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The Open-Fronted Surface Ignition Engine.

BY F. G. BUTT-GOW (Member),

READ

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CHAIRMAN: MR. J. B. HARVEY (Member of Council).

THE modern Semi-Diesel, Hot Bulb or Surface Ignition Engine has not gone through so many radical changes of construction as the marine steam engine did in its early days, and in its present day construction it very much resembles the engine from which it probably originated—the Two-stroke, or perhaps more correctly, Two-cycle.

This engine depended on electric ignition. One of the first marine oil engines to use the hot bulb system of ignition was the Mietz and Weiss; and with very few exceptions marine oil engines of a moderate compression—that is 200 to 250 lbs. and depending on a hot bulb or plate for ignition—are still built in the same form as when originally made.

In Holland, which was one of the first countries to employ the marine oil engine to any great extent, many barges were fitted with horizontal oil engines using tube ignition; but this I think was for the same reason that the horizontal engine, either trunk or return connecting rod, was in use for a considerable time with steam vessels, *i.e.*, on account of head room, and also owing to the fact that the bulk of oil engines as made then were horizontal. With few exceptions, some of which are illustrated, the Semi-Diesel or surface ignition, termed the closed, has always been built as a closed-crank case engine. It is true that one Two-cycle engine was put on the market in the smaller sizes with the compression space separated from the cylinder and fitted with a piston rod and stepped-piston. In the larger sizes with four-cylinders, these were made with an open crank case and fitted with piston rods and guides, compression taking place as in the smaller engines.

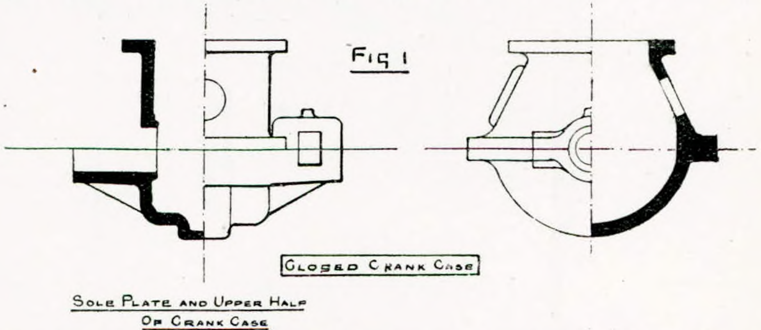
However, as the majority of the firms who took up the marine oil engine had been engaged in land work they built marine engines as they had been accustomed to for land use, which may account for the large number still made with a closed crank case. I was told by a representative of one very old firm of oil engine builders that they did build an open-fronted oil engine, but gave it up owing to the expense of manufacture; this point I will refer to later.

Now that the Semi-Diesel is getting on in years and also in size, the question has arisen " Is the closed crank-case with its defects the best design for a marine oil engine? " It has been said that, if the Semi-Diesel is to be successful in the larger sizes, the closed crank case must be done away with. I may be unduly favourable to the open engine, but the only points I can see in favour of the closed engine are less height and less weight.

An open engine is naturally higher than a closed engine, but except in smaller sizes the question does not often occur. The extra height, comparing engines of similar horse-power, is from 2ft. to 2ft. 6ins. In a tug boat or auxiliary vessel this extra height can be easily spared.

As to less weight this does not always apply. Various builders of the closed engine and their representatives with whom I have discussed the merits of the two types are willing to admit that the open engine is a good one: their great objection seems that it costs more to build. In the smaller sizes up to, say, 30 or 40 h.p., this may be true; I am not in close enough touch with manufacturing costs to be able to pass an opinion. In the larger sizes I do not think there can be very much difference in the cost of manufacture between the two types. To a firm not engaged in marine steam work, there is no doubt the closed engine appeals; but the majority of Marine Engineers with whom I have discussed the point, favour the open engine, and it has been referred to on several occasions during the various papers that have been read at the Institute. I will now take the two types, a closed engine and an open engine and compare them with one another. In the first type we have :—

Fig. 1. The lower half of the crank case forming the sole-plate, and the upper half of the crank case forming bottom of cylinder. In a four-cylinder engine with about 80 to 90 h.p.



per cylinder, these two castings represent a considerable amount of pattern making, foundry work and machining; the lower part of the crank case in particular requires a lot of work and also entails, in the larger sizes, special machinery.

There are several engines in which the cylinder and upper half of crank case are made as one casting. This is shown in Fig. 2. As can be seen this also entails a considerable amount of labour in both the pattern shop and foundry and heavier plant in the machinery. It also means more delay in progress through the shops, as unless special machinery is provided not more than one operation can be carried out at a time, whereas with Fig. 1 the cylinder casting can be boring out whilst the upper half of the crank case can be on a planer or miller as the case may be.

The Open Engine.—Coming to the construction of the open engine the most general form is as shown in Fig. 3, consisting of sole plate, back column and front column. The sole plate is very similar to that of a marine steam engine except that in one style of oil engine made of the open type the crank pit is not left open to the bilge, but is arranged with one or more sumps for the used oil to drain to. This does not require so much work as an enclosed engine, no provision being needed for sealing round the crank shaft at the main bearings. These are fitted as in a marine steam engine. In the majority of open engines the front columns are forged and turned, this is not a complicated piece of work, a forging with flanges top and bottom. The back column is a casting as shown. It does not present any difficulties in casting or machining, the pattern is also a simple one. In addition to the back and front columns

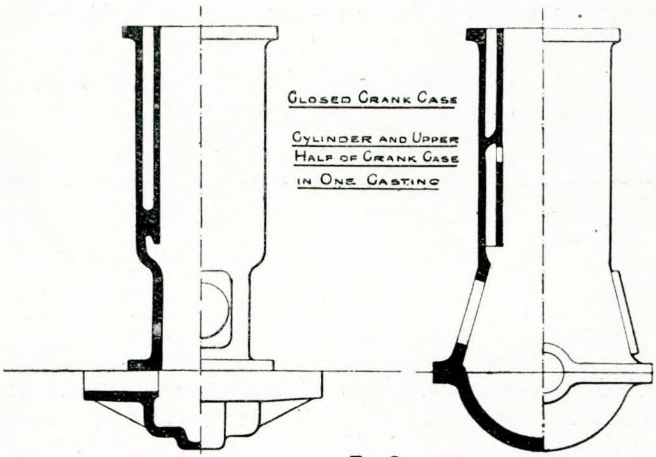


Fig 3.

in one type of engine the upper portion of the compression space is a separate casting, this contains the piston-rod gland and stuffing box and air-inlet valves. There is no reason, however, why this should not be a part of the cylinder as the gland could be bolted on to allow for a boring bar passing through when first the cylinder is bored or should it require boring at some future period.

The cylinders on the two types of engines shown in Figs. 4 and 5, are not very different, possibly that of the closed engine may be slightly longer. The piston on the open engine may be made considerably shorter than that of the enclosed engine as it does not have to perform the duties of a slide in the cylinder walls which serve as guides. The open engine has a piston rod in most cases flanged at the top end for bolting to the piston and with a tapered and screwed end for attachment to the crosshead.
most cases flanged at the top end for bolting to the piston and with a tapered and screwed end for attachment to the crosshead,
though the crosshead can be made with a single brass, and piston rod secured by taper end and cotter.

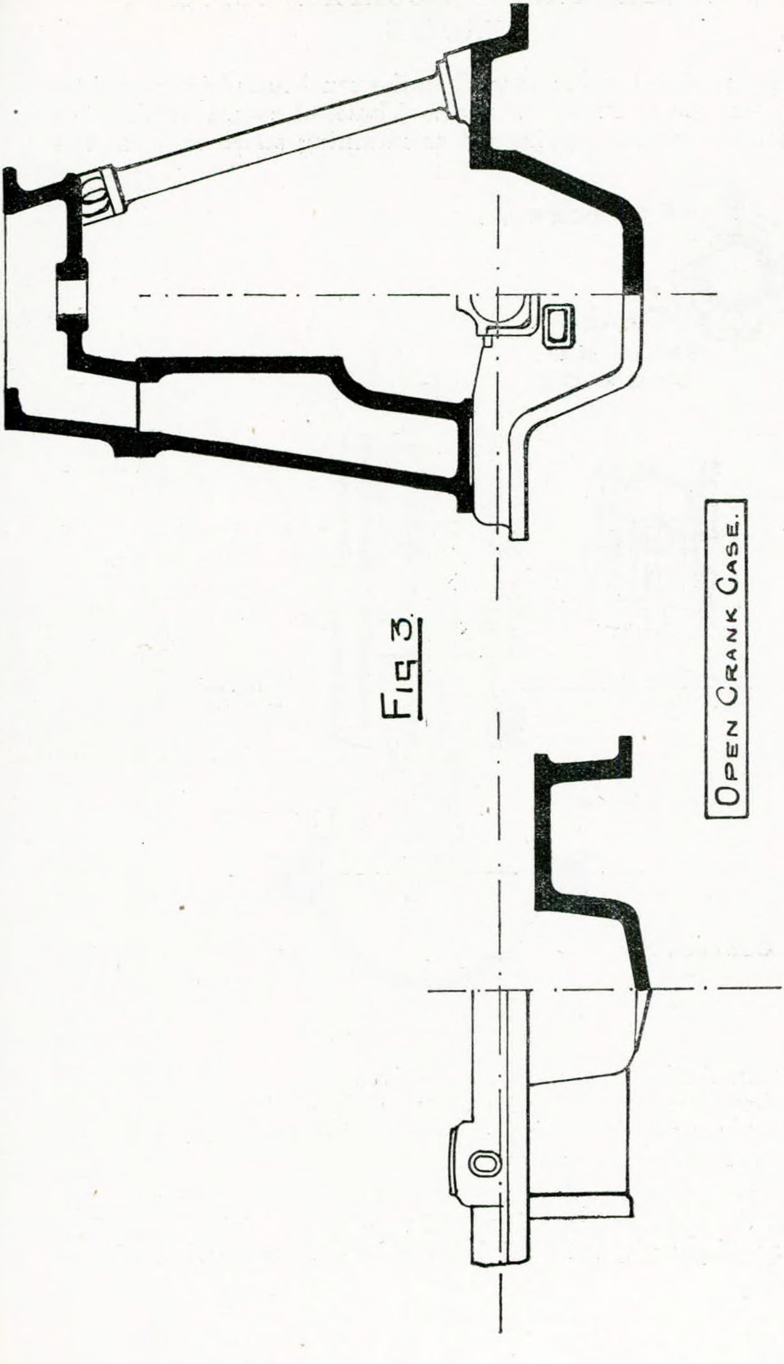


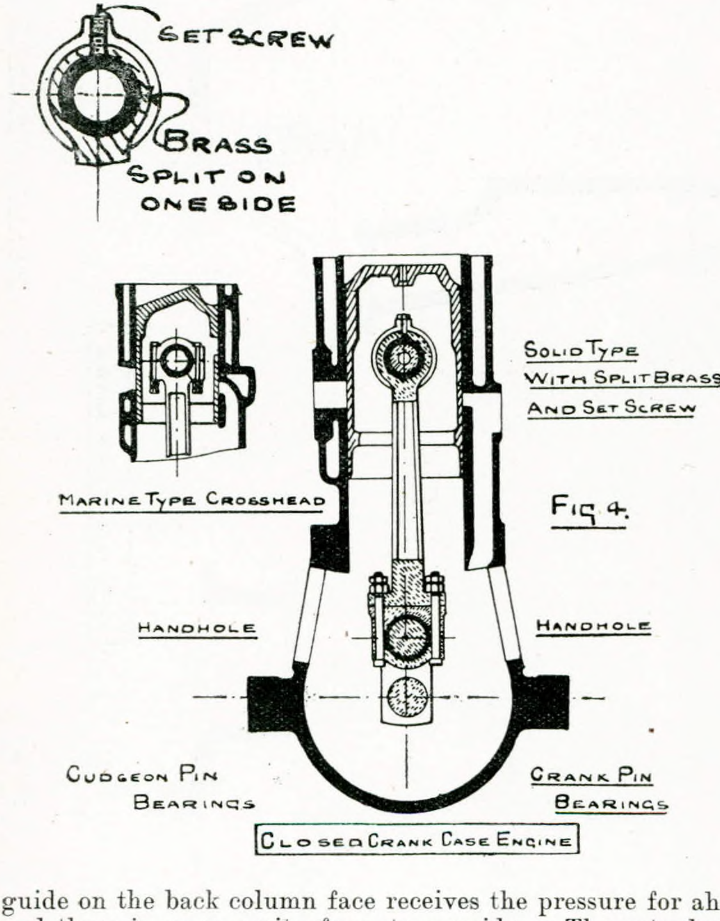
Fig 3.

Sole Plate and Back Column. And Front Column

Open Crank Case.

Sole Plate.

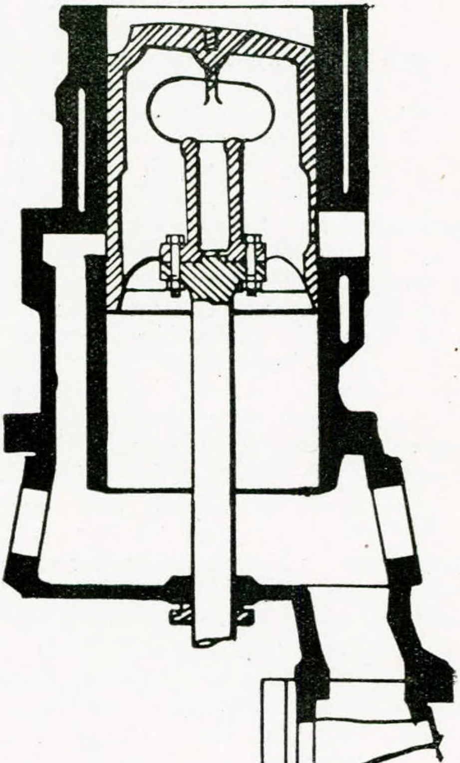
The crosshead and slide work in the usual form of open guide, with side strips for astern wear. These, of course, in the case of a non-reversing engine act as retaining strips only, as the



guide on the back column face receives the pressure for ahead, and there is no necessity for astern guides. The actual additional parts required for the open engine are piston rod and crosshead with slide and guides.

To go thoroughly into the cost of manufacturing the two types, the open and closed, would take up more time than this paper will permit, but I think it can be seen, from what I have briefly touched on, that the cost of manufacture of the open engine should not be very much more than the closed engine and in the larger sizes, *i.e.*, 60 to 100 b.h.p. per cylinder, it ought to be less owing to the use of smaller castings and subdivision of parts. More work could be done to the component

Fig 5.



PISTON. OPEN ENGINE

parts of an engine in the same period and the machine tools need not be so heavy. Another point is the question of lubrication in the closed engine. The fitting of banjo rings and piping requires more care and planning than is necessary on the open engine, the oil piping of which is very similar to a marine steam engine. I will take up the lubrication question more fully in another part of the paper, dealing now with the question of running an open engine as against a closed engine.

There have been several articles appearing lately in the *Motor Boat* giving accounts of the running of marine oil engines, and from what can be gathered the bulk of the trouble has been with top and bottom end brasses, loss of compression through main bearings wearing, and reverse gear; this last point I will not go into as the fact of whether an engine is open or closed will not in any way affect the reversing. When reference was made to cylinder wear occurring, it was usually put down to the use of water injection, but as considerable wear is found in closed engines which do not use water, I think the use of a trunk piston, which is necessary with a closed engine, is responsible for a lot of this wear. I think a Marine Engineer used to steam would rather be shipmates with an engine more nearly resembling a marine steam engine. I do not doubt that there are many interested in oil engines who will think that I am old-fashioned in advocating the open type of oil engine for marine use, but I think the practical man would certainly prefer an engine in which the working parts are in view and can be felt. In a previous paper the use of thermometers in submarine engines was mentioned, but I do not think the average engineer wants to spend his time on watch taking thermometer readings.

In the open engine the main bearings, top and bottom ends and guides are in full view all the time. Light splash-plates are fitted, usually hinged just under the cylinder bottoms and the bottom portion made removable for inspection of bottom ends and main bearings.

In a closed engine the main bearings only are in sight; the crank pin must be to a very great extent taken on trust; as the lubrication to this is in most cases forced and not fitted with sight feed, it must be taken for granted that the oil is going in and doing its work.

I read some time ago that the heat of the crank pin could be judged from the blow back at the air inlet valve, but crank pins have a way of heating up without giving warning. In the case of a closed engine the only guide apart from this is the temperature of the crank case, the engine slowing down, or possibly pulling up.

In the case of the gudgeon pin, I have not heard of any way by which this can be gauged as to how it is running except sound. I do know, in my two years' experience in charge of motor-craft in France, the percentage of repairs to gudgeon pins and brasses was very high.

Lubrication.—On the closed engine the lubrication is generally effected by some system of forced lubrication, though with the exception of the main-bearings, I must say it is rather a stretch of imagination to call it forced, on many engines. The crank-pin brasses are usually supplied with oil by means of banjo-rings or centrifugal lubrication. The gudgeon-pin brasses are lubricated from the supply of oil which is forced through the cylinder walls, this oil passes to the pin and brasses through a hole bored axially through the pin and in connection with a hole at right angles. Some engines are fitted with a scraper to collect the oil.

In an open-fronted engine the lubrication is practically the same as on a marine steam engine; either an ordinary open drip system may be fitted, or a drip with sight feeds open or closed, if desired, forced lubrication by piping as shown by the late Lieut. Windram in his contribution to the Transactions in 1918, page 209. It can be either pressure or gravity as may be preferred. Up to the present I have found the system of lubrication adopted in the Bolnes engine as very reliable and fool-proof. In this engine the oil passes from a receiver fitted with a sight gauge through an open sight feed to the various bearings or sumps, the used oil drains to a sump in the crank-pit, from there it is pumped up through a filter and strainer to the receiver; the amount of oil passing to each bearing can be regulated by the small drip cocks. If it is required to supply any one or more bearings with extra oil it can be poured down the supply pipe of these bearings; on stopping the engine for any considerable time the valve or cock between the various feeds and the receiver may be shut, but if this should not be done no great harm will happen, as the capacity of the crank-pit is greater than that of the receiver the oil will drain to the pit. On starting the engine it will be pumped up again to the receiver and circulate through the various bearings. A very similar plan is now fitted on the Sumner open engine.

As Mr. Warne mentioned in his paper of December 14th, a compromise has to be made over the question of lubrication on the usual (closed) type of Semi-Diesel. If an excess of oil is used it will accumulate in the crank case, and if care is not taken to keep this drained, considerable damage will be done to the engines if lubricating oil is taken up with the scavenging air.

On the open engine there is no such trouble: more oil can be circulated through the various bearings than on a steam engine, as the excess or used oil will drain to the sump, and from there pass through to the receiver: should the pump break down or choke, it can be seen at once, and if it is not possible to get the pump going, the receiver can be filled by hand and the crank pit drained when necessary with a hand pump.

It cannot be denied that the closed engine is very heavy on lubricating oil, but this is not so much on the amount of oil that is used as on what is wasted, *i.e.*, drained into the bilges to avoid the possibilities mentioned previously.

A careful driver or engineer would drain off any accumulation of oil at regular intervals, but as in many engines this drain is at the lowest part of the crank case, it is a simpler matter to leave it open sufficiently to allow the oil to drain out into the bilge It is not an easy matter to get exact figures of lubricating oil consumption.

Lubricating Oil Consumption.—A correspondent to the *Motor Boat* writes that on a new 90 b.h.p. closed engine the consumption of lubricating oil for a 240 mile journey is 20 gallons. He also mentions having to renew crank-pin brasses every three months.

In a tug fitted with a "Bolnes" open engine of 130 b.h.p. the lubricating oil consumption over a working period of 36 hours was three gallons.

It must also be taken into account that at least 50 per cent. of that three gallons is still fit for service, as it is either in the crank-pit or ready for use in the receiver, as will be understood from the description of the system of lubrication fitted on the "Bolnes."

An engine of rather more power, *i.e.*, 160 b.h.p. of the closed type and working under similar conditions is stated to have had a lubricating oil consumption of 14 gallons in a working period of 48 hours.

On a basis of lubricating oil consumption per b.h.p. per hour the following figures may be of interest.

"Bolnes" 130 b.h.p. ·005 pints per b.h.p. per hour.

Closed Type 160 b.h.p. ·010 pints per b.h.p. per hour.

Closed Type 90 b.h.p. ·52 pints per b.h.p. per hour.

In the case of the 90 b.h.p. engine the working hours have been taken as 34, this is allowing an approximate speed of seven knots per hour, if a higher speed is allowed for, the consumption of lubricating oil will be higher in proportion.

Maintenance.—Running repairs are less on the open type than the closed engine. By reason of the crosshead and guide taking up the side strains, the walls of the cylinders do not tend to wear as in the closed type where the piston rings and cylinder walls are subject to this strain. Also by having a piston rod and connecting rod, the reversal at each revolution is smoother. Any slight wear can be taken up, such as slackness in a crosshead or bottom end, without having to dismantle the engine. The gland through which the piston rod passes requires very little attention, as it only has the compression of the scavenging air, which should not exceed six or seven lbs.

Overhauling.—When it comes to the question of carrying out an overhaul, I do not think anyone can deny that the open engine is very much superior to the closed engine. Starting from the top, cylinder covers and hot bulbs are the same for either type. But when we come to removing a piston, it is quite a different matter. In a closed engine, if it is required to remove the piston for examination, hand hole doors must first be removed, crank pin brasses disconnected, and in most cases piston and connecting rod lifted bodily out. It must also be remembered that all these parts are smothered in oil, and that the space for handling spanners and removing brasses is limited.

Gudgeon-Pin Adjustment.—This is one of the most unsatisfactory features of the closed engine. In some cases no provision is made for adjustment: the connecting rod top end is fitted with a solid brass and a hardened steel gudgeon pin, which is secured to the connecting rod jaws by set screws. Many will say that there are closed engines running that have had little or no trouble, but is the life of a gudgeon bearing anywhere near the life of that of an ordinary marine engine? In many cases on examination it means not only new brasses but a new pin, and it very often happens that the eye of the rod requires boring out. There are many steam engines running now that still have the spare top end brasses bolted up on the bulkhead amongst the spare parts where they have been for ten or fifteen years. But I doubt if there are many closed type oil engines running over five years that have not had at least one set of new gudgeon brasses and possibly pins put in. In cases where the brasses are adjustable, it cannot be said that the adjustment is an easy matter in cases where the brasses are split as shown in Fig. 4 centre view, in this case the adjustment is usually made by a set screw on the top. To adjust this it is necessary to remove the piston and connecting rod, make the required adjustment and replace. It must not be forgotten that this adjustment is not made at the working temperature so that, to be on the safe side, it must be left, if anything, on the slack side. This type requires good workmanship, and a man who can handle a file, to ensure that the two faces bed equally and are brass and brass.

The other method, Fig. 4 top corner, right-hand side, brass split on one side, which is not much in use, is only fit for small brasses, but it comes in very handy in the event of a rod with a solid bush; where no spare bush is available a hole is drilled and tapped and a set screw fitted. It will also be found that after a time, however good the pin fits the eyes of the rod, it will show signs of slackness in some cases so much as to require a new pin and the eyes removed or bored to suit. When in charge of motor repairs during 1917-18-19 I had several cases in which this had to be done. Some engines are fitted with a regular marine type crosshead brass, Fig. 4 shown left-hand side, but this again cannot be properly adjusted without removal, as if liners are fitted it is not a very easy matter to remove or replace these, and for reasons of safety it is better to do without them and fit brass to brass.

Crank-Pin Adjustment.—This is an easier matter than the gudgeon pin or top end, but even with hand holes made as large as possible it is not a simple matter, and when it comes to 80 B.H.P. and over on one cylinder, it means a good deal of man-handling and knack, combined with strength: there is not room for working small chain blocks, at any rate not in any that I have seen, and again there is not too much light. Also if it is required to examine a crank pin, or perhaps go over with a stone, it is not everybody's job, or one to be envied.

To sum it all up, in most closed engines to remove a piston you must disconnect crank pin brasses though they may be perfectly satisfactory. To examine the gudgeon pin brasses you must remove piston: this means dismantling cylinder cover, and disconnecting crank pin brasses. To overhaul crank pin bearing in the majority of closed engines you must remove cover in order to hang up the piston and connecting rod. I have not yet seen any provision for doing this in any other way. From this it will be seen that to do any one of three different jobs, the whole or part of one of the remaining two must be either wholly or partly done. I will now take the same three jobs on an open fronted engine.

Removing Piston.—After removing cylinder cover, if the engine has the box type of crosshead, the cotter is knocked out and piston and rod drawn: in the case of the double crosshead, the nut is removed: it will be noticed that neither crosshead nor crank-pin are disturbed. To adjust crosshead and crank-pin brasses, the crosshead can be hung up by a bar across the guide face, as is done in ordinary marine steam practice.

Main-Bearings.—These, as now placed in most closed engines, are outside the crank-case and are accessible, but it must be remembered that with age the shaft will be down and loss of compression result; sealing rings require attention, and if it is required to remove the shaft it means removing cylinders and upper half of crank case.

In an open engine, to remove a crank-shaft does not mean any more than disconnecting and removing top brasses, but with a good quality white metal it should be a long time before this is necessary. At any rate there are no sealing rings to worry about, as the compression is not affected by the shaft being down. To prevent loss of compression on an open engine, it is only necessary to watch the air inlet valves and the piston rod glands, which is not a difficult matter as the pressure on the gland does not exceed seven to ten lbs. So far I have gone into the question of:—

(1) Cost of manufacture of closed engine against cost of open engine.

(2) Running closed engine and open engine.

(3) Overhauling the two types of engine.

(4) Lubrication.

(5) Extra height of open engine.

Note on Fitting Drip Trays.—In an open engine such as the "Bolnes" it is not necessary to fit a tray under the engine as must be done in the closed engine. There is no possibility of lubricating oil accumulating in the bilges. All the oil finding its way to the crank-pit is accounted for by the pump

I should like to go into the question of working the various pumps required: fuel, cooling, lubricating and air compressing, and bilge. Taking the fuel pump first. In most of the enclosed engines this is driven from an eccentric, the same eccentric also drives cooling and lubricating pumps. These last are principally ratchet driven from the eccentric. As regards the compressed air supply some engines are arranged to do this by means of the exhaust, others are fitted with a compressor driven by another eccentric in addition to that driving fuel pumps, etc. There are also several engines having the pumps partly driven from eccentrics, the remainder by an arrangement of gear wheels. In an open fronted engine one of the simplest ways of working the various pumps is a similar arrangement to that used on a marine steam engine, *i.e.*, by levers from the crosshead as shown in the figure. At the back are fitted two circulating pumps, one bilge pump and air compressor, from another lever in connectiton with a bell crank the two fuel pumps are driven. The lubricating pumps, engine and cylinder, are also driven from these levers by a system of rods and bell cranks. In the larger engine, of course, the compressor is better as an independent installation, but in engines to 150 B.H.P. the above arrangement has been very successful. The bilge pump can be arranged to use as a cooling pump in case of necessity and up to four cylinders the levers from the crosshead of one cylinder will do all the work required when an independent compressor is fitted.

Spare Parts and Renewals.—The principal working parts of an open engine are so similar to a marine steam engine that overhauls can be carried by any firm of engineers accustomed to steam engine work, with perhaps the exception of the fuel pumps, and though many builders of marine oil engines are in the habit of laying great stress on the extreme accuracy required for these, I have never been able to see that there was anything in these pumps that could not be carried out by the average repair shop working to the usual degree of limits required at the present time.

The heaviest items on the repair list in the closed engine are: pistons, cylinders (re-boring), gudgeon-pin and crank-pin brasses.

In the open engine with piston-rod, connecting-rod and guide the upkeep of these parts should be very little heavier than a marine steam engine.

The most successful Diesel engines are those fitted with crosshead and guides, and I think that if oil engine builders of the semi-Diesel follow on the same lines they will find it to their advantage and that of the engineers who will have charge.

Since 1912, when the "Bolnes" works started building the open type of oil-engine they have built these engines for all classes of vessels with the most satisfactory results.

In America the Sumner Company have built several sets, all in the larger sizes and all the reports I have heard have been very favourable.

ADDENDA.

VARIOUS TYPES OF OPEN CRANK CASE ENGINES.—About 1905 Messrs. Webster and Bickerton brought out a two-cycle or two-stroke engine in which the compression of the slow in-going air and explosive mixture was not carried out in the crank case. Fig. 6 illustrates this. In the larger engines the principle was

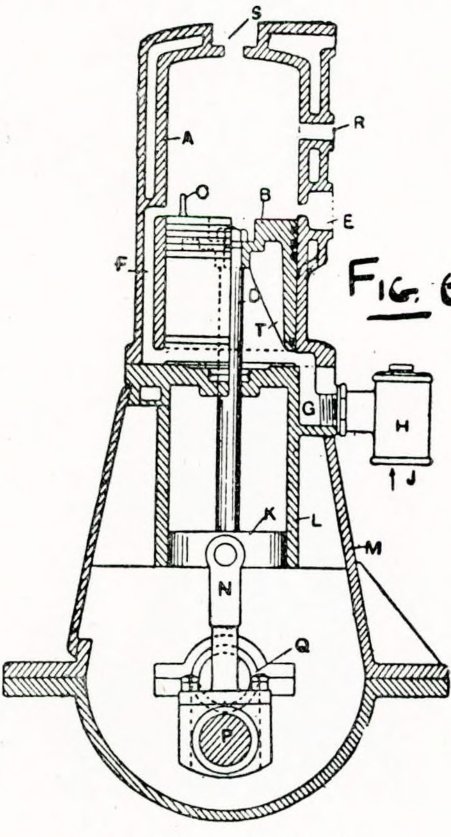
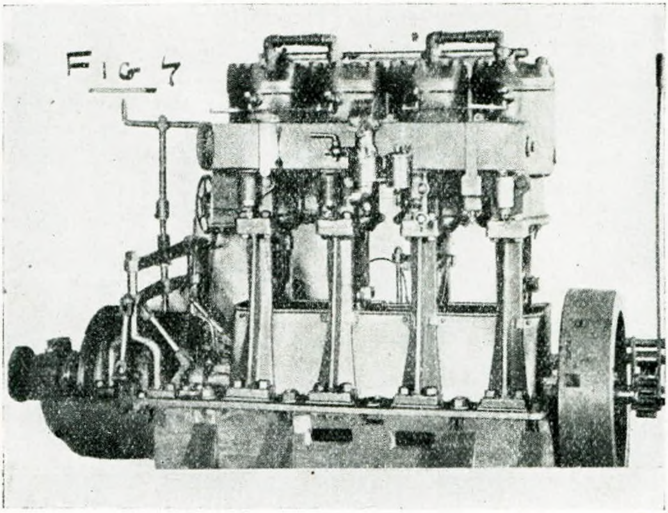
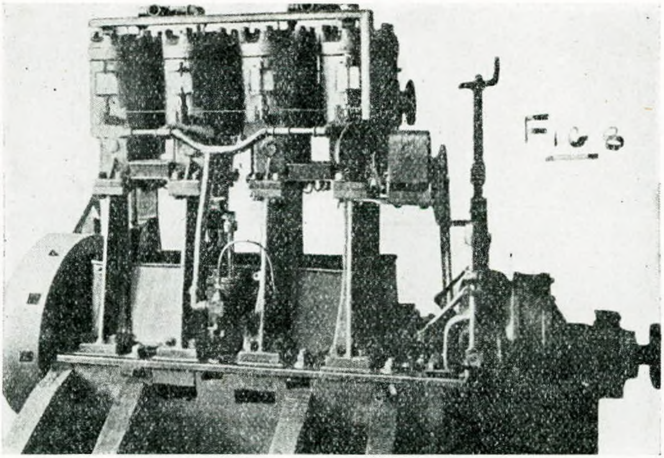


FIG. 6

Section of the "Reliable."

carried still further. Figs. 7 and 8 shows the engine as made in the larger sizes, *i.e.*, 25 and 50 H.P. on four cylinders. I have never seen one of these engines, but I saw one of the first





pattern in London: these engines were afterwards made on the Thames, but eventually the manufacture was dropped. The weak point of this engine is the short connecting rod.

The *Motor Boat* said of this engine at the time:—

"The lubrication troubles hitherto experienced in two-stroke motors are eliminated, for since the charge never comes near the oil in the crank case, none can be carried up behind the piston. Mechanically, the advantages are that the piston may have an easier fit; rocking and gudgeon pin troubles are eliminated; and there is no possibility of the cylinders being worn oval."

The first open crank case hot-bulb engine that I have been able to trace as actually on the market as a marine engine is the Bolnes. Fig. 9 shows this engine as first made in 1912: as can be seen, it has double columns. The later types have all been made with cast back columns and turned front columns.

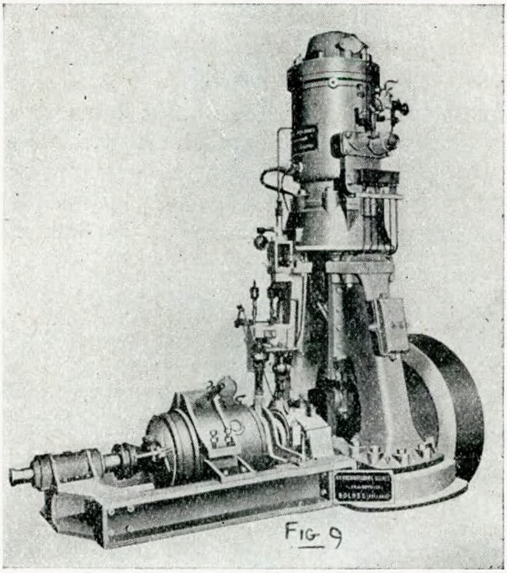


FIG. 9

Figure 10 shows the largest power made up to the present date, 130 B.H.P. There is at present being built a four-cylinder engine of 320 B.H.P., and it is intended to commence the construction of a single cylinder engine of 150 B.H.P. These engines are coming largely into use: in the illustration the guards which are fitted have been removed to show the various working parts of the engine. As can be seen, it is made on

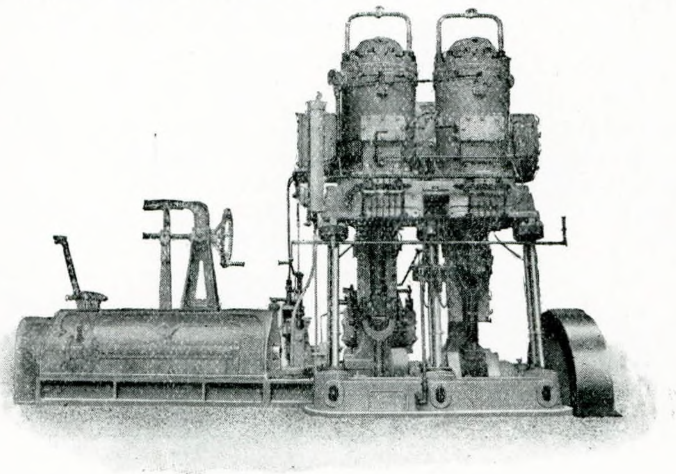
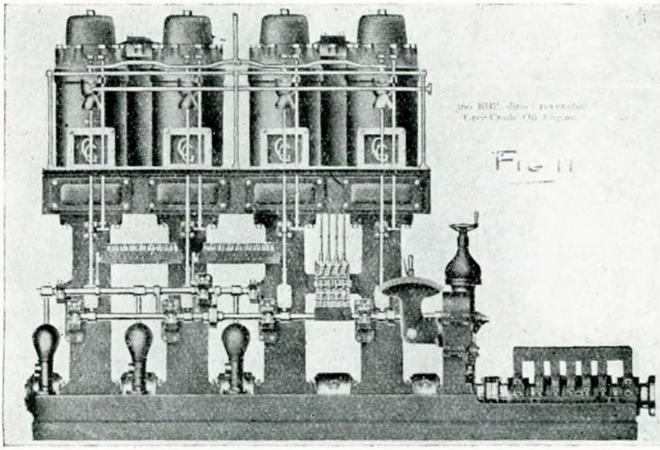


Fig. 10.

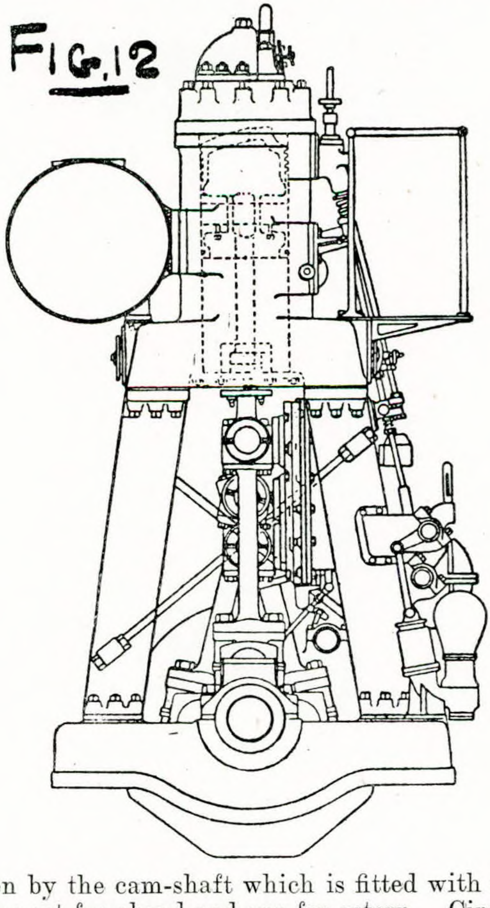
regular marine engine lines, the pumps being worked from the cross-heads by levers as in steam practice. These will be seen better by referring to Fig. 21

Figs. 11-12.—This shows the Grei engine, as made by Messrs. Gulowsen, Christiania, who make up to 360 B.H.P. in the



closed type. As can be seen, this is made with double cast columns, the bottom of the piston compressing the scavenging air in a very similar manner to the "Bolnes." The pumps are driven by cam-shafts in connection with spur gearing from the crank shaft: the reversing is by compressed air, the fuel pumps

FIG. 12



being driven by the cam-shaft which is fitted with a double set of cams—one set for ahead and one for astern. Circulating and bilge pumps are also driven off the main shaft. I am not aware if any of these have been actually built.

Figures 13, 14 and 15.—This engine was designed by Messrs. Lambert and Adie, primarily to work on the Brons System of ignition, but can be adapted to surface ignition. In addition to the compression of the scavenging air under the piston, an auxiliary compressor for scavenging is fitted: this is about 20 per cent. of the capacity of the main cylinder. The pumps are driven by levers, as shown: forced lubrication is fitted: the main

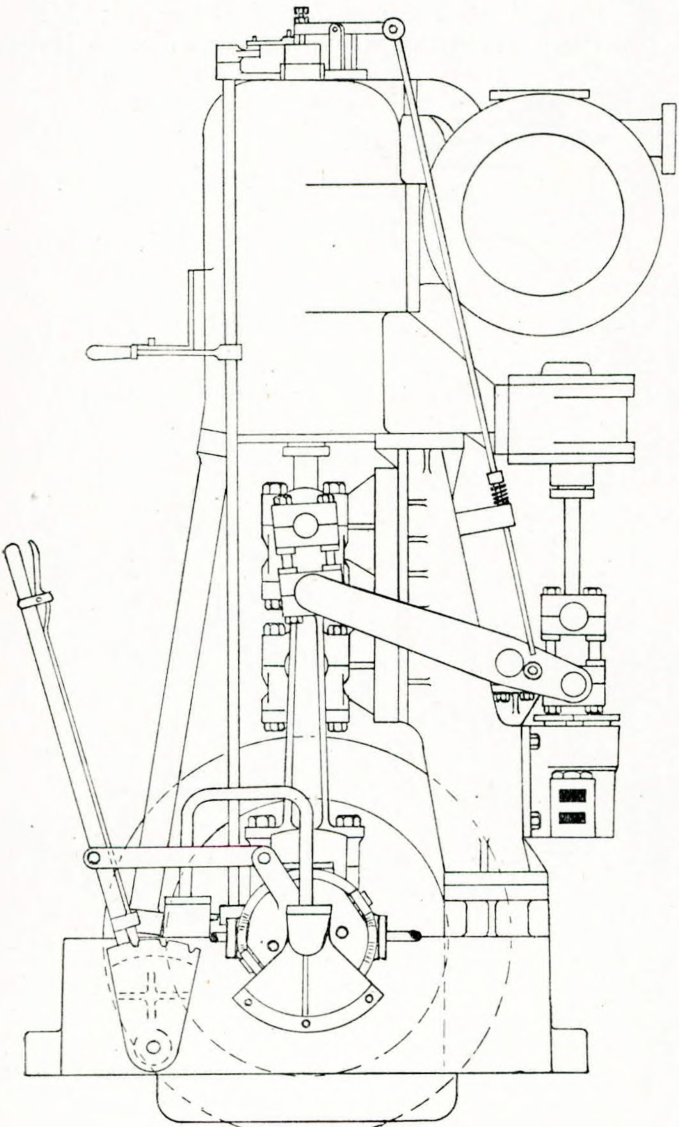


Fig. 13.

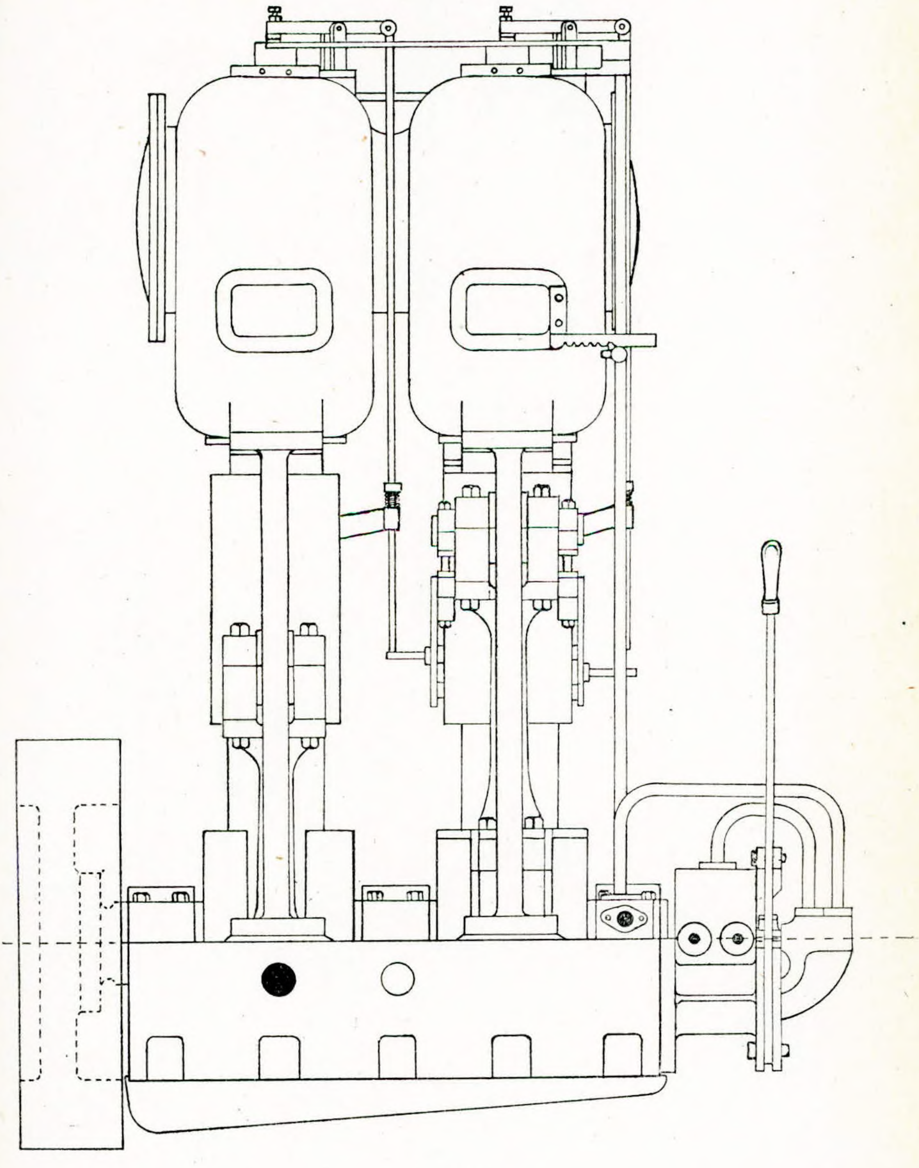


Fig. 14.

THE OPEN-FRONTED SURFACE IGNITION ENGINE.

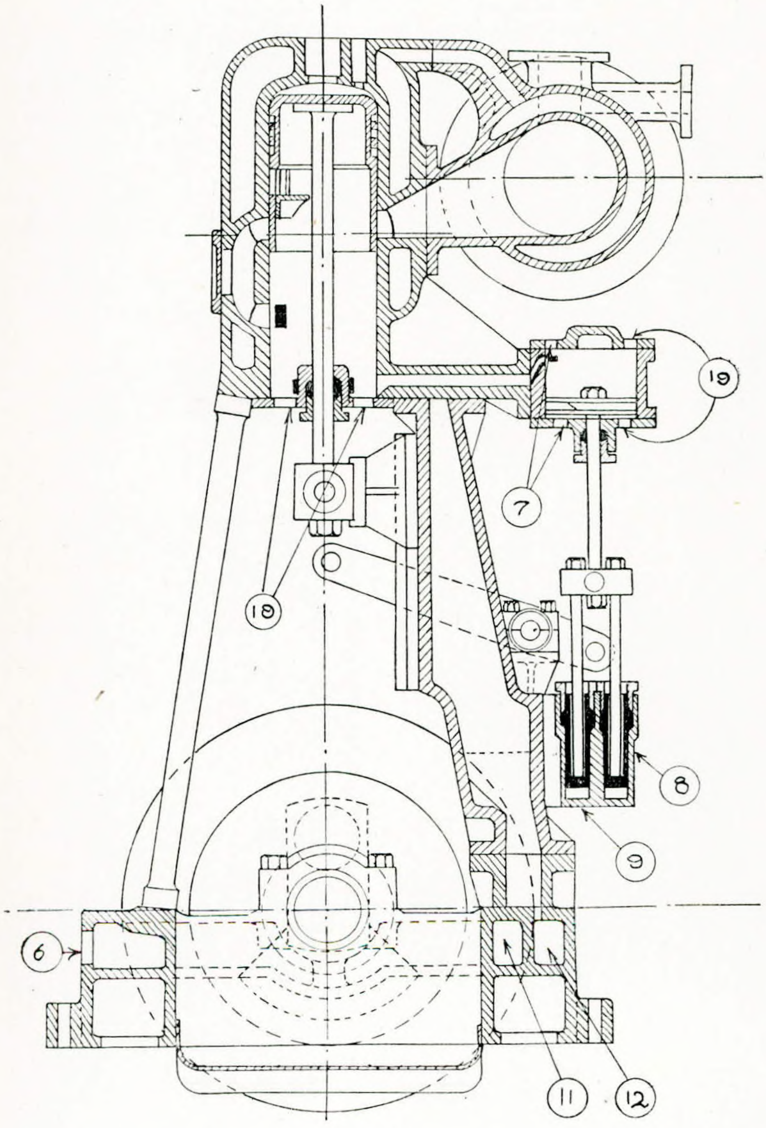


Fig. 15.

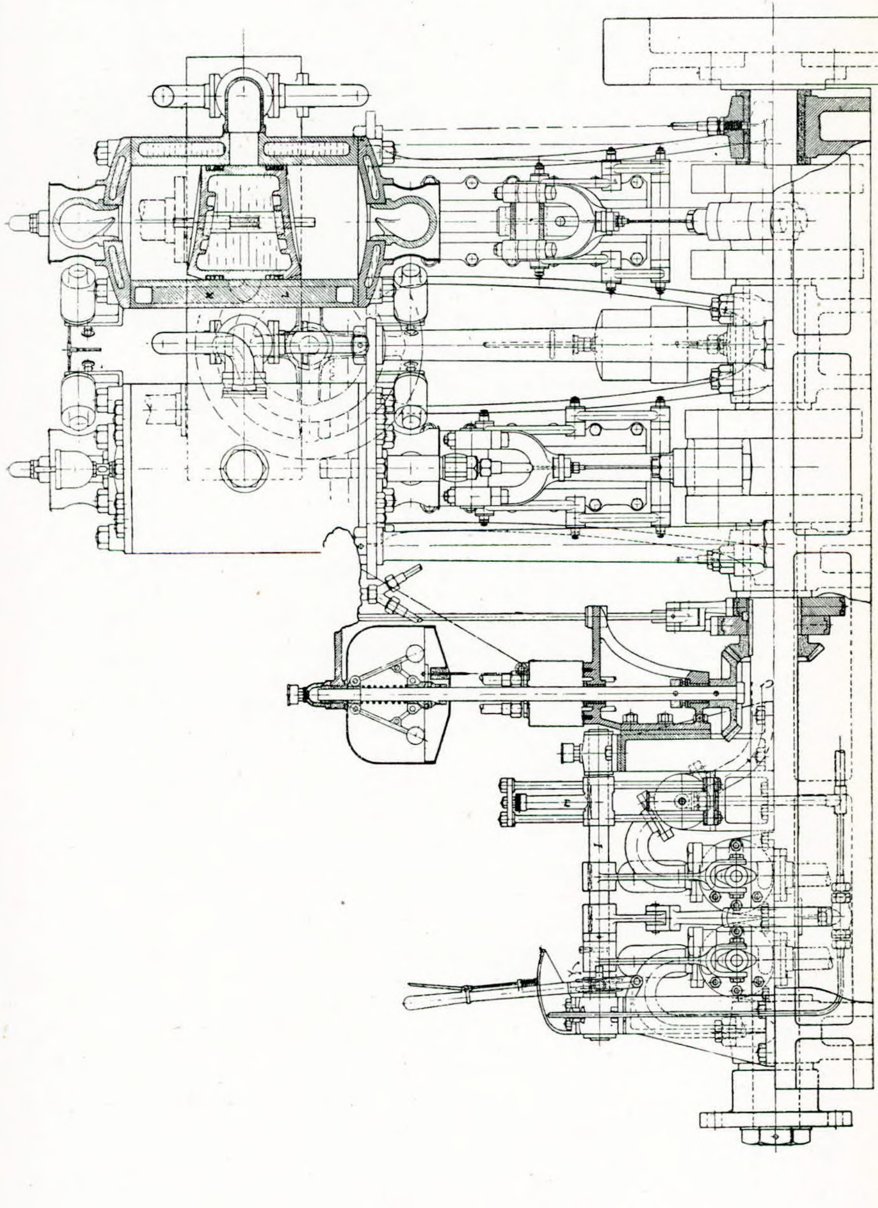


Fig. 16.

bearings and guides are also water-cooled, as can be seen by the sectional view. This engine has not yet been put on the market, but, to my mind, it represents a really serious attempt at simplification of oil engine design, and is well worth taking up by engine builders. Messrs. Lambert and Adie, like myself, were both in charge of oil engine repairs in France, and from our experience of some dozen different makes of engine, we came to the conclusion that the closed crank case has many defects which would be eliminated by following steam engine practice.

Figures 16 and 17 show a double acting hot bulb engine that has been recently patented: this was illustrated and described in a recent number of the *Motor Boat*, the publishers of which kindly gave me permission to use the blocks.

Personally, I cannot help thinking that the patentees have rather gone out of their way to introduce complications, and my comparison as to the relative cost of manufacture of closed engine and open engines would not apply.

I have not sufficient time to give a full description of this engine, but briefly, it is as follows:—

In a two-cylinder set, as shown, there is one working cylinder, and two scavenging cylinders. Referring to the Figure which shows Cross-section: A is the power cylinder, whilst B and C act as scavenging and induction pumps: a pin connecting the three pistons passes through the walls of the power cylinder working in the slots provided: an arrangement is fitted for sealing this, consisting of the side rods E and F. Fig. 17. It is claimed that this arrangement is effectual, but I must say I think it is rather doubtful. The working cycle of this engine is as follows: On the downward stroke of the engine air is drawn in through a valve into the cylinders B and C: on the upward stroke the air is trapped after two-thirds of the stroke is completed; the passage K. Fig. 16 communicates with the top of the pump cylinders B and C and the bottom of the working cylinder A. where, upon the downward stroke of the engine, compression takes place. At the proper time the explosion takes place. Whilst this has been going on in the bottom of the cylinder, a similar cycle of operation is going on in the top end. All the pistons and side rods are water-cooled. Circulating pump. fuel, lubricating and bilge pumps are driven from a rocking shaft operated by eccentric on main shaft; the air compressor drives off the same shaft. The engine shown is rated at 60-70 B.H.P. at 500 revs., which is a very high speed for the H.P.; space occupied is said to be 5 ft. x 2 ft. x 4 ft.; weight approximately 2 tons 5 cwt. Reversing is by air; the compressor allows supplies of air for injection with the fuel. There are two points

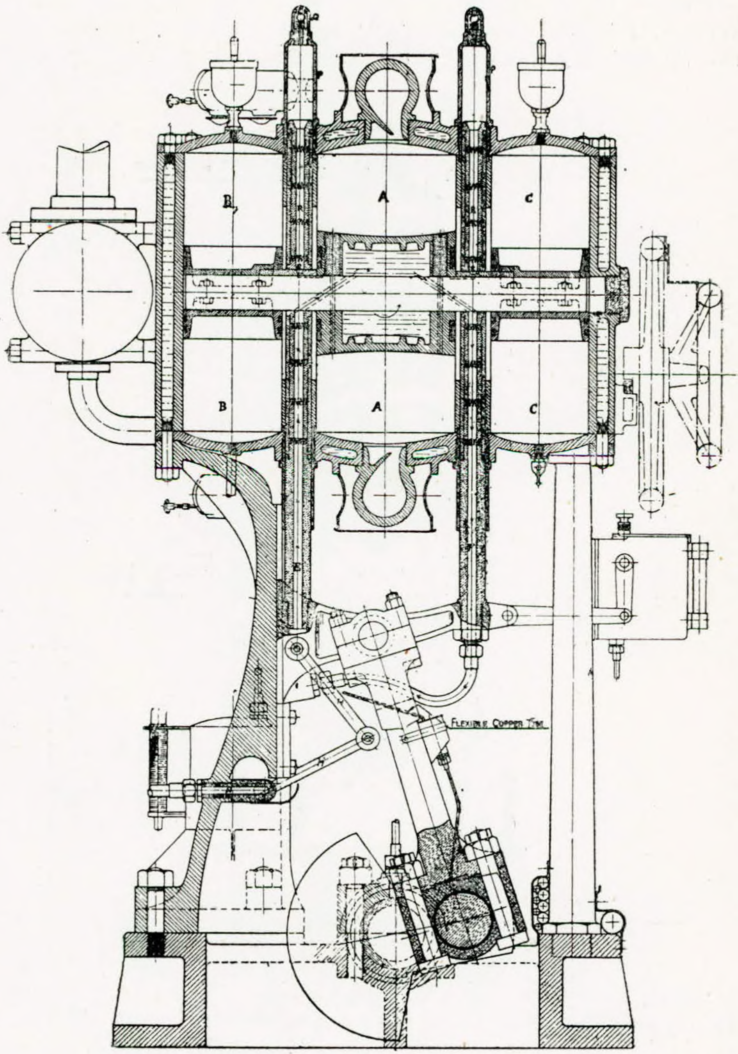


Fig. 17.

against this engine in its present form; in my opinion, the sealing arrangement to cylinder A, and all the pumps centred on the one eccentric.

Figure 18 shows another type of double acting hot bulb engine, The Stallard. As will be seen from the sectional view, the bottom hot bulb is placed at the back of the engine. A

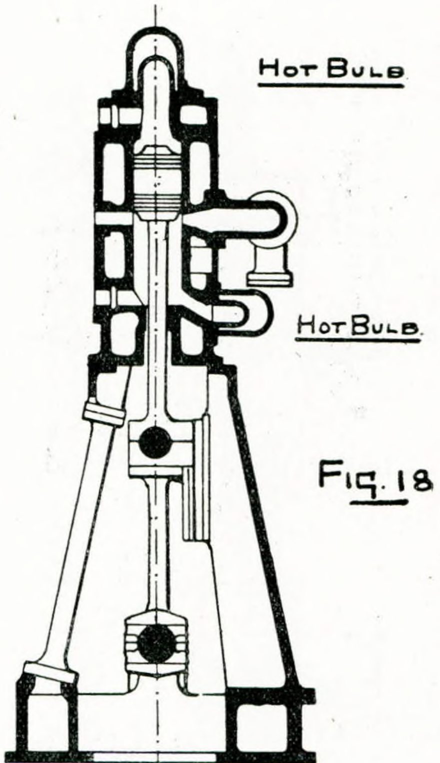


Fig. 18

STALLARD DOUBLE-ACTING ENGINE

separate scavenge pump is fitted, worked, as shown, by levers: this pump is designed to give a pressure of about 80 lbs. per sq. inch. The piston and rod are water cooled. I am not aware if one of these engines has been actually built.

I hope I have not made myself wearisome, and I am afraid that I have only been able to touch on the principal points, but if I have been able to show a little of what has been done to do away with what is one of the principal objections of the marine engineer to the modern marine hot bulb engine, I shall not be dissatisfied. I think I may add also that the engineer in charge of Diesel or Semi-Diesel engines at sea and on shore would sooner have an engine where he would be able to see and get at more of the working parts than is possible at present.

In conclusion I should like to have shown some more of the earlier attempts at open engines, but it is not easy to get particulars of these without a great deal of research for which I am afraid I cannot find the time. I must also thank Mr. Walter Pollock for his permission to publish the illustration of the Stallard engine; and Messrs. Lambert and Adie, Anderson, Lewis and Siddal, H. W. Sumner and Co., and the editor of the *Motor Boat*, Mr. Chalkley, for all the information which they have supplied me with.

Figs. 19-20 represent the Sumner Engine. This represents the largest engine of the hot bulb or surface ignition type made as an open-fronted engine. The builders of this engine took a very bold step, as instead of building in the small sizes, one of their first engines was 600 H.P. It possesses many notable features: electric ignition, forced lubrication and separate compressors for scavenging air: it has, I believe, proved very successful, and I am sorry that I have never had the opportunity of seeing one at work. The other illustrations represent engines that have been proposed, but I have no knowledge if they have been actually built and tried commercially.

In order to give a better view of the "Bolnes" engine Fig. 21 is an end elevation in section.

Since writing this paper I have had the opportunity of reading extracts from the report of Mr. R. E. Mathot, one of the best known continental authorities on oil engines.

He has been studying the question of the use of vegetable oils for use with various types of oil engines, made by English, Italian, Belgian and Dutch engineers.

He reports very strongly in favour of the open type of engine. A very full report of Mr. Mathot's investigations will be found in *Gas and Oil Power*, May 5th, 1921.

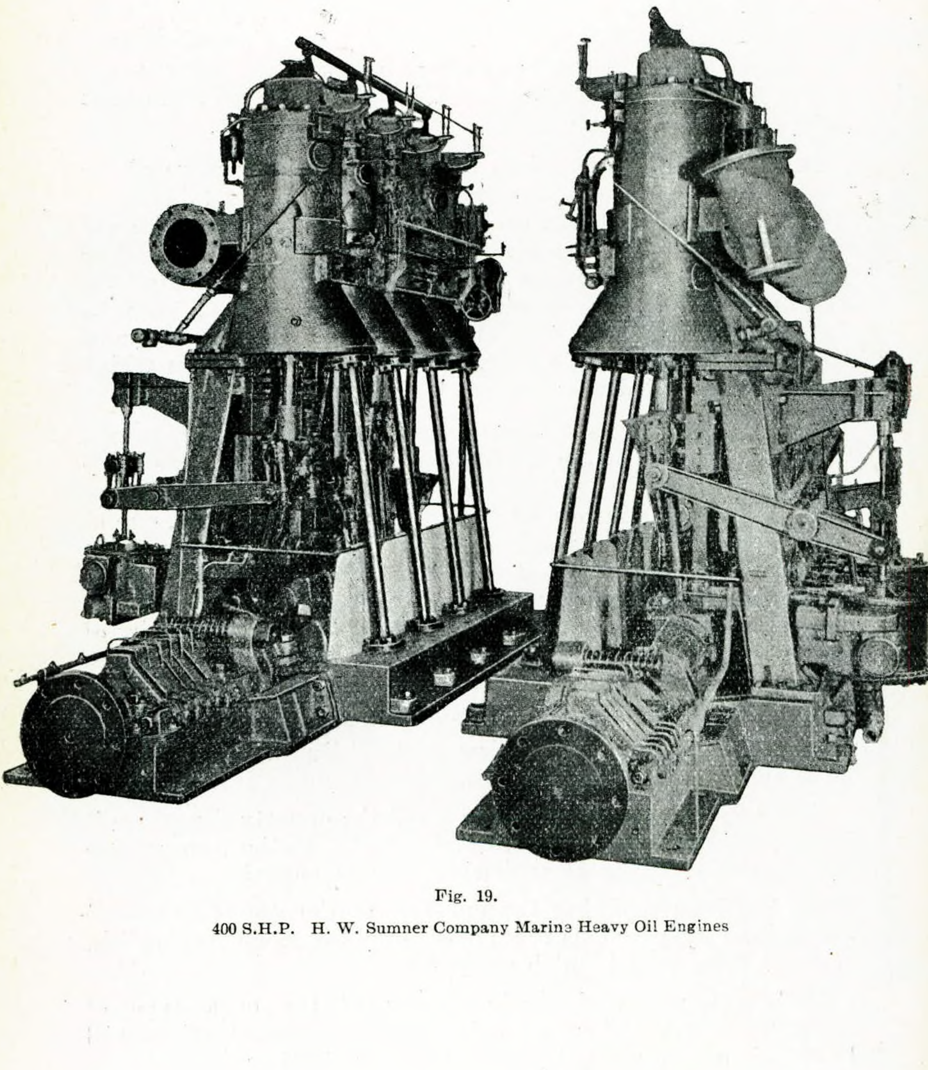


Fig. 19.

400 S.H.P. H. W. Sumner Company Marine Heavy Oil Engines

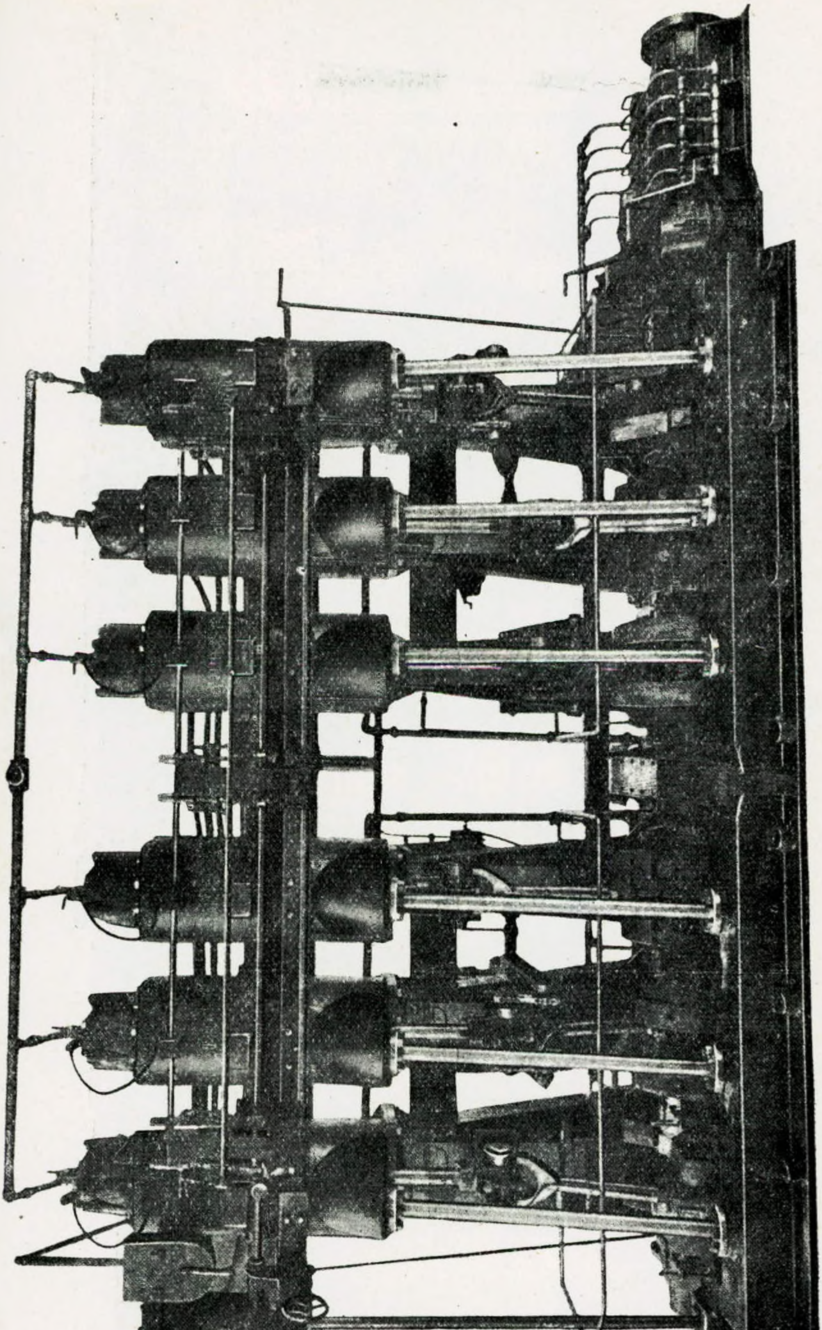


Fig. 20.
Front View. H.W. Sumner Company, 600 S.H.P. Marine Heavy Oil Engine.

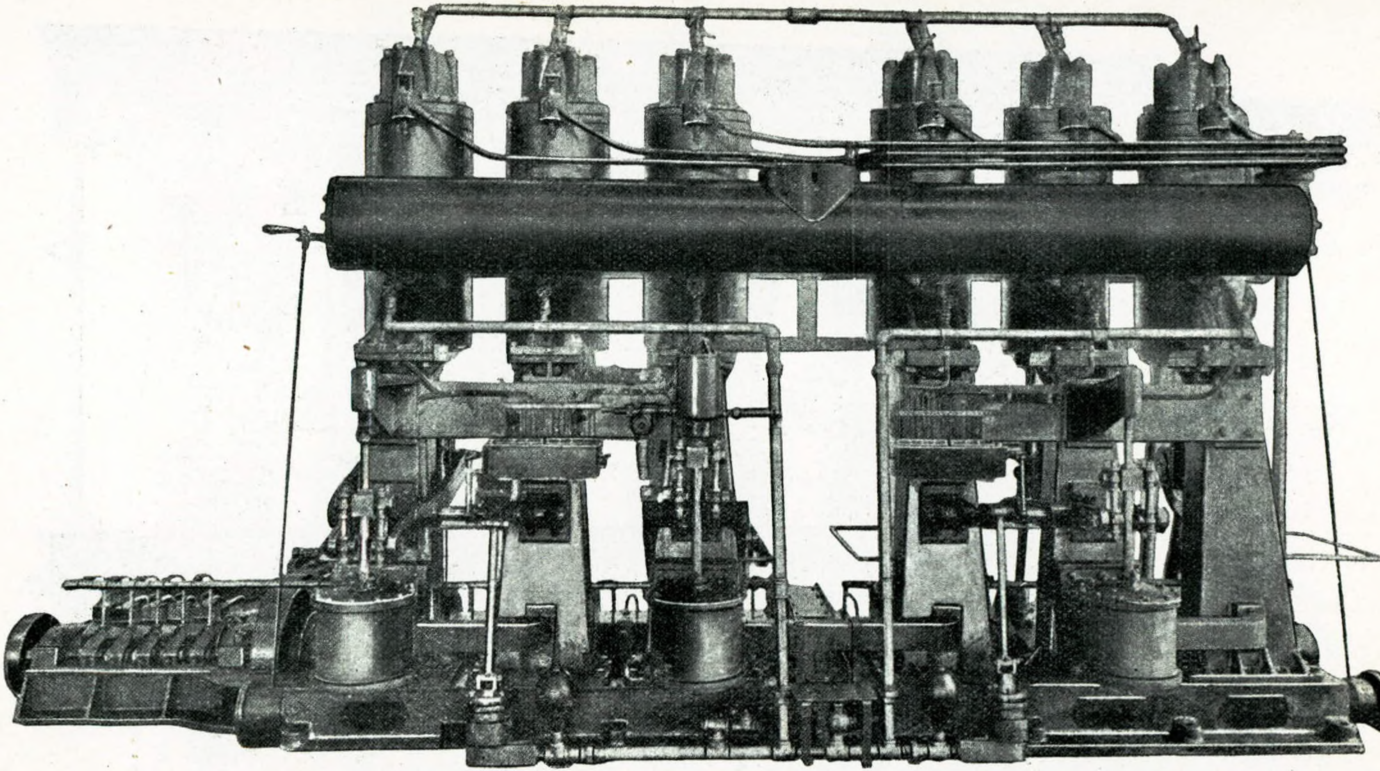


Fig. 20.
Back View. H. W. Sumner Company, 600 S.H.P. Marine Heavy Oil Engine.

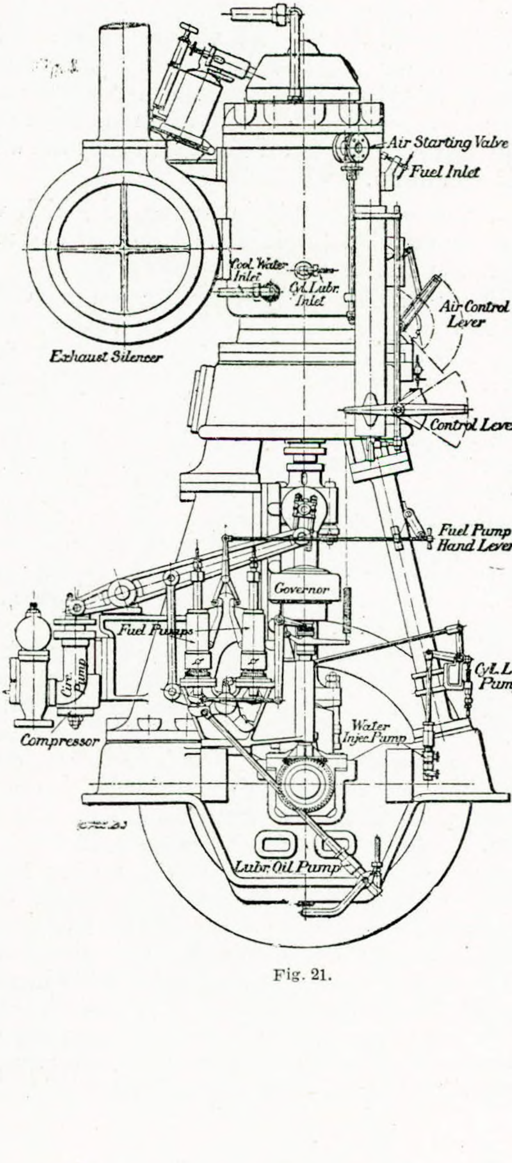

Air Starting Valve
Fuel Inlet
Cool. Water Inlet
Cyl. Lubr. Inlet
Air Control Lever
Exhaust Silencer
Control Lever
Fuel Pump Hand Lever
Governor
Fuel Pumps
Circ. Pump
Cyl. Lubr. Pump
Compressor
Water Injec. Pump
Lubr. Oil Pump

Fig. 21.

The CHAIRMAN: You have all heard the very interesting and practical paper which Mr. Butt-Gow has read to us, I am sure a number of members present are men who have been at sea with steam engines, therefore they will appreciate all the author has stated about the Open-Fronted Engine. There is no doubt that a man after years at sea with a steam engine where he can see everything that is taking place, is rather dubious of what is taking place inside the casing of an enclosed engine; he has to trust that everything is all right and that the oil pump is doing what it should do.

There are a number of points in the paper which we should like to hear other members' opinions on, so will call upon those present to start the discussion.

Mr. W. McLAREN: This paper seems to be a valuable one, in that it criticises the critics who have been putting forward their views in regard to this series of Internal Combustion Engine papers. Mr. Butt-Gow has brought in some practical experience that some of us have not been able to obtain. He has also helped up the steam engineer and advanced the advantages of the open engine type; therefore, we are getting on very favourably now, and we are getting to the end of the series, for this session at least. I always see that something creeps in about the workmanship; where are we going to get the workmen to keep this on the old system of aiming at perfection when so much depended on handicraft? Now that they have so many tools and there is a fight between output and non-output, or a slackening of the output, which the author goes into very fairly. I do not quite agree with him in some of the cases about the varied machines that may be employed in connection with certain engine building. There is the pattern making for instance. No doubt the pattern has to be made; if it is to be made wholly as an enclosed engine it certainly will bring itself home in cheapness, in the amount of metal generally used, but if the material rises 1s. a cwt. up goes the cost. Then there is the question of cores and core boxes to be considered with a view to economy. When it comes to the marking off table it is only a centre line in the right angle for the bore of the cylinder or guide crank shaft bearings, and machined with only once setting up, cheapening cost. The author speaks of the piston rod being flanged to the piston and at the other end tapered to go into the cross-head; should it not be tapered at both ends for nutting-up at each end? I think all marine practice and land practice is to have a flanged piston rod nutted on to the piston, even if there is a spigot fitted on to it. In regard to lubrication, I think I am at one with the author that the open engine has the advantage of being lubricated with economy. There is no question of the lubricating oil mixing with the internal combustion oil. That brings up the question of cross-head pins. I have never seen a trunk built up engine, either steam or otherwise, that did not give serious trouble with the pins, even now when case-hardened. In my young days case-hardening was never thought of, except for the cylinder cover nuts. These pins and brasses certainly will wear oval and not being able to let them together, the swing of connecting rod partly inside a trunk piston does not lend itself to the best work, and if they are solid brass it means a new brass and pin, or if it is a split brass the thickness taken off the pin wants the clearance taken off also. With the four-cycle engine, at one time she is pressing either on the compression or explosion, but there is another time where she is light and the flywheel is running away with the piston rod, and therefore you have not an even bearing all the time. I do not think there is much more I can say except by getting into some of these maintenance trifles. But I cannot sit down without expressing my appreciation of a good practical paper which is a fair wind-up of the series we have had up to now.

Mr. J. B. Hall: I am rather surprised to hear Mr. McLaren say he does not know what a piston rod bolted with a T-end to a piston is. There are any amount of them in gas engines in connection with the work I have to handle. There is no necessity, when you have a constant thrust, to have the usual marine fitted piston; when the greater thrust is all downwards you can have a T-ended piston rod bolted to the piston so sufficiently strong as to carry any strains from the scavenging side. Further, in regard to the gudgeon pins: We have any amount of gas engines fitted with gudgeon pins and trunks, and if designed, as I would suggest those I am referring to must have been, we have very little trouble with them,—very little trouble indeed. The great point is in connection with the surfaces. In the early days, and in new ideas, very great loss, or very great trouble, comes in when trying to undercut the amount of surface that is necessary for satisfactory working. If the surface is of ample area I think you will find that a good steel gudgeon pin with brasses will not give trouble. Not that I am in favour of that class of connection, I only refer of it because the previous speaker referred to it as being troublesome. Coming to the paper generally, I am of opinion that had this paper been read earlier in the series instead of now, there would have been considerably more marine engineers on the side of the oil engine. We have been given to run away with the idea that it was almost a necessity for the oil engine to have it enclosed. No doubt, after years of experience with an engine in which you practically can see and handle all the moving parts, that was a point that went very much against marine engineers, as a body, taking to their bosoms readily the oil engine. The author has shown that it is not a necessity, and some of the engines which have been shown on the screen, are, I hope, running. He says he does know that they are running. They are undoubtedly a move in the right direction. I don't think a marine engineer cares whether he uses gunpowder, or oil, or steam, as his motive force is in the cylinder; but he does like to be assured that what is going up and down, and round, is not trusting to Providence for its success. When you make an enclosed engine, if it goes to pieces badly it is one of the greatest incentives to a badly conditioned engine. If people put their heart and soul into the case of producing an engine to run quietly, and then at the end of the run, not sufficiently long to show any faults, they begin to say " Why trouble about it? " Well, once you get an attitude of " Why trouble about it " you get a badly conditioned engine. There is another point in connection with this I had personally in my own mind, and perhaps many more attending this series of papers had it also. You generally have the idea that when an engine is made such as these enclosed engines are, that it is done with some ulterior motive. It is done either for cheapness—generally, it is done for cheapness—and I think myself that if you are going to have a closed engine where nothing can be seen from the time it starts, well, so soon the time will come that engineers of ability, certificated men and so forth, are going to be cut out of it. If you put an engine into a vessel that only requires starting, the class of men driving it will be the class of men who drive our locomotives, able men no doubt, but they are not engineers. They know they push a lever this way and the engine goes. They pull another lever and the brakes are put on. But if, as has occurred to me in a run down from the North of England, you find yourself held up at a railway station, you have to send for another engine to be brought down. When they have any trouble with any part of the machine, they have to wait for an efficient man, an engineer, to come along. If you are going to put in front of engineers the suggestion that oil engines are not capable of being designed in the way that the marine engineer has been accustomed to—to see his working parts, then he will get the idea into his head, "How long will my work last, and when will my donkeyman be able to do it?" I congratulate the lecturer on such an able paper as he has put before us.

Mr. W. McLaren: I would like to point out, in regard to Mr. Hall's remark, that the trained engineer is being safeguarded by the Board of Trade. One paragraph in the regulations states that for a 2nd Class Motor Certificate "He must have served four years as an apprentice or journeyman Engineer. Not less than two years of this service must have been spent at fitting or erecting or repairing internal combustion engines. The remaining two years may be occupied on the same kind of work or spent at an approved technical school, or in work on internal combustion engines at one of the other branches of the trade named in Paragraph 40, with the allowances specified therein." We are no worse off to-day with this regulation than we were in our later years since 1900, but I do feel a little soreness with regard to this regulation, and I am afraid it will cause difficulties. The man who has put in a vast number of years as a certificated marine engineer has I think, by this regulation, to go and qualify again to get this extra diploma. I think something should be done to modify the regulation. They ought to give it to the certificated steam engineer under a proviso, stipulating certain experience and knowledge of the internal combustion engines, especially in view of the honour he deserves for sticking to his duty and his country amid the stern necessities of the recent years.*

The Chairman: There is one question I should like to ask the author; he states in the paper before us:—"The use of trunk pistons which is necessary with a closed engine, is responsible for a lot of this wear." Why is it necessary to have a trunk piston with an enclosed engine? I have seen closed engines of the Diesel type with an ordinary piston, only deeper, and the piston rod instead of going through the piston was connected by means of a flange and studs in the bottom of the piston, the cross-head guides and connecting rod were in every way the same as an ordinary open fronted steam engine, this arrangement has proved quite satisfactory, and the top and bottom ends and guides are easily overhauled. The only reason I can see for a trunk piston is a saving of head room. With regard to

* This subject is under consideration, and the proposed rule referred to will probably be modified.

gudgeon pins being fitted with split bushes and a tap bolt through the top of the connecting rod to adjust the brass, this did not prove to be satisfactory, and the solid bush, fitted tight into the connecting rod and a nice working fit on the gudgeon pin had to be adopted, with the latter practice it is necessary to make sure the pin is not too tight, and to see that the oil is getting to the pin before the engine is started, otherwise the engine will pull up after making a few revolutions, then you will have all the trouble of lifting the cylinder head, and taking out the piston and connecting rod to free the pin before making another start.

Regarding lubrication, my opinion is that forced is the best for high speed small engines, but with large engines I fail to see the advantage, because if you have forced lubrication it is necessary to have a closed engine, which is far more costly to build, and the engineer in charge can't tell if every bearing is getting the correct supply of oil.

Mr. Hall remarked that if engines were made perfect, marine engineers would not be required any longer; no matter how perfect engines are made, accidents are liable to happen at sea, and the cause is often the fault of some careless man while the ship is in port, no matter how thorough the supervision might be. Who would the man going round with an oil can go to for advice if he thought something was not working quite right; he could not run to a repair shop and get help if a breakdown occurred, but would have to wait for anotner ship to come along and tow them into the nearest port. Another thing, I can't see how the marine engine is to be made perfect without the experience of practical men who had been at sea and have seen engines working under the worst conditions; therefore it will be detrimental to all if the day ever comes when marine engineers are no longer required on board ship.

Mr. T. R. Stuart: I should like to congratulate the author on his advocacy of the simplification of the oil engine. But I do not think there is anything against enclosed engines. We cannot, I think, trust the piston to be the guide and I can see difficulties in using the crank case for compression. I have in my mind the electric light engines of large power made by such firms as Belliss and Morcom and Willans. Those engines are absolutely reliable. I think I can challenge any engineer to suggest any open type engine which will give the service those engines give. It is due mainly to excellent workmanship and careful selection of materials. It is due in the case of the Belliss engine to the successful system of forced lubrication. As a marine engineer who has watched both types of engines for a considerable number of years I cannot conceive of any system of drip lubrication doing so well. I would suggest that this matter be thrashed out by this meeting and at subsequent meetings in the endeavour to discuss the two points. I would try to maintain the closed trunk case and a satisfactory system of forced lubrication. The illustration showing the crosshead with split bush and set pin is to my mind a freak, and I think it ought to be set up as an illustration to be jeered at instead of one suggested by practical oil engineers. It is a thing that might be put on a toy, but not one to go to sea with. There are many things like that in the illustrations we have seen to-night. They are absolutely freaks. I congratulate the author on his endeavour to show how they can be overcome in a reliable, simple, and satisfactory engine. If this paper succeeds in doing that the author is to be congratulated.

Mr. W. J. Dibb, R.D., R.N.R.: The paper Mr. Butt-Gow has given to us to-night presents many interesting details, and which will, I am sure be greatly welcomed by the marine engineers, viz., his partiality for the open fronted type of engine, and after the various discussions that have taken place during the session, he seems to have filled in just the salient points that are mostly interesting to marine engineers.

I venture to state that what is required for marine engineers is an engine that will inspire confidence, and I feel quite sure with the enclosed engine this is far from doing so, and I maintain that when you enclose an engine and trust to forced lubrication, everything inside the casing is out of sight and must be largely left to conjecture until something goes wrong (such as a hot bearing, etc.), then it is too late to do anything to alter it.

Mr. Shannon mentioned that the only way to find out if the bottom ends were running cool was to feel the two main bearings and when they became hot it denoted that the metal in the bottom end was probably run out.

I would ask any engineer if this is likely to give him any confidence in such an engine as he describes.

The last speaker mentioned some engines in electric light stations on shore where engines with forced lubrications have run well. I have also seen the same thing, but they were generally small engines and motors, and which depended very much on the oil they used and the attention they received, and if anything went wrong it was an easy job to 'phone to the makers for new spare parts or a new engine complete. I am afraid we must place ships in a different category to this.

We all know that ships have a nasty habit of rolling badly, also taking heavy lists to port or starboard and sometimes big seas have been know to come down the skylights. In fact ships have actually disappeared altogether, and in that case of course the " next of kin " would be notified. This term has been rather familiar during the last few years.

It is quite apparent to every engineer that the internal combustion engine is going to depend very much upon the human element who will be responsible for the efficient working and upkeep, and in this I quite agree with Mr. McLaren, where are we going to get these specially trained men from?

We all know what steam has done in the past and is still able to do; I therefore think it will be a long time before the steam engine has passed away; as more oil is used its price must increase and then we shall have to come back to coal again.

The late Andrew Carnegie was once shown round some famous stables, with a view to purchasing some horses, and at the finish of the interview he said: Well gentlemen you have very kindly shown me all your good old " has been's "; also your very good " going to be's "; but what I am looking for is an " Iser."

Well, Mr. Chairman, I think that is exactly the position of marine engineers to-day, they want an engine that is equal to the steam engine for reliability, and please let us have an open-fronted job so that we can see what is going on, also an efficient system of oil lubrication which shows at a glance where the oil is going to, without trusting to anyone.

I therefore thank Mr. Butt-Gow for his very excellent paper and feel sure it will be read with much interest by all the members of this Institute.

Mr. F. O. Beckett: Both in regard to the paper and the discussion it has very truly gone all round, but there is a point about this gudgeon pin which seems somewhat perplexing. I think you will find that the greatest trouble is that the thrust is too great on the small area provided, particularly if there are trunk pistons. For large power I consider there should be as large and ample a crosshead pin provided as possible, consistent with the angularity that the connecting rod will make. Those I have had anything to do with unfortunately erred on the small side rather than on the larger, and the consequence was there was a greater pressure per square inch in area of thrust. The author makes a very pointed remark upon the adjustment of this particular bearing, and that it is done cold, *i.e.*, when the engine is cold; and with him I very much agree that it is an unfair thing no matter how fine the mechanism is to him who adjusts it. There is the possibility of over-heating in the cylinder walls, so that his adjustment may be thrown all out, through it being adjusted cold without due allowance being made for end thrust perhaps. I recall a very peculiar bearing in my experience. It is a new ship I am speaking of. That vessel was constructed for a speed of 16 knots on the trial, but they could only get 14 knots with the aid of the big fire hose pipe. We had to use that on No. 3 bearing because the heads of the coupling bolt were perhaps 1/100 part of an inch too long, and were touching the cheek of the No. 3 bearing, which was getting very hot. After getting $\frac{1}{8}$ of an inch clearance taken off we got the 16 knots all right without a trial. I think there is something like that as regards the internal combustion engine trouble. There is no clearance allowed and engineers lose their temper and condemn a thing before they really know where they should start to reason from. That is why I fancy some of these new born engines come into disgrace. So far as I can say of the lecture this evening, undoubtedly it is an opening out for the marine engineer in regard to the open front or the encased engine. I think a fork connecting rod is far to be preferred to a single connecting rod. Even with a shorter bearing you get nearly twice the bearing surface circumferentially. There is less shock taken up by the connecting rod bolts when the crosshead is of large area. This is a moot point but it is one that has given engineers a lot of trouble; that is, that connecting rod bolts should be annealed every year or every million revolutions, or should be renewed every year owing to the crystallization of the steel in the body of the bolt due to this explosive shock, anything from 40 to 120 per minute, varying with the speed. A point has been raised as to the poor old engineer having to take a back seat. I do not think that will come. I quite understand the point raised by Mr. McLaren, and the thought that a worthy engineer may have to take a back seat, with the youngsters coming along. Well, I think that law is very much to our good; there is a proviso or safety limit. I think it was in 1861 that the law was passed that an engineer should take a first-class certificate when going to sea, but he must have had so many years experience in the engineering profession, and it was possible that bringing this point in of two years' internal combustion engine factory or manufactory experience, I suppose that has its limiting factor there. So we shall not get the man from the drilling machine or the tube condensers, who are both worthy in their own place, but are not of the same efficiency as a man who has devoted most of his time to the furtherance of engineering in general and of the internal combustion engine in particular. We have much to thank the Board of Trade for in helping the right folk, as well as in preventing undesirables coming in by a side door, because, as you remark, Mr. Chairman, if you have a break-down in mid-ocean there are no back doors there. By means of your wireless you will get plenty of help, but very often the help will only be asked by worthy engineers when they are quite helpless, and not before. I have much pleasure in adding my small testimony to this paper, and my thanks to the author for the lecture we have listened to this evening.

The CHAIRMAN: There are quite a number of points which could be discussed. If any members wish, they can send written criticisms to the honorary secretary which will be published in the usual way through the medium of the Transactions.

I will now call upon Mr. Butt-Gow to reply to the questions that have been asked.

Mr. BUTT-GOW: As regards Mr. McLaren's question of the flanged piston rod, I think Mr. Hall has answered that for me. You will quite understand how it is fitted. It is quite a usual way; in fact it is the only way you can do it. Then in regard to forced lubrication. Well, I look at it this way. If people want to have forced lubrication they can have it, and if not they can have the drip system. There is a lot to be said for both. Personally, as far as the Bolnes open-fronted engine is concerned I know the builders will fit forced lubrication if people want it, but up to the present it has not been fitted and the drip system has worked very satisfactorily. Our chairman has raised the question of the trunk piston. Of course, one of the points that the closed engine people make about their engine is the small head room needed, and that is one of the things they generally argue against the open engine. There is no reason why a closed crank engine should not be fitted with a piston rod and connecting rod on the same principle of that first engine in this paper, the "Reliable," which has a trunk guide with a connecting rod. Of course the connecting rod should be made longer than shown to give good results. In respect of Mr. Beckett's remarks and the crosshead; as far as the Bolnes is concerned you can have either type of crosshead you like. I prefer the double crosshead. It is far easier for adjustment, and also easier for overhaul and gives better results. Apart from that I do not think there is much more to answer. If anybody would like to write in any questions I shall be very pleased to answer them.

Mr. W. Brawley: I rise to propose a vote of thanks to the author for a very practical paper. I am sorry I could not take part in the discussion, because I have only had a little experience with the closed type of engine. If I were going to sea again I know which I would prefer, and that would be the open type of internal combustion engine. I thank the author for his paper.

Mr. W. J. N. Brett: I beg to second that resolution for a vote of thanks to the author. Personally I should like to see the oil engine on the open system. I think it would certainly facilitate repairs, for there is a considerable difficulty in taking out the crank shafts in the enclosed engine as made now.

The vote of thanks was cordially agreed to.

The Marine Diesel Engine: Its Reliability in Service.

By Mr. Andrew J. Brown.

READ

Tuesday, April 26, 1921.

Chairman: Mr. George Adams (Vice-President).

The Chairman: This evening we have before us the concluding paper on internal combustion engines for this part of the session. I have not had time to go through it, but it appears to be a most interesting paper. Mr. Brown has journeyed amidst the difficulties of travelling at the present time from Glasgow to read his paper; we therefore give him a hearty welcome, and I think we shall have much pleasure and undoubtedly profit in listening to his paper.

THE MARINE DIESEL ENGINE: ITS RELIABILITY IN SERVICE.

The intention of this Paper is to give the question of the Marine Diesel engine practical consideration and to try to show how its reliability is ensured.

Considering the cycle of operations; with the Diesel engine of to-day we have two types to choose from, viz., two and four stroke. This has been the subject of controversy ever since the advent of the Diesel engine, the leading authorities being divided in their opinion, some advocating the two and others the four stroke cycle. The relative advantages and disadvantages of both have been so often enumerated that it is scarcely necessary to investigate them again. The possibilities of simplification of the two stroke engine are great, where the cylinder head is concerned, but it is done at the sacrifice of the most vital part of the engine, viz., the cylinder liner. The presence of the exhaust ports in the cylinder forms the limitation of the engine, as it is through the bars of these ports that the most serious heat stress is set up. Where scavenging ports are used—and these must be adopted if the cylinder head is to be kept simple—the unequal temperature of the liner around the ports causes distortion and consequently affects the piston rings, resulting in unequal wear throughout the liner. In the author's experience of two stroke engines, both port and valve scavenging, the great weakness and the unreliable part has always been the bars of the ports. If scavenging valves are resorted to, the cylinder head has no advantage in design over the four stroke, and judging from many existing designs of two stroke engines where three or four scavenging valves are used in addition to the fuel, starting, and relief valves, the design of the head is much worse than that of the four stroke engine where the number of valves is limited to five, viz., inlet, exhaust, starting, fuel and relief.

Perhaps the best way of showing the reliability of the Diesel engine is to consider each point of design individually and consider what each feature entails.

Bedplates.

Examining current practice in bedplate design, it will be found that the general course followed is much the same as has been adopted in steam engine practice, viz., the cast iron, box pattern which has been well tried out and is of proven reliability.

In one design of engine the bedplate sections are provided with male and female spigots which run all round the joints.

The presence of the spigots prevents any variation in height of the main bearings, such as is sometimes experienced with bedplates in ships, due to the working of the hull in a seaway.

The general practice for main bearing bushes is to make the shells of cast iron or cast steel and line them with whitemetal. If a good brand of whitemetal is used and is properly secured to the shells, the bearings may be set up to 6/1000th clearance where forced lubrication is provided. Of course, good alignment must be ensured, while, if there is any doubt as to the alignment, such as caused through straining of the ship in a seaway or unequal cargo loading, it is better to keep the clearance at 10/1000th.

Main bearings show up extremely well under service conditions, the amount of wear being small. In the author's experience of four stroke, forced lubricated engines, there have been instances of 12 months running during which time the wear was practically negligible.

CRANKSHAFTS.

In the crankshaft of a big engine it is usual to divide the shaft into sections, as in steam practice, and build it similarly. In the case of a six cylinder engine, two sections usually suffice, the sections being joined by flanged couplings. The compressor crankshaft is in almost every case a separate section joined to the main shaft by either a flanged coupling or else by male and female castellations. In the Diesel engine crankshaft the space taken up by the couplings is not lost, as it is usual to mount the cam shaft driving gear on the rim of the coupling flanges.

In the slow running Diesel engine, which is the type under consideration, sufficiently good balancing is usually obtained by the crank dispositions, and so, it is unusual to find counterbalanced crankshafts.

CYLINDERS.

In cylinder design great diversity exists as to type and construction.

In the four stroke engine the cylinder is a simple barrel whose function is to act as a water jacket for the liner, and, in most cases, to carry the tension load.

In the two stroke engine the cylinder is not so simple, as it has to provide an exhaust belt, and, in the case of a port scavenging engine, a scavenging air belt in addition.

The various designs of cylinders can be classified as follows:—

(1) Liner, jacket and cylinder head all one casting.

(2) Liner, jacket and cylinder head in two castings, the liner and jacket being cast together.

(3) Liner, jacket and cylinder head in two castings, the liner and cylinder head being cast together.

(4) Liner, jacket and cylinder head in three independent castings.

There are numerous examples of the above types to be found in service and from the results obtained, there is much to be said for each design. The advantages and disadvantages are more the concern of the designer rather than that of the marine engineer.

To give each class consideration from a practical point of view:—

Class (1) is generally confined to small engines and for inspection of the piston it is necessary to remove the whole cylinder.

Class (2). The liner and jacket being cast in one makes reboring somewhat difficult, and, in the case of a two stroke engine where cracked liners are not uncommon, it means greater expense in renewals.

Class (3). The liner and head being cast in one gives advantages in keeping the metal of even thickness throughout, and assists the cooling of the head, but it has distinct objections in that the two most susceptible parts of the cylinder are in one, and fracture of either means renewal of both. Moreover, inspection of the piston is rendered more difficult unless considerable ingenuity is displayed, as in the case of one Continental design of engine where the pistons are removed for inspection from the bottom of the cylinder.

Class (4) has probably found greatest favour amongst designers, and is the most attractive, as each part is separate and therefore of the simplest form.

In the mounting of the cylinders many means are adopted, take for instance the two stroke "Krupp" engines of M.S. *Hagen*. The cylinder of this engine comes under category (3) while it being a two stroke, valve scavenging engine, the exhaust belt will also be noticed. The cylinder is bolted down on to a cast iron entableture which is, in turn, supported by cast iron columns.

Fig. 2 shows a section through the well known "Burmeister and Wain" engine, from which it will be seen that the cylinder comes under category (4). The bottom of the water jacket forms a distance piece and is secured to the "A" framed crank-case by means of long bolts extending upwards from the bed-plate. The cylinder head is secured by means of studs screwed into the top of the water jacket.

The "Beardmore-Tosi" engine cylinder is also under category (4). The cylinder is bolted direct to "A" type columns, while the head is secured by bolts to the bulged water jacket. In this engine the cylinder liner is provided with a spiral rib cast integral on its outside diameter surrounding the combustion space. The provision of this rib allows of greater strength where it is most needed and also assists the cooling, as the water is carried over the whole surface at high velocity.

Fig. 3 shows the "Werkspoor" design of cylinder and framing from which it will be seen that the cylinder comes under category (3) while supporting is by means of large turned steel columns extending from the bedplate.

The most general practice in Diesel engine design has been to adopt guides of the single slipper pattern, in which the ahead side is usually water jacketed. In design and construction the guides and crosshead shoes follow that of orthodox steam engine practice.

As an example of what may be expected from good design and construction, the author's experience has been, that, with forced lubrication, a year's running without adjustment of the guides is quite normal behaviour.

Pistons and Piston Cooling.

In this connection, no standard has, as yet, been adopted. In all probability there are no two makers who adopt the same design of piston in all its features, although there are many points of resemblance in them all. In the majority of cases, the concave form of crown has been adopted, as this type allows of the easiest and most direct fuel injection being used. The convex form of piston top necessitates the use of radial injection, which is a drawback, while its greatest advantage lies in absolute

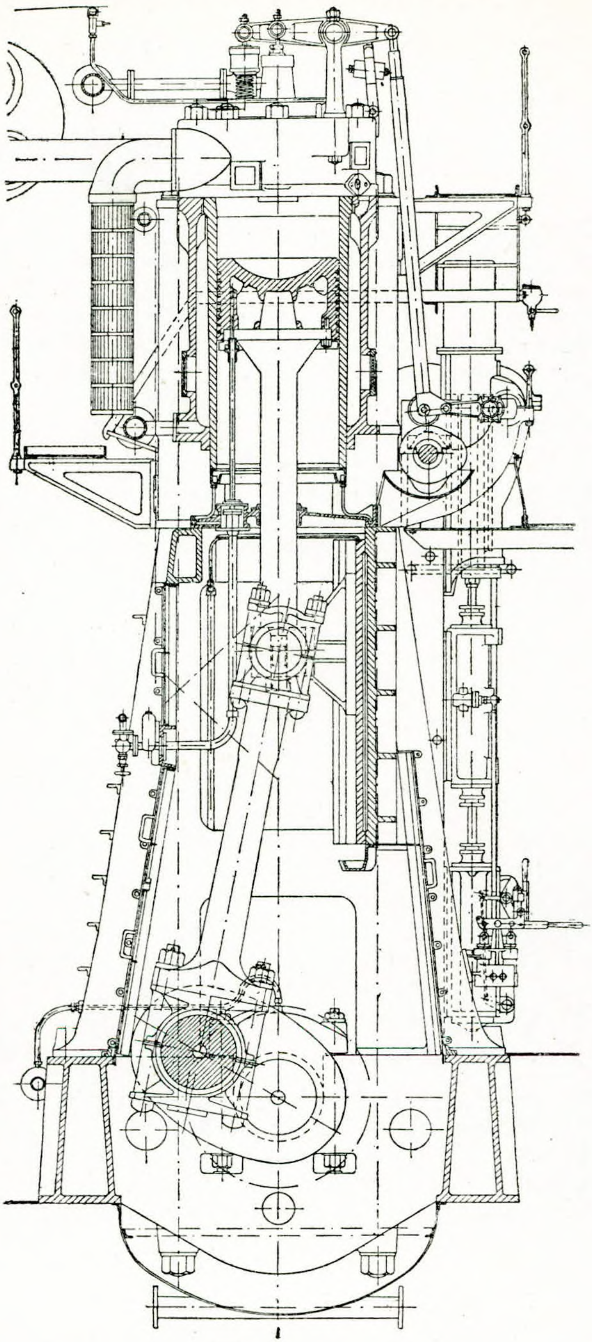


FIG 2.

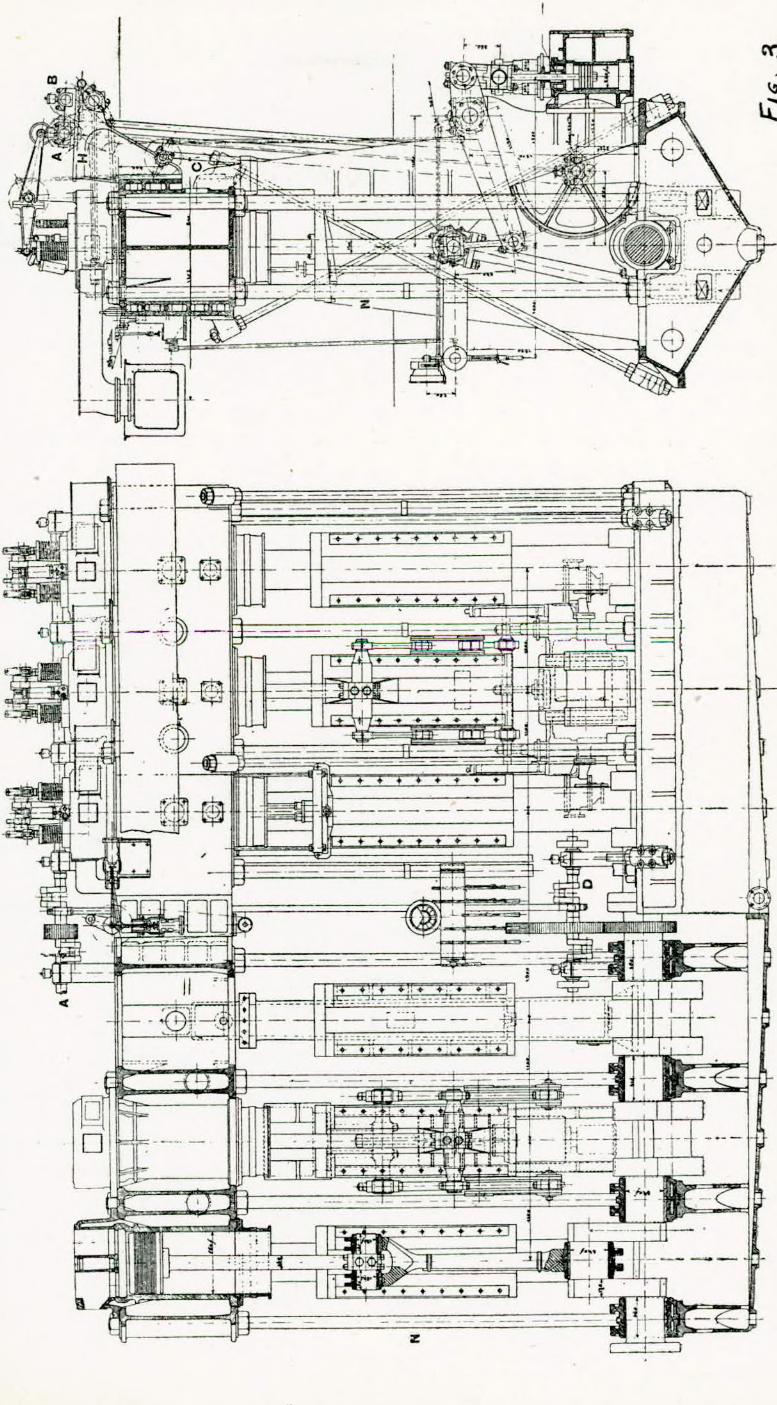


Fig. 3.

End View.

Front View.

safety in starting the engine. When an engine is being started and misfiring takes place, a pool of oil may collect in the piston top when of the concave form. When the oil does become ignited, if in the presence of starting air, a dangerous pressure results, which often lasts over a few strokes, while its effect on the engine is scarcely beneficial. A convex piston obviates this occurring, as any unburnt oil runs off the piston top. The effect of this is to gum up the piston rings and cause compression leakage, so it will be seen that the result of misfiring with any type of piston is highly undesirable, and, if anything, more so with the convex pattern.

Variation in the form of piston top is met with in several engines where a certain peculiarity has been adopted in order to meet special requirements.

Irregular shapes are undesirable, not only from the unequal heat stresses imposed, but from the point of view of repairs in the event of fracture. When the regular form is maintained, *i.e.*, convex or concave, a cracked top can be repaired by recessing the crown and inserting boiler plate, when the piston should be capable of considerable service before being scrapped. The author has had experience of this repair being carried out in several cases, and it proved, in every way, eminently satisfactory.

Fig. 4 shows a sketch of such a repair to an uncooled piston of $12\frac{1}{2}$ in. diameter. It will be seen that the piston crown is recessed to the same curve as the original concave, the new diameter formed taking in the whole length of the crank. The plate inserted is made from a $\frac{7}{8}$ in. boiler plate machined and roughly bedded, and is secured by eight $1\frac{1}{2}$ in. studs. The holes in the plate are countersunk and the studs riveted over. The piston top is again machined to a smooth finish, when the joint lines of the plate and rivet heads are indistinguishable.

In the author's case, after a year's running with such a repair, the joint lines of the plate and rivets were only visible, and no slackness whatever was apparent: moreover, there were no signs of deterioration through combustion. It is the author's belief that such a repair is equally applicable to the largest water cooled pistons, provided the workmanship is good and the necessary expansion allowed for.

Regarding piston cooling, water is the medium most generally in use in nearly every large engine. Oil has been tried in order to simplify design, but, unless the circumstances are exceptional, the results are not warranted. Due to deterioration of the oil through exposure to such great heat, the resultant wear in bearings is greater, while, of course, more oil is con-

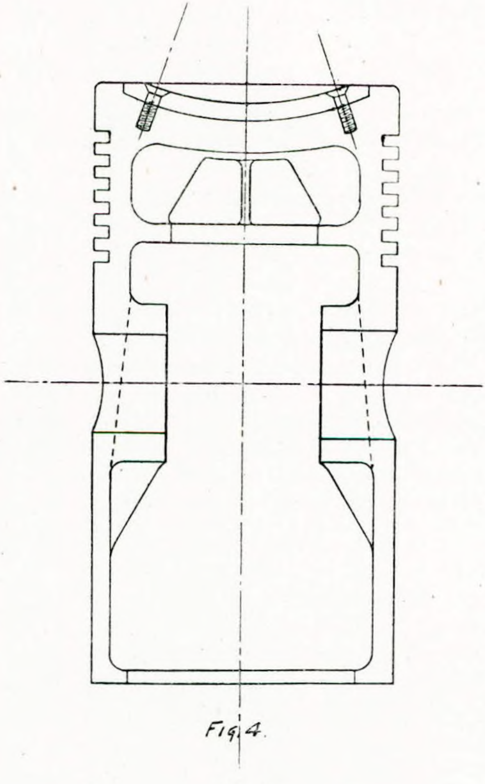


Fig. 4.

sumed than if merely used for lubrication, and its life is considerably shortened. Systems have been tried wherein separate oil is used for piston cooling, but as this entails the use of special gear, its advantages are mostly lost. Again, the design of an oil cooled piston calls for more care, as much better circulation must be ensured due to the greater temperature of the cooling medium and its lower specific heat.

Where water is the medium used for piston cooling, it is usual to find that fresh is preferred to salt. The use of fresh water entails additional complications in the way of tanks and coolers, but, all things considered, the system is amply justified. There is no appreciable loss of water through evaporation, and, with a good system, leakage is either very slight or else non-existent. With the quantity usually allowed, one filling of water will last three or four months, at the end of which time it is advisable to pump it overboard and clean and refill the system.

The importance of piston cooling water filters and the necessity for having them accessible may here be noted. The formation of scale and deposit is unavoidable in any water system, and its presence in rough weather becomes apparent through the filters choking and the pressure dropping. The only course open to the engineer on watch is to change over from the running pump to the spare and clean the filter that is choked. With the ship rolling and pitching, it should be readily appreciated that accessible filters are desirable, and yet, there are designs in existence where changing the filters necessitates going under the floorplates, and lying on one's back to the accompaniment of cooling draughts of bilge water with every movement of the ship. Such is an example of design, wherein the designer has apparently trusted to a special manifestation of Providence preventing the necessity of his gear ever needing examination.

The best design is that where two interchangeable filters are provided to each pump, or else that of having the one filter of each pump interchangeable with that of the other, and, most important, having them accessible. Filters are essential, as if any scale or deposit gets into the system, trouble may be encountered with overheated pistons and undue wear of parts.

Fig. 5 is a diagrammatic sketch of a piston cooling gear of the telescopic pipe pattern. This is the most satisfactory type of gear in service, and little, if any, trouble is experienced with it. The only glands incorporated are easily kept tight and seldom need repacking. The success of the gear lies in perfect alignment, and this must be ensured. Mal-alignment means that rapid wear will take place in the tubes, which become useless in consequence, as the wear, being all on one side, makes it impossible to cure the trouble by repacking the glands.

Fig. 6 is a diagrammatic sketch showing the inlet and outlet fittings combined in one.

Under service conditions with gear of the telescopic pipe pattern, it is advisable to withdraw the injector pipe every four

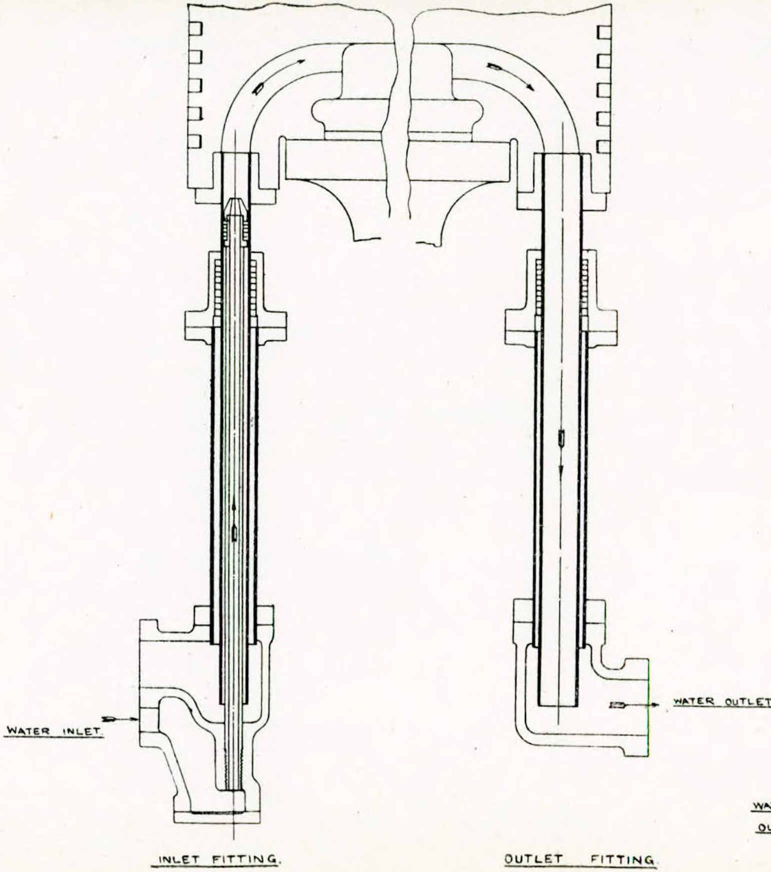


Fig. 5.

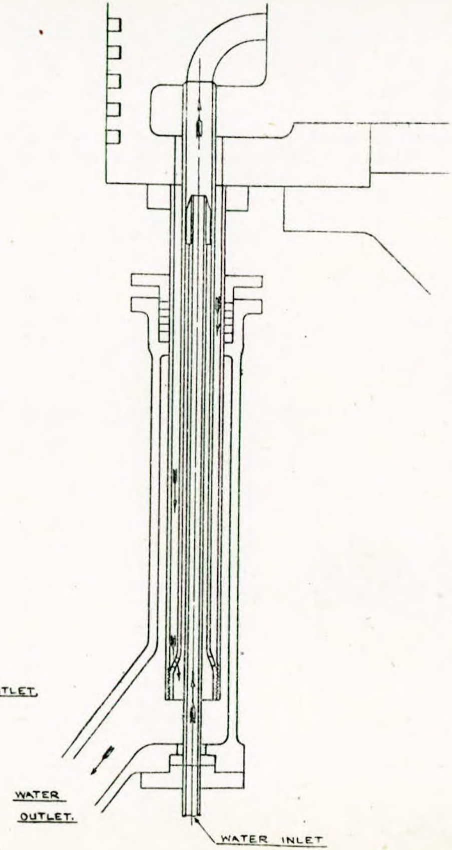


Fig. 6
Combined Inlet and Outlet Fitting.

Telescopic Pipe Pattern Piston Cooling Gear.

or five months and examine the packing rings. If new rings are required, the best practice is to turn them out of a piece of ebonite, as this ensures their being a better fit than if standard size spares were carried.

PISTON RODS AND CROSSHEADS.

The piston rod of a single-acting Diesel engine is usually a solid, mild steel forging, attached to the piston by a flange and studs and to the crosshead by a single nut in the usual manner. In some engines the piston rod is hollow, this being to allow of its functioning as a piston cooling medium.

The only gland fitting round the piston rod of a single acting four stroke engine is that which divides the cylinder from the crankcase. It is usual to provide a tray under the piston to prevent any oil or carbon that may drop from it mixing with the lubricating oil. Also, where forced lubrication is used, it is desirable to prevent any oil or oil vapour from coming in contact with the cylinder walls or piston, hence the use of the stuffing box. Such glands are usually packed with metallic rings in sections held in place with springs, and seldom, if ever, need be renewed.

Crossheads are invariably of the square block centre type with a gudgeon pin extending on either side, and the crosshead shoe held in place by studs. The best practice is where the gudgeon pins are thoroughly case hardened and ground to a finish.

With forced lubrication, it is not altogether necessary to have the crosshead shoes lined with whitemetal, provided the bearing pressure is kept low.

In the "Beardmore-Tosi" engine the centre line of the cylinder and that of the crankshaft are not co-incident, but are off-set to about 60m/m. This setting is known as "De Saxé" and amongst its advantages are the following:—

The length of the connecting rod can be reduced. The overall height of the engine is also reduced accordingly. Bearing pressures on the ahead and astern guides are equalised, giving low bearing pressures for ahead running. A better impulse is given to the piston at the commencement of combustion.

CONNECTING RODS.

The forked top-end, marine type is that most generally in use. The bushes follow standard practice in that the shells are usually of cast steel lined with whitemetal.

The four stroke cycle forced lubricated Diesel engine shows up much better in service than an open steam engine where top and bottom ends, and indeed, all bearings are concerned. The author's experience has been that where the oil pressure is maintained correct and the filters kept clean, examination of the top ends every six months and of the bottom ends every nine months should suffice.

CYLINDER HEADS.

In the case of a four stroke cycle Diesel engine the cylinder head usually houses five valves, viz., a fuel injection, an air inlet, an exhaust, a starting air and a relief. The principal problem involved is to provide adequate cooling at all parts, so that good circulation of the cooling water must be ensured.

The general practice for securing cylinder heads is to have from eight to twelve studs screwed into the top of the water jacket and extending through holes in the cylinder head with the nuts bearing on facing strips. An alternative to this is to have the top of the cylinder water jacket bulged in the form of a flange of box section suitably stiffened, and allowing of the use of bolts in place of studs. This system obviates the risk of breaking associated with studs, while it gives ease of alignment and also allows the spigot joint between the cylinder head and cylinder liner to be reground with a minimum of labour.

In order to simplify construction and to ensure better circulation and cooling effects, it is usual to arrange the fuel injection valve inside a removable liner in the cylinder head. An idea of the congestion that results if this is not done can be grasped readily on examining one. The liners are made of gunmetal or bronze and are either expanded or screwed into place in order to make them watertight. As a method of securing, screwing forms the best medium, as then there is no danger of the liner being drawn out along with the fuel valve when the latter is being removed. It sometimes happens that the joint between the fuel valve body and cylinder head leaks, and when this occurs, carbon is formed between the valve body and the liner. The valve is then very difficult to remove, and, when excessive strain is applied to loosen it, the liner, if expanded into place, invariably comes away as well. Similar seizures are caused through water and lubricating oil that may be lying about the cylinder heads passing down between the valve body and the liner becoming oxydised and forming a scale which has the same effect as escaping products of combustion. This latter cause can be prevented by placing a rubber ring joint under the valve body head and so sealing the valve port.

As an illustration of the extent of such seizures, the author has seen valve bodies break before loosening, while several hours were spent in removing a single valve under such circumstances. It is imperative that the joint between the valve body and the cylinder head should be made perfect, while it is advisable to draw all fuel valves at least every four months to ensure against any such mishaps.

In almost every case the joint between the cylinder head and cylinder liner is formed by a spigot, the male being on the head and the female in the liner. Various modifications of this have been tried, but the most successful is when the joint is made metal to metal with only a little graphite and tallow interposed between the faces. Copper ring joints are too susceptible to the effects of combustion, and as absolute tightness is essential, it is better not to use them.

Cases have come before the author's notice where, due to overheating of the cylinder head joint a slight leak has started and in developing has necessitated a stoppage. When the cylinder head was lifted it was found necessary to chip away part of the male spigot and dovetail a new piece in place of it, this also having to be done in the case of the female spigot in the cylinder liner. It is interesting to note that such a repair was carried out with the engine running on its remaining cylinders. It was first stopped and the cylinder head lifted, then restarted and kept running until the head was again ready for lowering into place.

Valves and Valve Gear.

Fuel Injection Valves are divided into two distinct classes, viz., "Mushroom" or downward opening valves, and "Needle" or upward opening valves. There is much to be said in favour of each type, and concrete proof can be brought to bear in support of the claims. The greatest advantage attached to the mushroom valve is that a very evenly distributed spray can be maintained. Further, the spray is in the form of a hollow cone spread over a relatively large area, thus giving every opportunity for good vaporisation. It is possible that this type of valve renders the piston top more immune from the burning action which generally takes place when the oil injected continuously strikes one particular spot. Against these advantages there is the liability of the valve head being burned in the event of the valve sticking open, the effect of which necessitates an immediate stoppage of the engine. Again, it is necessary to withdraw the complete valve when it is desired to examine the seats; also, there is the danger of the valve dropping into the cylinder should the stem break, but this point need not be emphasised as it equally applies to all the valves in the cylinder head.

The needle type has to its advantage (*a*) immunity from burning due to the valve sticking open; (*b*) capacity for being removed and examined, and even reground without removing the cage; (*c*) greater delicacy of injection due to increased lift.

The fuel and injection air connections are arranged in the head of the cage and mostly consist of cone couplings. It is general to find the fuel led down through a $\frac{1}{4}$in. hole in the side of the cage and admitted near the top of the atomiser. The injection air is admitted near the top of the cage well above the fuel inlet. Atomisers are seen in many forms, but the most common is the "plate" type. This consists of a number of plates mounted on a sleeve and kept apart with distance pieces. This sleeve also acts as a guide for a valve stem. Each plate has a number of holes or else slots cut in it, and is so arranged that the holes or slots do not coincide with the adjacent plates. The effect of such an atomiser is to give the fuel a zig-zag motion during the injection period. Fig. 8 shows an atomiser of this type. It will be seen that the sleeve holding the plates has a cone screwed on to the end of it. This cone is provided with special grooves, so that the final passage of oil and air is in the form of a swirl.

The stuffing box shown in Fig. 8 is typical of that used in most fuel valves, and it may be said that packing forms the greatest source of annoyance in connection with this part of the engine. The trouble with fuel injection valve stuffing boxes is to keep them tight, and, at the same time, prevent the valves sticking through them. Fuel injection valve spindles invariably show up badly where the packing has worked, even after a short time in service, and nothing much can be done to cure the trouble. The spindles are usually rough and scored and pitting takes place most readily at that section. The author has seen all sorts of packing tried—leather fibre rings, fibre shavings, whitemetal rings and whitemetal shavings; standard soft packings and standard hard, semi-metallic packings; as-

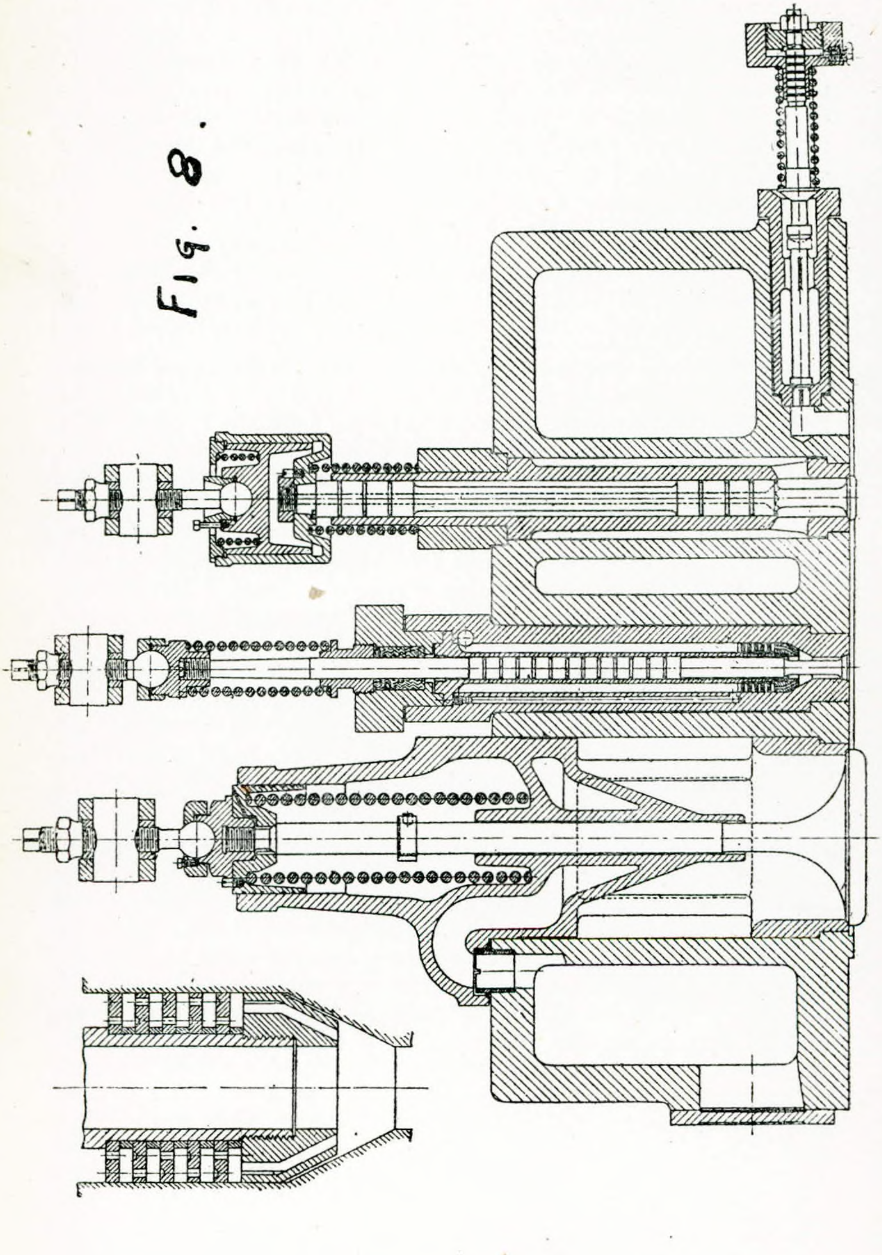


Fig. 8.

bestos cord and plaited lamp wick; a soft pliable mixture of asbestos, rubber, graphite and other ingredients.

With the stuffing box filled with this last packing and a turn of plaited lamp wick to keep it in place, the best results were obtained, but even these left much to be desired in the condition of the spindles at the end of three months running. The correct solution of the difficulty is to abolish packing glands altogether.

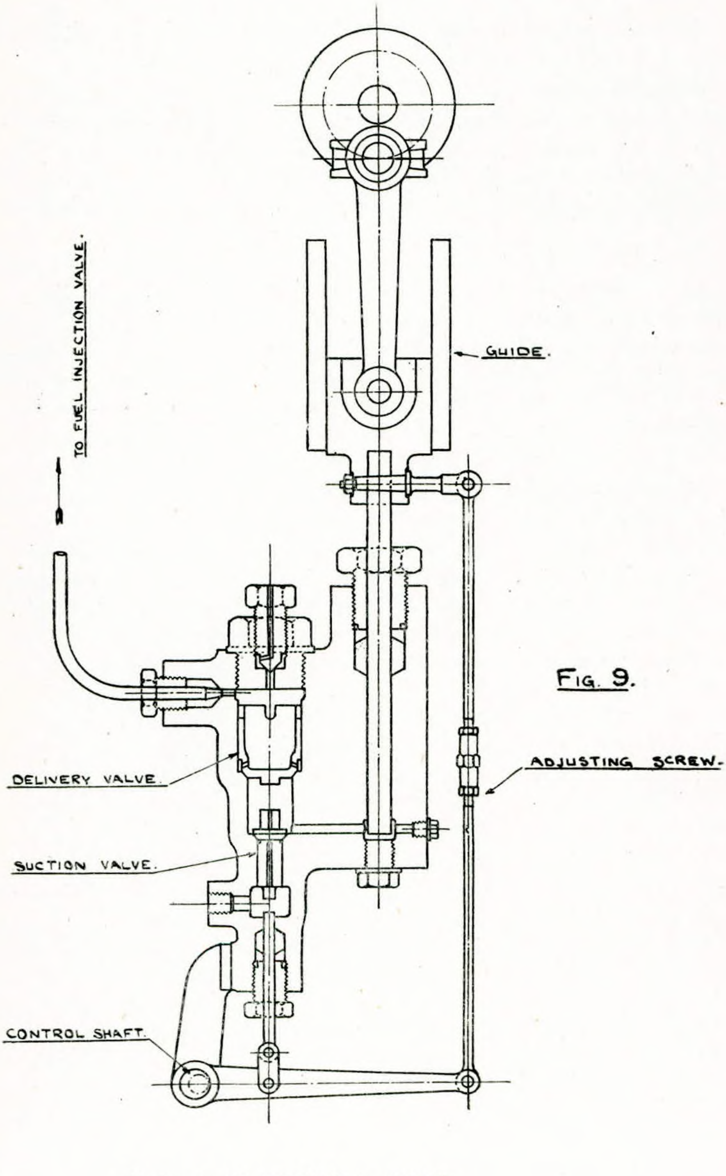
FUEL INJECTION PUMPS.

As the working balance of a Diesel engine lies in the even distribution of fuel to each injection valve it will be readily appreciated that the main consideration is the distributing gear. To obtain evenness of supply, some makers use a single fuel pump which delivers the oil into a common pipe, and through it to a distribution box, and then to each individual fuel injection valve.

The other system, which is the more all-round satisfactory in service, is to use a battery of fuel pumps each supplying one cylinder. While this necessitates increasing the number of parts, it is amply justified in practice by its evenness of supply and absolute reliability. The adjustment of the quantity of fuel to each injection valve is positive and easily effected. Moreover, in the event of anything happening to a fuel pump, only one cylinder is cut out. Again, if anything happens to a cylinder necessitating the fuel being cut off this can be done without altering the load on the remaining cylinders. Perhaps the greatest consideration of all is the fact that should a fuel pipe burst only one cylinder is affected, while a new pipe can be fitted without stopping the engine.

Fig. 9 is a sketch of a fuel injection pump and, in principle, is typical of most types used in Diesel engine. Differences in design lie in the disposition of the pumps, whether placed vertically or horizontally and in the method of operating them. The most common drive is by means of eccentrics, but in some cases a separate crankshaft is used, it being driven through gearing from some part of the engine. Differences also lie in the number of delivery valves fitted and their accessibility. The best practice is where the valves are fitted in removable cages as this facilitates regrinding.

The quantity of fuel pumped and therefore the speed of the engine is controlled by varying the timing of the fuel pump suction valves, which are mechanically operated. The suction



Fuel Injection Pump.

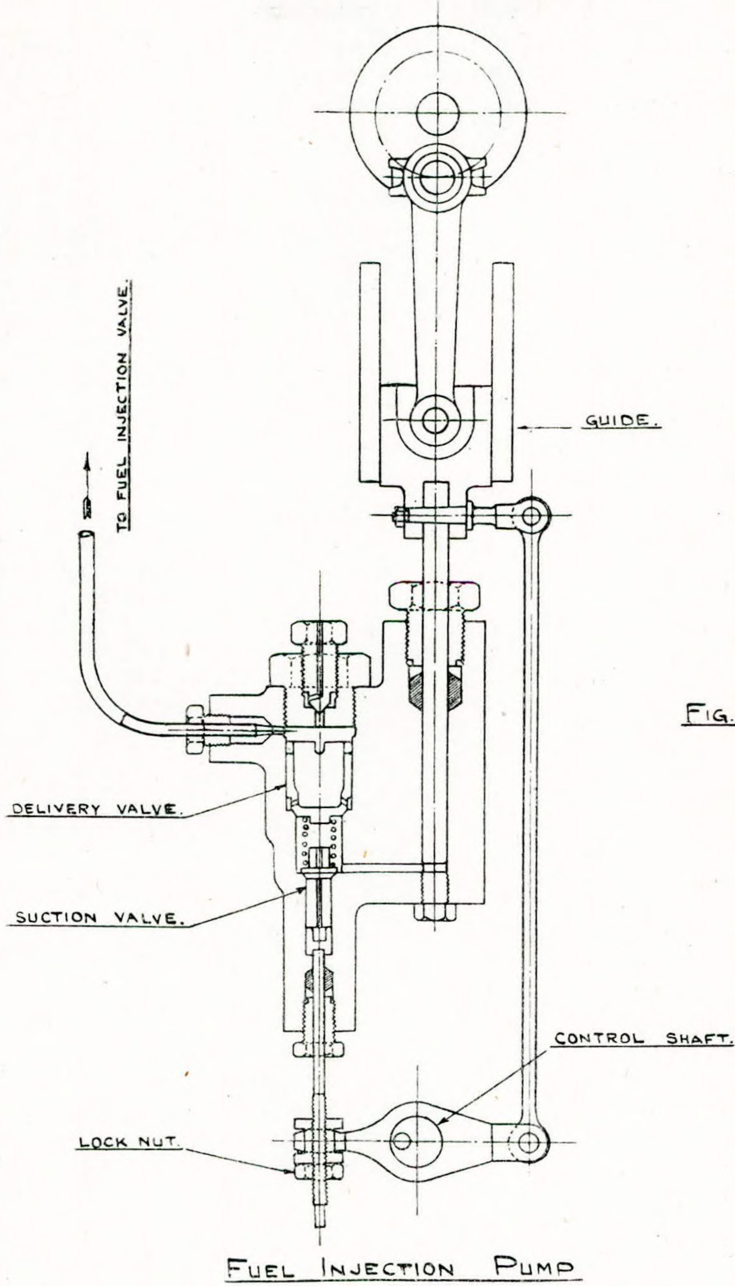


FIG. 9.

FUEL INJECTION PUMP

valves are usually operated by links from the pump crossheads, while the timing is varied by mounting one of the links eccentrically on its fulcrum and by rotating this last member.

Fig. 9 shows the suction valve operation and control, also the delivery valves.

Fuel injection pumps, on the whole, give very little trouble and need little attention. Provided the plunger is well guided and made a good fit in the pump barrel, the packing should last at least six months if the right material is used and the work is done properly. It is usual to examine and regrind the suction and delivery valves at the same time the pump glands are being repacked, but it is not a very big job and is done easily by a man who understands his business.

INDUCTION AND EXHAUST VALVES.

The valves are all of the mushroom downward opening type, and the only differences encountered are constructional and in the form of seat and cage used. Fig. 8 shows the "Burmeister and Wain" type of exhaust valve from which it will be seen that the valve is set in a removable cage and that the stem guide is watercooled. The valve in this case is turned out of steel and has a removable cast iron seat (not shown). The induction valve used by this firm is similar, in that the same cage is used although the cooling water is not passed through it. The inlet valve is made of steel and has no detachable seat.

In another design of an induction and an exhaust valve the exhaust valvé is made with the head of cast iron and the stem of steel screwed into it. It is placed in a removable cage with the stem guide water-cooled. The induction valve is made of steel and seats directly on the cylinder head and is provided with a removable guide bush.

The use of separate cages for exhaust valves prevents the seats from being properly cooled owing to their great distance from the water jacket. This necessitates the examination and regrinding of the valves at least every three months, and more frequently if the engine is run at near full power all the time. To overcome this difficulty, some makers use an internally water-cooled exhaust valve, for which claims of six months continuous service without examination are made. While the overheating of the seats is to a certain extent overcome by this method, the cylinder heads water spaces still remain unduly restricted owing to the presence of the valve cages.

In the "Beardmore-Tosi" engine a director valve controls the inlet and exhaust. This valve is arranged to work in a port in the cylinder head and controls the flow of gas to and from the combined inlet and exhaust valves by means of ports interconnecting the inlet and exhaust passages. These passages are alternately brought into communication with the combined inlet and exhaust valve by means of the "director" valve which shuts off either one or the other. Driven by an eccentric, the "director" valve is so timed that as the piston rises on its exhaust stroke with the combined inlet and exhaust valve open communication is made with the exhaust manifold, while the induction manifold is shut off. As the piston passes the top centre to descend on its induction stroke the combined inlet and exhaust valve remains full open, while communication is made with the induction manifold by means of the "director" valve, which at the same time shuts off communication with the exhaust manifold.

The combined inlet and exhaust valve is thus first exposed to the heat of the exhaust gases, but is immediately afterwards cooled by the incoming charge of cold air, further, on the induction stroke, through the action of the air entering the cylinder through the valve, the face is cleared of any soot or deposit that may be lying on it. The "director" valve is situated above and behind the combined inlet and exhaust valve, while accessibility is through a door mounted on the side of the cylinder head. Two "director" valves are fitted in each cylinder head, there being one for each combined inlet and exhaust valve. To ensure the maximum cooling effect, the combined inlet and exhaust valves are made to seat directly on the cylinder head. The advantages gained from the method are such as to render a water-cooled exhaust valve totally unnecessary and to reduce grinding-in to a minimum. Another advantage of the system is that it permits of smaller and lighter valves being used, two being in action instead of one as is the usual practice, this simplifying the design of the cylinder head.

The life of an exhaust valve seat depends greatly on the grade of fuel used, as with bad oil it may be necessary to change the valves every month.

Induction valves can be relied upon for a year's service without regrinding, and even then they are generally in good condition.

STARTING AIR VALVES.

In the majority of engines the mechanically operated type of valve is used, its great claim being positive action. The above-mentioned valve usually consists of a cast iron cage with the valve spindle running through it. Ports are arranged at the bottom of the cage corresponding with the air inlet port at the bottom of the valve pocket in the cylinder head. The valve is made with an ordinary mushroom head, while the spindle is enlarged in diameter above the air inlet ports. From four to eight cast iron ramsbottom rings are fitted, one above the other, on the enlarged diameter of the spindle and serve to make it air-tight. The end of the spindle extends above the cage and is fitted with a retaining cap which holds the valve spring in position against the flange of the cage. The valve is cam-operated through the medium of a rocker lever. Some engines use the pneumatically-operated type of starting valve, it is similar to that just described, but is operated by the starting air acting on a piston formed by the enlarged end of the spindle. This type of valve necessitates the use of a timed air distributor driven by the cam shaft or through gearing from the crankshaft. Another system in use at present is that of having non-return valves fixed to the engine cylinders and working in conjunction with a timed distributor as in the case of the pneumatically-operated valve described.

Air starting valves, particularly the mechanically operated type, are perfectly reliable and are capable of long service without needing an overhaul. Their condition can be watched closely while the engine is running on fuel, and, if the valve faces are leaking, indication will be given by the starting air supply pipes becoming hot. Again, if the spring rings on the spindle are also leaking it will be shown by the gas escaping past them becoming visible to the man on watch. Bad leakage from any starting valve would necessitate a stoppage to have it replaced with a spare, but the author has never experienced such a case, it has always been possible to stop the escape by turning and grinding the valve on its seat. To ensure the satisfactory operation of the starting valves it is advisable to shut off fuel and give the engine a few turns on starting air after every six or seven days running on a long voyage. While this is being done an engineer can watch the behaviour of each valve and if there is any sticking or leakage apparent it can be rectified at the time. Such procedure is also advisible 12 hours before entering any port, as it obviates the possibility of any hitch occurring in the manœuvring of the engine.

VALVE GEAR.

The most usual method of operating the valves of a Diesel engine is by means of cams and rocker levers. In some few cases eccentrics have been adopted, but their use has never become general.

The cams are usually made of special cast iron, ground to a finish and fixed on the camshaft by means of feathers. In existing designs the cam shafts are disposed at the level of the bottom of the cylinders in some engines, and at the level of the top of the cylinders in others. The advantage gained from each position are special, in that the greatest benefits are only apparent when the whole system of valves, valve gear and reversing arrangements is reviewed for each individual engine. Thus, each position has certain disadvantages which are compensated for by other features.

Different methods are used for operating the camshaft, amongst which are the following:—

(*a*) By a train of gear wheels extending from crankshaft to camshaft.

(*b*) By a vertical intermediate shaft and spiral gear wheels arranged top and bottom.

(*c*) By means of two or more rods operated by eccentrics mounted on a half-time shaft driven from the crankshaft by gearing Fig. 3.

The rocker levers used are invariably of cast steel and differ most generally in the type of tappet adopted. Where a low-level camshaft is used the valves are operated by means of push-rods which have rollers fixed at the bottom, bearing on the cams, while the top ends are fixed to the forked end of the rocker levers by means of swivel eyes and pins. Where a top-level camshaft is used the rollers are mounted on pins fixed in the forked outer end of the rocker levers, thus cutting out intermediate levers and pins.

In four stroke engines two cams are provided for each valve, these being one each for ahead and astern running. The usual arrangement is to place the cams adjacent, but in the early type of "Werkspoor" engine, two camshafts were used, as will be seen from Fig. 3.

Where the top level camshaft is used the usual method of starting and reversing the engine is to mount all rocker levers on a fulcrum shaft, while the fulcrums are arranged eccentrically. By rotating the fulcrum shaft, the roller ends of the levers are raised clear of the cams and the engine is then in position to be set for ahead or astern running. There are several ingenious ways of reversing at present in use, but the commonest is to move the camshaft longitudinally, thus bringing the ahead or astern cams under the rollers in accordance with the desired direction of rotation. When the position is set, the rollers for the induction, exhaust and starting valves are lowered by further rotating the fulcrum shaft, and the engine is put in motion. After making a revolution on air the fulcrum shaft is again rotated in the same direction and three starting valves are cut out, whilst at the same time three fuel valves are cut in. When the engine picks up on fuel the fulcrum shaft once more rotates and the remaining starting valves are cut out, while all fuel valves are brought into action. When stopping the engine the fulcrum shaft is finally rotated until all rollers are again clear of the cams. The complete rotation of the fulcrum shaft is one revolution, while it will be seen that this type of gear corresponds to the "all round" gear on a steam engine. With large Diesel engines it is usual to rotate the fulcrum shaft and move the camshaft by means of air servo-motors, while an emergency hand gear is provided in addition.

Another method of reversing is by mounting the rollers in forks wide enough to permit of their being moved over either the ahead or astern cams. This system obviates the use of a servo-motor to move the camshaft as the operation is carried out easily by hand. The sequence of starting and stopping is the same as that just described.

Where the low level camshaft is used, as in the "Burmeister and Wain" engine (Fig. 2) the system of starting and reversing is as follows:—

The roller ends of the push rods are attached by drag links to cranks on a lay shaft running along the front of the cam shaft. In reversing the engine the lay-shaft is rotated and all push rods and rollers are drawn clear of the cams. At the same time the camshaft is moved longitudinally, this operation being performed by the same servo-motor, and when it is set the rollers are returned to their running position over the cams by a further rotation of the lay shaft. The engine is started by admitting air to the automatic starting valves (Fig. 8) and after a revolution the starting valves are cut-out and fuel is admitted to the fuel valves, the engine then operating normally. It will be observed that the fuel valves are always in action but that no fuel is admitted to them while the engine is running on starting air. This is carried out by making one hand lever control both starting air and fuel, the adjustments being such as to keep the fuel pump suction valves off their seats until the starting valves are cut out.

In most large Diesel engine installations, pyrometers form part of the equipment. These consist of thermo-couples placed as close as possible to the exhaust valves in each cylinder, while the wires are led into an interpole switch and the readings are taken from a common dial usually marked in degrees centigrade. Pyrometers are invaluable for denoting the condition of the exhaust valves, if used in conjunction with indicator cards, while the balance of the engine can be approximated also by their use provided the condition of the valves is known.

FUEL INJECTION AIR COMPRESSORS.

It is usual to find that the air compressors in use are of the three-stage type for large engines although two-stage and four-stage types are also in service. The principal differences that exist in the various designs are, piston disposition, number of valves per stage and method of operation and control.

The number of valves and variation of type used in each stage differs greatly according to the design. L.P. stages are fitted with from one to five suction and from one to four delivery valves, while I.P. stages are fitted with from one to three suction and delivery valves. The H.P. stages are usually limited to two suction and delivery valves as maximum.

The type of valve used does not matter so long as it is capable of continuous service, but with regard to number the fewer used the better.

With the earliest Diesel engines great trouble was experienced with the air compressors, but this has now almost disappeared. The probable reason is that insufficient attention was paid to the balancing of the stages when running at reduced output, which resulted in increased temperatures being encountered with deleterious effect on valves in particular.

Most troubles now encountered are caused through carbonised lubricating oil adhering to the valves and causing them to stick open. This can usually be remedied without stopping the engine, but it could probably be abolished by the use of proper compressor lubricant and the insulation of the compressor cylinders from the engine crankcase.

Piston rings do not give much trouble if the intercoolers are kept well drained and not too much lubricating oil is used.

Intercoolers vary in design, but the commonest and best practice is where they are of the condenser form, *i.e.*, with tubes and tube plates. The most general trouble that seems to have been experienced with intercoolers is where a coil of piping has been used for the H.P. air. The oxidisation of the metal wears it thin through time, and unless the coolers are kept properly cleaned, bursting may result. For this reason the best practise is where the H.P. cooler is made up of long jacketed straight pipes, as this design allows of ease in cleaning and permits of the bore of the pipes being examined.

Regarding the operating of air compressors, systems differ here as in the other details connected with them. Compressors are driven either by the main engine crankshaft or by beam levers from the crossheads, or else are installed and driven as separate units. Either of the first two systems of operation is preferable to the second, in that the main engine is much more capable of sustaining the drive over long periods than is an auxiliary engine. An auxiliary engine is, necessarily, of lower horse-power and of higher revolution speed than the main engine, and is, therefore, more susceptible to breakdown. Even if the compressors are electrically driven the auxiliary power installed in the ship is greater than is desirable and must be in duplicate to provide against contingencies.

Drawn steel reservoirs are provided between the compressors and the fuel valves and are fitted with shut-off valves. In a carefully arranged system complete immunity from stoppage even through burst pipes is provided for. Blast air pipes are generally made of solid drawn steel with cone-couplings brazed in place.

STARTING AIR COMPRESSORS.

Starting air to the Diesel engine may be regarded in the same way as steam to a steam engine, *i.e.*, each is essential for manœuvring. An auxiliary compressor is always installed, while its power is decided by the special requirements of the ship. Starting-air is usually stored in steel reservoirs at a pressure of from 300 to 500 lbs. per sq. inch. In a single screw ship the auxiliary compressor is usually of the H.P. type, and is made capable of supplying the main engine with sufficient blast air to run it at full power, so that it can be used in the event of the main compressor being incapacitated.

In a twin-screw installation each main compressor is usually made capable of running both main engines at from 80 to 90 per cent. full power, so that no H.P. auxiliary compressor is installed, as the likelihood of breakdown of both main compressors at once is very remote. The auxiliary compressor installed in twin-screw ships is usually an I.P. machine of the two-stage inverse-tandem type, *i.e.*, with I.P. stage at the bottom and the L.P. stage mounted on top of it, and is just capable of compressing to the starting air pressure.

It is not always necessary to use the auxiliary compressor when manœuvring the main engines, as a great quantity of starting air can be made from the blast-air supply. This is done by opening the main compressor suction intakes to their maximum, thus making the greatest quantity of air, and by slightly closing a shut-off valve that is placed in the pipe-line at the control platform between the blast air bottles and the fuel injection valves. The result is that the blast bottle pressure rises while the blast air pressure drops. A pressure of 800 lbs. per sq. inch is maintained in the blast bottle while the surplus is blown off into the starting air reservoirs. The surplus air that can thus be got usually suffices to manœuvre the engines through the normal operation of docking ship.

LUBRICATION.

Past experience has proved beyond all doubt that the correct way to lubricate the main working parts of a Diesel engine is to enclose them and supply the oil under pressure. By so doing, a generous quantity of oil is ensured to each bearing, with the result that wear is considerably lessened and the oil consumption reduced. Forced lubrication has been in vogue with four stroke engines for a considerable time now, and in every case has been amply justified. The benefits to be derived are further borne out, in that the most successful two stroke engines have always been forced lubricated. Indeed, drip feed lubrication has been the principal cause of failure of several two stroke engined motor-ships, while in other cases where drip feed lubrication is used and the results, as regards wear, are passable, the oil consumption is abnormally high. The desire to have the moving parts always in view is bought at too high a cost, while the results attained can never justify the price paid. There is very little, if anything, to be gained from having an open engine, because, as a rule, the same indication of any part running amiss exists to practically the same degree as with an open engine. Of course, drip lubricated engines are still being built, but the number has decreased to a minimum and this type is approaching extinction.

The lubricating oil consumption in many motor-ships is high, but there is no doubt that economy could be effected by more attention being given to crankcase and other joints, and to more strict supervision of the quantity of oil used in the hand lubrication of valves and valve gear.

The most general forced lubrication system is to supply the oil from a common pipe through a branch to each main bearing whence it passes into the journal, through the adjacent web and into the crankpin. A central hole through the connecting rod leads it to each top end bush, while the final discharge is to the guides. Such a system can be closely supervised and any choking that my occur can be easily detected.

Before starting on a voyage, the oil is always circulated through the bearings with all crankcase doors open, and, for preference, with the turning gear in. When the oil is seen flowing at all points little anxiety need exist as to subsequent lubrication.

Throughout this paper it has been shown that the marine Diesel engine as it exists to-day, but particularly the four-stroke cycle, is not such an abnormal proposition as it is sometimes made out to be. It certainly consists of more parts than the reciprocating steam engine of corresponding horse-power, but it must be realised that many of the essential features are not subjected to abnormal conditions, and the wear is, in consequence, very slight, being in some cases negligible. When all points of design are considered it will be seen that the engine is not in reality so very complicated. Almost every part can be repaired, so that it is possible to create make-shifts and carry on in the event of a breakdown. Where pistons and the gear connected with each cylinder are concerned, disablement necessitating cutting out the part is rendered easy by virtue of the whole design.

Life on board a motor ship, where the engineers are concerned, is not always a picnic, and in many instances has proved the reverse. There is no doubt but that the work could in most cases be reduced by exercising greater discrimination where examination and overhaul of parts is concerned. With the facilities generally afforded, the condition and behaviour of each part can be ascertained within close limits, so that there is no necessity for working in the dark. The greatest testimony to the Diesel engine is that of the number of motor ships in successful operation to-day. Voyages are undertaken and marine conditions accepted without any trepidation because of the machinery installed.

The Chairman: We have listened with great interest to Mr. Brown, who has given a real practical paper on the subject which is becoming, and will become, of more and more interest to the seagoing engineer. Mr. Brown has given us a paper excellent in its qualities, interesting in its parts, and highly technical; further explanation of the technical parts will no doubt come with the discussion. He has given the leading points in a clear and lucid manner, so that we can carry these with us. There are points which have been elucidated and explained, and in the latter part of his paper the comments made are such that the internal combustion engine does not seem so formidable a machine as it was thought to be. In all engineering there is to-day no finality to it, and with the march of progress it behoves us to keep abreast of the times. It was for that purpose this Institute was founded, to bring together Marine Engineers for the reading of papers for their benefit and guidance, to keep themselves abreast of the times and be conversant with all improvements. We cannot appraise too highly the very clear and practical manner in which the author has explained the machine from top to bottom, and also the manner in which it is operated. There are many items in the paper which struck me, for instance, the long period the machines were running before being opened up for overhaul. It must be gratifying for shipowners and builders to hear such remarks; but there is a word of warning at the end of the paper which causes us to pause, where it is pointed out that the engine will be all right as long as it is properly attended to, and where it is urged that it must not be taken for granted that because we do not see any indication of wrong, all is well within. As Mr. Brown has said, the internal combustion engines are of 2 or 4-stroke, and there is something to be said for each. It is a matter in which we must be guided by experience gained, or to gain. The paper we have had this evening is a most practical one, and, as Mr. Brown is so throughly master of his subject, I have no doubt he will welcome any questions you may now put.

Mr. Thos. Drewry: We have heard a good deal about the troubles which have been met with in Diesel engines and other engines of a similar type. It has been brought to my notice that at times motor vessels have been delayed through engine trouble at different foreign ports. In the majority of cases there has been nothing extraordinary in the trouble itself, it has been due more to the newness of things, want of repair facilities and experience, also to the absence of spare parts. If the ordinary marine steam engine had been such a new thing or as badly provided for, probably the same delay would have occurred in its case. But now you have excellent facilities all over the world for repairing the steam engine and much experience too.

I had some experience with a Diesel-engined ship that had given a deal of trouble, so much so, that she was eventually towed into port. We had no Diesel experts on the job. I bought the best book I could get on the subject and gave it to someone else, with more time than I had, to study. We found quite a lot of things wrong, but they were transparently wrong and the way to put them right was equally plain. There was no question of "Is this right or wrong?" the faults were plainly evident as faults. We had to have three trials before we got things right, but we did succeed. The paper is very helpful in telling us what designs to avoid and in pointing out that some designs may give excellent results on a trial trip and still give very disappointing results on actual service. I make these remarks in order to start the discussion and not in any way posing as a motor ship expert.

The Chairman: I should very much like if you would ask Mr. Brown some questions. You know what it is when you have visitors to the engine room, and you take them round and tell them all about the machinery, you know how you feel when they ask questions. If they did not say anything or show much interest, you form a different opinion of them. I do not want Mr. Brown to go away having a diffident opinion of our members. He is willing to answer any questions you may put. The paper contains much information and a part may be new to us. If you are discussing a subject and are in doubt, ask questions, even though it may seem an exhibition of ignorance. Those who do not know must enquire of those who do know. That is one of the objects of the Institute. We want to elucidate points and get answers to queries we possibly would like to ask. Let not our modesty stop the way.

Mr. G. PLOWS: Mr. Brown in his paper refers to a difficulty in obtaining a successful packing for fuel valve spindles; also the numerous types of packings that have been tried to overcome same. I have been away from the type of engine referred to for some time, but with the earlier types, fuel valve and pump packings gave considerable trouble, and once the oil found its way through the gland it was difficult to check, and I think the best policy is to repack the gland as soon as possible. To tighten a gland while the engine is running, care must be exercised to prevent the spindle seizing. Until the above packing difficulty is overcome much time could be saved if the design allowed for ample room where possible for repacking and adjustment of the glands.

Regarding the question of piston cooling, the engine I have in mind was originally fitted with a water-cooled system via the crosshead journal similar to the "Stauffer" grease gear. This proved a failure, and was replaced by a lubricating oil cooling system with the oil returning to the crankcase, causing excessive wear in the bearings as the author states, also a high lubricating consumption. Later the oil system was replaced by fresh water cooling with the telescopic tubes as shown in sketch No. 6. I quite agree with the author that the success of the tubes depends upon perfect alignment and calls for close supervision when overhauled otherwise rapid wear certainly takes place.

Mr. J. B. HARVEY: The author speaks of trying the starting air valves before arriving in port, by giving the engines a few turns on starting air. I did not know this was a usual practice. I should like to know from the Author how this ought to be done.

Mr. F. M. TIMPSON: I have heard a number of engineers with considerable experience express doubt as to whether the Diesel engine did not require more repair than the ordinary steam engine. Can the author give any idea of the ordinary requirements for overhauling a Diesel engine in port, and how it would compare with the steam engine? There is another feature of interest and that is the relative space occupied by a Diesel as compared with a steam engine: also the saving there would be in regard to cargo space. I also believe there is considerable consumption of lubricating oil. It was an item of concern with earlier engines, although I believe economies have been made in later engines. It would be useful to have some idea of any means in design to avoid the use of special lubricating oils throughout, this being a feature which is brought up against the engine—its needing some special grade of oil.

Mr. J. B. HALL: I, as a steam engineer, find two or three points in this paper that I fail to understand, and no doubt Mr. Brown will be able to help me. He states that in one design of engine the bedplate sections are provided with male and female spigots which run all round the joints. The presence of the spigots prevents any variation in height of the main bearings, such as is sometimes experienced with bedplates in ships, due to the working of the hull in a seaway. Is it not rather strange to suggest that a cast-iron bedplate, which is not open to bend, can bend to such extent without breaking as to throw out of line the main bearings? We all know in the working of a ship that such a thing as the mal-alignment of a ship's shafting can take place, but up to the present I have not heard of anyone engine that suffered from mal-alignment in its crank shaft bearings through the working of the ship in a seaway. The only bedplates I heard of that gave trouble in that way were some of the old North-Eastern marine jobs. They had the condensers in the bedplates and the heat from the condensers, according to the temperature of the water the ship might be sailing in, caused great trouble. I should like that point further explained. Later on it is stated in the paper that in the slow running Diesel engine which is the engine under consideration, sufficiently good balancing is usually obtained by the crank dispositions, and so it is unusual to find counter-balanced crankshafts. If I mistake not, all the crankshafts we saw on the screen were balanced.

Mr. A. J. BROWN: No, not counter-balanced.

Mr. HALL: What revolutions per minutes may be termed a slow running Diesel?

Mr. A. J. BROWN: Anything up to 125 or 130.

Mr. HALL: Perhaps I misunderstood the diagram. I would like an explanation of what seems to me to be usual experience in steam engine practice, where it is stated as an example of what may be expected from good design and construction, the author's experience has been that with forced lubrication a year's running without adjustment of the guides is quite normal behaviour. There are hundreds of steam engines that are running which have not had the time in port to get guides adjusted, and have run well without much wear, provided they have not been under-surfaced. But that is one of the points you do not look for as a Marine Engineer, to keep on handling. In the paragraph under lubrication we read that the desire to have the moving parts always in view is bought at too high a cost, while the results obtained can never justify the price paid. That is a great question we have debated here on more than one occasion, the closed type with forced lubrication, and the open type, with hand lubrication. In regard to this question of forced lubrication, perhaps the author could state what quantity of oil is used per 24 hours under forced lubrication and the cost referred to. I have been chief engineer of a ship of 2,000 I.H.P., and our average consumption of lubricating oil was 4 to $4\frac{1}{2}$ gallons per day of 24 hours for all purposes. Is forced lubrication less expensive than that. The crux of the whole matter seems to come in under the paragraph which says that when all points of design are considered it will be seen that the engine is not in reality so very complicated. Almost every part can be repaired, so that it is possible to create make-shifts and carry on in the event of a breakdown. Is that the style of engine that Marine Engineers want to handle—something that is always liable to require makeshifts in order to carry on? Certainly that has not been so in the past. Speaking as one who went through the mill from junior to chief—after the first 24 hours at sea, if you get through that decently, you begin to lay back, and say, "Thank goodness, there will be nothing much to do till we come to port." If you are going to sea with an engine that is capable of being continually repaired, I think we have gone from something trustworthy to something exactly the opposite.

Mr. T. Drewry: There is a question that I should like to ask the author. When your Diesel engine is running very smoothly and well, sometimes a heavy knock will come on for a few minutes and then disappear again without anything having been done; those present who know the engine seem quite unconcerned about it, but to the uninitiated it is a little startling. The author spoke about the piston top being slightly hollowed or concave in some engines and so collects oil which might go for a stroke or two without burning or exploding, can this be the cause of the occasional knock to which I have referred? Possibly I misunderstood the author.

About breakdowns in motor engines, of course we do hear of these from time to time, and we never hear of the marine steam engine breaking down, or shall I say "Well hardly ever." I am a pretty old stager, and when I first started going to sea the marine steam engine was not quite the beautiful thing that it is now. It was much newer then to the world of experience and to itself. It was then no very uncommon thing for it to break-down. When the motor engine has been on the market as many years as the steam engine has, probably we shall find it as free from giving trouble.

Mr. W. J. Dibb, R.D.: It seems to me that it would have been much better if Mr. Brown had given us the benefit of his very valuable experiences early in the session, as it would have settled some of the many points we have only been able to elucidate by someone asking questions and then thrashing the matter out. Anyhow it goes to prove there is no royal road to knowledge, and from the words of our Chairman to-night, with which I quite agree, the Diesel engine has come to stay, and it will be the duty of Marine Engineers to educate themselves up in the working of the internal combustion engine, the application of this class of engine bristles with difficulties, and with the great saving effected it has many points to recommend it to shipowners. But what the price of oil will eventually go up to, it is very difficult to say. Therefore with ships burning oil or coal, which could always be obtained, ships would be safe to go to any part of the world.

This has been very amply proved by the British Navy having the ships mostly fitted by oil-fired boilers which could be quickly altered to burn coal as required. The acid test for the internal combustion engine, has it reliability on service? Mr. Brown has stated that the main engines gave very little trouble while the auxiliaries always keep the engineers busy off watch, and he has promised to tell us more about these in a future paper. and I am sure the members of this Institute will look forward with much pleasure to hear him again, and I am quite sure we shall give him a very hearty welcome.

The Chairman: You must remember, those of you who were present at the general meeting when our new President came before us for the first time, that he touched on this subject in rather a specific manner. He drew attention, as a business man, to the phase which the country was passing through, and might be passing through for some little time. You are all acquainted with the circumstances prevailing to-day unfortunately, and if ship-owning is to be run as a paying business, as all businesses should be, on their own basis and on their own bottoms without State aid, our President pointed out clearly that he and other shipowners would have to look round and see whether they were getting the tools that would give the best economy. Competition is the soul of business, and it behoves every man when he starts in business to see that he has the right plant and the right men to bring about that success. Our President spoke of the internal combustion engine, and said that it had been recommended to him. He did not speak as an engineer, but as a shipowner, whose interest was in his plant. He referred to the resources here for the proper economical working of ships. We all live to help one another, and through one another we live. We know that whilst there are ships there must be engineers, and he drew particular attention to the possibilities of the future of the internal combustion engine. Of course, there is a long way to go yet before we see the steam engine scrapped. As Mr. Hall has said, there is a sense of reliability and confidence begotten of long years and practice in the use of the steam engine, and when any new venture comes along it is quite a time before it becomes universal. One cannot jump from the one to the other, because whatever has been the experience, we have not the men prepared to take it up with that confidence, that would justify it in fairness to themselves. It takes time to educate men, and it takes time to get all full information in regard to types of prime movers. We can see from the remarks of our President what the commercial world is thinking, and to what end they are turning their attention. He spoke of oil fuel, and in quite another phase to the internal combustion engine. Whether the oil fuel steamer, with the necessary personnel and the number of men you have to employ would be most economical, or the internal combustion engine, where some costs are eliminated, and it becomes a question of engineering ability. Given that the steam engine is running all right, the main thing is to get steam to push the ship along. In the Diesel engine that is eliminated, and you have to give all the skill and knowledge to the care of the engine. As to the bedplate, I do not think the author exactly meant what has been implied, but he spoke of some features of the bedplate of this engine as to which I was a little surprised. Sometimes you find bedplates, if they have not been properly wedged with iron as well as wood jacks, that they will go out of line and give you severe trouble. But if it comes to a trouble in a seaway there is something wrong. In the latter part of the paper I think Mr. Brown meant to show that the Diesel engine was not such a terrible affair after all, but that it was possible to repair it; not that it was going to stop every now and then, so that the engineer would have to keep at it daily. He wants to inspire confidence in those who perhaps look at it from another point of view from that point of view which he had in his mind. Mr. Timpson spoke in regard to the relative space occupied, and that drew me back to the remarks of the President. Anything that is to be put forward to-day in place of the present steam engine, whether it be turbine, or gearing, or electric drive, it all comes back to one thing—what can a shipowner obtain in the way of space? Can he carry more cargo and so afford to pay more money for extra plant? How much space will this internal combustion engine occupy that will justify him in making the changes, and is it worth it from an economic point of view.

Mr. W. McLaren: Do I understand rightly that the air compressing gear on these Diesel-engined ships is supplying sufficient air for working the engine, say for 30 minutes, or even off and on while docking ship and the necessary movements of the engines, do I understand these movements are carried out by compressed air only and that there is no fuel supplied to the cylinders to work the engine, but it is all done by compressed air? Reference was made to the packing, and I see lamp wick is one of the things mentioned. Has the author tried cotton packing, the cotton packing we have at the present day for the ammonia machine? I would be inclined to say that if I were put on to that job to test it that would be the packing I would use. Then I am also interested about taking the inner details out of the engine; that is, getting the piston out and in. There seems to be a lot of intricate dismantling, and then it is looked upon as an easy job, as you have no boiler work to worry your mind. Is there any other method of designing a piston so that it can be drawn from the top, or, is it always in all cases like this, drawn from crank end of cylinder? Apparently in some engines the piston is taken from the underside of the cylinder. And I should also like to ask the author if he is a two-stroke man or a four-stroke advocate.

Mr. A. J. Brown: I think that is obvious.

Mr. Timpson: Can the author give the relative cost per horsepower of the Diesel-engined ship as compared with the steamer? Are there any comparisons of upkeep and maintenance costs?

I think these are very important points, and we should like to have figures, if available.

Mr. Brown (reply to discussion): I have listened with great pleasure to the discussion on my paper, and will now answer the points raised in their order.

In dealing with the rapid advance of engineering to-day the Chairman emphasised the necessity for the Marine Engineer making himself familiar with current progress. Since the successful operation of the machinery on board ship depends greatly on the engineers, and, as the number of motor ships in service is increasing rapidly and the engine rooms have to be manned, the familiarity with the Diesel engine becomes imperative to all ambitious Marine Engineers.

The Chairman remarked on the long interval between examinations of parts of the Diesel engine, but also noted the necessity of strict attention being given to the running. As I state at the end of the paper, facilities are generally provided whereby the condition of the engines can be closely ascertained, and by the proper use of such facilities the work of examination can be reduced.

Mr. Drewry mentioned having heard of motor ships having been delayed in foreign ports through engine trouble, and that the trouble was, in the main, due to inexperience, also to lack of facilities and the absence of spare parts. In my reply to Mr. Adams, I emphasised the necessity for Marine Engineers being familiar with the plant under their care, because, if they are not, then troubles are bound to accrue. Regarding facilities for repairing Diesel engines, and the amount of spare gear carried on board a motor ship, my experience has always been that the amount of spare gear carried is usually sufficient to overcome any troubles likely to be encountered on any one voyage, while there are very few parts of a Diesel engine that cannot be copied and remade by any ordinary engine repair shop. It is to this question that I refer in the second last paragraph of my paper. In proof of my statement regarding replacements, I have known an engineering firm in China replace the cylinder head of a four-stroke auxiliary Diesel Engine of which they had to make the pattern, cast it and machine it, and finally get it passed by Lloyds, while the whole of the work was done by Chinamen.

Mr. Drewry's experience with a motor ship goes further to prove that the Diesel engine is not an abnormal proposition, because the troubles encountered were apparent, and, I take it, were easily overcome once the work was understood.

Mr. Plows refers to troubles experienced with the packing of fuel pumps and fuel injection valves. Well, of course, the proper remedy is, as stated in my paper, to abolish packing glands where the fuel injection valves are concerned at anyrate, and I can assure him that this can be done successfully. Fuel pump glands are in no way comparable with the glands of fuel injection valves, as the packing gets such different treatment in each case. The fuel pump plunger is usually of relatively large diameter and has a good long stroke, while the packing is exposed to fuel pressure only. The fuel injection valve spindle, on the contrary, is relatively small in diameter, while its movement is limited to a 5/16ths inch lift as maximum. Then again, the gland has to remain tight against air, as well as oil pressure, and when it is considered that the opening of the valve approximates to a hammer blow, it will be admitted that packing of any sort is severely tried. Mr. Plow's experience with piston cooling gear bears out my statements, even to the dissatisfaction of oil cooling.

Mr. Harvey asks how starting air valves should be tested before entering port to ensure satisfactory operation. With the "all-round" gear described in the paper, all that is necessary is to open the starting air stop valve and set the servo motor in action, when the valve gear will go through its complete sequence, which includes all starting air valves in operation. With the "Burmeister & Wain" Engine (Fig. 2) the test is carried out by pulling the control lever to "stop," then putting it to the "start" position, which puts all starting air valves in action, and, when the engine has made a few revolutions on air, returning the lever to the "on fuel" position. In carrying out this test with any valve gear, the engine never stops, as the way on the ship carries the propeller round.

Mr. Timpson raises the question of maintenance and overhauling requirements in port. Throughout the paper I have given the service time that may be expected from each part of the engine, and, as Mr. Adams remarked, the overhauling of each part is not frequent. The examination and overhauling time for each part being known, the Chief Engineer arranges matters so that the work is divided, in proportion to the duration of stay, over the ports of call. In this way it is possible to execute all main engine adjustments without the need for working overtime, just as in a steamship. Any troubles that are encountered with a motor ship are usually more due to the auxiliary rather than to the main engines.

Regarding the relative space occupied by Diesel as compared with steam machinery, this question depends entirely on the installation arrangements. With good design and layout a motor ship can have 5% more cargo space than a similar sized steamship, in addition to a much greater cruising radius.

Mr. Timpson mentions the lubricating oil question and in this particular as to running costs, I would refer you to a paper read by Mr. James Richardson, before the Institution of Engineers and Shipbuilders in Scotland, and entitled "The Present Position of the Marine Diesel Engine." In it he quotes as follows:—

Table V.

Comparison of Running Costs of Diesel Ships and Steam Ships of 2,400 Brake Horse-Power.

	Twin-screw. Diesel, 2400 B.H.P.	Single-Screw, Double-Reduction Geared, 2400 S.H.P.		Single-Screw, Reciprocating, 2800 I.H.P.	
		Coal.	Oil.	Coal.	Oil.
Fuel, lbs. per H.P. per hour	·45	1·5	1·1	1·75	1·25
Consumption, tons per day	11·6	38·6	28·3	52·5	37·5
Consumption, tons per 30 days	348	1,158	849	1,575	1,125
Price of fuel per ton ...	£11	£5	£10	£5	£10
Cost of fuel per 30 days	£3,828	£5,790	£8,490	£7,875	£11,250
Lubricating oil consumption, gallons, per day	21	3	3	5	5
Lubricating oil, cost per gallon	5/-	5/-	5/-	5/-	5/-
Lubricating oil, cost per 30 days	£157 10	£22 10	£22 10	£37 10	£37 10
Personnel—					
Chief Engineer ...	1	1	1	1	1
Assistant Engineers	6	3	3	3	3
Greasers	3	3	3	3	3
Firemen	—	9	6	9	6
Trimmers	—	4	—	4	—
Donkeyman ...	1	1	1	1	1
Electrician	1	—	—	—	—
Total engine-room staff	12	21	14	21	14
Total wages, 30 days...	£252 10	£380 10	£265	£380 10	£265
Total keep per 30 days, at 7/- per day	£126	£220 10	£147	£220 10	£147
Total wages, fuel oil, and keep for 30 days...	£4,364	£6,413 10	£8,924 10	£8,513 10	£11,699 10
Ratio	1	1·47	2·04	1·95	2·68
Net saving per annum of 200 days sailing, Diesel over Steam ...	—	£13,650	£30,390	£27,645	£48,850

Note.—In addition to the above, the following savings are effected. Fuelling costs, less demurrage, additional cargo capacity, less accommodation for engine-room staff, no stand-by losses, less cleaning ship, higher average-speed in a sea-way, reduced fuelling appliances required, etc.

TABLE VI.

COST OF FUEL OIL AND COAL AT PRINCIPAL PORTS, JULY, 1920.

PORT.	FUEL OIL PER TON.	COAL PER TON.
Alexandria	250/-	186/- to 200/-
Adelaide	180/-	40/-
Batavia	150/-	127/-
Bombay	150/-	45/-
Buenos Aires	265/-	170/-
California	62/- to 92/-	69/-
Christiaña	224/-	210/-
Calcutta	250/-	25/-
Cape Town	220/-	46/9 Transvaal.
Colombo	150/-	102/6
Curacao	80/-	125/-
Glasgow	250/-	115/- Welsh.
Hong Kong	150/-	115/- Welsh.
Havana	142/6	125/-
Karachi	150/-	45/-
London	250/-	115/- Welsh.
Liverpool	250/-	115/- Welsh.
Lisbon	250/-	160/-
Madras	150/-	45/-
Melbourne	180/-	35/-
New Orleans	58/2	40/- to 69/-
New York	47/6	55/- to 68/-
Palembang	125/-	127/-
Pensacola	80/-	42/-
Port Said	250/-	186/6
Panama	75/-	125/-
Rotterdam	220/-	160/-
Rio de Janeiro ...	250/-	185/-
St. Thomas	160/-	124/-
Sydney	175/-	21/3

Average price per ton :—Coal = 104/- ; Fuel Oil = 191/-

The heavier lubricating oil consumption of the Diesel engine is accounted for by the quantity used in the cylinders and air compressors. The bearing oil consumption is much less than that of an open type drip-feed lubricated steam engine in which the bearing oil used is not recovered.

The brand of lubricating oil used in the Diesel engine does not form a problem in need of a solution. For a forced lubricated engine, any straight mineral oil will give perfect satisfaction, and one grade can serve all purposes. Turbine oil, which is a straight mineral product, is procurable at all important centres in the world, so that the motor ship is in no danger of running out of supplies.

Mr. Hall takes exception to my statement regarding the distortion that can take place in a Diesel engine bedplate, and quotes his experience of steam engine bedplates in comparison. In the first place, the bedplate of a Diesel engine is considerably longer than that of a steam engine of corresponding horsepower, and, of course, as the length increases, so does the tendency to distort when the hull of the ship is working in a seaway. Apropos of this, it will be found that in the latest "Werkspoor" engine, wedges are provided under each main bearing and provision is made to adjust them, by having a long bolt attached to each, passing out on the front of the bedplate.

Regarding the duration of service for guide plates, Mr. Hall's view is that a year's running without adjustment is less than ordinary behaviour for even a steam engine. Well, I have often had cases of steam engines brought before my notice, where attention to the guides was required at least every six months, and the wear during that period was considerable. Of course, the trouble may have been due to lack of bearing surface, which, as Mr. Hall grants, can cause excessive wear.

Mr. Hall states that the question of the totally enclosed, force-lubricated engine, as opposed to the open type with hand lubrication has been discussed here on many occasions, and that it still remains a debatable point. As I have stated in my paper, past experience gained with Diesel engines would appear to leave very little doubt as to which is the better system of lubrication, and, if examination is made of the various designs of engine building to-day, it will be found that the vast majority are force-lubricated. Mr. Hall, in his remarks on the lubrication economy of the steam engine, asks if force lubrication could show an improvement on the figures he quotes. Well, if a comparison be made between hand and force lubricated *steam* engines, then I think it will be found that the latter type will show a saving of 80%.

In his concluding remarks, Mr. Hall has, I am afraid, sadly misinterpreted my statement regarding the degree of reliability of the Diesel engine. I fail to see how any statement in my paper can convey the idea that the Diesel engine is in need of continual repairing, far less being "something that is always liable to require makeshifts in order to carry on."

When I wrote this paper and took each engine part in detail, I wanted merely to give a survey of all the parts involved and to show that the design of the Diesel engine is such, that should any part break down it is possible to repair it. The reliability of anything is ensured from the point of view of design, and while the engine should be capable of long and continuous service, we cannot guarantee that there is not the remotest chance of its ever breaking down. Then, so long as that doubt remains—as it must always remain—absolute reliability is only ensured if it is possible to make repairs.

The knock sometimes occurring, referred to by Mr. Drewry, would probably be caused by a fuel injection valve sticking open momentarily, the fault lying in the packing being too tight. Sticking is an inherent trouble with nearly all fuel valves which use packing, and its effect is to raise the compression in the cylinder to an abnormal degree, which results in an augmented explosion pressure and consequently a heavy knock is heard. The compression is raised by the blast air continuously entering the cylinder, and while its effect is negligible during the exhaust and firing strokes, it raises the initial pressure at the beginning of the compression stroke with the results I have already mentioned. In connection with such an occurrence, a further claim can be made for the system of providing a separate fuel injection pump per cylinder. When this is done it is impossible for any one cylinder to get more than its measured quantity of fuel, so that, when the fuel valve sticks open, the other cylinders are not starved as would be the case if only one or two pumps were fitted and all the fuel valves were connected by a common pipe. Further, where the "common rail" system is adopted and a fuel injection valve sticks open, the resultant explosion pressure will rise tremendously, due to the unlimited quantity of air and fuel entering the cylinder. The effect of misfiring, which I state in the beginning of my paper, is similar, but the pressures involved are not so high.

Mr. Drewry's remarks regarding the steam engine are intensely interesting. Improvements have taken place so rapidly in design, and already so much experience has been gained, that I think it may be truthfully said of the modern 4-stroke Diesel engine that one hears of break-downs, "Well, hardly ever!"

I can hardly agree with Mr. Dibb when he says the application of the Diesel engine "bristles with difficulties," because, if that were so, it would scarcely recommend itself to shipowners as he grants it does.

Mr. McLaren mentioned the use of cotton packing with the ammonia engine. As I have said, it is not so much a question of packing as the service it has to perform. Then in respect of the removal of pistons—at the beginning of my paper, I enumerated the various designs of cylinders. In the majority of cases, to remove the piston the cylinder head is lifted and the piston is drawn up after removing the piston rod nut. In the "Werkspoor" engine the pistons are removed from the bottom of the cylinder, while in the "Beardmore-Tosi" engine either system is applicable.

The question was raised as to whether I am an advocate of the two or the four-stroke engine. As matters are at present I am an advocate of the four-stroke cycle.

The Chairman spoke of the possibilities of the Diesel engine. Well, of course, progress with the Diesel engine, like everything else, must be slow and sure. Our safest action lies in slow and careful development where each size of cylinder is tried out, and the many problems involved are carefully solved. As we advance slowly we advance surely. Where big engines have been tried, engines of 2,000 B.H.P. per cylinder, I am afraid they were started at a date when there was insufficient knowledge of the Diesel cycle to warrant such an experiment, with the result that the data derived has not been of any particular service to Diesel engine designers.

The Chairman raised the question as to the training of engineers and the time it would take to get steam engineers acquainted with the motor engine. With the advent of the Diesel engine, a demand arose for the supply of engineers capable of handling the machinery, but the difficulty was met by steam engineers volunteering for service. After having from six months to a year's experience in the shops in the erecting and testing of the engines, they were capable of going to sea under a guarantee engineer supplied by the firm, and so the engine rooms were manned and the ships operated very successfully. To a man of average intelligence, and one who can adapt himself, there is no great problem involved in the training, whilst, of course, presence of mind and readiness will stand for any machinery and anything that is encountered.

The Chairman spoke of having steam engines running all right, and the trouble of keeping a steady head of steam.

I recall once going through the Red Sea in an abnormal temperature. We were rated as an eleven knot ship, and we passed a Holt liner rated at thirteen knots, while it took her several days to catch us up in the Indian Ocean, the reason being, I take it, that it was practically impossible for the steamer to keep up a steady head of steam, owing to excessive heat in the stokehold. With Diesel engines we maintained steady revolutions without needing any adjustments whatever. Even when running through heavy weather very little variation is noticed with Diesel engines. The revolution speed has a tendency to drop and the M.E.P. to rise as with the steam engine, but all that is necessary is to shut in the fuel control lever should the M.E.P. become too high. A safe figure to maintain with the four-stroke engine is 90 lbs. per sq. in. 1 H.P. basis. It will be found that the Diesel engine maintains a steady average speed over a voyage including varying weather conditions.

Mr. Timpson asks the relative cost of steam and Diesel machinery. Quoting Mr. Richardson's paper already referred to, he states that at present the cost for Diesel machinery varies from 25% to 30% more than for a steam plant, depending on the type of auxiliaries applied to the oil-engined ship, and whether comparison is made with reciprocating or double-reduction turbine steam machinery. He also shows the great saving effected by the use of Diesel machinery, of which the table I read is an example.

Mr. F. N. Timpson: We are indebted to Mr. Brown for the very clear and useful paper he has given us. It deals with a subject in which a large number are interested, and is a very useful finish to our present series of lectures to have the large Diesel engine dealt with in such a manner as it has been put forward to-night. We are also indebted to Mr. Brown for coming here to read his own paper. He has given a very valuable addition to our "Transactions," and I am sure you will accord him a very hearty vote of thanks which I now propose.

Mr. Drewry: We have all listened with great pleasure and profit to his paper. He has dealt with the subject in a very practical manner indeed. He has put a tremendous lot of hard work into his paper, and I am sure we all appreciate that and his great kindness in coming so far in order to read it in person; also for the carefully thought out and courteous replies that he has given to our questions. We regret that there are not more present to-night, but he will quite understand that most of our members are at sea, abroad or at out ports. However, we have a very large number of members, and a copy of his paper will be sent to every one of them, in this way it will reach every part of the shipping world and will be of great interest and cause much discussion beyond this meeting. We may not particularly yearn to be in charge of a Diesel or motor engine, but as Marine Engineers we cannot afford to neglect the study of it. This is the Institute of Marine Engineers and not the Institute of Marine Steam Engineers. There is now a national duty put upon us as Marine Engineers to go ahead.

The miners say that they will not allow us to have any more coal from the mines, in the meantime at least. The transport workers and railway men say they will not allow us to obtain any coal from elsewhere. Thanks to the efforts of the author, and to others like him, we have now enough vessels running on oil to prevent this country being starved out.

It is up to us as Marine Engineers to do our part in placing the Mercantile Marine of this country in such a position that it is beyond the power of the miners to threaten us with national starvation every few months, and to make a stranglehold upon the lives of the people impossible.

A question has been raised about the advisability of trying the air for manœuvering before going into port; that is very like what we do now with the steam engine. We should not think of approaching port without seeing that the steam reversing gear had been heated up and moved backwards and forwards to free it and make it handy. As to the question of reliability, the fact that a motor ship owner will accept any charter that is acceptable to the owner of a steamer and also that the charterer will accept a motor vessel, readily shows their point of view on the matter.

We have had an interesting series of papers on motor engines and oil burning, and this paper is a very fitting and notable close to that series till we reopen. We are indeed fortunate in having such a fine practical paper for the conclusion of our present course.

I have much pleasure in seconding the vote of thanks to the author.

Mr. Andrew Brown: I can assure you I am very much gratified with the reception my paper has had. The points have been gone over, and I think everything is more or less made clear. I should have liked to treat the auxiliary Diesel engine on board the motor ship more fully, but of course it was not possible within the scope of this paper. It is with that engine that perhaps most of the troubles have been encountered, even right from the beginning, while the tendency is that it always will be so. It is just a parallel case with the steam ship when it is not the main engines but the auxiliaries that keep everyone busy and create field days.

Regarding the acceptance of the engine and the question of liking it—well, I daresay when every point is fully investigated, it will be found that the Diesel engine is kind to its adherents and advocates, and that life on board a motor ship is not necessarily martyrdom.

The CHAIRMAN: May we express a hope that next session Mr. Brown will find an opportunity of giving us his experiences with the auxiliaries? Then we shall have an opportunity of hearing how he overtakes these little difficulties.

The Application of Oil to Power Purposes.

BY SYDNEY H. NORTH (Assoc. Inst. P.T.).

Read at the Shipping and Engineering Exhibition, Sept. 14th.

I should like to open my brief review of the application of oil to power purposes, with a protest against those alarmists who delight in predicting the precarious state of supply. Theorists are useful provided they base their conclusions on sufficiently broad premises and allow a wide margin for uncalculatable possibilities.

It is easier to estimate the extent of the deposits of a solid mineral than of a liquid, yet estimates concerning the former have gone hopelessly astray. A man who sets himself therefore to gauge the unmeasurable is assuming an element of omniscience with which no human has yet been endowed. I leave it at that and pass on. The production of petroleum on a commercial scale commenced in the year 1859. The first application of oil to fuel purposes dates from 1861 and was initiated in Russia. For many years after this date, however, its use in this direction was only of a local character and it was not until the oil tanker came into general service that fuel oil began to make progress. Although oil was being used for steam raising in Russia and Roumania prior to 1885 this year my be fixed as the date for the inception of the oil fuel period, for it was this year that saw the construction of the first tank steamer, S.S. *Gluckauf*. The recognition of oil as a fuel came very slowly and the extension of its use grew chiefly in those countries, which were naturally endued with large supplies. The great obstacle, however, to its adoption by countries not possessing deposits was price, which compared very unfavourably with that of coal, at the same time, its advantages became more widely acknowledged and the difficulties of the fuel supply during and since the Great War gave an impetus to its use which it had not hitherto received.

Thus the progress of oil as a fuel has been dependent on abnormal conditions and it has to be admitted that in spite of the many advantages it offers over the solid fuel it has not gained advance on its merits. It is a case of the first in secures the advantage. If prospective users would only strike a balance between the cost of oil and the cost of coal, taking every item into consideration, they would find that the former had the advantage.

Until they adopt this method of estimating the comparative values of the two fuels there can be little progress for what is incomparably the better fuel. There are what might be termed concealed factors of economy in the use of oil which cannot be properly appreciated unless they are either tabulated or ocularly demonstrated in practice. I leave these disclosures to Engineer Commander Addyman when he reads his paper on Oil *v.* Coal in Ships on September 27th, and I would suggest that he sets out in detail the items on which a saving is effected, placing economic value on each. We need greater analysis because of the concealed factors referred to and because unless they are given a name and value to, they are not even vaguely realised by the average fuel consumer.

A full appreciation of the advantages of oil as fuel must be attained before we can hope to see the arbitary or artificial conditions such as initial cost counterbalanced by the great inherent qualities of the fuel itself. This means lucid propaganda, a remedy which would cure many of our national ills, if engaged in more extensively. There is one very important factor which should appeal to industrial and transport concerns in the adoption of oil, namely, the reduction of the human element in its use. It is an aspect which should make a strong appeal in these days of labour dissatisfaction and of high wages. A system which can show a reduction of even 50 per cent. in the employment of manual labour is eliminating a factor which is more difficult to deal with them any mechanism.

At the present time we have available only two forms of the application of oil to power production, one is by burning the oil itself, the other by internal combustion. The former is the simplest, the latter the most efficient; the former, however, has the advantage of being capable of wider application, and may be adapted to existing plant, upon which a large capital expenditure has been incurred. When I hear people railing against the method of burning oil under boilers in its natural state as involving a gross waste of oil, I wonder whom they are considering, the consumer or the producer and whether they have ever seriously considered the far greater and more criminal waste involved in burning coal in its natural state under boilers. It is quite legitimate for the shipowner or power user to adopt the fuel or any other facility which will give him the greatest efficiency and it cannot be expected that he should scrap his expensive steam plant to equip his vessels with the Diesel engine, because it is the most economical method of using oil. By the adoption of direct oil firing in place of coal he secures far greater efficiency, a great reduction in wages, a considerably increased earning capacity and can retain his steam engine. The people responsible for the large consumption of oil in oil fuel systems are the engineers who are, however, slowly improving their plant. I hear also that a system has been invented which reduced the consumption of oil by one half, and if this is a working proposition it will bring oil fuel burning within the region of the Diesel engine from this point of view.

The progress of the use of oil for power production is entirely dependent on our engineers and chemists; the former for introducing a system which will attain the greatest evaporative power on a minimum consumption, the latter, for adapting the large variety of oils available to the purposes for which they are required. Up to the present time, the former have restricted their efforts to the identical lines laid down as far back as the 60's, which involved the forcing of oil in its natural state through a small orifice, thus splitting up the oil into a fine spray enabling combustion to be obtained more readily. It is true that improvements have been made in the burner itself, and the arrangements in the interior of the furnace have been carefully studied, but the main principle remains the same. It is always difficult to deviate from a fundamental idea once it has been adopted and worked on for many years, but if our oil fuel engineers would think outside the one dominating the burning of oil under boilers they might arrive at a system of producing power from oil which would effect a very great reduction in the consumption of the fuel and attain greater efficiency. It might be worth while bringing the oil fuel system into juxtaposition with the principle of obtaining power in the Diesel Engine and the Hot-Bulb Engine and ascertaining whether any part of the method employed in the latter could be adapted or modified in such a manner as would give the desired improvements in direct oil firing.

The progress which has been made in oil fuel practice during the last thirty years is well indicated by figures relative to the evaporation per lb. of petroleum. On a gunboat belonging to the French Navy the water evaporated per lb. of oil is stated to have been from 11·56 to 11·58 lbs.; on a French torpedo boat in 1890 the quantity of water evaporated was 11·36 lbs.; while it was regarded as quite an achievement when this factor attained the figure of 13·25 lbs. Twenty-three years later in the results obtained on a Chilian battleship fitted with a Kermode oil-fuel installation the quantity of water evaporated varies between the average of 12·12 lbs. and 15·72 lbs. in tests of two hours duration, while in later tests under marine boilers, with which the pressure jet system was used, the evaporative efficiency rose as high as 16—16·74 lbs. per lb. of petroleum. Similarly, in regard to the consumption of oil per i.h.p. The figures given for this item on an Italian battleship some 20 years ago were 1·25 lbs. of oil compared with 2·13 lbs. of coal, while at the present time the consumption of oil ranges from ·95—1·02 lbs. of oil per i.h.p. and for coal from 1·5 to 1·6 lbs., showing that in both liquid and solid fuel practice great advances have been made. These figures are an excellent indication of what has been achieved in bringing oil fuel appliances to a high standard and of the propress made by both engineer and chemist in the science of oil fuel burning.

The practice is sometimes adopted of burning oil and coal combined, though this is not very generally done. In several evaporative trials carried out on a vessel attached to the French Navy with the boilers heated by mixed fuel and the burning mixture consisting of 45 per cent. of petroleum the water evaporated amounted to 11·34 lbs. per ton of fuel. This showed an evaporative increase of 25 per cent. over that of coal. With the proportion of oil increased to 64 per cent. 14·12 lbs. of water were evaporated, showing an increase of 56 per cent. over that of coal when used alone.

We are, therefore, discovering the method of squeezing a greater efficiency out of oil than we secured twenty years ago. This is something, but we want more than this.

Adaptability and convertibility are outstanding characteristics of oil and it is the latter feature which has inspired engineers to design an engine in which heavy oils are used for producing power by compression. The efficiency of the engine known as the Diesel Engine, of which there are now many varieties, is the highest yet attained in the use of oil for power production; for whereas with an oil fuel system 2 tons of oil equals in heat units three tons of coal; in the internal combustion engine one ton of oil will do the work of four tons of coal. This is an economic feature of unquestionable importance, but it is not the only one that shipowners, for instance, have to consider, and as I have previously mentioned, they have to weigh up the advantages of converting their ships to Diesel Engine driving against the loss involved in scrapping their existing steam plant and the outlay of additional capital.

There are mechanical points in the design and construction of a Diesel type of engine in which improvements are still essential, and into which it is not within the province of my paper to enter. That remarkable progress has been made in bringing this engine to a higher state of efficiency is proved by figures quoted a short time ago by Sir Dugald Clerk. Comparing the progress made with that of the steam engine between 1882 and 1914 the results were as follows:—

	Steam Engines. Thermal efficiency to heat of steam supplied to engines.		Internal Combustion Engines. Thermal efficiency to heat of gas supplied to engines.	
	Indicated M.E. 90%	Brake.	‡Indicated M.E. 90%	Brake.
1882 ...	13·7%	11·4%	16·0%	14·0%
1914 ...	23·0%	19·5%	37·0%	23·4%

These figures are instructive, for they not only indicate that at the earlier date the thermal efficiency of the internal combustion engine was considerably greater than that of the steam engine, but that the advance made between the years quoted was

‡ Page 243. Gas, Petrol and Oil Engines—D. Clerk. J.A.

enormously in favour of the former. Expressing the improvement in percentage figures it reads that with the steam engine the progress made represented by increased indicated horsepower was 81·10 per cent. and in brake horse-power 71·05 per cent.; for the internal combustion engine, the percentage progress during the period was in indicated horse-power obtainable, 131·25 per cent., and in brake horse-power 121·15 per cent.

There can be little doubt that the future holds very great promise for this form of oil power, the more so that engineers are quite alive to the directions in which improvements are needed, not only in design, but in construction. Another vital aspect of this employment of the heavy oil engine is that of the descriptions of oils available for the purpose. It is here that petroleum chemists can render great service, although it is contended by some that the oil engine designer should adapt his engine to the heavy oils now on the market. This shelving of responsibility will not help us much and it is up to both the engineer and the chemist to work on the problem from their respective sides independently of one another. I have no time to enter into this most important subject and only indicate in what direction we must move if oil as a power producer is to attain its fullest development.

Other directions there are also in which this perfect fuel is beginning to gain a footing. A considerable number of locomotives of many of our railways have been converted to oil burners, and while for this puropse great advantages are afforded they cannot be compared with those derivable from its use on ships. The oil-driven train gains nothing in regard to increased passenger or goods space; its economies are restricted solely to those obtained by the substitution of a more efficient fuel for an inferior one by the ease of manipulation, the absence of solid residue and its cleanliness. These, however, are conspicuous advantages, but with the propinquity of the coal mines to the bulk of our main services, oil is not, we fear likely to go very far, unless prices can be still further reduced.

For steam raising in land boilers a slight impetus has been given to oil, but the progress is rather of an artificial nature and until our power users realise to the full the superiority of oil, both chemically and economically they are not likely to hurry over the abolition of coal. For metallurgical purposes oil has, undoubtedly, a great future and its advantages are clearly apparent, but the same dictum is appliable here.

I will conclude on a note of economy. By its very nature, oil lends itself readily to wastage. Vast quantities are wasted in production, in transportation, in storage, in local distribution, and in use. Fortunately we cannot burn oil in the same unscientific, insane manner in which coal is burnt, but we must keep a sharp eye on every leakage that occurs from the time it comes from the well, to the moment it is converted into power. By doing this we shall prolong the oil supplies of the world, of which, however, I do not believe we have yet tapped a hundredth part.

Notes.

ECONOMICAL WORKING OF BOILERS.—The following is an excerpt from the first of a series of advisory papers issued by the Fuel Economy Committee of the Federation of British Industries, engaged in research work with a view to an increase in boiler efficiency throughout industrial undertakings and conservation of fuel. We are indebted to " The Iron and Coal Trades Review " for the loan of the illustration, and although this shows a land boiler, there are similar points applicable to marine work.

It is pointed out in the report that the efficient working of boiler plant depends upon the utilisation of heat to the best advantage from the class of fuel used, and as completely as possible delivering it to the heating surfaces in the form best suited for transmission to the heating surfaces for the generation of steam, also the avoidance of heat losses from the boiler plant, and the utilisation of steam as economically as possible for the boiler plant requirements, in order to give the maximum proportion to the main purposes.

The illustration shows graphically where waste of fuel is likely to occur. The summary of the recommendations are :—

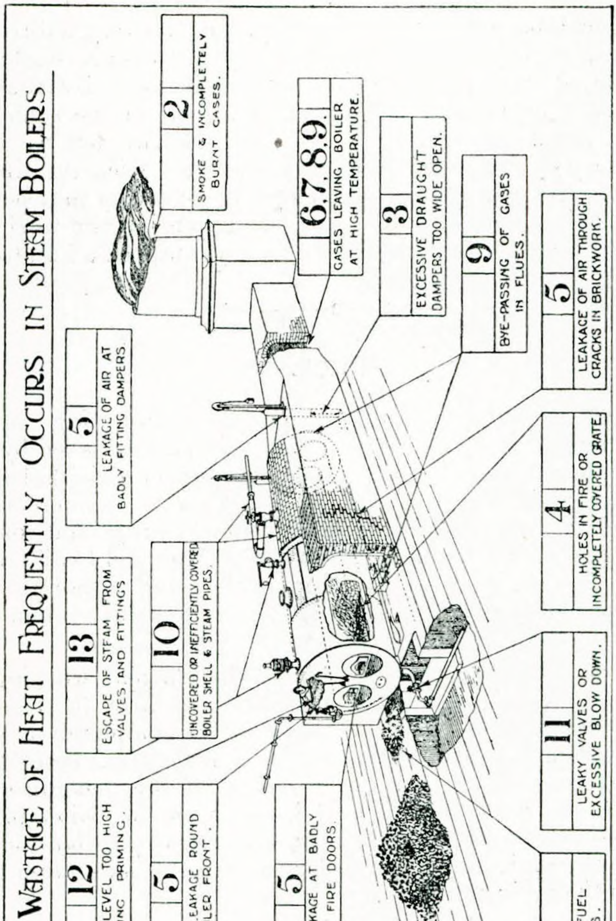


Diagram Indicating the Chief Sources of Waste or Loss of Heat in Steam Raising. (For Guidance of Boiler-House Staff.)
By courtesy of "The Iron and Coal Trades Review."

Furnace Conditions.—(1) Avoid unnecessary wastage of cinders in the ashes by cleaning the fires carefully and by providing suitable firebars. (2) Avoid the production of unnecessary smoke or incompletely burnt gases by regular and frequent firing of coal in small quantities, and by keeping a proper depth of fire. Open the air checks in the furnace doors only after firing, at other times keeping the checks closed. (3) Regulate the draft by the damper to burn the coal with a minimum excess of air. Try to obtain 12 per cent. CO_2 in the furnace gases, and, if necessary, reduce the grate area to secure the result. (4) Keep the grate covered, the fires level and free from holes. Use the rake when necessary. (5) Carefully examine the setting and stop all leakages of air.

Boiler Conditions.—(1) Keep the heating surfaces free from soot and flue dust. (2) Keep the internal surfaces free from scale. (3) Do not force the boilers unnecessarily. (4) Examine flues and baffles carefully. Repair when necessary to avoid by-passing.

Heat Losses from Plant.—(1) Efficiently lag the boilers and steam pipes (including flanges). (2) Do not blow down the boilers unnecessarily. (3) Keep the boilers filled to the working level by a continuous and steady feed. (4) Avoid leakages of steam from boiler fittings, drains, etc.

Use of Steam.—(1) If steam is used in pumps or auxiliaries, use the exhaust for pre-heating the feed water. (2) If steam jet blowers are used, keep the jets in good condition by renewal as necessary and regulate the pressure on the jets to the minimum necessary for the load.

Efficiency.—(1) If economisers are provided record the temperatures of water entering and leaving. (2) Make periodical measurements of CO_2 in, and temperatures of, flue gases leaving the boiler under average conditions, to estimate the approximate boiler efficiency.

RESULTS OF STUDENT GRADUATES' EXAMINATION. — The number of candidates who sat for the examination this year were: Aberdeen, 32; London, 2; Newcastle 27; total 61. The following passed in all subjects:—

Aberdeen: Jas. Brandie, Jas. Brown, Jas. Eddie, J. B. Ewing. W. Littlejohn, D. Moir, Jas. Robertson. *London*: J. F. Cowell. *Newcastle*: (Rutherford Technical College): J. H. Dodd, T. A. Porteous, G. Waters. W. M. Smith completed the pass in which he failed last year.

The results show the highest marks in each subject were gained by the following:—

	First.	Second.
Theoretical Mechanics ...	Jas. Brown, Aberdeen.	G. C. Whyte, Aberdeen.
Heat and Heat Engines ...	G. C. Whyte, Aberdeen.	Jas. Brown, Aberdeen.
Machine Const. & Drawing	G. H. Moore, Newcastle.	T. A. Porteous, Newcastle.
Applied Mechanics ...	J. H. Dodd, Newcastle.	J. Eddie, Aberdeen.
Mathematics	G. Waters, Newcastle.	E. Atkinson, Newcastle.
English and General Knowledge ...	J. Will, Aberdeen. J. Ritchie, Aberdeen.	G. P. Fowlie, Aberdeen.
Electrical Engineering ...	T. A. Porteous, Newcastle.	G. Waters, Newcastle.
Highest Aggregate in Total	G. P. Fowlie, Aberdeen.	Jas. Eddie, Aberdeen.

NOTICE.

An invitation has been received from Sir George Beilby to visit H.M. Fuel Research Station, Greenwich, on Friday, October 14th, at 3 p.m. Will those who wish to avail themselves of the opportunity please advise as early as convenient in order that the necessary arrangements may be made.

—o—

Election of Members.

Members elected at a meeting of the Council held on August 30th, 1921:—

Members.

William Robertson Bell, "Linita," 2nd Ave., Willoughby, Sydney.

John Watt Cameron, Baidland Mains, Falry, Ayrshire

Ernest Bernard Collins, Royal Mining Naval Depot, Wrabness, Essex.

Harold Davies, 9, Strathmairn Street, Roath Park, Cardiff.

Alexander Davidson, Seaforth Cottage, Charlestown, Fifeshire.

James Wilson Harper, 13, Warbeck Road, Aintree, Liverpool.

Wm. Geo. Norman Henderson, 4, Prospect Terrace, Grove Road, Ventnor, Isle of Wight.

Frederick Herman Malcolm Klee, 110, Aln Street, Hebburn-on-Tyne.

John Lyth Macdonald, 67, Grange Road, Thornaby-on-Tees, Yorks.

David Aitchison Purves, 2, Torres Building, Kowloon, Hong-kong.

Charles Edwin Tyreman, Singapore Harbour Board, Singapore.
Alexander Webster, 34, Avenue Desguin, Antwerp.

Associate-Members.

Stuart Robert Fogarty, Belvedere House, Fontlay, Hants.
Edward Ernest Wood (Wr. Engr., R.N.), 34, Derbe Road, St. Anne's-on-Sea, Lancs.

Associates.

Albert Edward Fennings, "Estour," 90, Osborne Road, Forest Gate, E.7.
Edward Alec Smith, "Glendair," Kirkley Park Road, Lowestoft, Suffolk.

Graduates.

Edward James Edge, 13, Weardale Ave., Walker, Newcastle-on-Tyne.
Alfred Harold Jobling, 25, Blenheim Avenue, Ilford.
Thomas Edward Cecil Tonks, 28, Rossett Road, Blundellsands, Liverpool.

†3359. Suffield, C.C., 51, Arragon Gardens, Streatham, S.W.
†4339 Tonks, Thomas Ed. Cecil, 28, Rossett Road, Blundellsands, Liverpool.

† These names were accidentally omitted in the list of Graduates recently published.