of the pump, the vane is stationary in the slot, but when it begins to move inwards to pass over the reduced radius of the separating division, the following vane which is then stationary in the slot, acts as a seal. As the fluid is admitted to the slot on the under side of the vane, the space occupied by the latter has a displacement value equal to its full width. The discharge is consequently perfectly uniform, ensuring silent running and enabling high speeds to be maintained.—*"Shipbuilding and Shipping Record", Vol. LIII, No. 12, 23rd March, 1939, p. 370.*

Welded Boiler Drums.

A description of the methods employed in the U.S.A. and Germany in the welding of boiler drums and shells, was recently given by Dr. S. F. Dorey in a paper read before the Liverpool Engineering Society. He mentions that welded boiler drums are manufactured by two processes, which might be generally termed forge-welding and fusion-welding. The welding of boiler drums is in its infancy in the U.K., but over 100 fusion-welded boiler drums have been constructed in this country for export. At the present time fusion-welded boiler construction has almost completely superseded riveting and forge-welding in the U.S.A., not only for pressure vessels in the oil and chemical industries, but also for both land and marine boiler construction. In 1930, the boilers of three U.S. light cruisers were built with fusion-welded joints. The four largest manufacturers in the U.S.A. have, between them, constructed more than 10,000 fusion-welded pressure vessels of various sizes up to 14ft. in diameter and 10ft. in length, with thicknesses up to 5½in. The author then deals with forge-welding and remarks that the main factors which affect the quality of the weld are: (*a*) Material; (*b*) welding technique; and (*c*) heat treatment. He briefly describes the classes of material generally used for the purpose, the welding technique adopted in Germany, and the heat treatment applied. The highest standard of forge-welding cannot, however, produce physical test results comparable with those obtained with fusion-welding. Dr. Dorey states that the latter process had until comparatively recently been used for boiler drums only in the U.S.A., but that both British and Continental boiler manufacturers have now come to appreciate its advantages. These comprise: (1) Increased thickness of large cylindrical shells above that considered safe for riveted construction, and for manipulation; (2) elimination of caustic cracking at the riveted seam; (3) more uniform distribution possible, due to reduction of local stress concentration and stiffness at riveted joints, and also to thermal stress relieving, and (4) reduction in total weight of the boiler. In the U.S.A. the present practice is for practically all drums of water tube boilers to be of fusion-welded construction, while in Germany developments also indicate that an increasingly large number of boilers are being built with fusion-welded drums, particularly where drums of heavy plate thickness are required on account of high pressures. The author refers to the reluctance displayed in this country to adopt this method of boiler construction and to the British preference for forged drums, which, he anticipates, will have to be abandoned in the course of time owing to the progress made in fusion-welded boiler construction. Dr. Dorey also deals with the materials, welding technique and heat treatment of this method of boiler manufacture, and concludes his paper with a few remarks on X-ray examination and testing procedure, which he observes, if combined with a very careful inspection at various stages in the construction of a boiler drum, ensure the production of a safe and reliable welded structure.—*"Lloyd's List and Shipping Gazette", No. 38,810, 22nd March, 1939, p. 18.*

Wear-built Geared Turbine Cargo Vessel.

The geared turbine cargo steamer "Silverlaurel", built by Joseph L. Thomson & Sons, Ltd., Sunderland, for the Silver Line, is an open shelter deck vessel with lower 'tween decks, 465ft. 1½in. in overall length, 58ft. 8½in. in moulded breadth, and 39ft. 3¾in. in moulded depth to the shelter deck. At the load draught of 26ft. the d.w. is 9,750 tons and the gross tonnage 6,142. The ship has a raked stem and cruiser stern, the stern frame being of cast steel, with a semi-balanced streamlined double-plated rudder. Three deep tanks to carry 2,500 tons of oil cargo are provided, the fuel oil being carried in the double bottom and engine-room side tanks. No. 2 upper and lower 'tween decks are arranged as insulated spaces for refrigerated cargo, the refrigerating machinery being electrically driven. Welding has been extensively used in the construction of the ship. The officers and engineers' accommodation is in a large house amidships, where there are also five double-berth and two single-berth staterooms for passengers, a dining-saloon, smoke room and lounge. The crew are berthed aft. The propelling machinery consists of a set of high-pressure, intermediate and low-pressure turbines arranged in series, driving a single screw through reduction gearing. The service power is 4,500 s.h.p. at 110 r.p.m., the astern turbine giving 65 per cent. of the ahead power. Steam at a pressure of 400lb./in.^{2} and temperature of 750° F. is supplied by two five-drum Yarrow-type water-tube boilers, fitted with superheaters and vertical tubular air heaters. The total heating surface of both boilers is 6,000ft.^{2} and they are arranged to burn oil only under the forced draught closed air-duct system. There are also two vertical boilers, each with a heating surface of 1,100ft.^{2}, supplying saturated steam for auxiliary purposes at 125lb./in.^{2} under natural draught conditions. There are two 40-ton evaporators for make-up feed and ship duties. The auxiliary and deck machinery is steam driven, but electric current for lighting and other purposes is supplied by two 25-kW. 110-volt steam-driven generator sets and two 60-kW. 200-volt sets driven by Diesel engines. The trials of the ship were carried out with about 3,500 tons of ballast and fuel oil on board, and the power to be developed by the turbines limited to 3,600 s.h.p. The vessel was run continuously under these conditions for 24 hours, the fuel consumption being 26 tons per day for all purposes. The mean speed of the ship during three runs over the measured mile at this power, was 14·8 knots, the designed service speed at 4,550 s.h.p. being only 14·5 knots.—*"Fairplay", Vol. CL., No. 2915, 23rd March, 1939, pp. 588-589.*

Intensive Feed-water Heating.

The use of auxiliary exhaust is always the most economical method of heating feed water. since heat is being recovered from what would otherwise be waste. The temperature of the feed water entering a boiler of an installation equipped with an exhaust steam heater only, and working at 200lb./in.^{2} (and therefore a steam temperature of 387·5° F.) is generally about 200° F. A second-stage heater can increase the feed temperature by about 100° F., and result in a saving of 100 per cent. in coal consumption, while with water-tube boiler installations, where it is sometimes the practice to pass superheated steam through a de-superheater or steam cooler instead of taking saturated steam direct from the drum for auxiliary purposes, the possibilities in feed heating are greatly increased, as this steam may be utilised for a further stage of feed heating, thereby obtaining still greater economy. If funnel gases are used exclusively for air heating and exhaust steam for feed-water heating, there is a double gain, as heat is here recovered and the rate of heat transmission increased. The nearer boiling-point the temperature of the feed water entering a boiler, the greater will be the efficiency, and the economy achieved thereby will amply compensate for the extra cost of the equipment required.—*"The Journal of Commerce" (Shipbuilding and Engineering Edition), No. 34 677, 23rd March, 1939.*

Economical Diesel-powered Dredge.

A new Diesel-powered dredge working on the Ohio River near Careyville, Kentucky, is setting up a record for low-cost gravel production, by producing 60 cubic yards (100 tons) of road gravel at a fuel cost of less than $0·35. which is equivalent to about 0·7 pence per ton. The dredge in question is a flush-decked wooden vessel, 74ft. long and 28ft. wide, fitted with an 8in. Holz dredge pump driven by a Cummins-Diesel engine. The latter is equipped with both front and rear drives and runs at 1,200 r.p.m. The rear end drive, through a clutch and outboard bearing, carries a 13·4in. V-belt sheave, from which six D-section V-belts 180in. long, drive the 40·2in. pump sheave at 400 r.p.m. The engine is cooled with river water by a gear-type water pump, no radiator or fan being fitted. The front end drive, which can take the full engine power, consists of a solid coupling, shaft and outboard ball bearing. The shaft carries an 8in. crown pulley driving to a 24in. pulley on a single drum hoist for raising or lowering the suction line of the pump by means of double and triple sheaves on the boom, which has a line pull of about 60ft./min. An 8in. pulley on the same shaft drives a small Gardner-Denver centrifugal pump which provides washing water for the sand and gravel screens, by a flat belt drive. The vertical pumping head from the dredging pump to the screens, including line friction, is approximately 50ft. Pumping is usually done from depths of 12 to 30ft. This Diesel-engined dredge has been in continuous use since October, 1938, working 10 to 12 hours a day, an earlier petrol-engine dredge having been completely destroyed by fire. It is stated that the adoption of a Diesel power unit has enabled sand and gravel to be produced at a cost of from 20 to 25 per cent. below that at which similar petrol-engined dredges working on the same river can be operated.—*"Motorship and Diesel Boating", Vol. XXIV., No. 3, March, 1939, p. 161.*

The Use of Welded High Tensile Steel.

According to G. Schaper in an article recently published in *V.D.I. Zeitschrift,* the steel normally used for constructional purposes in Germany was St.37. with a tensile strength of 23·5 tons/in.^{2}, but St.52, with a tensile strength of 33 tons/in.^{2} was introduced about 10 years ago and has been widely used for bridge construction, building frames, railway vehicles and shipbuilding. The German Navy is said to have had satisfactory experience with welded St.52, the welded joints resisting the stressing due to the motion of the ship in a rough seaway, the firing of heavy guns and various other severe shocks. The German Navy specifies a quench bend test for welds in St.52. A bend test piece of the usual dimensions is heated to 162° F., quenched in oil at 36° F. down to 900° F., and then allowed to cool in air. After this treatment it must be capable of being bent 180° over a rod of diameter equal to twice the thickness. Plates up to 1in. thick with butt and corner fillet welds are used in German naval shipbuilding. In the case of welded railway bridges of St.52, there were several instances of cracking in the welds, and after a thorough investigation it was concluded that the composition of the steel was at fault, the quantity of alloying elements being too great, in consequence of which the rapid cooling of the metal away from the weld led to hardening. and the hardened metal was broken by contraction stresses. As a result of this experience a revised specification for the maximum percentages of the various elements was laid down and an extensive series of experiments to investigate the causes of cracking at welds is now in progress.—*S. M. Dixon, M.A., "Civil Engineering", Vol. XXXIV, No. 393, March, 1939, p. 86.*

"Paper-hanging" a Ship's Bottom.

Built in 1925, the steel hull plating of the American Diesel yacht "Nenemoosha", although of sound construction and workmanship, gradually began to show signs of corrosion, and by 1938 no fewer than 50 holes below the waterline had had to be patched. It therefore became necessary to renew the hull plating of the ship's bottom throughout, and as the dimensions of the vessel were 130ft. long, 22ft. 3in. beam and 7ft. 4in. mean draught, the cost of this work, if carried out in the conventional way by cutting all the old plates off the frames and riveting on new plating, would have been of the order of £10,000. It was, accordingly, decided to simplify the job by leaving the old hull plating intact and sheathing it with a complete new welded hull below the waterline, without disturbing the inner structure. The work was carried out by a Brooklyn firm in 20 working days, with four welders working in two 8-hour shifts, and the total cost was under £3,300. The total amount of material used on the job was 10 tons 50lb. of $\frac{3}{16}$in. plate and welding rod and the consequent increase in the vessel's draught was just over 2in.—*"Motorship and Diesel Boating", Vol. XXIV, No. 3, March, 1939, pp. 148-149.*

High Pressure Machinery for a U.S. Maritime Commission C-3 Cargo Vessel.

An experimental high-pressure high temperature set of propelling machinery is to be installed in one of the six C-3 cargo vessels ordered by the U.S. Maritime Commission in November, 1938. It is stated that the working pressure will be 1,200lb./in.^{2} and although no official information regarding other details is yet available, it is probable that the steam temperature will be 950° F., boiler efficiency 87·5 per cent. and vacuum 28·5in. Under these conditions, with machinery developing 8,000 s.h.p., which is only slightly less than that specified for the C-3 design, a fuel consumption of 0·47lb. per s.h.p./hr. is to be expected.—*"Marine Engineering and Shipping Review", Vol. XLIV, No. 3, March, 1939, p. 102.*

Shop Trials of Machinery of Dutch m.v. "Oranje".

The builders of the Sulzer Diesel engines of the Dutch liner "Oranje", launched at Amsterdam on the 8th September, 1938, guaranteed a fuel consumption of 0·375lb. per b.h.p./hr., plus or minus 5 per cent. Two of the ship's 12,500 b.h.p. 12-cylinder, single-acting 2-cycle Sulzer Diesel engines were installed in the ship without undergoing any test, but the main engine and all five of the 1,800 b.h.p. Sulzer Diesel auxiliary engines were run on the test bed at the builders' works under conditions which were made to approximate as closely as possible to those which will obtain in the ship. The scavenge blowers, lubricating oil pumps, cooling water pumps, etc., were operated by one of the auxiliary generator engines, running at the same time as the main engine. The fuel consumption for the main engine alone was found to be 0·334lb. per b.h.p./hr., while that for the main engine and auxiliaries was 0·368lb. per b.h.p./hr.—*"Motorship and Diesel Boating", Vol. XXIV., No. 3, March, 1939, p. 165.*

The Acid Bessemer Process of Steel-making.

The first part of the paper is in the nature of a historical introduction and gives some notes on the early use of the process in three works with which the authors have been associated. Statistics of production are then quoted and the development and application of the acid Bessemer process in Sweden, Germany, France, the U.S.A. and the U.K. are briefly considered. The plant and process of the Workington Iron and Steel Company are described in detail, the functions and construction of the mixers and converters (old and new) being explained and the operation of casting the ingots set out, followed by some general notes on Bessemer practice. The properties and uses of acid Bessemer steel are dealt with, the points referred to including gases in acid Bessemer steel, oxygen, hydrogen and nitrogen, mechanical properties, wear resistance, reaction to cold working or the work-hardening factor, embrittlement, case-hardening, resistance to corrosion, and creep properties. The authors' concluding remarks stress the fact that there is no justification for the view that acid Bessemer steel is in any way an unreliable material, but that it merely differs from open hearth steel in its degree of response to cold working, although this difference can be minimized where necessary by adjusting the composition of the metal and taking special steps to control the finishing operations. In other directions, this difference in response to cold working is regarded as an advantageous characateristic and full use is made of it. The text of the paper is illustrated by five plates and five drawings, in addition to diagrams showing two sets of curves. There are also 17 tables giving various technical data, while the statistical information given in the paper is amplified by five statistical tables dealing with production in various countries, world output of steel, and average prices of hematite pig iron and heavy steel scrap in this country for the last 30 years.—*Paper by T. Swinden and F. B. Cawley, "Transactions of the Institute of Marine Engineers", April, 1939.*

Extracts.

The Council are indebted to the respective Journals for permission to reprint the following extracts and for the loan of the various blocks.

Aluminium Alloys in Marine Construction.

"The Shipbuilder and Marine Engine-Builder", March, 1939.

While the question of weight reduction in shipbuilding is, as in other forms of transport, one of great importance, the good resistance of aluminium and certain alloys to sea-water corrosion also explains in part the increasing application of this metal in marine construction. In view of the exacting conditions of marine atmosphere, the choice of material requires very careful consideration. While sea-water itself is remarkably corrosive, the submerged portion of a vessel in harbour is liable, in addition, to contamination from decayed matter, and the superstructure is exposed to the destructive combination of spray and air.

Research work on aluminimum and certain of its alloys has revealed many interesting features, and not least the fact that, properly applied, they offer a resistance to corrosion superior to that of many other metals. Alloys in exposed positions, however, vary greatly in behaviour; and before dwelling on actual applications of aluminium alloys in marine construction, a brief description of the most suitable types of alloys may not be out of place.

Casting Alloys.

While many heat-treatable wrought alloys have, in the past, proved to be susceptible to intercrystalline corrosion, research has shown that faulty technique or composition was frequently the cause. In comparison with other metals, aluminium and its alloys have a high solution potential; and if placed in contact with copper, brass or steel in the presence of saline moisture, corrosion will occur. Alloys containing manganese only, or those with percentages of magnesium up to 10 per cent. such as NA. 350 in the cast group, however, offer excellent resistance to marine atmosphere. Test bars in NA. 350 exposed for six months between high and low-tide levels showed only slight brown flecking on the surface at the end of the period. Tensile tests revealed that no deterioration in mechanical properties had occurred. Table I. gives guaranteed minimum figures, together with the properties regularly obtained in production, which, it will be noted, are considerably higher.

TABLE I.—NA. 350 CASTING ALLOY.

	Guaranteed Minima.	Typical Values.
	Obtained on 1in. dia. Sand-cast Test Bars.	
0·1 per cent. Proof Stress, tons/sq. in.	11	13
Ultimate Tensile Stress, tons/sq. in.	16	20
Elongation, per cent. on 2in.	7	11/2
Brinell Hardness No. ...	—	75

The specific gravity of NA. 350 is about 8 per cent. less than that of aluminium alloys of the 4 per cent. copper type, enabling a useful saving of weight to be effected. The impact resistance, high shear strength, elongation and corrosion resistance of NA. 350 alloy indicate the suitability of such castings for a wide range of applications, wherever shock stresses or severely corrosive conditions are met.

Aluminium alloys containing from 5 to 13 per cent. silicon are most useful to the shipbuilder. These alloys possess an excellent combination of properties in relation to corrosion resistance, foundry characteristics, low specific gravity as compared with that of the majority of aluminium alloys, ductility and high impact strength, and are usually selected for large sand castings for marine and general engineering work. A typical alloy in this category is NA. 160, of which the mechanical properties are quoted in Table II.

TABLE II.—NA. 160 CASTING ALLOY.

	Specification BSS.L. 33.	Obtained in 1in. dia. Test Bars.
0·1 per cent. Proof Stress, tons/sq. in.	3½*	4½*
Ultimate Tentile Stress, tons/sq. in.	10½	13*
Elongation, per cent. on 2in....	5	8*

*Values specified for information purposes only.

WROUGHT ALLOYS.

Turning next to the wrought alloys of

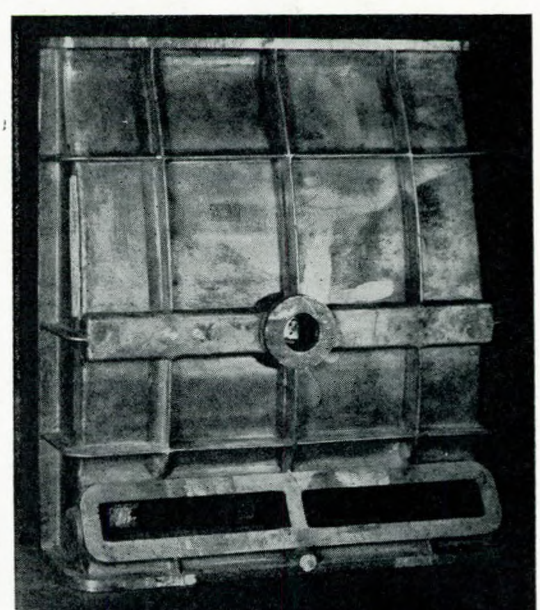


FIG. 1.

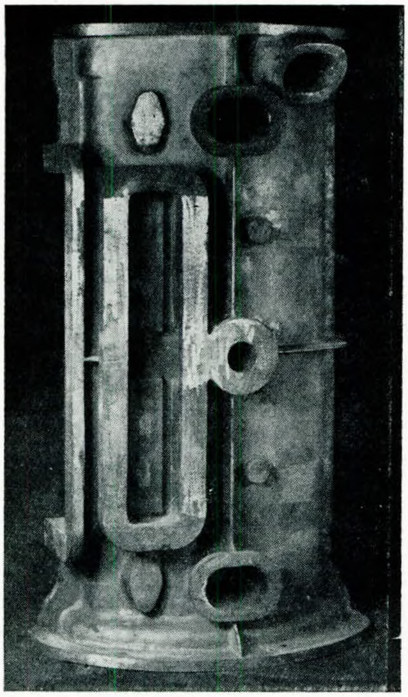


FIG. 2.

aluminium, the addition of manganese to the pure metal produces an alloy having greater strength and hardness, with the same excellent corrosion resistance, but with slightly lower ductility. For marine-construction purposes, an aluminium-manganese alloy usually contains about 1·3 per cent. manganese. It is not amenable to heat-treatment, and is generally used in sheet form, being suitable for a considerable degree of forming.

By the addition of a small percentage of magnesium to the aluminium-manganese alloys, a considerably higher strength is obtained without impairing the corrosion-resisting qualities. NA. 4S alloy belongs to this group. It is a wrought non-heat-treated alloy, produced in the form of sheets, plates, tubes, extruded shapes, bars, etc., and can be recommended for applications in which severe service conditions are encountered. Treated in strong corrosive media such as salt spray, it is not liable to inter-crystalline corrosion, and therefore maintains its strength well. The typical mechanical properties of sheet in the half-hard conditions are given in Table III.

TABLE III.—MECHANICAL PROPERTIES OF NA. 4S½ H SHEET.

0·1 per cent. Proof Stress, tons/sq. in.	14
Ultimate Tensile Stress, tons/sq. in.	15½
Elongation, per cent. on 2in.	6

One of the latest additions to the range of work-hardened alloys is NA. 57S. It is a wrought non-heat-treated aluminium-magnesium-chromium alloy with somewhat higher ultimate strength and higher ductility than NA. 4S. Its behaviour under conditions of exposure shows that NA. 57S is one of the best corrosion-resisting alloys produced, and the various tempers have practically the same resistance to corrosive attack. One of the great advantages is that, when subject to salt-spray attack, it is not liable to inter-crystalline deterioration. NA. 57S has better forming properties than NA. 4S, and is suitable for an even wider range of applications. In the half-hard conditions the figures are as given in Table IV.

TABLE IV.—NA. 57S½ H SHEET.

0·1 per cent. Proof Stress, tons/sq. in.	13½
Ultimate Tensile Stress, tons/sq. in.	16½
Elongation, per cent. on 2in.; thickness of 12 gauge and upwards	7

The foregoing notes have dealt mainly with alloys in cast and sheet forms, which constitute the bulk of the tonnage of aluminium hitherto used. Extruded sections in aluminium alloy have, however,

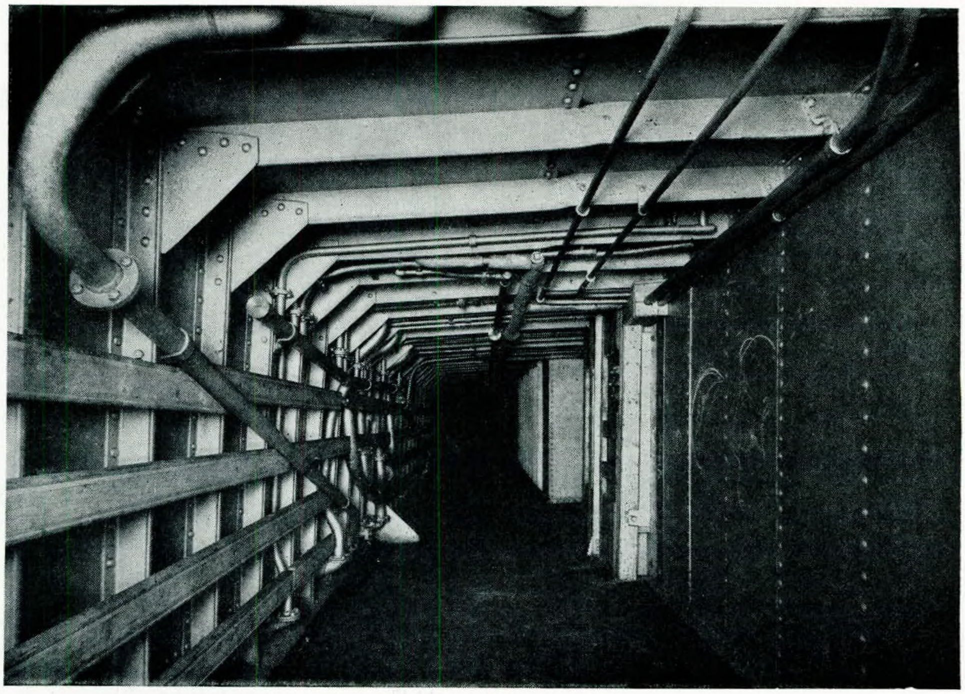


FIG. 3.

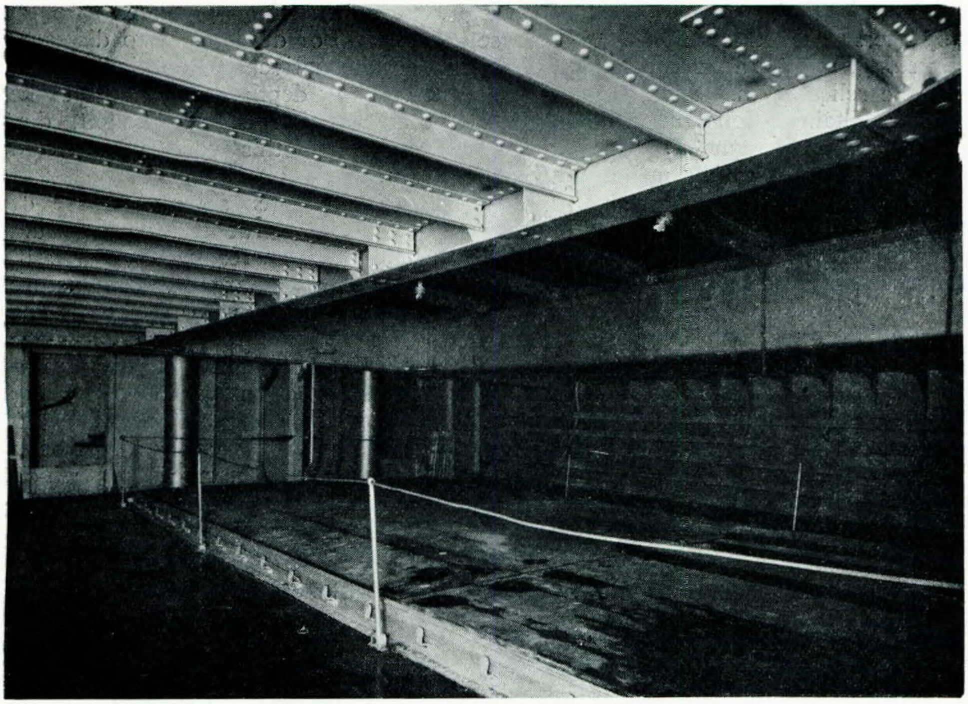


Fig. 4.

the chomic-acid process, is produced by the use of an electrolyte containing principally dilute sulphuric acid. On pure aluminium or low-percentage alloys, a very good base for absorbing dyes for decorative purposes is obtained by this process. Furthermore, the hardness and abrasion resistance of the film surpasses that of the chromic-acid film. It is colourless on commercial aluminium, turning to deep mottled brown on silicon alloys.

Anodising provides excellent protection and gives a very attractive appearance to the metal. Due to the power of the oxide coating to absorb vehicles and media, a good surface for painting is obtained, and this is particularly valuable where decorative work is concerned.

In the case of certain alloys falling in the categories mentioned in the foregoing, the anodic process before painting can be dispensed with. Alloys possessing such high resistance to corrosion have been so developed of late that only when conditions are unduly severe does the need for the anodic-oxidation process before painting arise. A

already found their place in the construction of cabin furniture, bulkheads and other varieties of framework, as well as in the structure of small craft; but it is not so widely known that a range of alloys exists which in extruded form is eminently suitable for use in connection with the more highly stressed parts of hull construction. While it is not proposed to discuss these alloys in detail, it may be mentioned that they have been specifically developed for marine purposes. Their behaviour under conditions of exposure to salt-water attack is excellent, their ductility is high and the cost competitive.

Protection against Corrosion.

Aluminium alloys, however, as with steel, require certain methods of protection to withstand marine conditions. In addition to thorough cleaning and the application of priming coat and paint, various special processes are used with the object of increasing their resistance to corrosion. In order to increase the resistance of the film of oxide which automatically forms on the metal, an electrolytic method—known as the anodic oxidation process—has been developed, whereby the thickness of the oxide film is artifically increased. The resistance of the film to corrosive attack is increased, and an ideal basis for subsequent painting is produced.

In 1924, Bengough and Stuart patented the chromic-acid process. The film varies from colourless to opaque grey, but it is very porous when freshly formed and comparatively soft, requiring sealing and a period of about a month or so to harden.

A film, more transparent than that obtained by

Fig. 5.

protective paint is always recommended and, after obtaining an efficient key by chemical pretreatment, sand blasting or scratch brushing, a good adhesion of the painting material can be relied upon. Such satisfactory results have been obtained following these methods of treatment that the demand for aluminium alloys, including NA. 57S, is steadily increasing.

While red-lead paints have been acknowledged as most suitable for direct application to sea-going steel vessels, ultimate breakdown of the film occurs and corrosion of the steel commences despite frequent repainting. Of late, aluminium pigment has been advanced as possessing remarkably inhibitive properties under the exposure conditions referred to.

Due to the leafed formation of the pigment layer, aluminium paints also protect by exclusion. An orientated layer of metallic pigment particles forms upon the surface of the paint film, protecting this latter by its opacity and preventing ingress of corrosive influences. Aluminium paint may be used as a primer on woodwork and to follow a primer on all above-water steel.

Conventional white paints may, after a time, show a tendency to "chalk" or rub off, due to the disintegration of the vehicle and subsequent release of the pigment particles. In aluminium paint, however, the protection of the vehicle is assured by the pigment layer, and no tendency to "chalk" is apparent even after prolonged exposure under such severe conditions as are to be met on shipboard.

On deck, aluminium paint may be applied with advantage on all plates, booms, chains, deck-rails, winches and other deck machinery; while between decks it may be usefully employed in staterooms and public rooms as a decorative medium and as a priming paint for all painted timber. In machinery spaces it has been extensively used for engine and machine beds, boiler casings, pumps, piping, fans and ladders. Furthermore, the reflectivity of an aluminium paint surface may be commended for brightening dark interiors in galleys and refrigerated rooms, where its non-toxic qualities offer an added advantage.

It should be observed that when aluminium paints are used the saving in weight is considerable. A "leaded" paint may weigh between 20 and 30lb. per gallon, whereas an aluminium paint rarely exceeds 10lb. per gallon. A reduction of over 50 per cent. on the weight of paint is an important consideration.

Weight Reduction.

One of the problems of ship design is the extent to which weight reduction may be possible by the use of light alloys. In cargo vessels, any possible economies in the light weight will, with given displacement, be reflected in increased deadweight, or, alternatively, given deadweight may be carried on a smaller displacement. In either case, the advantage of weight saving is realised through the increase in the ratio of deadweight to displacement. As a further alternative, the adoption of light alloys would permit the depth of the hull to be increased, without variation of deadweight, displacement, or draught, and this would be reflected in additional cargo capacity.

In the case of passenger ships, the use of aluminium alloys for superstructural parts would tend to increase stability by decreasing their weight, or would allow the erection of larger superstructure with increased accommodation, without sacrifice of stability. Due to their elastic properties aluminium alloys would readily adapt themselves to the straining action of a ship's movement without incurring excessive local stresses.

Miscellaneous castings and ventilators on deck come to mind as further instances in which aluminium alloys could be used to advantage, while aluminium lifeboats have already been supplied to the liner "Awatea" of the Union Steamship Company of New Zealand, Ltd., and to the "Nieuw Amsterdam", of the Holland-America Line. It is also stated that complete installations of similar lifeboats are in hand for a Royal Mail liner under construction at Belfast and for a Swedish-American liner being built at Monfalcone, Italy. In addition to the saving in the weight of the boats themselves afforded by the use of aluminium alloys, the reduction in maintenance—through the need of less frequent repainting and the elimination of seam trouble by reason of the alloy's corrosion-resisting properties—suggests that the lifeboats will outlast the life of the ship. Moreover, davits, winches and lifting gear can be lightened, thus producing a cumulative saving in weight without sacrificing the strength necessary to handle the boats efficiently.

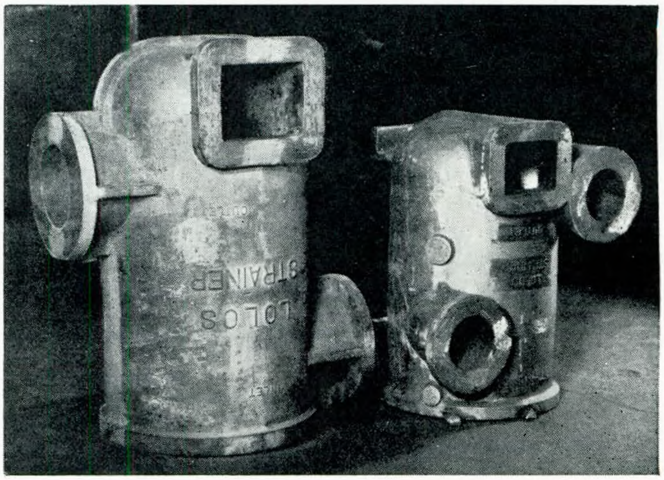


Fig. 6.

Aluminium-silicon alloy castings are already being largely utilised for portholes and skylight frames. Such parts are easily operated and have been successfully produced in extruded form from wrought alloys. The side scuttles and window frames fitted in the Canadian Pacific liner "Empress of Britain" were composed of this alloy. Aluminium-silicon alloy castings have been found suitable for binnacles, brackets, control gear, hand-wheels, pedestals, searchlight parts, stanchions, etc.; while wrought alloys are preferred for other purposes, such as ventilating trunks and fans.

Aluminium Alloys for Interior Epuipment.

It is confidently felt that the future will see an extended use of aluminium alloys for the interior equipment of vessels. The experimental stage has long since been passed. When the recently broken-up "Mauretania" was constructed over 31 years ago, the installation of an aluminium-alloy lift provided an excellent example of utility and decorative aluminium work. The great French liner "Normandie" is equipped with many attractive first-class staterooms having aluminium-alloy walls and furniture, in all about 25 tons of the material being employed. The value of this decorative metal in modern style was exploited in the construction of the Cunard White Star liner "Queen Mary", in which the beauty of colour and finish of aluminium alloys was fully utilised. The heating and ventilating fittings in staterooms are now being increasingly manufactured from suitable alloys of this metal.

Protection against Fire.

Fire has always been one of the greatest risks to liners, and to minimise this hazard steps have been taken to replace inflammable wooden partitions and bulkheads by metallic constructions. Cabin bulkheads, however, must fulfil certain requirements, such as those concerned with sound and heat insulation, and composite panel bulkheads which it is claimed meet these conditions have now been introduced. In addition, these bulkheads are non-creaking, and possess vibration-damping and non-absorbent properties. In essence, they consist of slag wool, asbestos or similar material, in solid or corrugated form, sheathed on each side with aluminium sheet. Aluminium extruded sections hold these panels in position, and are so arranged that the panels are easily removable for access to electrical equipment, pipe-lines, etc.

Aluminiun Foil.

Increasing use is being found for aluminium foil in connection with refrigerated spaces. In place of cork, by a patented process, aluminium foil is lightly crumpled, and then "sandwiched" between sheets of aluminium or other material. As the adjacent layers of the foil have only small points of contact, the conducing path is minute, while the polished surfaces reflect the heat and reduce radiation. As thin aluminium foil weighs only a fraction of the weight of cork required to give the same insulating value, a large reduction in weight is effected.

Aluminium Alloys in Naval Vessels.

While many other examples of the application of aluminium and its alloys in marine construction could be quoted, special reference must be made to their use in Naval vessels. In merchant ships

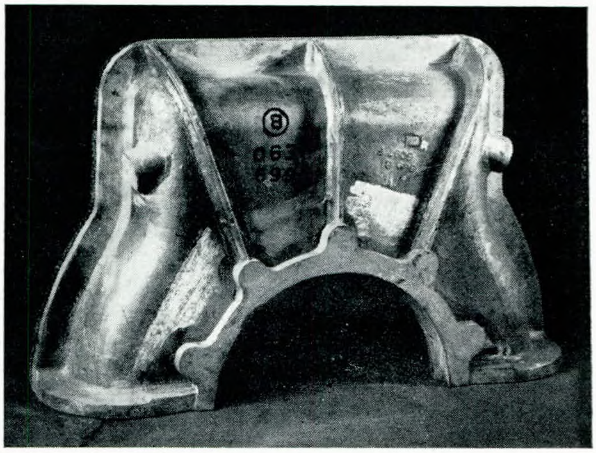


FIG. 7.

comparatively little aluminium is used as the relatively high cost operates against its employment, but large quantities are used in Naval construction. The ratification of the Washington Conference, limiting the displacement tonnage of battleships and other war vessels, gave prominence to economy of weight and led to the extensive use of aluminium alloys. As an example, it is estimated that a saving in weight of nearly 200 tons per ship was effected in the "Kent" type of cruisers, and the experience gained has been made use of in later ships. In the engine-room, where most metals are

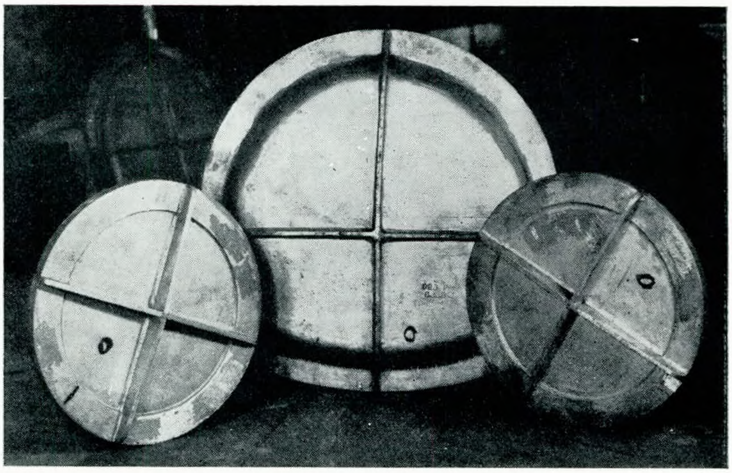


FIG. 8.

continuously covered with a film of oil, the question of corrosion hardly arises, reduction in weight consistent with strength again being the major consideration. Not only are the mechanical properties of the silicon alloys good, but the dense structure of these alloys renders them suitable for components in pumps and in fuel and lubricating systems. Other parts made of castings of similar alloys include gear-casing covers, small bedplates and crankcases, air-ejector covers, valve wheels, and pipes and bends for oil-fuel services. On the engines themselves the use of aluminium for the inspection doors is obviously advantageous, as one man can remove an aluminium inspection door which in iron or steel would tax the strength of two.

The increased efficiency of many types of Diesel engines has been largely due to the adoption of pistons cast in "Lo-Ex" (NA. 162) alloy, which is widely used for pistons required in all types of internal-combustion engines. This alloy combines the low expansion characteristics of a high silicon content with good mechanical properties at elevated temperatures. Equally important features are its low specific gravity and excellent qualities as a bearing material. Pistons in NA. 162 "Lo-Ex" alloy are supplied in ranges from about 400lb. for Diesel engines down to the smallest in use for petrol engines.

Extruded sections and half-hard rolled aluminium sheet have been found suitable for cabin linings, kit lockers, racks, dressers, cupboards, shelves, etc., also in messes, kitchens and storerooms, while in some recent warships aluminium furniture has been used in the officers' accommodation.

Aluminium alloys have also been extensively adopted for electrical work including parts of electric-light fittings, switches, fuse boxes and junction boxes not exposed to the weather. The end covers and casings of electric motors could be satisfactorily constructed of the strong cast aluminium alloys, and pure aluminium is eminently suitable for conductors in the form of busbars and round rod connections. Altogether, due to the many possibilities offered by means of the installation of aluminium electrical equipment, a very considerable reduction in weight has been effected in all types of Naval vessels.

Aluminium Alloys in Hull Construction.

It will have been observed that little reference has been made to the application of aluminium alloys to hull construction. The mistaken idea that the resistance of aluminium to corrosion is so low that it cannot withstand salt-water attack is a bogey which has affected its use for more than 40 years.

Mention could be made of individual vessels with all aluminium hulls, an outstanding example being the 65ft. patrol boat "Interceptor" used by the Royal Canadian Mounted Police. As already stated, lifeboats are now being largely constructed in aluminium, but their active service period afloat, is, happily, limited to very short periods. Similar isolated instances apart, it would seem that, though based on false premises, the bogey referred to above against aluminium in hull construction still continues to persist.

Partly with the object of counteracting this prejudice, but primarily to determine the possibilities of aluminium through periodical tests under conditions obtaining at sea, an aluminium vessel was built in 1935 and moored in Chesapeake Bay. It was considered to be representative of future construction in regard to high-speed harbour police boats, patrol boats and fishing craft.

This vessel was planned in such a manner that its behaviour in salt water could be compared to

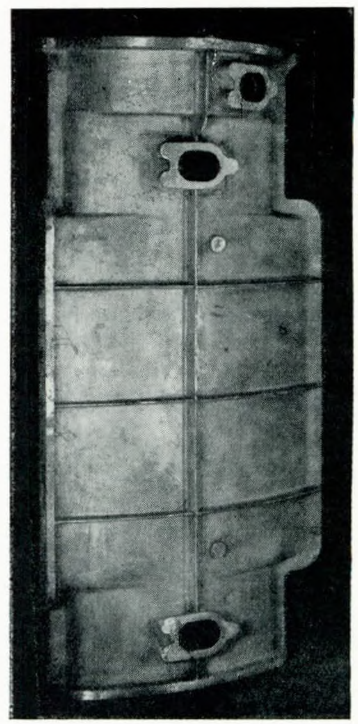


FIG. 9.

that of a 100ft. boat having the same thickness of plating and size of structural members. The hull plates were made of aluminium-magnesium-chromium alloy, while for the frames, gussets, girder webs and rivets an aluminium-magnesium-chromium-silicon alloy was adopted. The overall dimensions were scaled down, the resulting appearance of the vessel being similar to the centre section of a long narrow craft. The length was 15ft., the breadth 10ft., the depth 5ft., the draught 2ft. 4⅝in., and the total displacement including lead ballast 11,800lb. Two dummy propeller blades and shafts were installed, one of bronze and the other of steel, and the vessel was constructed entirely without recourse to special tools or processes. Plates and shapes were sheared, punched and formed on the same equipment used for steel. Prior to and after assembly, all structural parts of the hull were thoroughly painted with zinc-chromate-iron-oxide, the outside of the underbody below the water-line received one coat of red anti-fouling paint, and above the water-line two coats of standard Navy grey enamel were applied.

During the two and a half years in which the vessel was subjected to salt water, six official inspections were made. The latest inspection showed that the aluminium alloys had help up splendidly, notwithstanding the fact that the hull was frozen in solidly for more than two weeks during February, 1936, and received severe buffeting in the subsequent break-up of the ice. There were no leaks in joints or seams, and the tests proved beyond doubt that aluminium is definitely seaworthy if electrolytic corrosion is controlled by correct methods, and providing protection is afforded by a studied painting system.

. . . .

The following is a descriptive list of the illustrations accompanying this article:—

FIG. 1—Main-gearcase Cover for Turbine, 300lb. approximate, NA. 160. This illustration is reproduced by permission of the Wallsend Slipway & Engineering Co., Ltd.

FIG. 2—Oil-sprayer Cover for Turbine-gear Casting, 150lb., NA. 160; also reproduced by permission of the Wallsend Slipway Company.

FIGS. 3 & 4—'Tween Decks and After 'Tween Decks of the Motorship "Palomares", built for Messrs. MacAndrews & Co., Ltd., by Messrs. William Doxford & Sons, Ltd. These illustrations are reproduced by the courtesy of the owners and Messrs. Bryce Weir, Ltd., whose "Brysolex" aluminium paint made from "Noral" paste was used.

FIG. 5—Fan for Ventilating Plant, 113lb. approximate, NA. 161 to DTD. 240. Reproduced by permission of Thermotank, Ltd.

FIG. 6—Lolos Oil-strainer Bodies; larger, 230lb. approximate; smaller, 120lb. approximate. Reproduced by permission of Auto-Klean Strainers, Ltd.

FIG. 7—Oil Baffle for Turbine-gear Casing, 80lb., NA. 160. Reproduced by permission of the Wallsend Slipway Company.

FIG. 8—Observation Doors, 100lb.; and End Doors, 50lb.; NA. 160. Reproduced by permission of the Wallsend Slipway Company.

FIG. 9—Pinion Cover for Turbine-gear Casing, 450lb. approximate. NA. 160; also reproduced by permission of the Wallsend Slipway Company.

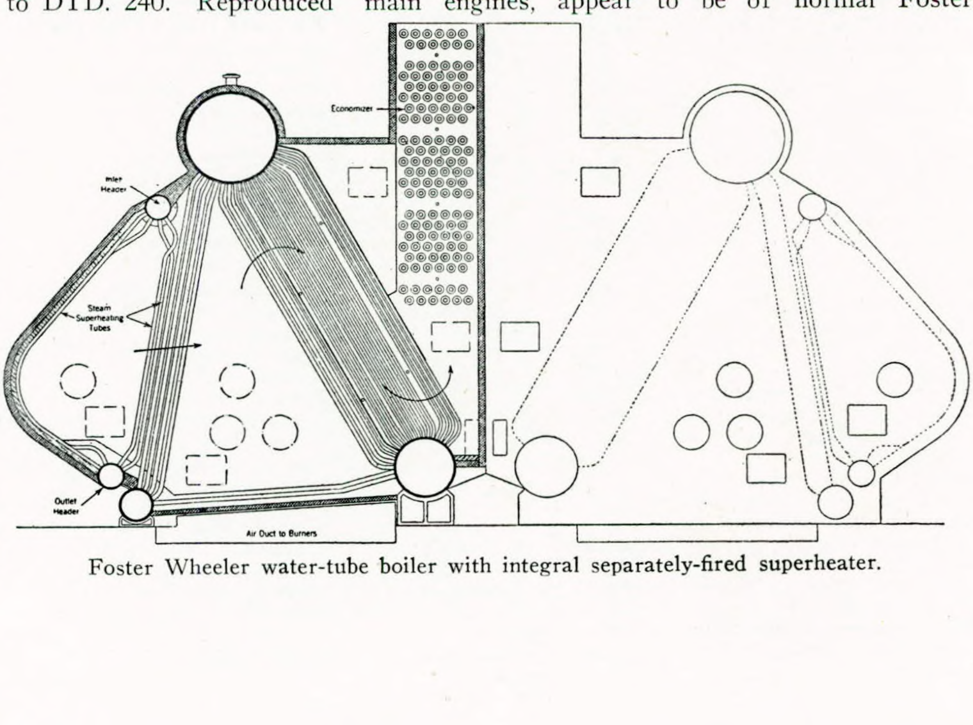
Control of Superheat.

"The Shipping World", 14th September, 1938.

The control of superheat in a marine boiler is a problem of the utmost importance and difficulty. In land boiler installations it does not arise to the same extent for there is no manœuvring, with its sudden call on the capacity of the superheater and its consequent rise of superheat temperature—often to dangerous limits. With the increased superheat temperatures now used more attention has, of necessity, been given to this question, and some interesting pioneer work is at present being done in connection with automatic control of superheat and combustion. One solution of the problem has recently been introduced by the American Foster Wheeler interests, and has been applied to the boilers of the American tanker "Associated", which, as recorded in a previous issue of *The Shipping World,* has been built by the Sun Shipbuilding and Dry Dock Co., of Chester, Pa. Propulsion is by means of a General Electric double-reduction cross-compound geared-turbine of about 3,600 s.h.p.; this gives the tanker, which is of nearly 13,000 tons deadweight capacity, a service speed of 13 knots; the normal steam conditions are 375lb. per sq. in. pressure, and 725° F. final steam temperature. Steam is generated in a pair of Foster Wheeler oil-fired water-tube boilers of the special type shown in the accompanying illustration.

Separate Superheater Section.

As this shows, the boilers, which are arranged side by side in an elevated position just aft of the main engines, appear to be of normal Foster



Foster Wheeler water-tube boiler with integral separately-fired superheater.

Wheeler design on casual inspection. Actually, however, the superheater section is quite separate from the generating part of the boiler, and has its own auxiliary furnace and oil burner. The products of combustion from both sections pass, as the drawing shows, to a common uptake by way of the economiser, which is of the standard gilled tube Foster Wheeler type. The superheater furnace, it will be appreciated, is virtually a radiant heat tube line chamber with upper and lower header drums and, clearly, the temperature of the superheated steam, can be controlled with great accuracy by the rate of firing to the superheater furnace. If the superheater oil burner is not in action, a small degree of superheat is imparted to the steam from the main combustion space. A system of emergency control for the protection of the superheater has been adopted so as to protect the parts against overheating, when there is a small quantity of steam passing through the superheater, and hence insufficient cooling of the superheater elements. A spring-loaded valve, which is solenoid-operated, controls the flow of oil to the burner in the superheater furnace, the trip mechanism included in the system being so arranged that it is not reset except by hand; this simple provision ensures that the mechanism comes under the direct attention of the engineer when it has operated, and thereby provides a useful safeguard. It will be interesting to see how the installation in the "Associated" operates in practice. The idea certainly seems to have much in its favour.

BOARD OF TRADE EXAMINATIONS.

List of Candidates who are reported as having passed examinations for certificates of competency as Sea-Going Engineers under the provisions of the Merchant Shipping Acts.

Name.	Grade.	Port of Examination.
For week ended 2nd March, 1939:—		
Gemmell, James	2.C.	Glasgow
Peat, Thomas	2.C.	"
Dickson, George McD. ...	2 C.M.	"
Atkinson, Robert Richard...	2.C.	Newcastle
Dowson, John	2.C.	"
Ferguson, William Ivor ...	2.C.	"
Jackson, Robert	2.C.	"
Jones Arthur William ...	2.C.	"
Lamb, Stanley Tweedy ...	2.C.	"
Lumsden, George	2.C.	"
Anderson, John H.... ...	2.C.M.	"
Martin, William Cairns ...	2.C.M.	"
Williamson, Alan	2.C.M.	"
Bowers, James Patrick ...	2.C.	London
Green, Frederick John ...	2.C.	"
Fairclough, George E. ...	2.C.	Liverpool
Henderson, Charles T. ...	2.C.	"
de Jong, Arthur	2 C.M.	"
Soens, George	2.C M.	"
Brierley, John Leonard ...	2.C.S.M.	"
Black, John Alexander ...	2.C.	Leith
Forbes, George	2.C.	"
Rennie, William J.	2.C.	"
Brydon, Leslie James ...	2.C.	"
McIntosh Angus Marshall	2.C.	"
Isaac Walter James ...	2.C.	Hull
McCarter, James	2.C.M.	Belfast
Rees, David Picton ...	2.C.	Cardiff
Aitchison, Thomas E. ...	2.C.	Glasgow
Brown, Robert F.	2.C.	"
For week ended 9th March, 1939:—		
Ferguson, William W. ...	1.C M E.	Glasgow
Campbell, George T. R. ...	1.C.	Newcastle
Grieves, George C.	1.C.	"
Johnson, William B. ...	1.C.	"
Meadows, Henry T. ...	1.C.	"
Thomson, George R. ...	1.C.M.	"
Chalmers, Arthur G. ...	1.C.S.M.	"
Allan, John	1.C.M.E.	"
Appleby, George C. ...	1.C.M.E.	"
Brooks, Robert W.... ...	1.C.M.E.	"
Chambers, Robert	1.C.M.E.	"
Fawkes, Harold G.... ...	1.C.M.E.	"
Hanwell, Hilton B. ...	1.C.M.E.	"
Robertson, Alan	1.C.M.E	"
Smith, Alexander	1.C.M.E.	"
Taylor, Donald A.	1.C.M.E.	"
Taylor, John Green ...	1.C.M.E.	"
Robertson, Andrew	1.C.S.M.	Leith
Geekie, Ralph O.	1.C.	Glasgow
Kirkaldy, Angus B. ...	1.C.	"
Love, Andrew	1.C.	"
McCrindell, John H. ...	1.C.	"
Russell, James B.	1.C.	"
Hutcheon, John	1.C.M.	"
Colahan, Joseph J.	1.C.M.E.	"
Cubitt, James C.	1.C.M.E.	"
Gamble, Alexander	1.C.M.E.	"
Smail, James B.	1.C.M.E.	"
Harrop, Herbert W. ...	1.C.	Liverpool
Herrick, Grahame B. ...	1.C.M.	"
Huntingford, Alan	1.C.	"
Montgomery, Wilfred H....	1.C.	"
Moir, Reginald H.	1.C.M.E.	"
Cairns, Harry	1.C.	Newcastle
Brain, Henry	1.C.	London
Hulkes, Ernest H.	1.C.	"
Moody, Philip J.	1.C.	"
Welch, John A.	1.C.	"
Sherratt, Bruce G.	1.C.M.	"
Dick, Robert C.	1.C.M.E.	"
McLeod, Joseph B. ...	1.C.M.E.	"
James, James H. T. ...	1.C.	Cardiff
Moore, Bernard	1.C.	Hull
Brimblecombe, William R. C.	1.C.M.E.	Cardiff
Lewis, Geoffrey R. H. ...	1.C M.E.	"
Veal, John R.	1.C.M.E.	"
Wickett, Hector G. ...	1.C.M.E.	"
Keady, Herbert L. ...	1.C.M.	Hull
Swanson, James	1.C.	Leith
For week ended 16th March, 1939:—		
Mather, Matthew	2.C.	Newcastle
Walker, Sydney	2 C.	"
Flett, John Alexander ...	2.C.	London
Ross, Sydney Thomas ...	2.C.	"
Downs, Albert E.	2.C.	Liverpool
Reid, David	2.C M.	"
Williams, John	2.C.M.	"
Campbell, Charles	2.C.	Glasgow
Murray, Donaldson ...	2.C.	"
Naismith, Robert B. ...	2.C.	"
Stephen, David	2.C.	"
For week ended 23rd March, 1939:—		
Macaulay, Alexander N. ...	1.C.	Glasgow
Main, John	1.C.	"
Muir, George	1.C.	"
Robertson, John	1.C.S.E.	"
Forbes, John C.	1.C.M.	"
Mitchell, George J. ...	1.C.M.	"
Bowan, Henry S.	1.C.	Liverpool
Garner, William R. ...	1.C.	"
Rutherford, Eric M. ...	1.C.	"
Gibbs, Thomas H.	1.C.M.	"
Ressich, John V.	1.C.M.	"
Bannerman, Robert B. ...	1.C.M.E.	London
Findlay, Thomas N. ...	1.C.M.E.	"
Phillips, Alfred H. ...	1.C.	Newcastle
Thompson, Charles H. ...	1.C.	"
Darnell, John R.	1.C.S.E.	"
Grey, William	1.C M.E.	"

The late Engineer Vice-Admiral Sir HENRY JOHN ORAM, K.C.B., F.R.S.

Portrait by] [*Vandyk*

OBITUARY.

Engineer Vice-Admiral Sir Henry John Oram, K.C.B., F.R.S.

We regret to record the death of Engineer Vice-Admiral Sir Henry John Oram, Honorary Member, which occurred on Friday, May 5th, at his home at Kilmory, Cranleigh, Surrey, at the age of eighty years. By the death of Sir Henry, who was formerly the Engineer-in-Chief of the Fleet and served for 38 years on the active list of the Navy, from 1879 to 1917, naval engineering has lost one of its leading exponents.

Sir Henry was the son of the late Mr. J. J. Oram of Plymouth, and was born in June, 1858. He received his education at private schools, and afterwards attended the Royal Naval College at Keyham, from which he entered the Royal Navy in July, 1879, as assistant engineer. On leaving Keyham he spent some time at Greenwich, and in 1882 was appointed to the iron troop ship H.M.S. "Crocodile", becoming engineer in 1884. That year he returned to London to take up a post as assistant engineer in the Department of the Engineer-in-Chief at the Admiralty. With the exception of the first few years of his naval career, Sir Henry was destined to spend the whole of his time, covering a period of over thirty-three years in this Department. His appointments and promotions rapidly succeeded one another. In 1889 he became Chief Engineer, in 1893 Staff Engineer, and four years later Fleet Engineer. In 1897 he was specially promoted to the rank of Inspector of Machinery, became Chief Inspector in 1901, and Engineer Rear-Admiral in 1903. In the latter year he was made Deputy Engineer-in-Chief, and in October, 1907, he was called upon to succeed the late Engineer Vice-Admiral Sir John Durston as Engineer-in-Chief. His period of office coincided with one of unusual activity in naval engineering circles, following the introduction of the water-tube boiler, oil fuel, and geared turbine. The carrying through of these important innovations gave Sir Henry a task which exceeded that of his predecessors, both in its range and its engineering interest. The responsibility of developing the engineering equipment of the post-"Dreadnought" fleet fell upon his shoulders, and the thoroughness with which his work was done was shown when the Great War tested the engineering equipment of the Navy and never found it wanting.

As befitted his office, Sir Henry was always in close touch with the scientific and engineering institutions, and in 1917 the Council conferred upon him the rare distinction of Honorary Membership of The Institute. He also held office as Vice-President of the Institution of Naval Architects and as President of the Institute of Metals and of the Junior Institution of Engineers. His work on many Government Committees included that of the Royal Commission on Oil Fuel and Engines, under the chairmanship of the late Lord Fisher.

Sir Henry received many honours. He was made C.B. in 1906 and K.C.B. in 1910. In 1912 he was elected a Fellow of the Royal Society. His collaboration with the American Navy was recognised by the bestowal of the American Distinguished Service Medal. He practically rewrote Richard Sennett's "Treatise on the Marine Steam Engine", which has seen many editions.

Although with increasing age Sir Henry's retirement became more and more complete, he occasionally visited the Athenæum, of which he had been elected a member under the exclusive Rule II in 1915. Up to the last he retained his health and his faculties.