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Gas Engines and Gas Producer Plants.

BY HUGH CAMPBELL.

READ

Tuesday, January 9, 1923, *at* 6.30 *p.m.*

CHAIRMAN: ENGINEER VICE-ADMIRAL SIR GEORGE G. GOODWIN, K.C.B., LL.D. (President).

The CHAIRMAN: It gives me much pleasure to introduce the lecturer, Mr. Hugh Campbell, the well-known maker of gas engines. Mr. Campbell has come a long way, from Halifax, to read his paper to us to-night. He has only recently returned from abroad and has prepared the paper in a very short time and, I am afraid, at some inconvenience. It may be some recompense to him to know that we highly appreciate his resolve to keep his promise to give us this paper, and the interest which he has thereby shown in the work of the Institute.

I will now ask him to be good enough to read his paper.

Mr. CAMPBELL: I have to offer my apologies to you gentlemen to-night, not having had the opportunity to let Mr. Adamson have the paper in time to have it printed beforehand, as he only received the paper from me this morning.

I do not propose in this paper to deal with my subject of "Gas Engines and Gas Producers" from an historical point of view, and I propose to assume that my audience is somewhat acquainted with a little of the history, and also with the elementary cycle of operations in both the gas engine and the gas producer. I shall, however, be very pleased, if, at the close of the paper I find I have assumed that you possess perhaps a little less information and knowledge than I have given you credit for, you will be good enough to ask me as many questions as you like so that an excellent discussion may be provoked.

I am not going to deal with the progress of gas engines and gas plants that has taken place even within my own life time, for if I did that the time at my disposal would be too short to deal with the matter fully, because both of these have developed in such a marvellous manner during the last forty years that more than one paper would be necessary if I attempted to describe what has occurred.

I am going to take a few different types of engines and show you illustrations of them on the screen and describe them in detail to you, and I propose to deal with the gas plants in exactly the same manner, showing you on the screen gas plants of various types and made for using very many different types of fuels.

After that I propose to give you some idea of the fuel consumptions, economies, etc., obtained through the use of gas engines and gas plants.

Slide 1.—To begin with I will show you a picture on the screen of a horizontal gas engine and suction gas plant, this being a typical illustration of an ordinary arrangement of both gas engine and gas plant.

Before going into detail I will throw on the screen a section of a marine engine and describe this in detail to you so that you may more intelligibly follow after remarks.

Slide 2.—A section of a Campbell single-cylinder single-acting horizontal gas engine of 150 H.P.

Having described the construction of the engine, I would like to show you some details of the construction, particularly of the governing and control of the speed of the engine as well as the composition of the mixtures used in the cylinder or cylinders of the engines.

Governing.—The methods of governing gas engines are somewhat varied, for instance there is the old-fashioned method of governing by what is very commonly known as the "hit and miss" method in which the governor admits either a full charge of gas to the cylinder or none at all. This method is still employed on engines using town gas and of small power, and it is remarkable that no other method of admitting gas to cylinders of engines has proved quite as economical as the old-fashioned method of "hit and miss" governing. It is, however, unsuitable for use in large engines because the working parts are always subject to the maximum stresses caused by the ignition of the full charge of gas and air in the motor cylinder, whereas by the more modern methods the parts are only subjected to the maximum stresses when the engines are working up to full or maximum power.

The two principal methods in use to-day for the control of gas engines are by varying the quantity of the mixture of gas and air or by varying the quality of the mixture of gas and air.

Slide 3.—Illustrates a very simple form of governing on what is termed the "throttle" system, but more correctly should be called, governing by quantity. This you will see is formed of a double beat valve, which is held under control by the governor and admits more or less gas and air in suitable proportions to the cylinder. This method is adopted principally in multi-cylinder engines of the vertical type.

Slide 4.—This picture shows an arrangement of governing effected by a movable fulcrum. The fulcrum is under the control of the governor and allows the inlet valve for gas and air to be opened more or less according to the load on the engine. This method of governing is by movable fulcrum and is that of the quantity method. The amount of mixture of gas and air drawn into the cylinder is controlled by the variable fulcrum operated by cam and lever. This system of governing is used largely on single-cylinder horizontal engines, and while it is quite a good system of governing, yet it is complex in arrangement, and not so easily understood by the average engine attendant.

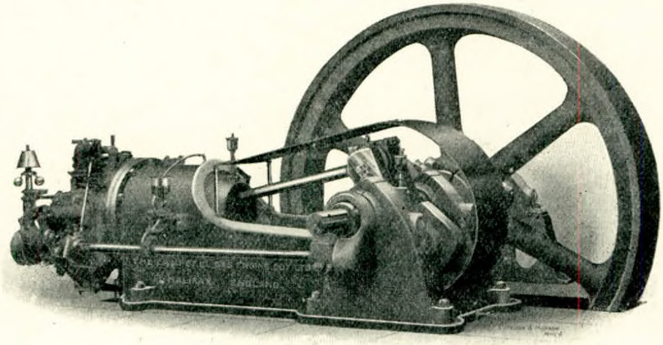
Slide 5.—This picture shows a section through the inlet valve and throttle box for governing on the quality method. You will see that there is a throttle valve inserted in the inlet gas pipe, and this throttle valve is under the control of the governor so that the gas is only controlled by the governor. In this way you have what is called "quality governing," that is the quality of the mixture is varied to suit the load.

Slide 6.—The next slide gives a picture of the external arrangement of this gear. This arrangement of governing is to my mind the most simple and perfect of all systems of governing, and is economically sound.

Slide 7.—It is interesting for you to note this slide, giving you a comparison of both methods of governing, that is the quality and quantity governing.

Having now discussed some of the details of engines, I will throw on the screen some pictures of horizontal engines.

Slide 8.—Illustrates a 50 H.P. single-cylinder horizontal engine with hit and miss governor.



Slide 8.

Slide 9.—A horizontal engine of 50 H.P. with variable fulcrum governor.

Slide 10.—A horizontal engine of 120 H.P. fitted with hit and miss governor and with loose cylinder mounted upon bedplate.

Slide 11.—Picture of horizontal side by side engine, each engine fitted with independent governor on the quality system.

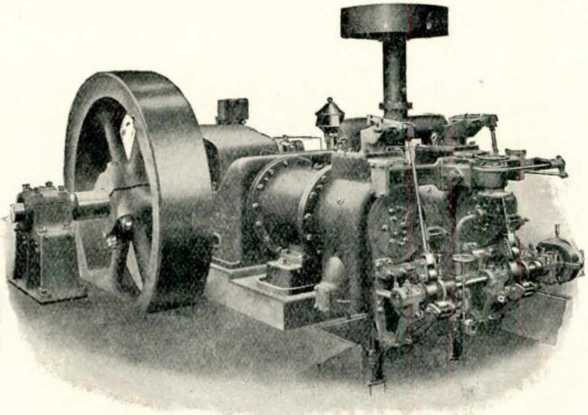
Slide 12.—Horizontal single-cylinder single-acting engine of 200 H.P. fitted with water-cooled piston and governing on the quality method.

The whole of the foregoing are single-cylinder engines.

I wish now to show you (*Slide* 13) an illustration of a 350 H.P. double-cylinder tandem single-acting engine.

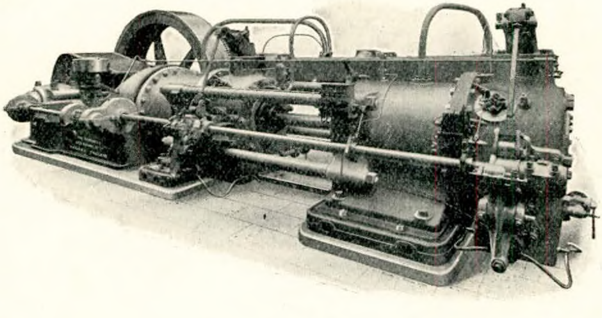
Slide 14.—The whole of the foregoing were single-acting engines, and I throw on the screen a sectional elevation of a single-cylinder double-acting 350 H.P. engine made by the Nurnburg Company, of Nurnburg.

Slide 15 shows the section on a larger scale of a piston, cylinder and valve, with the methods of water cooling employed in a double-acting engine.



Slide 11.

Slides 16, 17 *and* 18.—I will now leave the horizontal engines and take you to the vertical type, of which my firm were the pioneers, and I am going to show you a picture of two of the first vertical gas engines of any size that were made in this country.



Slide 13.

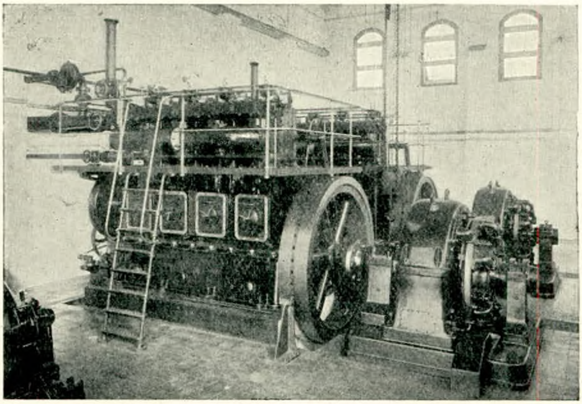
Slide 19.—A sectional elevation of the vertical engine.

Slide 20.—A diagram showing the effect of the offset of the connecting rod in the vertical engine cylinders.

Slide 21 shows a picture of a four-cylinder vertical gas engine taken from the top platform showing the valve gear.

Slide 22.—Picture of three vertical gas engines at the Great Western Railway Works, Swindon, 350 H.P. each.

Slide 23.—Picture of vertical gas engine working on the go-downs and wharves of the Blue Funnel Line, at Pootung and Kowloon.

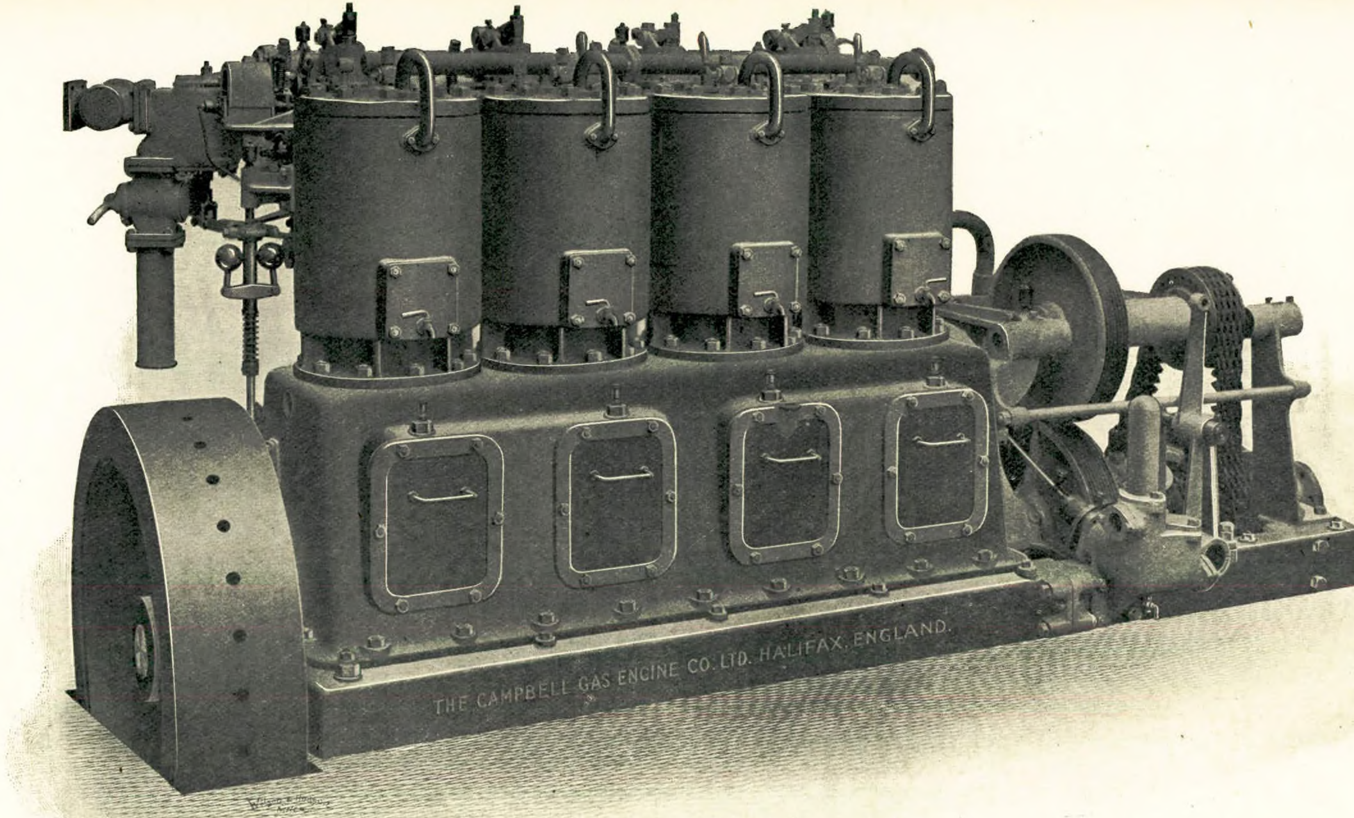


Slide 23.

Before I leave the subject of engines I wish to draw the attention of the audience to an attempt which we made some 15 years ago to introduce gas engines and suction gas plants on board boats.

Slide 24.—The next picture which I am going to show you is that of a tug boat which was built in Rotterdam and for which we supplied the engines and gas plants for use in plying in the docks, canals, and harbours of Rotterdam.

The plant consisted of a 100 H.P. four-cylinder vertical gas engine and suction gas plant using anthracite coal, and coke. The tug boat shown on the picture obtained a speed of 11 knots on the river at Rotterdam and was thoroughly satisfactory both as to work and consumption of fuel. The engine, however, proved to be a failure, not because of any defect concerning the engine or the gas plant, but solely because of the difficulty of manœuvring the engine in the congested docks, canals, bridges, etc., that exist at Rotterdam, and anyone who knows this harbour will know that a very quick and facile system of manœuvring is necessary. The original arrangement on board the boat was



Slide 24.

done with clutch and reversing gear, and this very quickly proved to be defective and unsatisfactory in that while the engine could be reversed from full speed ahead to full speed astern in a comparatively short period, yet there was not sufficient grading between full speed ahead and full speed astern to admit of close and accurate manœuvring. Hence we abandoned the reversing gear and fitted a reversible propeller to the boat. This proved also to be defective because the amount of power required to reverse the propeller blades was more than one man could do efficiently and quickly, and when it is understood that one man on board these tug boats in Holland acts as steersman as well as engineer, and holds the steering wheel with one hand and a lever controlling the steam engine with the other, it will be understood that the time we estimated to compete in this respect with the steam engine with our method of reversing, either by gearing or by the propeller, proved to be a failure, and ultimately the engine was taken out of the boat and a steam engine and boiler replaced it.

I do not think that such a calamity would happen to-day, because during the last fifteen years a good deal of knowledge and experience has been gained by ourselves as well as other internal combustion engine makers about the manœuvring and reversing of engines of both large and small powers, and should another opportunity arise I have not the slightest doubt that complete success would be obtained.

I am not now going to enter into the question of the durability or superiority of the gas engine for marine work over that of either steam engines or crude oil engines, except just to say that one of the difficulties standing in the way of a completely successful arrangement of gas engines and gas producers on board ship would be in the distribution over the world of a satisfactory fuel. Gas producers to give the best results possible are a little particular in the quality of the fuel supplied to them. The suction gas producers work best and most economically and effectively either on small size anthracite coal or small size coke. I am quite well aware that there are many types of gas producers in use which have a much wider range of fuel than a suction gas plant, but in my opinion they are not suitable for putting on board ship, and the determining factor about the application of gas engines and gas plants to marine propulsion would be largely determined by the ability to obtain a regular supply of suitable fuel.

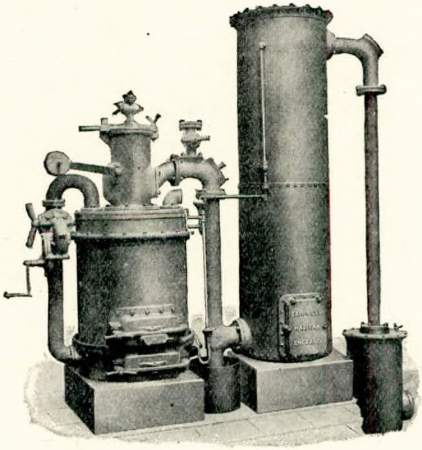
With oil power this has become very widely distributed over all the world and as the months go by it is even penetrating into what may be termed the "Wilds" in advance of Western civilisation, so it seems to me that the dice are loaded in favour of crude oil except for land work in our own country or in countries where anthracite and coke are easily and cheaply obtained.

Gas Producers. Slide 26.—A section of a gas producer working with steam or air.

Slide 27.—Section of pressure producer plant.

Slide 28.—Section of a closed base suction producer plant of 150 H.P.

Slide 29.—Outline picture of closed base suction gas producer.



Slide 29.

Slide 30.—Outline of gas plant with two producers and one set of cleaning plant of 350 H.P.

Slide 31.—Section of open hearth suction gas producer.

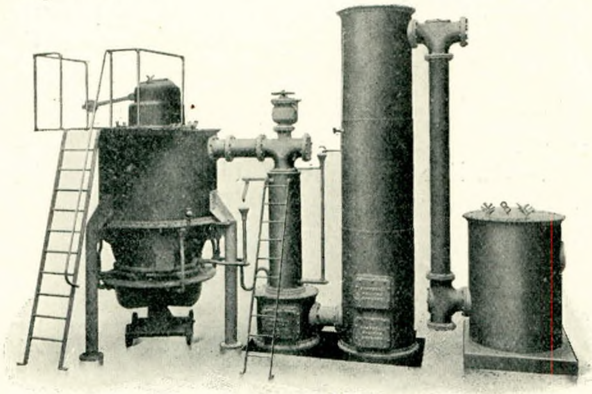
Slide 32.—Section of another open hearth plant of larger power.

The foregoing gas plants have been designed for and are usually operated by anthracite, coke or charcoal, but I am now going to show you a gas plant which is specially designed and used for bituminous coals and lignites.

Slide 33.—Section of bituminous gas plant.

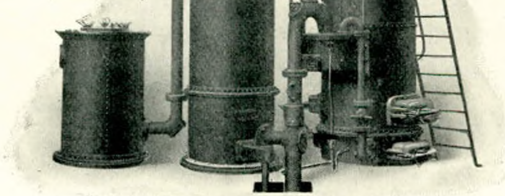
Slide 34.—Picture of bituminous gas plant.

A considerable number of gas engines and suction gas plants are now being used for what can be accurately termed "waste products." It is surprising to know how much refuse there is in the world, and how much of it can be satisfactorily and successfully used.



Slide 31.

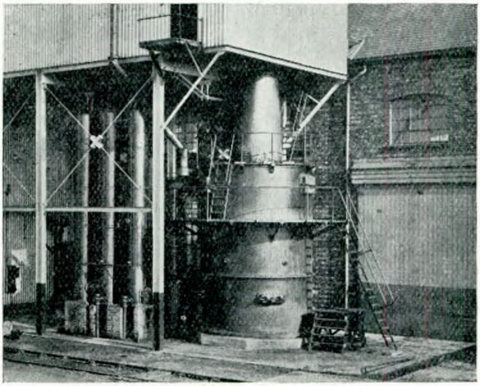
I have here samples of some of the waste products which we are asked to use in gas plants. Rice husks or paddy, the refuse from flax, shavings, sawdust, chips of wood, locomotive smoke



Slide 34.

box char, olive refuse, cotton seeds, cork refuse, maize corn cobs, etc. All these and others have been used quite successfully in generating gas for power and heating purposes.

Slide 35.—I am now going to show you one of the first wood refuse plants we ever made and which is working at the Locomotive Works of the Great Western Railway at Swindon and is of 350 H.P.



Slide 35.

Slides 36 *and* 37 represent the wood refuse gas plants working at Messrs. Bryant and May and also the fuel loft showing two producers each of 500 H.P., which gasifies about 10 tons of wood refuse per day consisting of damaged match boxes, spoilt matches as well as sawdust, and the refuse of wood used in match making.

The great bulk of the power required by Messrs. Bryant and May in their works is produced from the wood refuse left over in their business.

Slide 37 gives another view of the wood refuse gas plants used by the Great Western Railway Company, Swindon.

Slide 38.—Rice husks have proved in the East to be somewhat of a nuisance to dispose of. I am told that in Burmah it was customary to dump the rice husk refuse into the river, but it has become so great a nuisance owing to the swelling of the husk after it is put into the river and also to the offensive smell given off when the rice husk is rotting that this method of disposing of the refuse has been stopped, and efforts have been made to find suitable outlets for using it. In connection with this the suction gas plant has come to the satisfactory rescue, and is proving to be a very satisfactory investment.

Slide 38 shows an arrangements of a rice husk suction gas plant, and in connection with this I may mention an interesting feature, that we have made engines for the East which are convertible to use either gas made from rice husks or to use crude oil. Rice husk although it is produced in very large quantities is only produced in one season of the year and therefore to make sure of a supply for the whole of the year for power purposes it has to be stored, and as it is somewhat bulky material the space occupied is somewhat great considering its weight. Hence the demand has arisen for an engine which can use rice husks when they are available and when they are not available to use crude oil. Those conditions apply particularly to Southern India and Burmah.

Slide 38 shows an engine which is adopted for using both crude oil and gas made from rice husks.

I have left the question of economy of engines and gas plants to the end of my paper, and I am sorry that it has been impossible for me owing to my absence abroad to have this paper printed in advance so that the figures which I have at my disposal could be examined with attention and care, but I shall be pleased to answer any questions that are sent in after the paper is read so that the questions and replies can be printed.

Briefly, however, I may state the figures which I shall set forth in detail on the paper when printed.

Anthracite Plants. — We have recently carried out a test on a 100 K.W. vertical four cylinder gas engine with an open hearth producer gas plant working with small anthracite coal for the Corporation of Dorchester. The results of the six hours test were as follows:—

Test No. 1.—The fuel consumption per K.W. hour 1·1 lb. and assuming the efficiency of the dynamo to be 90% the consumption per B.H.P. hour ·76 lb.

Test No. 2.—Another test of a two cylinder horizontal side by side engine of 250 H.P. gave a fuel consumption on anthracite of ·89 lb. per B.H.P. per hour.

Test No. 3.—Open hearth gas plant of 250 H.P. supplying gas to three engines gave a fuel consumption of ·95 lb. per Indicated H.P. per hour, the total horse power generated at the time of the test being 204 I.H.P.

Test No. 4.—With Mexican bituminous coal containing practically 15% of ash, 6½% of moisture, and sulphur and volatiles 34%, and fixed carbon of only 43½%, the consumption in a suction gas bituminous plant was 1·26 lbs. per B.H.P. per hour.

Tests made on suction bituminous gas plants with Western Australian and New Zealand lignites give a consumption of 1·25 to 1·7 lbs. per B.H.P.

Test No. 5.—With locomotive smoke box char of the Great Northern Railway. This char contained 12·5% moisture, ash 24·77%, sulphur ·6%, volatiles 3·11%, fixed carbon 58·93%, total 100%. A test was made on an open hearth suction gas plant using this fuel on an engine of 120 H.P. vertical four cylinder type, the consumption was 2·13 lbs. per B.H.P. hour.

Test No. 6.—Wood refuse consisting solely of sawdust with a single cylinder horizontal engine of 50 B.H.P., duration of test was 8 hours, and the fuel consumption was 3·4 lbs. per B.H.P. hour.

Test No. 7. Rice Husks. The fuel contained 18·6% ash, volatiles 57·24%, moisture 10%, fixed carbon 14·11%. A test of six hours on a plant of 50 H.P. gave a consumption of 4·25 lbs. per B.H.P. hour.

Test No. 8.—Wood refuse gas plant and four cylinder horizontal gas engine, 260 H.P., $2\frac{1}{4}$ lbs. per B.H.P. hour.

Test No. 9.—I throw on the screen the complete figures of a gas engine and wood refuse plant of 140 H.P., giving the chemical composition of the fuel, calorific value, consumptions and so on. *(For table of tests see page 495.)*

Before concluding my paper I wish to draw attention to the very valuable feature in connection with the use of gas engines and gas plants, and that is the standby losses as compared with those of the steam engine.

First of all there is the consumption of fuel in steam boilers during standby hours. This slide not only gives the amount, but also the authorities for the figures as well as the types of the boilers.

Similarly the next slide shows the consumptions of fuel in gas plants and gives the horse power and the authorities for these figures.

I leave these figures to speak for themselves, they need no further comment from me.

The CHAIRMAN: As Mr. Campbell has remarked, he will now be very pleased to hear any criticisms on what he has told us, or to answer any questions.

Mr. J. L. CHALONER: The paper to-night deals with a specific aspect of internal combustion and Mr. Campbell has shown that much can be learnt by a study of the gas engine.

Mr. Campbell asks why we as marine engineers are interested in gas engines, but he answers the question himself by the results of his own work. Anyone studying the oil engine must admit that after all the gas engine has afforded much opportunity of analysing the many technical problems which are directly applicable to the oil engine. We are attempting much to-day in connection with the oil engine, which has already been accomplished in gas engine practice: single acting 4-stroke, single acting 2-stroke, double acting, gas turbine, are all represented to-day in some form or other. I see from the technical press that a compound gas engine is under construction.

On reflecting as to where lies the primary difference between the two types it is seen that whereas with a gas engine there is a distinct and separate plant—the producer—for providing fuel in a suitable gaseous form for mixing and burning inside the engine cylinder, the oil engine cylinder embodies the producer with the combustion chamber. The oil must be converted into a gas—or at any rate, gas and vapour—to become suitable for complete and efficient combustion.

As marine engineers we are naturally anxious to investigate the possibilities of the application of the gas engine for marine propulsion. Mr. Campbell has indicated as the main obstacle the difficulty of obtaining adequate—that is suitable—fuel supplies. I am not satisfied with that as the main reason, and would like to off-set it by the following suggestion.

Mr. Campbell has shown us a producer capable of burning almost any residue or waste products. He has also allowed us the privilege to view the first photograph of a new combined gas and oil engine. Why not, therefore, instal such a combination; use during the first part of the voyage the waste products in the producer and gas engine, collecting at the same time the tar by-product in the double bottom or deep tanks, burn during the second part of the voyage this liquid fuel together with bunker oil in the oil engine.

As a matter of fact, the difficulty lies in a different direction. Large gas engines have not yet been designed to meet marine requirements. The producer is an accessory which is taking up much valuable space on board. Also the result of leaky pipes, the danger of gas pockets, the complications necessitated by an effective ventilation system are points on which both the Board of Trade and Lloyds' would be compelled to impose restrictions which would make the whole scheme impracticable.

I was interested in the two sets of diagrams showing the result of qualitative and quantitative governing and the test results as indicated by Mr. Campbell are clearly confirmed by the respective relationship of the two combustion lines.

Referring to the pressure curve showing the thrust on the cylinder walls, Mr. Campbell gave me the impression that the resultant difference of the two sets of pressure curves are due to an off-set of 1½in. I would suggest that the two sets of curves refer to the compression and explosion stroke respectively. The off-setting of the centre line of the cylinder forward off the crank centre is to increase the effective length of the connecting rod without unduly increasing the height of the engine. Supposing the C.R. is 5 crank lengths, then off-setting the cylinder 1½in. is equivalent to increasing the C.R. to 6 crank lengths. The angularity of the C.R. is reduced accordingly and with it the maximum wall pressure to the extent of about 20 per cent.

This refers to the explosion stroke, and it should be remembered that there is a corresponding pressure increase during the compression stroke. The net effect is a reduction in the maximum wall pressure and an equilisation of the pressure during the compression and explosion stroke.

Off-setting has been tried with oil engines, and one of the reasons was to reduce the danger of piston seizure, because by off-setting it was possible to increase the piston clearance. Other reasons, however, prevented the standardisation of this arrangement.

Mr. Campbell quotes some instructive figures as to the stand-by losses for gas and steam plant. I am rather surprised to hear this ratio to be something like 3½ for gas to 74 for steam. I should like Mr. Campbell to confirm these figures.

Nothing has been said about exhaust gas utilisaton. In gas engines the available exhaust heat is greater than with a corresponding oil engine, and from a marine point of view it is highly desirable to have some authentic figures on this point. In several instances the exhaust boilers installed on board were not capable of carrying the designed load, owing, no doubt, to wrong calculations on the total available heat in the exhaust gases on entering the exhaust boiler.

I should like to know from Mr. Campbell what his views are on aluminium pistons for gas engines, and what is the largest diameter of this type of piston as applied to gas engine practice.

It has been a great pleasure to me to listen to Mr. Campbell. His plain and honest deliberations are characteristic of the policy that has been responsible for the fame and reputation of the manufacture that bears his distinguished name. May I add my thanks to Mr. Campbell for favouring us with such an admirable exposition of his pet subject.

Mr. E. SHACKLETON: I am sure we are all interested in this paper by Mr. Campbell. It is particularly interesting to me, being one of the old gas engineers*. In 1907 I read a paper on "Gas Engines for Marine Propulsion." Since that date I have considerably modified my ideas.

Mr. Campbell spoke about a number of minor problems of interest to the marine engine designer. As far as I remember Messrs. Campbell were one of the pioneers of the Joy's valve gear in this country.

The last speaker expressed surprise that combined gas and oil engines had not been tried on ship board. The reason is that shipowners desire to carry passengers as well as cargo, which would be impossible with this arrangement.

Mr. Campbell may rightly claim to have been a pioneer of the gas engine in this country. If the gas engine makers had had the assistance which the Continental Diesel engine makers have had, we should have a different tale to tell in this country. The gas engine maker took all the risks. With regard to exhaust boilers, I think the gas engine world is again the pioneer, and it can show one hundred exhaust boilers for every one outside the gas engine power generating plants in the country. The nature of the recoverable heat is different in a gas engine as compared with a Diesel engine. The exhaust as a rule from a gas engine has great heating properties. It is also highly destructive. The exhaust from an oil engine is not so hot, nor has it such destructive properties. In oil engine practice you may leave a certain quantity of exhaust gas in the cylinders without deteriorating a new charge.

As far as the relative merits of two and four cycle engines go, there is no doubt that the two-cycle gas engine in this country has proved itself a failure. Thousands of pounds have been spent in demonstrating the two-cycle engine, but at the present moment there are no builders of two-cycle engines in this country.

The example of a small suction gas plant which Messrs. Campbell installed in a boat was very interesting. One can

*cf. Vol. of Transactions XX.

only regret that such enterprise had not gone forward to a successful issue. There have been many attempts in this country to popularise the gas engine. Of late years all attempts have been at a standstill. On the Continent the gas engine is still making progress for lighter powers.

Speaking about the wiredrawing of the charge, it is significant that practically the majority of Diesel engine builders to-day have very little data regarding the wiredrawing or throttling of the air. Another phenomenon is worthy of comment in the case of the gas and oil engine. The gas engine is classed as a crude, violent explosion engine. The Diesel engine is supposed to be a slow burning engine with steady combustion and without expansion. Now it is very singular, however, that breech liner, breech end, and cylinder cover troubles have been and are to-day a bone of contention with large oil engine builders, whereas the crude explosion gas engine builders have long ago finished with these troubles.

It means that with gas engines we have mastered the whole process of combustion, whereas in the design of oil engines the laws that govern the combustion are practically unknown; in other words the heat eddies encountered in oil engines are much more difficult to understand than in gas engines.

As to the reliability of gas engines, the best performance of any known oil engine is entirely overshadowed by that of the gas engine. Non-stop runs of close on six months have been accomplished by the gas engine. The most perfect oil engine has never yet assailed this very praiseworthy non-stop performance.

We all appreciate Mr. Campbell's remarks. They are written by a builder who could probably keep us all entertained for many hours.

Mr. B. P. Fielden: I should like to ask at what size of engine is it usual to start to water-cool the piston?

Mr. F. O. Beckett: I should like to ask the lecturer if he could say in turning the cranks what amount of spring he would allow between the top centre and the bottom centre? I was pleased to hear his remarks about the connecting rod bolts, as there are certainly difficulties concerning these bolts which have to be considered. From the remarks made concerning the taper cotter it appears that the makers have now overcome the difficulty, but I can quite see that the concussion acting on the gudgeon pin must be enormous. I had also intended to ask the question put by Mr. Fielden—as to the water-cooling of the pistons.

Mr. Campbell : I am afraid I do not quite follow the question regarding spring of the shaft.

Mr. Beckett : I meant that when the engine is disconnected and you turn the crank I find there is a certain amount of spring between the top and bottom centres.

Mr. Miller : In the vertical engine, does Mr. Campbell use the trombone type of cooling pipes? I was sorry to note that he condemns the method of cooling by means of oil.

Mr. W. McLaren : With regard to an earlier speaker's remarks concerning the early days of the gas engine, I think it is about 45 years ago since I was concerned in the conversion of a gas engine into a steam engine. I should like to ask Mr. Campbell how they arrived at the correct amount of offset of the crankshaft from the centre line of the cylinder.

Mr. H. C. Matheson : Could the lecturer explain the cycle in the double-acting gas engine? Also where the steam is obtained to mix with the fuel—the gas from the producer? Further, where the cylinder and crankshaft are out of alignment by $1\frac{1}{2}$ in., is there a dead centre?

The Chairman : I would like to ask the lecturer whether anything has been done more recently than in the cases he has indicated in the application of gas engines of any type for marine propulsion. That application has many attractions, especially in point of economy of fuel, but as far as I know the subject it is also attended with many difficulties. One or two attempts have been made by the Admiralty in this direction, but they were attended with very little success, especially those which aimed at using bituminous coal. Recently I have seen on a very small scale an anthracite or coke producer which seemed to be much more promising, but of course in this case the gas is of a different character and the circumstances generally are more favourable than those accompanying the use of producer gas from bituminous coal.

In one of the attempts I have referred to, the plant was placed on board an old gunboat, and considerable trouble was experienced in obtaining satisfactory ventilation of the producer and machinery rooms. But another and greater difficulty was to produce gas of a constant quality. That was a real trouble and the machinery, in consequence, by no means met the requirements of the bridge.

In another case, a plant was made in the North of England and trials were made on shore, the plant being arranged in the same limits of space as it would have been had it been placed in the vessel for which it was designed. Here again in spite of the help that was given by engineers accustomed to problems of combustion and gasification of fuel, and of the experience of producer experts that was available, there was the same trouble on account of variation in the quality of the gas. Further trials with other producers after the plant had been installed in a naval shore establishment, were somewhat more satisfactory, but never sufficiently so to justify the plant being fitted for service afloat. In both these cases the fuel used was bituminous in character. But even if these troubles had been overcome, and some felt hopeful on this point, the greatest objection of all from the marine engineering point of view remained, and that was the enormous weight of plant required for the power obtained. Large as this weight was, I believe that the chief cause of our gas troubles was that, on account of the limits of space, the producer was too small for the duty expected.

But all this took place about 1908, and as the small scale case previously referred to showed a considerable improvement as regards weight, even after allowing for the fact that the fuel was of more suitable quality, and as other improvements have also been claimed, it would be interesting if the lecturer could tell us something more of any modern developments.

To go to another topic, if it is not a secret I should like to ask Mr. Campbell what is the material of the satisfactory connecting rod bolts he mentioned, and whether the material is subjected to any special heat treatment.

Mr. Campbell: I will do my best to reply to all these questions. First of all, Mr. Chaloner; the interchangeability of gas and oil engines is not quite a new thing, but the suggestion that they should be interchangeable on board ship is, I am afraid, impossible or impracticable, because you would be carrying a great bulk of material and occupying valuable space which you might only use for a quarter of the time. It is only in certain quarters of the World where you could obtain refuse, or coal suitable for gas producer plants. I am afraid that interchangeability in a gas plant is hardly practicable at the present time.

Regarding Mr. Chaloner's other question with reference to quality versus quantity governing, there is a slower rate of combustion in the case of the quality governing which gives what is known as a "fatter" card. You get a higher peak curve. In the slow burning quality you have slower burning with a constant compression, giving better results than with the quantity method of governing.

With regard to stand by losses, the comparison I made is quite fair. I spoke in averages when I gave a figure of 3·1 against 1·8. I should undoubtedly say that the stand by loss of a gas engine is one-sixth that of a steam engine. That could easily be proved in any good installation.

With regard to aluminium pistons, they have been tried, but are not successful. There may come a time when, with a suitable design with an aluminium head and an iron skirt they might be used.

I am afraid that want of time will not allow me to deal to-night with the question of waste heat. It is an important subject. I consider that in the near future, when business begins to revive, there will be a great increase in the use of gas engines in a scientific manner. I showed you a picture of a single-acting tandem engine in a Yorkshire mill. The exhaust from that engine is used for raising steam, and also for heating the mill. That is one very successful installation where the waste heat is utilised, but I may frankly tell you that we have before that made numerous attempts to use exhaust heat. As Mr. Chaloner has pointed out, the possibilities of the utilisation of exhaust heat are somewhat illusionary. You must not reduce the temperature below 400°-500° or you are likely to get trouble.

Mr. Shackleton has raised the question of two and four cycle engines. There are no two-cycle gas engines worth considering to-day. I began my engineering life by making two-cycle engines, and I have twice tried it, but have found it a failure. Until we are able to obtain suitable material to withstand the high temperatures in a two-cycle engine I think it will be more or less a failure. About a month ago I saw a two-cycle engine made by a well-known maker; it was of 1,000 H.P., and it had been in use two years. It had had seven cylinder liners fitted in the two years. It gave off more black carbon smoke than came out of a steam engine chimney.

The first thing we are "up against" is lack of knowledge of metallurgy regarding cylinder liners and pistons. Up to the present time a really satisfactory cast iron for these purposes has not been found.

I am sorry to disappoint Mr. Shackleton about the non-stop runs of gas and oil engines. I find from my own experience that oil can give as long runs as gas.

As regards Mr. Fielden's questions, like the Scotsman I should like to reply by asking Mr. Fielden another question. I would like to ask him what kind of fuel he has in mind. If you are dealing with fuel of a high calorific value the size of piston which you would water-cool would be lower than in the case of an inferior fuel. The natural gas such as is frequently found in oil fields, compared with the fuels we have to use in this country (taking it as meaning producer gas) show a very wide variation in calorific values. One has also to contend with the ideas of the designer. I am afraid we start water-cooling at smaller sizes than other makers. We find that some makers will not water-cool pistons under 40 in. diameter, whereas we water-cool pistons of 20 in. diameter. Where you wish the engine to maintain its full load for long periods together it is desirable to have water-cooling. If at the end of a long run you look at the trunk of an engine with pistons of say 18 in. or 20 in. diameter, which are not water-cooled, you will find the end of the piston red hot. That is naturally a very bad state of affairs. We should start at about 20 in., but I repeat that it depends to a certain extent on the designer.

Mr. Beckett asked about the spring of the crankshafts. I am afraid I do not know anything about that. I do know that if a crank is out of alignment the webs will be wider at the top centre than at the bottom centre; but I feel sure that is due to bad alignment.

Mr. Miller asked about the water-cooling system I would use for a vertical engine. He commented on the trombone pipes versus walking pipes. I should not think there is any doubt that the walking pipes, with their joints, etc., are out of the question for an engine which has to run with a minimum of overhaul. It may be expressed in a nutshell, fit walking pipes wherever possible. The ideal system is neither walking pipes nor trombone pipes. The water is certainly admitted to the pistons in a vertical engine through a trombone pipe, but the water is allowed to flow freely away through a water pipe which couples up three, four, or perhaps six cylinders.

Mr. Matheson asked what cycle was the double-acting gas engine. What I showed was a 4-cycle engine, and the same cycle obtains on each side of the engine, namely, induction, compression, expansion and exhaust. He also asked where the steam comes from for the producer. I showed on the slides how the steam vapour was either drawn in by the incoming air or forced in with the fuel.

Another question was, is there a dead centre when the crank is offset? There is a dead centre in every combination of crank and connecting rod; in this case it can be easily found graphically.

Now I come to Sir George Goodwin's question. I am in ignorance of any more recent applications of gas engines to marine propulsion than those to which he referred. I am not sure how long ago those experiments were tried.

Sir GEORGE GOODWIN: About three years ago.

Mr. CAMPBELL: In 1914 there were some attempts being made by German makers on timber rafts going up and down the Rhine. It was at the same time that we were passing up and down, testing our engine.

I do not look upon the smell of a gas producer on board ship as being an objection or a danger. I think there should be no difficulty at all in that respect. Rather I think the difficulty would arise due to the space occupied by the producer. I have not gone fully into the question of gas engines for marine propulsion; I regret that I have not done so. I only gave one reason for the difficulty one would anticipate—the distribution of fuel. There are others; one is that to get pioneers to adopt the gas engine it is first necessary to overcome the objection due to the space occupied by the producer. With the more modern knowledge and experience which we have to-day it might be possible to modify that to some extent, but I do not know that we should be able to compare with the Diesel engine in this respect.

I am surprised to hear that there has been trouble due to variation in the quality of the gas. If one looks up the report of the trials carried out under the auspices of the Royal Agricultural Society in 1905 it will be seen that that was one point which was specially emphasised by the judges, and I think the three leading makers came through with flying colours. I think that although you have a quality of gas which is changing from time to time, the difference between the worst and the best is not more than 5 per cent., and I do not think that would trouble the bridge. It is not to be expected that an engine will run at no load and then at full load at an instant's notice. It is after a long period of running that one meets this difficulty of changing quality of gas, but it is never more than 5 per cent.

Regarding the quality of steel used for the connecting rod bolts, it is, I think, a 60 tons steel, containing 3 per cent. of nickel. I shall be very pleased to send the Hon. Secretary full details with the heat treatment necessary. I hesitate to give full details now because my memory might prove a little treacherous, and I may give you something not quite accurate. The range of temperature is not very great; I prefer to look up the data and give it to you in writing.

I think that exhausts the matter of the questions, and I have to thank you for listening to me for such a long time.

The CHAIRMAN: It is now my pleasant duty to propose that our very best thanks be given to Mr. Campbell for his able and instructive paper. We are indebted to him for the trouble he has taken, for coming so far at short notice, and for the information he has given us. Our thanks to Mr. Campbell, coming from marine engineers, will come very appropriately. We associate his name mostly with shore plant, but during the war Mr. Campbell was sent for and asked to turn his attention to marine work, and he did so with great success. He gave most valuable help in adapting his heavy oil engine to the country's naval requirements. We have all been most interested in the paper, and we feel that we want some more. Mr. Campbell told me before the lecture that he would be prepared to come again and give us a lecture on oil engines, or on another very interesting subject, that of the development of the gas turbine. I think we shall be very pleased to accept that offer, but we had better say that we will have both!

No better thanks can be given to Mr. Campbell than to ask him to promise to give us both papers.

Mr. CAMPBELL: I thank you very much for your kindness in passing this vote of thanks to me. I hope that you have been thoroughly interested in the paper. You may depend on Mr. Adamson letting me know of my promise regarding a future visit.

I want you to show your appreciation of Sir George Goodwin's presence in the chair to-night. You do not need me to "paint the lily" by referring at length to his services during the War. We accord him a very hearty vote of thanks for coming here to-night.

By Correspondence.

Mr. W. J. Esplin: When one views the illustration of the immense amount of clinker which clogged the working of the Gas Producer at the Mitylene Power Station, and then learns that this obstruction was obviated in subsequent working by simply augmenting the supply of steam or water vapour fed to the producer, it would be interesting to learn what practical means were adopted to ascertain the correct volume of water vapour to supply? If this can constantly be regulated to suit all rates of combustion then it would enable coke fired producers, at any rate, to run efficiently for much longer periods.

Mr. H. Campbell: In reply to the enquiry as to the material used in the manufacture of connecting rod bolts, the following are particulars:—

Guaranteed analysis of 3% nickel steel:

C.	Si. (Max.).	Mn.	S. (Max.).	P. (Max.).	Ni.
·30 – ·40	·30	·50 – ·80	·05	·05	2·75 – 3·25

Guaranteed mechanical properties of 1⅛ in. diameter bar, hardened and tempered:—

Yield ratio ...	... per cent.	... 65
Ultimate tensile	... minimum	... 45
Tons per sq. in.	... maximum	... 55
Elongation ...	... per cent.	... 22
Reduction of area	... per cent.	... 50
Izod impact ...	... foot-pounds	... 40

Treatment.

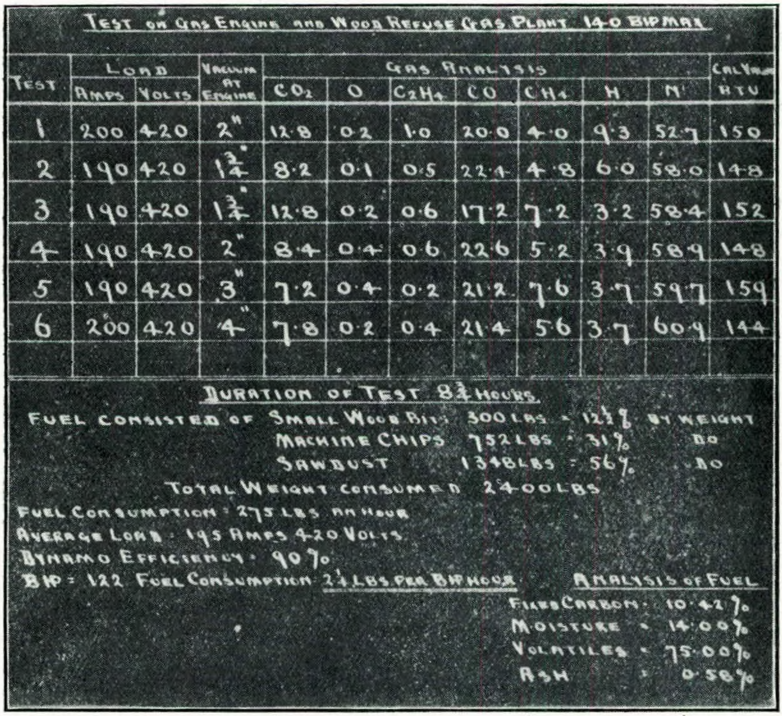
Forging.—Care must be taken that a temperature of 1150° C. is never exceeded, whilst forging must not be carried out below a cherry-red heat.

Note.—Bars and billets for forging are supplied untreated, in the condition as rolled.

Machining.—Bars for machining are delivered in the most suitable condition for this purpose. This steel, however, may be readily machined after hardening and tempering to comply with the mechanical properties given above. If it is desired to rough machine forgings and stampings before final heat-treatment it is recommended that they should be previously normalised.

Normalising.—Heat to a temperature of 830° C. and allow to cool in air.

Hardening.—Heat slowly and uniformly to 850° C. and quench in oil. It is desired to emphasise the necessity for uniform heating. If attention is not paid to this point unequal stresses may be set up on quenching, which will lead to distortion of the part concerned.



Test on Gas Engine and Wood Refuse Gas Plant 140 B.H.P. Max.

Test	Load		Vacuum at Engine	Gas Analysis							Cal. Val. B.T.U.
	Amps	Volts		CO_2	O	C_2H_4	CO	CH_4	H	N	
1	200	420	2"	12·8	0·2	1·0	20·0	4·0	9·3	52·7	150
2	190	420	1¾"	8·2	0·1	0·5	22·4	4·8	6·0	58·0	148
3	190	420	1¾"	12·8	0·2	0·6	17·2	7·2	3·2	58·4	152
4	190	420	2"	8·4	0·4	0·6	22·6	5·2	3·9	58·9	148
5	190	420	3"	7·2	0·4	0·2	21·2	7·6	3·7	59·7	159
6	200	420	4"	7·8	0·2	0·4	21·4	5·6	3·7	60·9	144

Duration of Test 8¾ Hours

Fuel consisted of Small Wood Bits 300 lbs = 12½ % by weight
Machine Chips 752 lbs = 31 % do
Sawdust 1348 lbs = 56 % do
Total Weight Consumed 2400 lbs

Fuel Consumption = 275 lbs an hour
Average Load = 195 Amps 420 Volts
Dynamo Efficiency = 90 %
B.H.P. = 122 Fuel Consumption 2¼ lbs per B.H.P. hour

Analysis of Fuel
Fixed Carbon = 10·42 %
Moisture = 14·00 %
Volatiles = 75·00 %
Ash = 0·58 %

Tempering.—To obtain the mechanical properties given above, re-heat slowly and uniformly to 630° C. and cool in air.

The makers of the steel supply the bars heat-treated ready for use, and the following are the figures which they guarantee:—

Guaranteed mechanical properties as delivered:

Yield ratio ...	... per cent.	... 65
Ultimate tensile	... minimum	... 45
Tons per sq. in.	... maximum	... 55
Elongation ...	... per cent.	... 22
Reduction of area	... per cent.	... 50
Izod impact ...	... foot-pounds	... 40

Respecting Mr. Esplin's point, the normal figure for water vaporised and gasified in the producer is that it should amount to about half the weight of the fuel consumed. This figure is approximately correct for Anthracite or any fuel of similar composition and characteristics. When a fuel contains an appreciably larger percentage of moisture than is found in anthracite, proportionately less moisture has to be passed through the fire.

If a plant is constructed to use some one particular fuel, then the vaporising arrangements are made to suit that fuel.

In a Suction Plant of a type which requires an evaporator, the amount of steam generated in the evaporator and drawn through the fire is governed automatically by the load on the engine. The greater the load, the hotter the fire and the greater the amount of steam produced.

With a sudden and considerable change in load the balance may be upset for a short time, and steam may be generated and not used, just as a steam boiler blows off when the engine is stopped unexpectedly, but the balance is soon automatically restored.

Films Showing the Works of Messrs. W. Beardmore, Glasgow.

Tuesday, January 23, 1923.

CHAIRMAN: SIR GEORGE G. GOODWIN, K.C.B., LL.D.

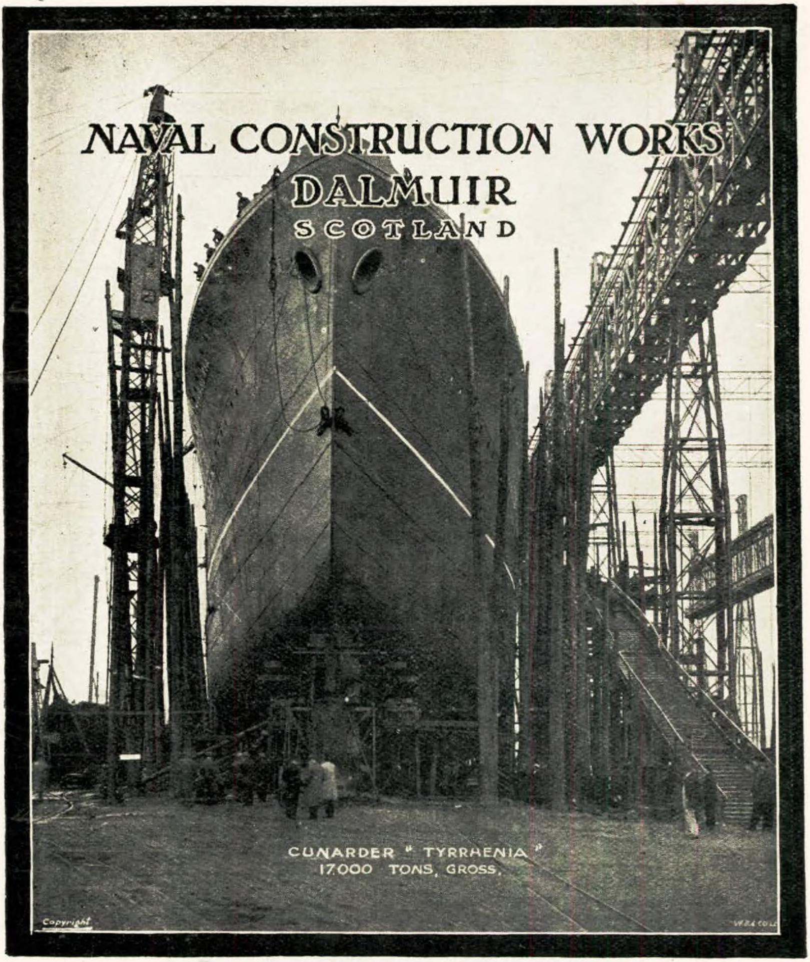
Shipyard at Dalmuir.—The film opened with a view of the shipyard showing a ship on the stocks with plates being lowered into place. Then various views of the iron workers' machine shops, showing first a general view, then a close-up of a gang moving a truck full of plates from the shops out to the yard. A sweep round from the east by south to the west side of the fitting-out basin, showing a destroyer, tender, submarine, and the 18,000 ton liner *Empress of France* in the basin, the latter in her war-time coat of dazzle painting.

Following on from this was shown an interior of the marine engine shops, where various parts of turbine machinery were being finished and assembled. The boiler shop came next with end views of the largest type of boilers in process of completion.

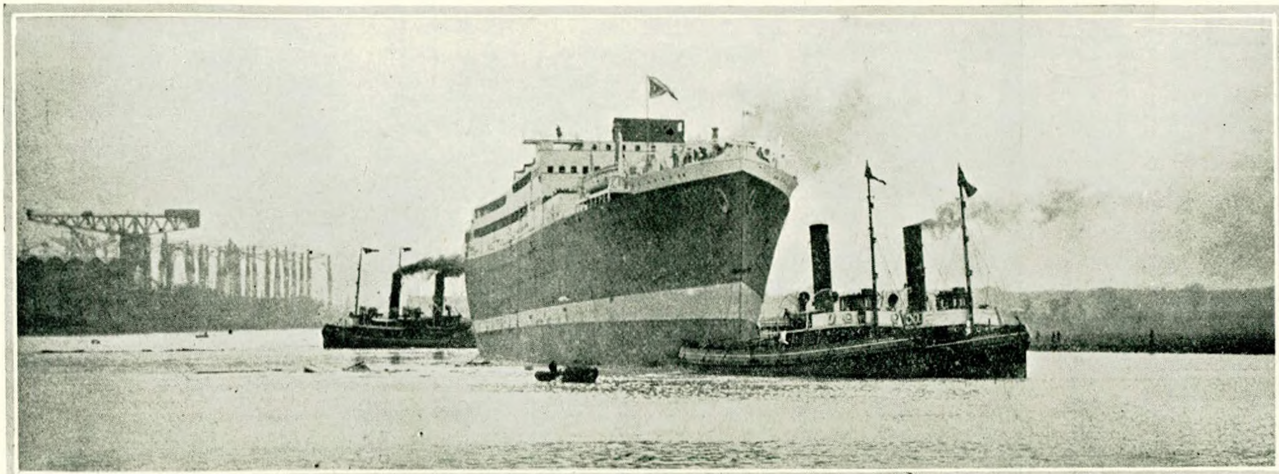
W. BEARDMORE, GLASGOW.

Returning to the shipyard again, the launch of the torpedo boat destroyer *Vanity* was viewed.

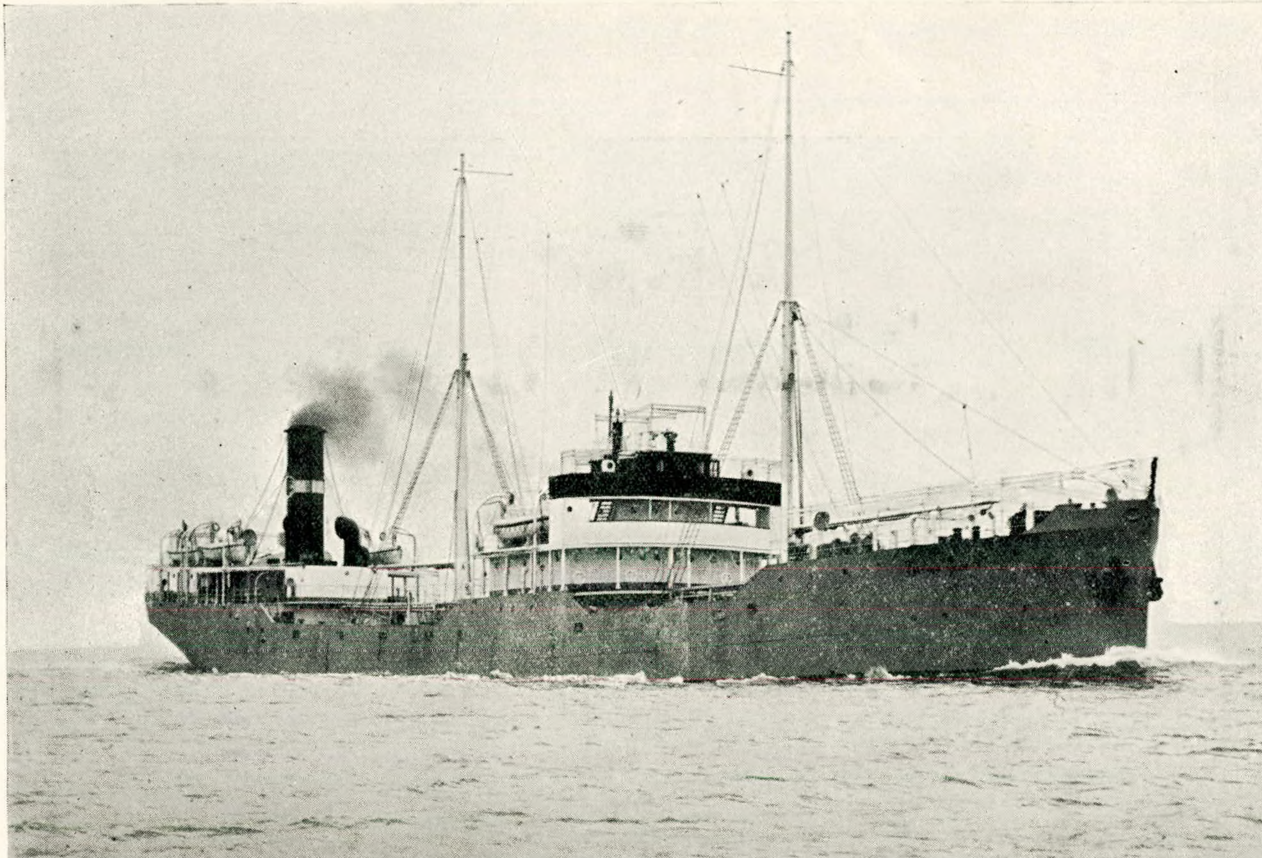
Aeronautical Engineering.—Various views were shown of H.M. Airship R.34, leaving the firm's Inchinnan Airship Construction Works, including the ship being man-handled out of the giant airship shed, and then released for the trial flight. A



Cunard Liner "Tyrrhenia" on Stocks

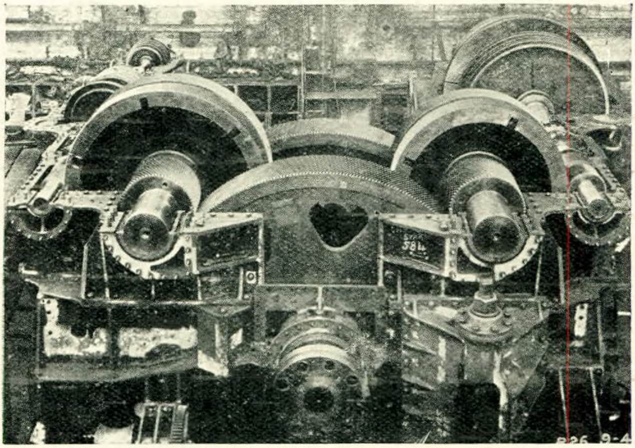


Launch of Lloyd Sabaudo "Conte Verde," 18,000 tons.—20,000 I.H.P.

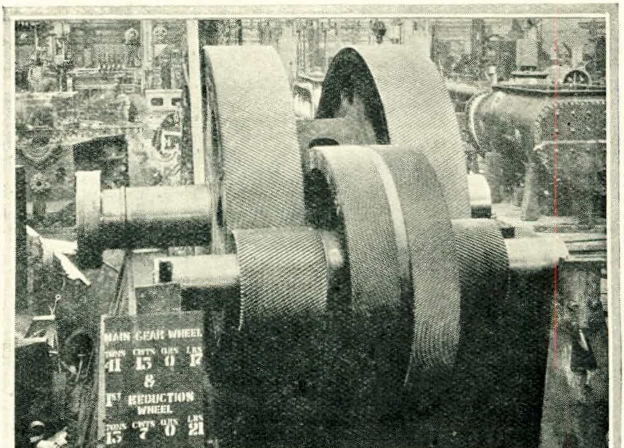


"British Trader." A 6,000 ton Oil Tanker, one of an order of five similar vessels for British Tanker Co. Ltd.

view of the airship coming home against a very striking evening sky was particularly good. The aeroplane works are then shown, the first view being of the interior of the assembling shed, showing Sopwith Pups being completed, and the folding wings used on sea-going aircraft being tested, followed by a



Marine Engine Department. Double Reduction Turbine Gearing



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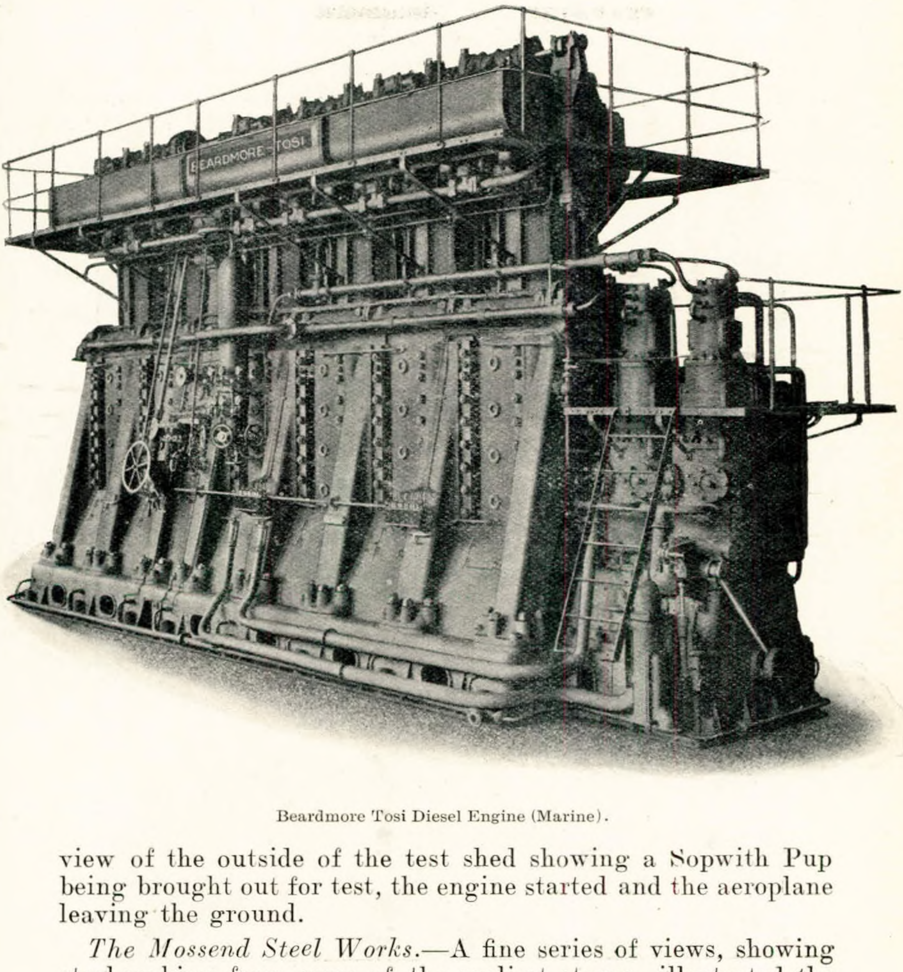
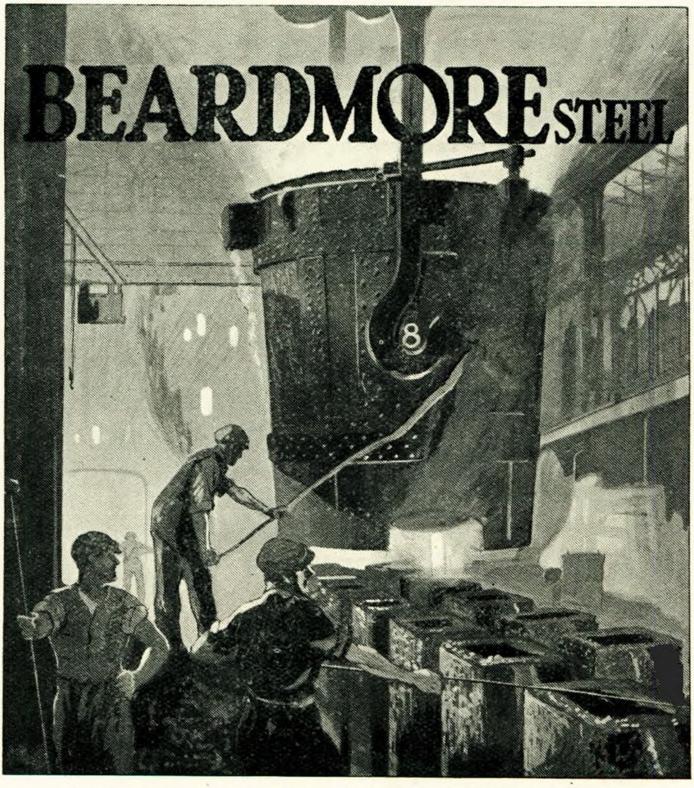


Beardmore Tosi Diesel Engine (Marine).

view of the outside of the test shed showing a Sopwith Pup being brought out for test, the engine started and the aeroplane leaving the ground.

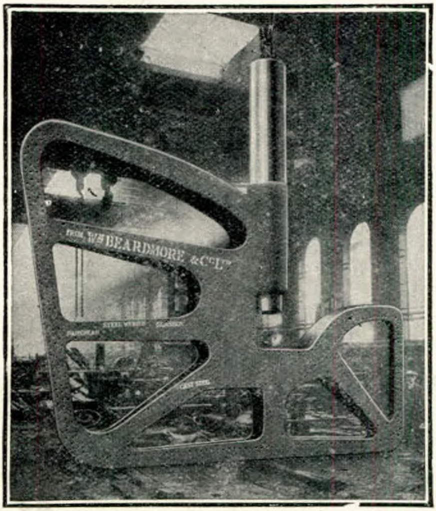
The Mossend Steel Works.—A fine series of views, showing steel-making from some of the earliest stages, illustrated the proficient methods in use by machinery which appeared to know exactly what to do. Tapping a 50-ton furnace, casting an ingot, cogging an ingot and rolling a plate were amongst the operations shown, the film being tinted to reproduce the ruddy glow from the metal.

Parkhead Steel Works.—The views shown of Parkhead were nearer the finishing operations than those at Mossend. The view of the forge showing a 20-ton marine engine shaft being forged under the 2,000-ton press, was good. In the forge machine shops there were views of the rough machining of a similar shaft, and boring a rotor rim. In the forge hammers department an excellent series of views showing the forging of locomotive axles, gave a good idea of the operation.

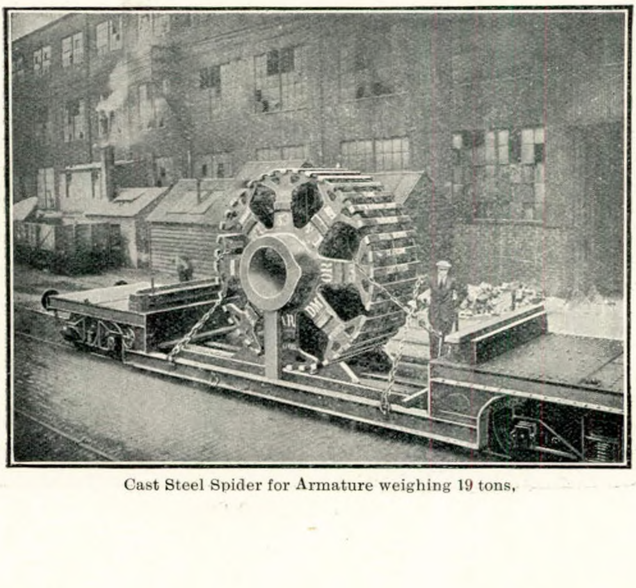


Casting Ladle. Pouring Molten Steel from Ladle, Parkhead Works,

The film now shifted to the foundry at Parkhead, and here the casting of a stern frame for a modern liner was followed by a view of the finished frame ready for despatch outside the shops. Stamping centres for rolling into locomotive tyres was another operation shown, added to by a view of the tyre mill finishing the job and turning out the complete tyre.



Cast Steel Rudder Frame for H.M.S. "Hood" weighing 50 tons.



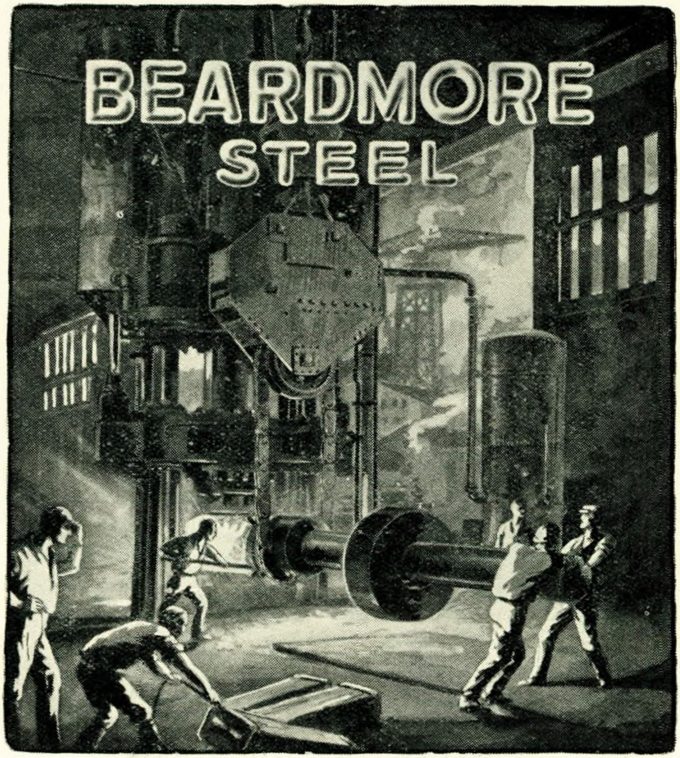
Cast Steel Spider for Armature weighing 19 tons,

FILMS SHOWING THE WORKS OF MESSRS. W. BEARDMORE, GLASGOW.

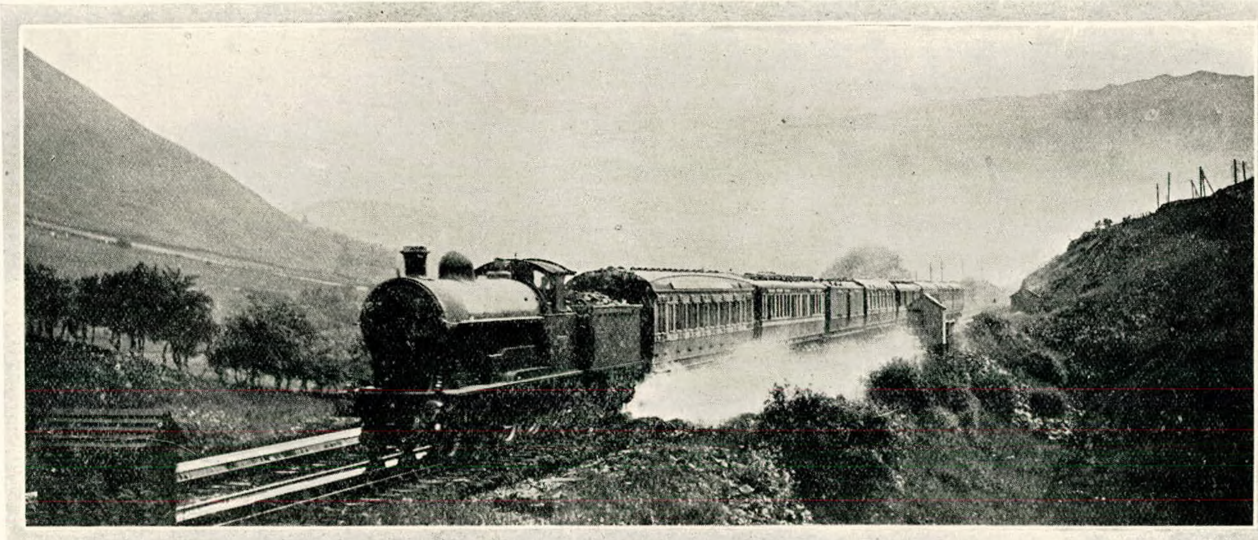
There were five extremely interesting action pictures of the making of modern wheels in the Wheel and Axle Works, Parkhead, including bending wheel spokes, glutting the wheel, turning wheels to gauge in the machine shop, and pressing the finished wheel on to its axle.

The concluding view was one of the rolling of a corrugated furnace, and this was a particularly interesting one.

Sir George Goodwin, after referring to their thorough and systematic methods developed by Messrs. Beardmore in carrying out their work, as illustrated by the views shown, proposed a vote of thanks to the firm for lending the films; this was carried by acclamation.



Forgirg.



L. & N.W. Railway Loco. built by Wm. Beardmore & Co., Ltd., travelling with train at 70 m.p.h.

Films illustrating Messrs. Hadfields, Ltd., Sheffield Works.

Tuesday, December 19, 1922.

CHAIRMAN: MR. J. SHANKS.

Sir ROBERT HADFIELD: It gives me much pleasure to be here this evening, for more reasons than one, as I wanted to show my sympathy with the work of the marine engineer and to express my appreciation of the Institute in the past and present.

I have been asked to present some films and slides to you to-night. We are showing some of the things we tried to do in Sheffield during the war. We employed at the outbreak of war about 5,000 to 6,000 men; before long that number had been doubled and eventually trebled, so that in 1918 our men numbered 16,000, who were helping the country through its trial. So you see that Sheffield did its best. To give you some idea of what was accomplished, I may say that the total output during the war was £36,000,000 in value. That, I think, is a good record for one firm. We made all kinds of war material, also many articles required in times of peace. One of the few benefits due to the war has been undoubtedly that it did show the steel maker how to turn out a large quantity of material and at the same time to keep up the quality. As you know, in the manufacture of high explosive shell it is very necessary to maintain the right quality, and in this connection I may say that I never heard of one of our shells exploding in the gun. The French had many disasters occur due to failures in this respect.

One of our feats was the manufacture of armour-piercing shells. These were made for guns up to 18in. calibre, weighing as much as $1\frac{1}{2}$ tons per shell. The weight of the gun itself was 150 tons, and the range 30 miles. At that range the shell would pierce armour 12in. thick. The Germans had no such Naval gun, nor did they in any way beat us. I have examined many German shells and I can tell you that in many respects the quality was inferior. They had, too, been preparing a long time while we were engaged in peaceful pursuits, yet they never surpassed us in any way.

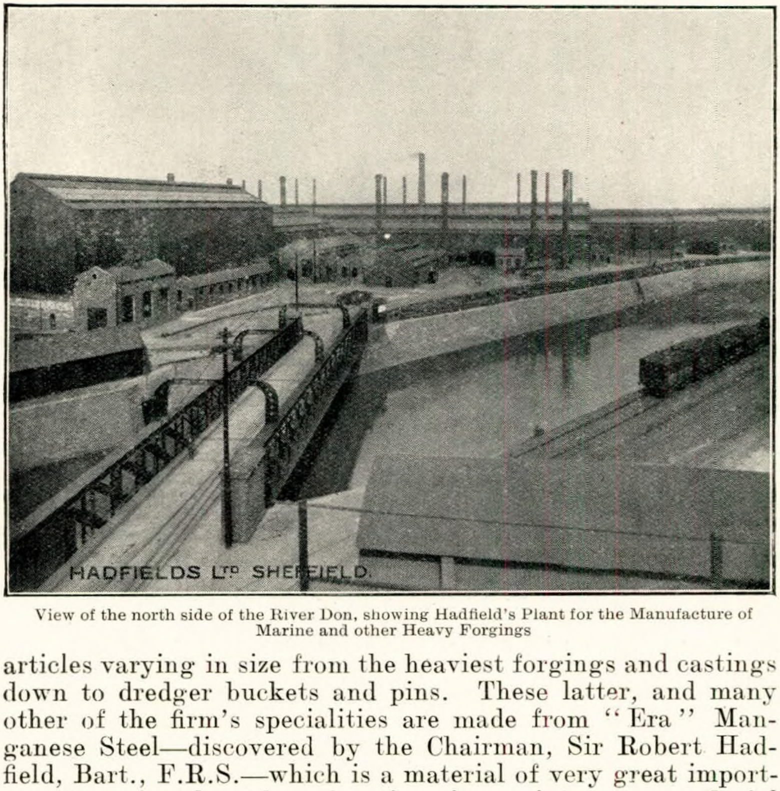
This is not a scientific paper; we were asked to give you some cinematograph pictures of our works, and you will realise, I am sure, that it is quite impossible to go into the scientific manufacture of the steel in the time at our disposal to-night. I am glad to tell you that the University of Sheffield now has a

Faculty of Metallurgy, so that this branch of science has been raised and is now alongside other branches of industrial science.

I admire the work of your Institute so much that if ever your members care to make a visit to our Works, I may say that you will be very heartily welcomed.

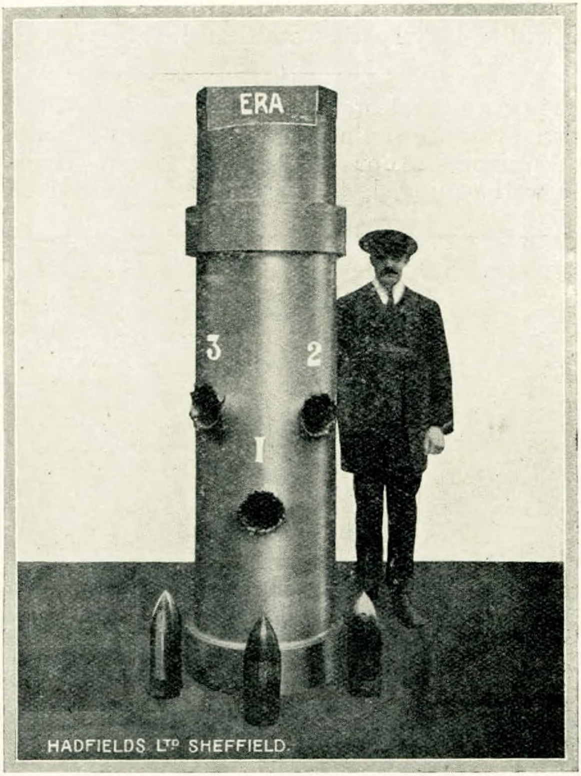
———o———

The views were selected more especially to illustrate the production of steel castings and forgings of importance to Marine Engineers. For this work Messrs. Hadfields are specially well equipped, the products mentioned comprising



View of the north side of the River Don, showing Hadfield's Plant for the Manufacture of Marine and other Heavy Forgings

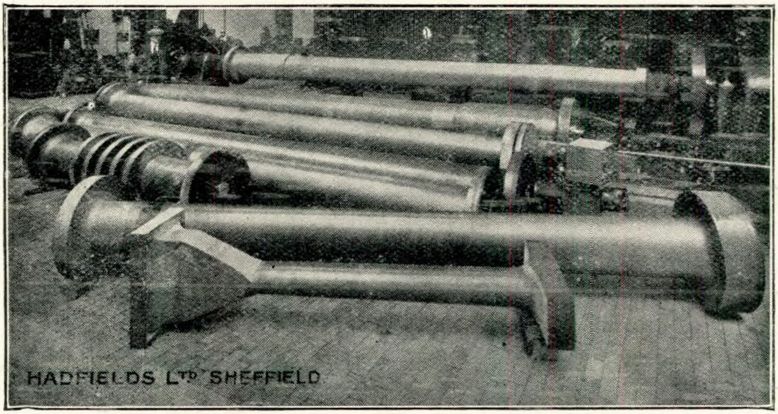
articles varying in size from the heaviest forgings and castings down to dredger buckets and pins. These latter, and many other of the firm's specialities are made from "Era" Manganese Steel—discovered by the Chairman, Sir Robert Hadfield, Bart., F.R.S.—which is a material of very great importance to various branches of engineering owing to its wonderful toughness and yet at the same time extraordinary durability. During the showing of the films the various features exhibited were pointed out and explained by Mr. S. A. Main, B.Sc., the following being a summary of the subjects shown.



Portion of Marine Shaft of Hadfield's Special Quality "Era" Steel after attack by 20½ c.m. armour-piercing projectiles.

Commencing with the manufacture of the steel, views were shown of a 40-ton Open Hearth Furnace including the charging operations by means of a mechanical charger, a view of the interior of the furnace, and subsequent tapping of the molten steel and casting into ingots by the special Hadfield System. The tapping of a 6-ton Electric Furnace was also shown.

The Hadfield System of casting sound ingots invented by Sir Robert Hadfield, was described, and its beneficial effects demonstrated by illustrations of ingots cast in this way compared with those cast by other processes. The system, which is the standard method employed in the Hadfield Works, not only ensures perfectly sound steel, a point of great importance to the Marine Engineer, but also effects considerable economies by the improved yield of useable material obtained from the ingot.



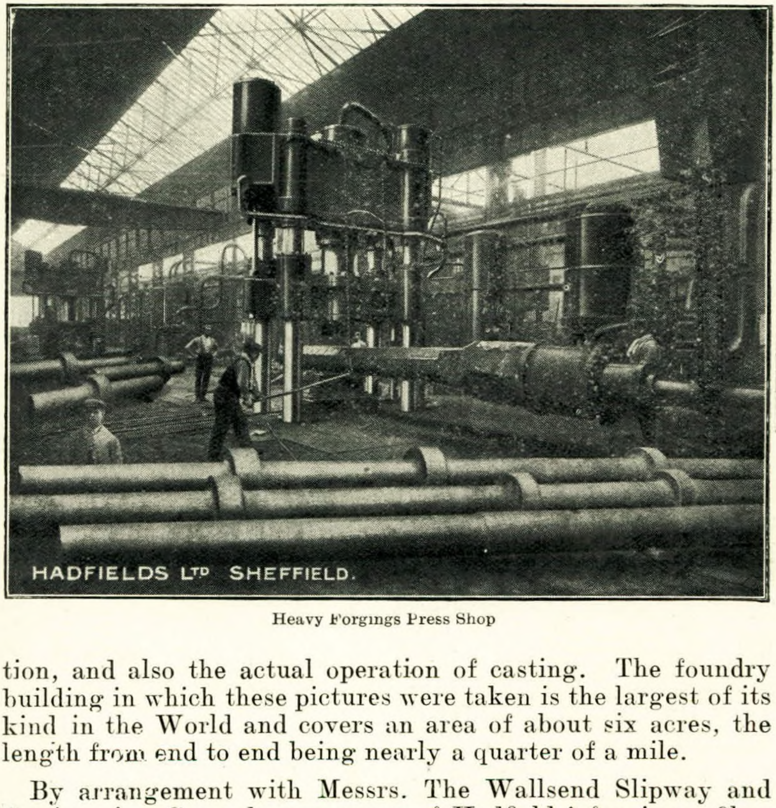
Group of Marine Shafts, etc., of "Hecla" Forged Steel.

Views were next shown of the large and up-to-date Forge specially erected and equipped, at a cost of nearly half a million pounds, for the production of large forgings, including marine engine shafts. The whole plant is so laid out for rapid and convenient handling of forgings of large dimensions, coupled with an arrangement for special heat treatment, that it may be correctly described as the last word in Steel Works engineering in this category. The equipment comprises two 1,500 ton quick-acting presses and another of 1,000 tons; also half a dozen heavy forging presses and steam hammers. The operations of forging a 25-ton ingot into a large marine shaft and its subsequent machining were demonstrated in their various stages.

The toughness of such shafts was well demonstrated by views of a specimen which had been submitted to the very severe test of the impact of armour piercing projectiles, which it had successfully withstood without developing cracks in any way. Further views showed the manufacture of smaller forgings, including the forgings of Dredger Pins of "Era" Manganese Steel.

510 FILMS ILLUSTRATING MESSRS. HADFIELDS, LTD., SHEFFIELD WORKS.

The manufacture of steel castings, for which Messrs. Hadfields have a very high reputation, was illustrated by views taken in the pattern shop and in the Foundry. These showed patterns and moulds of various forms in process of construc-



Heavy Forgings Press Shop

tion, and also the actual operation of casting. The foundry building in which these pictures were taken is the largest of its kind in the World and covers an area of about six acres, the length from end to end being nearly a quarter of a mile.

By arrangement with Messrs. The Wallsend Slipway and Engineering Co., who are users of Hadfields' forgings, films taken in their works and showing the construction of marine engines, both of the reciprocating and turbine type, were also shown.

This was followed by views of the work carried out at the Hadfield Works during the war in connection with the diversion of the River Don. This work was necessary in order to make better use of the land available, and to improve the traffic facilities. The demonstration concluded with pictures taken on the occasion of the visits of His Majesty The King, and other distinguished visitors to the East Hecla Works.

Machine Shop for Heavy Forgings.

The CHAIRMAN: Those of us who have been so fortunate as to be here to-night are to be congratulated, as I think you will agree that the films we have seen are extremely educational. We as marine engineers have a share in the claim made for the shipbuilders and engineers of this country that they are the best in the world, and also we claim to be second to none in the running of ships. To-night we have seen how the material is manufactured. I was very pleased to hear Sir Robert Hadfield invite us to come to Sheffield to see and understand what has been shown on the screen to-night. I am sure we are much indebted to Sir Robert Hadfield and Mr. Main for the very excellent evening's entertainment and instruction which they have so kindly afforded us, and I have great pleasure in proposing a hearty vote of thanks to them.

Mr. J. Thom: I have much pleasure in seconding this vote of thanks to Sir Robert Hadfield and his assistant. The films have been very interesting as a picture, but moreover as showing the enormous amount of work which has to be done on the material. What we were told about the electrical furnace was very impressive, namely, that it required between 2,000 and 3,000 H.P. to keep that furnace going. I am sure that all our young men who read and hear about this evening's lecture will thank Sir Robert very much indeed for the trouble he has taken in preparing it and in coming here to-night. I am sure that if Sir Robert could be persuaded to give us a paper on the subject of the material we should be very delighted; it would be most instructive to have some detailed explanation of these matters in a way we could easily follow.

Sir Robert Hadfield: I must return most grateful thanks for your kindness in moving this vote of thanks. It is a great pleasure to come and show that this country is quite able to hold its own. It is essential that we must maintain the highest possible training; that being granted, the British race can hold its own against all rivals.

Mr. Main referred to Manganese Steel. I happened to invent that steel some years ago, and it is particularly gratifying to know that it was of the greatest possible service in tne manufacture of the helmets worn by our soldiers during the war. Nothing has given me greater satisfaction than the fact that several millions of those helmets were made and issued to our men, and that they undoubtedly were the means of saving many valuable lives. I did my very best to help our French Allies early in the war by giving them information regarding the manufacture of this steel, but they did not take it up. I tell you this because we in this country are sometimes blamed for being behind. You could place four French helmets in a row, and a bullet at 900 ft. per second velocity would perforate them. At the same velocity a bullet simply flattened up against a helmet made of our steel.

You saw pictures of the very wonderful visit of the King to our works. No one felt prouder than I did on that day. His Majesty allowed me to present many scores of our workpeople, and he shook hands with every one of them. The result was that our output went up by ten per cent. So I say "God Save the King!"

———o———

Notes.

With further reference to the question raised in the course of the discussion on November 14th, 1922, the following is quoted by the permission of the Editor of 'The Power Engineer'':—

MINIMISING HEAT OXIDATION OF METALS.

Very definite economies in the replacement of metal parts subjected to heat are possible by their treatment by the Calorising Process.

Since Sir Robert Hadfield startled the engineering world by his colossal estimate of the cost of corrosion, many have been on the watch for methods by which this can be minimised in their particular spheres. Much corrosion is due to atmospheric impurities and to the action of alkaline or acid liquids, but quite a large proportion of the deterioration commonly included in the phase corrosion is due to more rapid action when articles are exposed to heat. For example, the life of the exhaust valves of some large internal-combustion engines is comparatively short because of the deterioration of the material of the valves through exposure to high temperatures; brickwork-retaining bolts on self-contained boilers suffer from rapid oxidation; superheater tubes are affected by their arduous conditions, and in many other instances replacements become necessary in relatively short periods from such causes. By subjecting such details to the process of "Calorising," their life can be increased in some cases five to thirty times, and we are indebted to the Calorising Department of the Scarab Oil Burning Company Limited, of Carlton House, Lower Regent Street, S.W.1, for some details of the process and its possibilities.

Calorising is the term used to denote the formation of a surface alloy of aluminium on ferrous and non-ferrous metals; this is achieved by placing the articles to be treated in an airtight retort, partly filled with the calorising mixture (which consists of finely divided metallic aluminium suspended in aluminium oxide) and subjecting it to a high temperature for several hours. During the process, a continuous current of hydrogen is passed through the retort to ensure an inert atmosphere. Before being placed in the retort the articles are required to be throughly cleaned and to have a surface free from grease, scale or other foreign matter, this being effected either by sand-blasting or pickling. The treatment, conducted at high temperature, so thoroughly infuses aluminium into the exposed portion of the metal being treated as to form a homogeneous alloy for a depth which ranges from a few thousandths of an inch to the permeation of the entire mass and is governed by varying the duration of the treatment and the composition of the mixture.

The essential difference between calorising and processes hitherto used commercially is that the protective surface is not imposed as a skin or finish upon the metal to be treated, but, on the contrary, enters into intimate association with it, forming a solid solution alloy. It must not be confused with any coating processes like galvanising, coslettising or oxide coatings. It is, moreover, distinct from the numerous homogeneous alloys, some of which, containing nickel or chromium, are highly resistant to oxidisation at high temperatures. Calorising differs from such costly alloys in that it consists of using relatively inexpensive metal, such as iron or steel, in itself readily oxidisable, but covered with a continuous protective alloy coating which becomes a homogeneous part of the metal treated and which is obtained at a comparatively low cost.

The coating consists of a comparatively thin alloy layer, which is very rich in aluminium, but on being subjected to high temperature under working conditions this aluminium layer penetrates or diffuses further into the base metal, forming a larger amount of homogeneous ferro-aluminium alloy. In addition to the alloy thus permanently established in the pores of the metal, an intimately allied external surface of aluminium oxide is formed, which is quite impervious to oxidisation at high temperatures up to 1,800° Fahr. This external protective surface is hard and somewhat brittle, although it will withstand all ordinary handling and abrasion; should, however, this layer of oxide become injured by severe use, it will be renewed again by the oxidisation of the alloy exposed, and this renewal of the protective surface will occur until the diffusion of the surface aluminium content is reduced to the point where breakdown occurs and the underlying metal commences to scale.

Mechanically, the base metal is practically unaffected, except to the extent of being annealed. From the nature of the hard and somewhat brittle protective coating, however, calorised metal cannot be hammered or bent cold, although at a bright red heat it may be bent without affecting its resistance to oxidisation. The principal machining operations should, therefore, be completed before calorising.

It is possible to leave untreated portions of any article, such as screwed threads or machined surfaces that are to be fitted or welded into objects which are not subjected to high temperature conditions, but, of course, the protection during calorising adds considerably to the cost of treating such articles. It is impracticable to machine calorised articles except by grinding, which may injure or destroy the alloy. Further, owing to the nature of the protective oxide film on the surface of calorised metal, articles treated cannot afterwards be satisfactorily welded.

Calorising is applicable to ferrous and non-ferrous articles, but is not recommended for ordinary castings on account of the usually poor structure of the metal. It is no protection against rusting under ordinary atmospheric conditions although it delays the process; it does, however, protect excellently against the deleterious effect of flue gases and sulphur fumes. The cost of treatment is not excessive, but in any case if the life of an article be increased say five times in length it would obviously be highly advantageous to pay even double its value for the protection. Further, there is a very considerable gain in production and plant efficiency by the minimising of the periods during which plant must be out of commission for replacements.

Calorising is applicable to the special needs of almost every industry where high temperatures are used as well as in heat engine work generally; it has already been adopted in more industries than space will allow enumeration. The process was invented by Mr. T. Van Aller, in 1911, and developed by the General Electric Company of Schenectady, U.S.A. Since its inception, however, the process has been the subject of extensive experimental work and, as practised to-day, is a modification and improvement on Van Aller's original invention. It is largely employed in America and the Scarab Oil Burning Company, Limited, own the sole right for the British Isles, France and Belgium.

Apropos this firm's activities we may add that a new type of oil burner has been developed to supersede that described in "The Power User" of April, 1920, and we illustrate the new burner and casing. It was developed primarily for locomotive work but is applicable to stationary conditions. The casing bolts on to the front of the furnace and the burner is mounted within it on two spherical pivots through which flow the oil and the steam or compressed air for atomisation respectively.

The fuel rises up through a well into a reservoir or trough, over the edge of which it flows on to a steeply inclined plane. This plane is provided with longitudinal ribs cast upon it to secure an even distribution of the oil, and is of progressively increasing angle to ensure an evenly thinned-out distribution of the oil film at the point of contact with the atomising agent. The lower extremity of the inclined plane is provided with a number of slots or teeth, which, in effect, split up the oil films into a number of finer films, and assist atomisation to a marked degree.

The design of the well and trough is such that regulation of the burner is instantaneous, and while giving an even distribution to oil over the whole width of nozzle at full output, the natural rise of the oil up the central well concentrates the feed to the centre of the nozzle at light outputs, enabling a minimum flame to be sustained with consequent economy. It will be recognised that this unique feature of obtaining a minimum flame without mechanical complication is of great economic advantage.

The steam or air forming the atomising medium passes through the opposite pivot into a chamber formed immediately under the inclined oil plane and issues through a suitable horizontal orifice in the form of a flat jet of high velocity. The oil film is met at right angles by the issuing jet of steam, and completely and perfectly atomised by the shock of angle impact and expansion of the steam.

It is claimed for this burner that it uses less steam for atomisation than any other design of steam jet burner on the market. Authoritative tests have shown a consumption of less than 3 per cent. of the total evaporation, which is undoubtedly a very excellent figure.

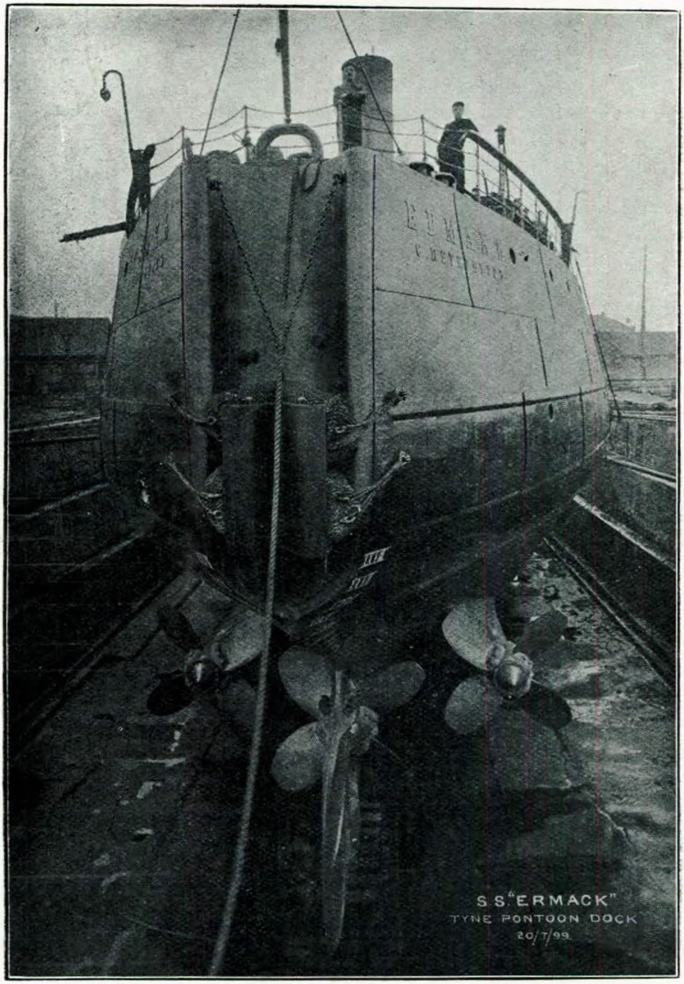
In connection with oil burning appliances we hear that the Scarab Company is about to make other innovations, of which we hope to keep our readers well informed.

Contribution received from T. W. Hayhurst, Member:—

Herewith please find enclosed a few photographs, which I have taken as opportunity served, of the Russian Icebreakers, the finest vessels of their type and all British built.

I am much afraid I cannot write up an article on these vessels, which I am sure would prove very interesting; however, these photographs and a few remarks may be sufficient for somebody more skilled with the pen than I am.

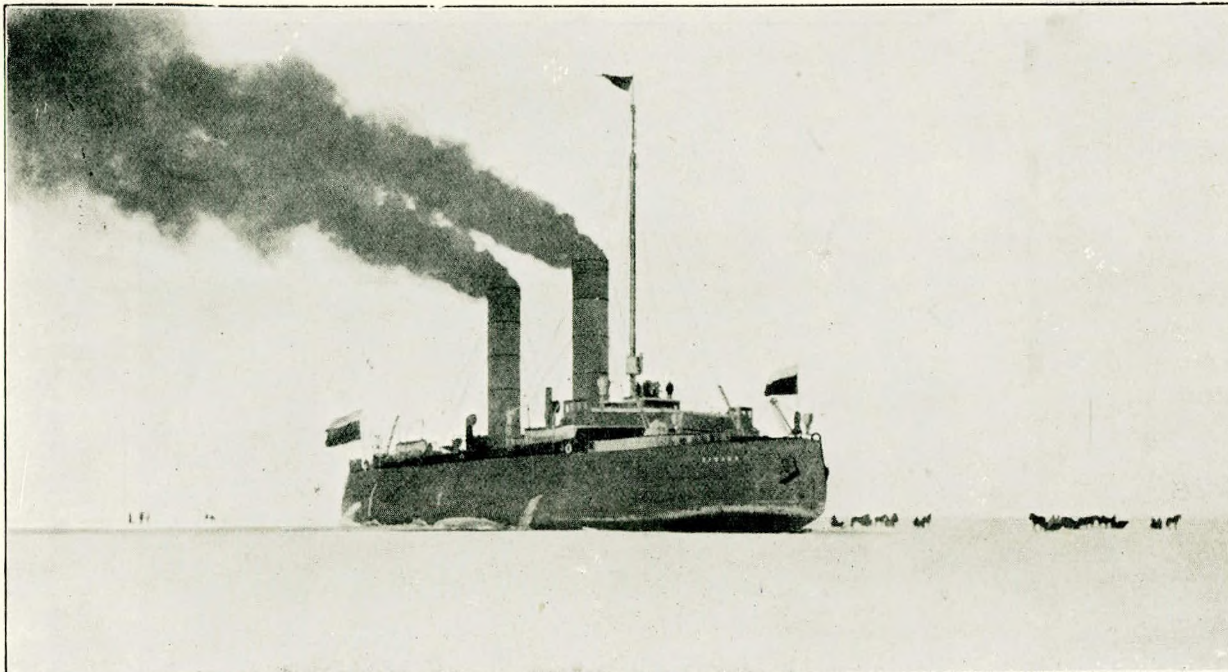
*No. 1. The Icebreaker *Ermack* working in the Gulf of Finland, 1921 and 1922. This winter was very severe and some very heavy ice was encountered, most especially in places where



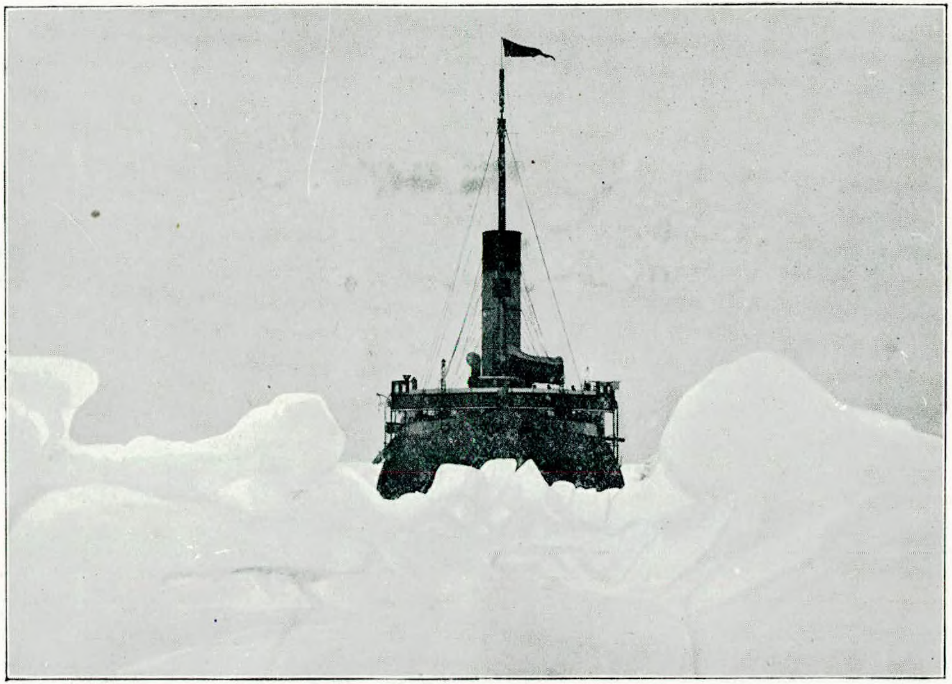
"Ermack" in Dry Dock.

drift ice had been piling. This ship is now 24 years old, but was working all right last winter.

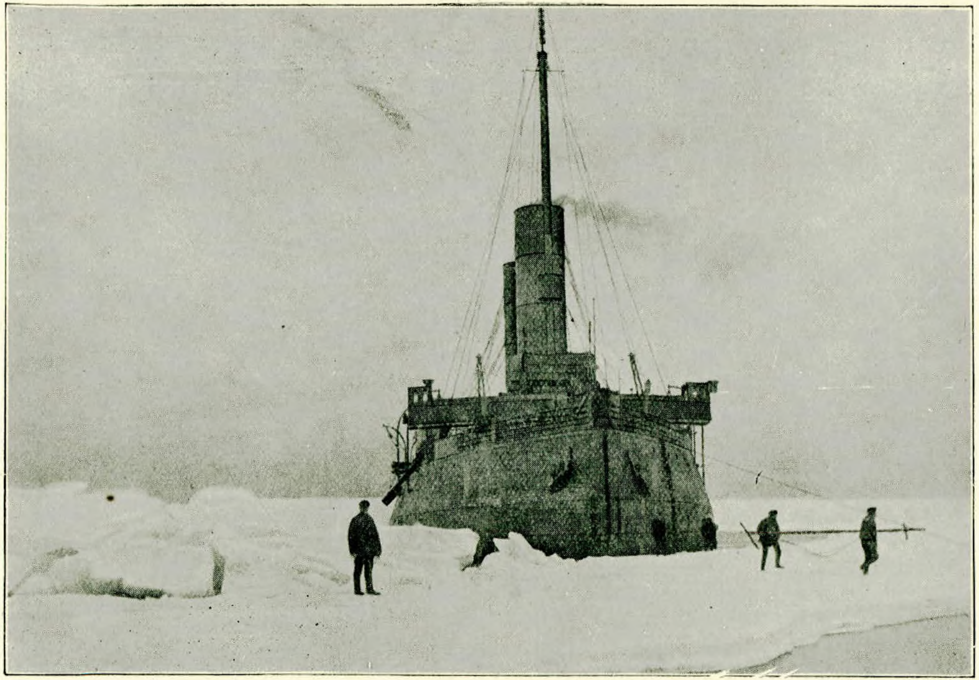
* c.f. Paper by A. Gulston "Voyage of the ice-breaker 'Ermack,'" January, 1903. A few of the illustrations from which are reproduced.



"Ermack" below Cronstadt.

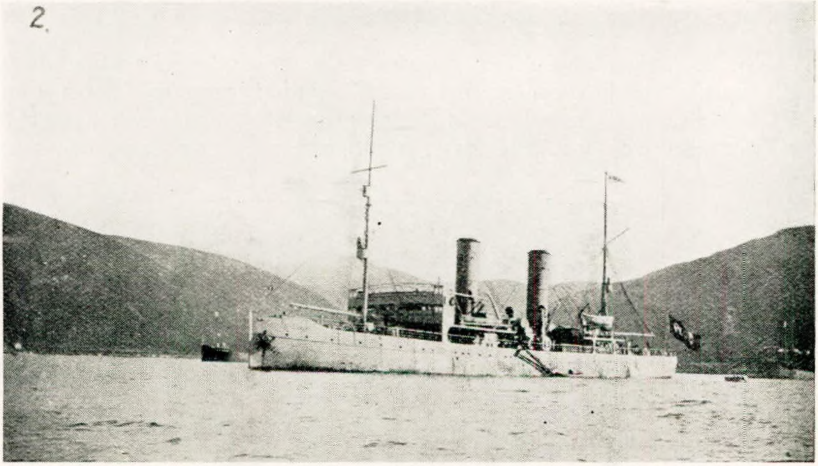


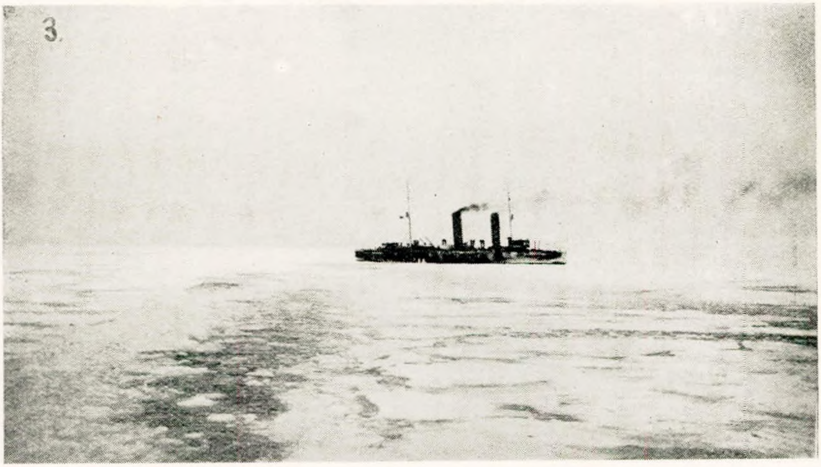
"Ermack" in Polar Ice, 81°24N.



"Ermack" at rest for Scientific Research.

No. 2. The Icebreaker *Lenin* lying at Tromso, in the North of Norway. This place was the starting point of the Kara Sea Expedition. During the summer of 1921 this vessel led an expedition of five merchant steamers to the Gulf of Obe (British master and crew). They encountered an enormous amount of Polar Pack Ice and every ship was more or less

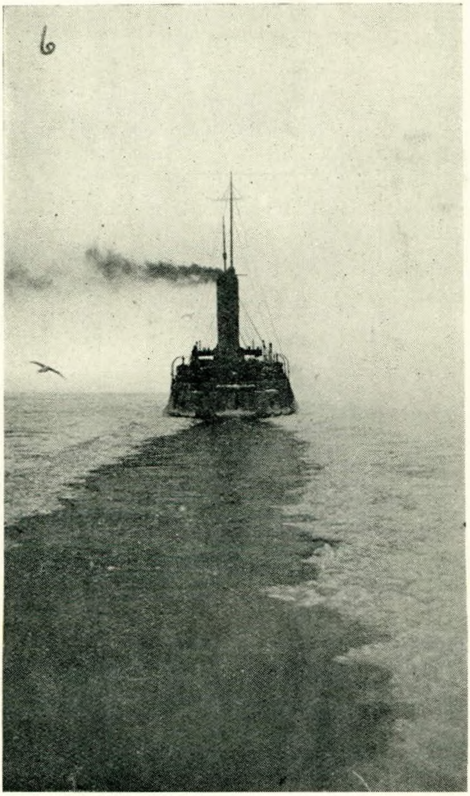




damaged, one ship, the *Tintern Abbey*, completely shearing her propeller blades off. The Expedition of 1922 was more fortunate, no ice was seen, and no damage done, the *Lenin* simply acting as leader of the convoy.

The *Lenin* was a triple screw vessel, with two astern and one bow propeller. The bow propeller was taken off owing to the propeller nipping a large piece of ice against the forefoot and bending the shaft. She is now working at Petrograd, manned by Russian crew and flying the Russian Flag.

No. 3. The Icebreaker *Sviatogor*, working in the Gulf of Finland. She is their largest vessel of this type, triple screws, all astern, with ten boilers developing 10,500 I.H.P. Last winter she was under a British master and crew, and did a

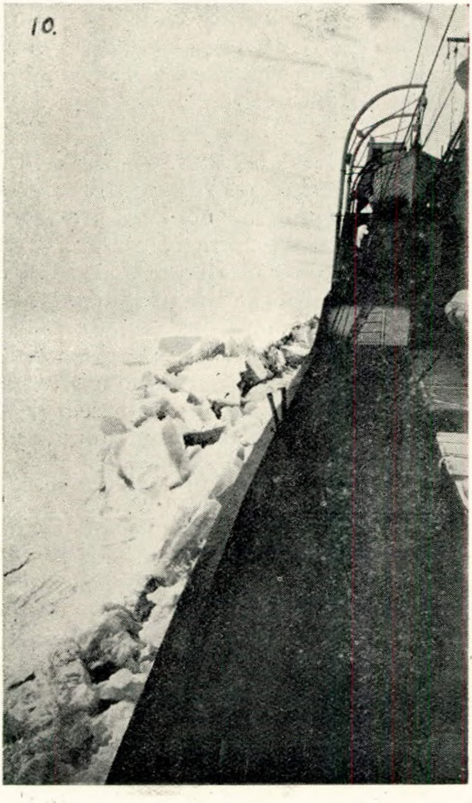


lot of work in the Gulf of Finland and the Baltic, convoying ships from Petrograd, Revel and Riga right down to the Sound. This year she is working in the Gulf with a Russian crew under the Russian Flag.

No. 4 shows the *Sviatogor* running close to the bow of the ss. *Elva Seed.* It also shows the broken track past the writer's ship.

No. 5 shows the *Sviatogor* bearing down on the writer's ship to clear her, the s.s. *Vneshtorg.*

No. 6 shows a good clear wake left by *Sviatogor*. This is not always the case. Should she go too fast it gives the ice time to come to the surface again and jam the channel, or should a



cross current or wind be in evidence the channel is liable to be quickly closed, then the average tramp steamer is helpless. This often occurs.

No. 8 gives a closer view of the *Sviatogor.*

No. 9 shows her backing astern to take us in tow. It also gives a good idea of the peculiar rounded construction of the vessel's sides, to prevent crushing when in big drifts.

No. 10 shows the ice packing up at our sides while we were being crushed in the drift. A fairly large field had split off to windward and came down on us and we were helpless, the *Sviatogor* had gone on ahead picking up and breaking the track. We were compelled to wireless for her immediate return to our assistance. The pack bent the rudder, and the side damage is not yet visible, but there is a slight leak into No. 3 hold. This grinding and crushing lasted for four hours, then the wind died down and the pressure eased off. To make matters worse we were just on the edge of a mine field a few miles north and west of Seskar.

"The Internal Combustion Engine."—"A historic sketch and comparison with the steam engine," by "Beicos"—R. Kingdom, Member. This paper, which has not been arranged for reading and discussion, being in the form of an essay, shows a very creditable effort on the part of its author to assemble a brief summary of historic facts in the life of the internal combustion engine, with a review of the most probable lines for its development. He traces the engine from its earliest form, a gun, in 1346, but of course only the briefest reference to the subsequent improvements is possible in a paper of this scope. His observations and deductions are throughout very sound, and his account of the defects found in the earlier designs of the modern types shows a very thorough examination of the subject.

In his review of the respective fields of usefulness for the various types of engine available to-day he is equally sound and accurate, and leaves little room for criticism; the paper, however, covers far too large a field for its size, and although it does not offer much for discussion, being largely a record of progress, its author will, we hope, follow it up by giving us a paper dealing with the later and more controversial elements of engine design.

"The Internal Combustion Engine," by "Juno"—S. Hiddleston, Member.—This essay is on similar lines to that referred to above, and it also contains evidence of research in the history of this type of engine. This paper does not cover so much ground as the previous essay, and deals more particularly with the Diesel engine and that largely in comparison with the steam engine. The author is counselled to persevere in the exercise of writing these essays, which is a most profitable form of study, and leads not only to a greatly increased knowledge of such subjects, but to an improved style in writing and composition, an accomplishment which engineers as a body are somewhat prone to neglect. There is no more agreeable evidence of a good education than the power of writing well, and even the most original and profound contribution to a scientific institution gains much in value if the form in which it is presented is well and carefully wrought.

(Prizes were awarded to the writers of these essays.)

INTERNAL COMBUSTION ENGINE BOOK.—Attention is directed to the following notices which have appeared:—

Engineering, February 23rd.—The development of heavy oil engines has been carried out so rapidly that comparatively few marine engineers have, so far, had extended experience of their running, and there has consequently not been much opportunity for the preparation of books on actual experiences with these engines or their reliability at sea. Marine engineers have always taken great interest in these matters, and for steam-driven plant have produced some valuable literature. The Council of the Institute of Marine Engineers, recognising the scarcity of general knowledge or experience with oil engines, wisely decided to remedy the deficiency by inviting a number of their members to contribute papers on sections of the subject. These concerned, not only the installation and running of the different types of internal combustion engines, air and solid-injection for Diesel engines, lubrication, auxiliary machinery for oil-engined vessels, and the discussion of constructional details of the plant, but also the available supplies of fuel, their properties and the testing operations necessary to determine their characteristics. In all 18 papers were contributed, and although there was much overlapping and also a considerable amount of diversity of opinion among the authors, the Institute is to be congratulated on its efforts and the results obtained. The lectures have now been reprinted and published by the Institute as a volume, entitled "Papers on Internal Combustion Engines," at a price of 12s. 6d. This forms a good supplement to the present literature, which is mostly concerned with the theory and design of the different types of this class of prime mover.

Marine Engineer, March, 1923. — Internal Combustion Engines. A rechauffé of papers read and discussed at meetings of the Institute of Marine Engineers during the last three years. Published by the Institute of Marine Engineers, at 85, The Minories, E.1. 6in. × $8\frac{1}{2}$in. × $1\frac{1}{4}$in. 595 pp. Price 12s. 6d. net. Illustrations and diagrams.

This book contains a collection of 18 papers dealing, with various aspects of the internal combustion engine, which have been read before the Institute of Marine Engineers. It is a production which should prove of value at the present time when the internal combustion engine is becoming such an important factor in marine engineering.

The Motorship, March.—That the Institute of Marine Engineers has kept pace with, and encouraged, the development of the marine oil engine is very evident. The passing of the steamship is signalised in various ways, more especially in the increasing numbers of papers dealing with internal combustion machinery read before responsible bodies of engineers; it is clear that the Institute of Marine Engineers considers such papers to be of outstanding importance, for a series of them, together with the discussions thereon, has been collated for publication in book form under the title "Internal Combustion Engines."

A wide variety of subjects is dealt with, practically every one of the important theoretical and practical features of large and small oil engines being touched upon, if not expounded at length. We have not previously seen a book which covers the same ground in a similar manner—on account of the quantity of information which relates to actual practice at sea. Moreover, the discussions are of great interest. They indicate, in particular, that amongst a proportion of marine steam engineers the gravest misapprehension has existed as to the merits of the Diesel engine and its reliability at sea. By giving publicity to the subject, this book performs an extremely useful service; it shows the errors into which the unwary have fallen, and indicates the need for a wider distribution of information calculated to dispel the doubts and correct the mistakes arising from the circulation of inaccurate information of marine oil engine installations, large and small.

We have not the least hesitation in commending the book to the attention of marine engineers, and more especially to those who have not yet had the opportunity to become practically associated with motor vessels. The Institute of Marine Engineers has done the motor ship movement a service in publishing the 18 papers and discussions which constitute the volume.

The Newcastle Chronicle and North Mail of February 28th. —The Institute of Marine Engineers, 85, The Minories, London, E.1, has published in a volume the papers on "Internal Combustion Engines" read and discussed at the Institute. There are eighteen papers in the volume. Many diagrams and illustrations are given. One of the results of the rapid evolution of the heavy oil engine is that this type of engine has gone ahead of popular ideas, says the introductory note, and is intimately known to a comparatively small section of marine engineers. This led the Institute to organise and publish the series of lectures which the volume contains. Copies of the volume can be had from the Institute, the price being 12s. 6d. net.

The Power Engineer, April.—Papers on Internal Combustion Engines read and discussed at the Institute of Marine Engineers. London: Institute of Marine Engineers, 85/8, The Minories, E.1. $8\frac{1}{2}$ in. × $5\frac{1}{2}$ in. × $1\frac{1}{4}$ in. 595 pp. Price 12s. 6d.

Rapid progress in oil engine design and application to both marine and stationary work threatened to leave operating engineers behind in their knowledge of this type of prime mover, and consequently—most wisely—the Institute of Marine Engineers organised a series of lectures on the subject. These are now published in a bound volume which is of intense interest and value because of its extremely practical appeal. Many authorities on the subject have contributed papers since 1920, and the members of the Institute kept the discussions at a high level of practical utility. In consequence, this book contains not only much authoritative information but many most valuable working "tips," both of which, in combination, should enable any ordinary engineer to obtain a thorough grasp of oil engine work in about a tenth the time he would otherwise require.

The Shipbuilding and Shipping Record, February 8th.—Internal Combustion Engines. A selection of papers read and discussed at the Institute of Marine Engineers and published by the Institute at 85, Minories, E.1. 6in. × $8\frac{1}{2}$in. × $1\frac{1}{4}$in. 595 pages. Price 12s. 6d. net. Illustrations and diagrams.

This book, which contains a reprint of selected papers, read at meetings of the Institute of Marine Engineers during the last three years, dealing with the internal combustion engine, is now complete and available to purchasers. The price, we are informed, has been reduced to the lowest possible limit, and the producers hope that the demand for the book will justify its publication and the work involved in its preparation. It is a book which contains a deal of useful information, and we recommend it to practical engineers.

The Steamship, March.—This is not a book in the proper sense of the term and so cannot be reviewed in the orthodox manner, because, as it contains a selection of papers, composed by authors of wide experience, which were read and discussed at the Institute of Marine Engineers during the last three years, and as the subject matter is of vital importance to every sea-going engineer, the duty of a reviewer in such a case is to point out the important fact that all marine engineers owe the Institute a deep debt of gratitude for giving them the opportunity of acquiring this additional knowledge on the subject of "Internal Combustion Engines." Its value will be appreciated when it is stated that it embodies eighteen papers and extends to 600 pages, and that the price is only 12s. 6d.

There can be little doubt that this book will be appreciated, not only by those engineers who at present have to deal with oil engines, but more especially by those who will in the future have control of the all-pervading internal combustion engine.

The Stratford Express, March 10th.—An important engineering publication. The Institute of Marine Engineers, of Tower Hill, E.C., which, it will be remembered, was founded towards the end of 1888, at Stratford, and for many years had its home in Romford Road, is to be congratulated on the publication of a volume of papers read before the Institute on the internal combustion engine. The papers have been collected and published in volume form by the Institute, as the internal combustion engine is one of the most important modern features of marine engineering of the present day, and the Institute was anxious to have available at a moderate price a book dealing with the subject. As the book, "Internal Combustion Engines," contains 18 profusely illustrated papers running into 600 pages, and is published at 12s. 6d., it is hardly necessary to say that it has been published for the benefit of the engineering profession, and more particularly the young engineers rather than with the idea of profit to the Institute. We understand the book has had a warm welcome from the engineering profession and Press.

Syren and Shipping Illustrated, February 7th.—We congratulate the Institute of Marine Engineers upon the work they have just published dealing with Internal Combustion Engines. The volume incorporates in its 600 pages the papers which have been read before the Society upon this subject, and it also reports the discussions which took place. We are quite sure that the work will be highly appreciated by the increasing number of engineers who have to deal with Diesel engines.

Books added to Library.

The following pamphlets have been added to the Library by the kindness of Mr. Thom:—

(1) On the design of railway waggons for the carriage of perishable foods.

(2) The Transmission of Heat by Radiation and Convection.

(3) Report on Heat Insulators.

(4) Interim Report on methods of freezing fish, with special reference to the handling of large quantities in gluts.

(5) The Literature of Refrigeration. An index of standard works and papers.

All the above are published by the Department of Scientific and Industrial Research (Food Investigation Board).

We acknowledge with thanks the receipt of a copy of the "Journal of the Institute of Metals," No. 2, for 1922. The high standard of the previous papers read at this Institute is again found in the present volume. All the papers represent valuable and original research on the part of their authors and the progress shown in this important branch of science gives us every reason to hope that solutions for many of the metallurgical problems of to-day will, before long, reward the efforts of the patient experimenters.

We are indebted to the Association for a copy of the Proceedings of the British Cold Storage and Ice Association, 1922-3, containing a paper on "Operating and Financial Reports for Cold Stores," by Mr. B. T. Aitken, with discussion.

Election of Members.

Names of those elected at Council Meeting of March 5th, 1923:—

Members.

Albert Edward John Arkley, Sunnyside, Stephenson Road, Cowes, Isle of Wight.

William Frederick Bennett, 26, Manchester Road, Chorlton cum-Hardy, Manchester.

Joseph Buxton, 25, Swallow Lane, Calcutta, India.

René Cross, 41, Kirkland Avenue, Higher Tranmere, Birkenhead.

George Reginald Ellis, Engr.-Lieut., R.N., retired, Grasmere Lodge, Bromley, Kent.

Robert Elhanan Gascoyne, 35, Chestnut Road, Plumstead, S.E.18.

Horace James Hoare, Messrs. Hoare and Co., 10, New Broad Street, E.C.2.

William Frederick Jacobs, 86, Aberdour Road, Goodmayes, Essex.

Edwin Alfred Lambert, 1, Knowsley Road, Bootle, Lancs.

Arthur Morgan, 11, Oaklands, Treharris, Glamorgan.

Samuel Laurence Parker, 12, Bowdon Road, Wallasey, Cheshire.

Herbert Shenton, 34, Selborne Road, Ilford, Essex.

James McIntosh Smith, Peacock Point, Balmain, Sydney, N.S.W. (temporary address: *c/o* Manor Powis Coal Co., 86, St. Vincent Street, Glasgow).

Arthur Edmund Winter, Engr.-Lieut., R.N., retired, 106, Rock Avenue, Gillingham, Kent.

Associate Members.

William R. Brimblecombe, 40 Milton Street, South Shields, Durham.

Stanley Harry Flood, 3, Oakdale Road, Herne Bay, Kent.

John Martin, 31, Orchard Street, Renfrew, Scotland.

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Marine Diesel Engines—Running Conditions and Operating Symptoms.

FURTHER REPLY TO DISCUSSION BY A. J. BROWN (Member).

As previously stated, the technical journals of to-day are reproducing a number of cards, and I may add that these are usually supplied by the engine builders and represent the best results from actual practice. In regard to Mr. Salisbury's remarks on watch keeping, which clearly show the improvement gained by the use of Diesel engines, I think that in time he will come to say "it is a far, far better thing I do."

As to any discomfort experienced with top platform control in bad weather, this would be compensated for by improved engineroom conditions in hot weather. In further comment as to Mr. Beckett's anticipation of a difficulty in accurately executing telegraph orders with the control platform arranged on top, and quoting steam engine control in comparison:—As a matter of fact, it is for the same reason, fundamentally, that controls are arranged on the bottom platform of an open-fronted steam engine, that I advocate the control gear of a top level camshaft Diesel engine being moved to the top, where the vital mechanism would be in sight. With the present arrangement the engineer has to depend entirely upon direction indicated to guide him, but it is not this feature that I deprecate, since it has been proved to be of unquestionable reliability in every case.

I can assure Mr. McLaren that, when well handled, the modern Diesel engine can be made to do anything but speak. The Beardmore-Tosi engine, for example, has a speed range of from 28 to 120 revs. per min., so that greater flexibility could scarcely be desired, and would certainly be superfluous. Again, this particular engine can maintain a dead slow speed for an unlimited time, the design of valve gear being such as to ensure continuity of positive firing and without choking the fuel injection valves. Mr. McLaren's remarks regarding the adaptability of marine engineers as a class are well founded, and the Diesel engine offers them great scope in this direction. The skill that is shown in the handling of a steam engine is not lost when handling a Diesel, because although the latter is arranged to be almost fool-proof, skill with the control levers is demonstrated by a more rapid execution of telegraph orders, and by a saving in starting air, which results in a greater manœuvring capacity of the engines. It has been the practice to make cams of hard cast iron, but for high speed work it would appear as though hardened steel is necessary. Fuel injection valve cams are usually made of hard cast iron with the hardened steel toe-pieces formerly referred to, and which, incidentally, are adjustable to allow of varying the valve setting. Apart from the excessive weight involved in regard to placing the auxiliaries, the balance of the usual auxiliary Diesel would prohibit such procedure as setting them on the middle platform being adopted. The usual auxiliary Diesel is a two or three cylinder engine, not balanced in any way further than that of crank disposition, hence the foundations require to be of the strongest construction to withstand the vibration set up when the engine is running. The time is coming when we shall have the light, well-balanced auxiliary Diesel engine running at 600-700 revs. per min., and which will be comparable with the high-speed steam sets. Then the middle-platform disposition may be arranged. The emergency lighting question applies to all ships regardless of propelling medium, while the same system would appear to be adopted in each case where the matter has been taken up.

Mr. Steinheil mentioned a most interesting point regarding indicators, viz., the difficulty in tracing the connection between the actual performance of the engine and the symptoms brought to light by the cards. It is this encountering of contradictory symptoms that makes the indicator card so unreliable, but it is, of course, in its way, a necessary evil. I agree with him as to the tediousness, apart from anything else, of changing the indicator over all the cylinders on the engine, and am of the opinion that more consideration would be given to indicator cards as a guide to performance, were it not that such labour is entailed in taking them. The practice on certain Danish motor-ships to take a set of cards during each watch after leaving port, until such time as the engines are thoroughly tuned up is good. It would be quite sound practice to take a set of cards every 24 hours at sea, but it is too much to expect from the engineers, who, as a rule, have quite enough on hand to keep them busy. It could be done, of course, were one indicator provided for each cylinder. The emptying of the pipe line between the blast bottle and the fuel valves each time the engine is stopped is not necessary, and Mr. Steinheil need have no fear as it is now the usual practice to fit a pressure gauge on the pipe line between the bottle and the fuel valves, so that unless the engineers were very negligent they would not fail to note whether the line was full or empty before attempting to break any joints. The totally enclosed engine with forced lubrication is now established beyond all dispute where absolute reliability is concerned. I am glad Mr. Steinheil endorsed my views on the top platform control question, but I cannot agree with him in thinking that anything in the nature of dual control is necessary. That top platform control will be established is a safe prediction, since apart from the advantages gained by it in handling and supervision of the most vital parts of the engine, is the question of cost of manufacture. Top control gear can be fitted at less cost than if all controls are led to the bottom platform, hence this influence will become manifest.

Regarding cylinder lubrication, my remarks on varying the amount of oil, were not intended to apply to the question of heavy and light loads, but referred to the nature of fuel injection and the state of the parts governing combustion, since it is the temperature in the cylinder at the various parts of the stroke that determines the efficacy of the lubrication. The light and heavy load question is automatically solved in the main engines, as the revolution speed varies in each case. Then, as the cylinder lubricators are driven by the engines, the amount of oil delivered is governed by the speed of revolution.

Regarding the control of the air compressor output, it is usual to regulate the amount of air compressed by throttling the

L.P. suction intake, or else by blowing off a certain amount of the air compressed in the L.P. stage. This gives the initial control, but it is usual to find that the blast pressure has a tendency to vary over a slight range. To check this tendency on the L.P. side would be most difficult, and so it is general practice to fit a blow-off valve in connection with the blast bottle or H.P. air line, and by means of it the pressure can be controlled to within the finest limits, and with the least possible trouble. Again, it is general practice to arrange the air services so that the starting air reservoirs can be charged from the blast system. Since there is almost certain to be some leakage from the starting air reservoirs during the time the ship is at sea, it is usual to make up this loss by using a little of the surplus blast air for the purpose. Then, when the starting air is fully charged, the surplus blast is blown off to atmosphere through the valve already mentioned.

The system of driving the necessary pumps from the main engine is a debatable one, as witness the case of steam engines. Formerly it was always the practice to drive the feed, air and bilge pumps from one of the cross heads, but now it is common to find all these pumps installed as independent auxiliaries. Practically the same argument for and against is applicable to the Diesel engine. Of course, if the auxiliaries are independent and electrically driven, it is the most economical form of power transmission that is being used. The presence of a steering gear necessitates some form of auxiliary power, and since the winches are usually electrically operated and dynamos for the power supply have to be installed, it is as well to electrify all the auxiliaries and run a dynamo to serve them. Mr. Steinheil's suggestion for a dynamo to be driven from the main shaft is one worthy of the fullest consideration.

With regard to Mr. Plows reference to compression cards, it is much better, when new to the ship at anyrate, to take compression cards with the blast and fuel shut off, as then the truest indications are given and can be referred to when analysing power cards. It is very useful to have reference cards showing the true compression curve, while a compression card from each cylinder will give a good idea of the volumetric efficiency as well as providing a good basis to diagnose from.

The cleanliness of auxiliary engine lubricating oil is a most important point, and can best be assured as suggested by the provision of a lubricating oil cleaning tank. By means of this, all or part of the oil in the engine sump can be pumped out and filtered periodically.

Regarding the question of cleaning the cylinder head water jacket spaces, and the liability to cracking if this is not done, the best procedure would undoubtedly be to have spare heads on board which could be interchanged with the working heads and so allow the latter to be thoroughly cleaned as time permitted. As the position stands to-day, there is not time on board the average ship to lift heads, clean the water spaces and have everything replaced in time for sailing. Then, as the matter stands, the engine builder cannot be expected to provide sufficient spares to meet these special requirements, so that it is up to the shipowner to see the matter from the correct standpoint and provide for the additional outlay. The gain would be his in the long run. Mr. Plow's idea of a jet for cleaning purposes is a good one. In the Beardmore-Tosi engine a permanent fitting is arranged so that the cooling water is always directed right to the fuel valve pocket, which is the hottest place, and distributes from there to the other water spaces in the head.

Mr. Plow's case of the cylinder liner is indeed phenomenal. That a ridge should form and yet no wear show in the liner is a matter that would take some explaining. I, also, have seen a ridge in a cylinder liner, but it was undoubtedly caused by wear since it never reappeared after the surface had been undercut to the level of half the depth of the top piston-ring with the crank on top centre. Had there been any piling of metal, such as Mr. Plows suggests, then it would have shown above the undercut.

Mr. Thom got at the root of air compressor trouble when he spoke of the difficulties encountered when the air suction is throttled to any extent, but it does not alter the fact that oversize compressors have to be dealt with, and hence, means have to be adopted to combat the evil. The reasons for having air compressors of larger capacity than is necessary for their specific purpose are many. There still exists a considerable diversity of opinion as to what is the correct amount of blast air to supply per horse-power, and even when a general figure is accepted, other factors are introduced in the design of the fuel injection valve. Then when the engine is built and run it may be found that quite a considerable surplus of blast air exists and so the problem of oversize is in being. Again, in order to reduce manufacturing costs, it is quite usual to find a firm making one size of compressor serve two different sized engines. In most of Messrs. Burmeister and Wain's large motor ships there is no auxiliary high-pressure compressor installed, and when during manœuvring extra blast air is required for the main engines, it is the surplus blast air from the auxiliary engines that has to augment the supply from the main engine compressors. That is a case where oversized compressors is the result of intentional design. However, air compressors can be made to function remarkably well, notwithstanding the handicap, provided attention, coupled with understanding, is given them.

The frequency of cleaning water jackets, the question raised by Miss Holmes, is determined principally by the time available in port and upon the accessibility of the inspection doors. Where the cylinders are concerned, not much in the way of cleaning is called for unless the ship has been operating in sandy water. It is advisable, however, to remove the inspection doors once every six months, when some idea of the state of the jackets can be formed, cleaning can best be done by boiling out with boiler compound, since to remove the liner and do the job properly is, unfortunately, out of the question. As a rule there is not much depositing of scale in the cylinder water jackets when salt water is used, as the water temperature is never high. It is the cylinder heads with their restricted water spaces and the higher temperatures involved that give most, if not all, the trouble that is encountered. This was dealt with in my reply to Mr. Plows. The theory put forward by Miss Holmes about liners becoming cemented in place, and so not being able to expand, is quite a probable one. I heard recently of a case where, owing to the force that had to be applied to free a liner when removing for examination, the liner was distorted and when replaced caused the piston to seize. Fresh water was used for cooling, but I think such a thing is unlikely to happen in a ship where salt-water is used and that always at a low inlet temperature.

In the Beardmore-Tosi arrangement described in the paper, the design is such as to ensure positive starting with a minimum consumption of air. The arrangement allows of a very rapid change-over from starting-on to fuel-on three cylinders, while the remaining three cylinders continue the air-impulse, thus ensuring a more positive start than if the gear allowed all cylinders to pass direct from air to fuel. An ordinary eccentric fulcrum gear, if arranged to pass all cylinders direct from air to fuel at once, while being very simple, would probably fail, as the time element introduced during the change-over would be too great. The result would be that the engine would not have sufficient momentum to ensure positive ignition at the time the fuel was introduced. As previously stated it may be necessary in cold weather to give the engines an extra air impulse to ensure an initial start on fuel, while I have known cases where with the "direct" gear (all air—all fuel) it has been found necessary to disconnect the fuel-pump controls from the starting lever, and then allow the engine to get changes of fuel at the same time as it was receiving air impulses. This is a dangerous practice, and is only permissible when all else has failed to make a start. With regard to selection of fuel I would emphasise that the few shillings saved per ton by buying cheaper grades is often false economy.

Referring to Capt. Durtnall's proposition, the increased size of the air engine which would appear to be necessary in view of the reduced charge weight which is the result of pre-heated induction, the manufacturing cost will be materially increased. Even with the reduced scantlings made possible owing to the lowered compression pressure, it is probable that the engine will cost as much as one working with the higher compression. In regard to cooling water outlet temperatures, any appreciable increase would call for cylinder heads designed for greater thermal conductivity. A high jacket temperature is, of course, invaluable when manœuvring and especially when leaving port. Some of the largest Diesel engines are equipped with steam-heating to the cylinder jackets, and by means of this a "hot engine" is possible at all times when starting, while the revolution speed can be reduced still more than if ignition were dependent upon a compression temperature evolved from atmospheric conditions. Even with the latter, positive ignition is possible at piston speeds as low as 150 feet per minute.

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