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The High-Speed Marine Diesel Engine.

READ

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CHAIRMAN: Mr. J. CARNAGHAN, (Chairman of Council).

THE author's main objective in presenting this paper is to promote the full discussion of a subject that will, before very long, claim the attention of every branch of the marine engineering profession. For this purpose, the review of the various makes of this class of engine will take the form of critical description, not of the example as a whole, but rather of such features as, in the author's opinion, comply or otherwise with the requirements of the main objective. The exact, and exacting requirements of the high speed marine engine will be reviewed and will be taken as the standard, and an endeavour will be made to show how this or that engine, or detail of an engine complies with these requirements.

In the first place there must be some clarification of the nomenclature, otherwise there may be misunderstanding, and as the title is inclusive it should suffice. The term "high speed" does not refer to revolutions, but to piston speed. Revolutions have very little bearing on this subject and therefore piston speed will be treated as the important factor, because it is on the square of the piston speed that we have to legislate.

The term "marine" will only apply to propulsion engines, and further, only to such engines as are coupled to the propeller shaft, either directly or through a reversing gear, and not to prime movers operating electric generators, even if the current is employed for propulsion.

What is a Diesel engine? If we are to be pedantic there are very few Diesel engines, and these are such only by accident. "Compression ignition" is an unfortunate term; the hot bulb engine will, no doubt, in the course of years prove to be the correct design. We are therefore left with one clear-cut characteristic, which is that the fuel is introduced into the combustion chamber as and when required. This fuel is injected, not aspirated; therefore the term "injection engine" covers the whole category, though for the sake of established custom we had perhaps better retain the word "diesel".

The Essential and Ideal Characteristics of the High-Speed Marine Diesel Engine.

These vary to a great extent in accordance with the size and purpose of the engine, though there are many features that may well be common to all types and also to the slow speed engine. As an illustration let us take that of watertightness, even submersibility, should the former term be challenged. It will be seen that whether the craft be a seaside "speed boat" with a 100 h.p. engine, a trawler, a naval pinnace, a cabin cruiser, a submarine, a cross channel boat, a motor battleship or even a coastal cargo boat, the engine should be entirely enclosed and protected against spray, dust and dirt from the quay side, bilge water, or the flooding of the engine room through any cause. Here is a readily attainable feature, which attainment nevertheless has yet to be accomplished in practice.

Rigidity of structure is essential, so that the engine can be secured to the tank top or bearers in such a manner that no ship movement can in any way stress the engine frame. Three point suspension is the ideal, and with a short, stiff, well balanced engine some form of flexible mounting can be employed and thereby the hull can be insulated from engine vibrations. It is here that the automobile engineer leads the way, and while we have yet to see the marine Diesel engine constructed on this system, there must have been over fifty million horse power in automobile engines in which this feature has been incorporated.

The lubrication of the smaller engine must be fully automatic, and the oil should be cooled and filtered without any attention. With engines of larger power and where there are many auxiliaries this system can be greatly amplified and yet in principle remain automatic. For instance, a complete oil service can be installed for all the smaller auxiliaries with separate interchange circuits for the main engines, and all this oil can drain from the units to a sump or sumps, from which it may be pumped through filters and coolers to a large tank placed high up in the ship and feeding to the circuits by gravity. This is but an amplification made to suit the particular conditions, and notwithstanding that there would be labour to supervise and watch, such a system could be quite automatic, even to the extent of using centrifugal or stream-line cleaners.

Our high-speed engine will, in all probability, be provided with constricted waterways, partly because there is little space to spare, but mainly for the reason that high velocity flow is desired. These spaces will be adjacent to walls made as slight as possible; there also may be steel in contact with the water, and therefore it will be essential that foreign matter should not enter and that corrosion should be prevented as far as possible. The obvious procedure will be to employ a closed fresh water circuit where clean, de-aerated and neutralised water can be used, with tubular scoopfed coolers for heat transfer to the sea water. This is generally recognised as an essential, though so far the employment of the system is somewhat rare, even by the automobile engineer, who should need no prompting. As regards the larger vessels, the battleship for instance, the author would certainly advocate this system, though perhaps, in due course, evaporative cooling of cylinders and exhaust will be employed and the steam so generated made use of in some suitable manner.

The control of an engine is of far more importance than would appear from the amount of attention paid to the subject by designers. With the small engine, where a reverse gear is employed, this question is far more acute than it is with a large engine. It is essential that the small engine should be capable of functioning without personal attention, and that the controls be placed in the wheel house ready for immediate actuation by the quartermaster, if necessary. In consequence, to the wheel house must be brought the reversing gear, throttle and starting gear controls, and as the quartermaster will have to be engineer as well through the night watches on many occasions, he must be provided with tachometer, oil and water pressure gauges and distant thermometers, while in a large important job there should be exhaust pyrometers as well. Also, as the Diesel engine is far inferior to the petrol engine in the matter of idling, there should be a governor controlling the idling speed so as to allow slow running without the danger of stopping; it would be preferable if the whole of the speeds were controlled by a variable governor.

The reverse gear, where such is employed, is often treated as a necessary nuisance and its wellbeing is not considered by the designer as it should be. There appears to be an air of mystery maintained in connection with this item, but there is no mystery and there are no secrets (except in connection with plate clutches) other than the fact that as there is a tendency for a rotating mass to throw the oil outwards, the lubricant must be supplied from the centre, and in a liberal manner. Also, as irregular parts rotating in oil raise their temperature and dissipate work, the case containing the reverse gear should be free of oil. These are elementals, but strange to say it is only just of late that they have been recognised.

A reverse gear must be constructed in such a manner that it can be operated from full ahead to full astern without appreciable delay and with impunity. Also, this operation should not depend upon any auxiliary operations, such as adjustments of the throttle, but should be a one-lever (or wheel) control with no possibilities of improper manipulation.

With larger engines, or even the small ones, where the engine is reversible, the same principle should apply and the reversing of the engine should be positive, rapid, powerful, and free from the necessity of selecting psychological moments, for one must always bear in mind (and it is here that the automobile engineer so badly fails), that the reverse gear is required for other purposes than backing out of dock; it is the emergency brake and may have to be manipulated at times of great discomfort and stress.

It is generally recognised that with the conventional engine, whether it be a ship's Diesel or a harbour launch engine, the ideal propeller speed is generally about half that of the most convenient engine speed. A compromise is made, and in consequence the power unit is increased in cost per b.h.p. and the efficiency of the drive is decreased. For this reason, in nearly every case there would be a considerable gain by the employment of reduction gear. Provided this gear is incorporated with the engine, is robust enough to sustain the usual shocks, is of a high order of mechanical efficiency, and is noiseless in operation and reasonable in cost, it can be accepted.

The weight and cost of an engine per h.p. is inversely proportional to its piston speed and b.m.e.p.; therefore, any increase in speed is of commercial value, provided it is not discounted in the manner outlined.

We know that toothed gears are available and that many are in use with a reasonable measure of success, but it would appear that there is a well-founded aversion amongst marine engineers to gear wheels. This being the case, and as nearly every reduction gear can be 2—1, it may be suggested that the crosshead and crankpin type of gear, as exemplified by the Burn gear, will comply with the requirements, as it contains all the desiderata that have been set out.

High Piston Speeds.

It may be assumed that the limiting factor of piston speed is the maximum and mean pressure per square inch of crank pin bearing surface. The gas pressure will remain fairly constant and at low speeds will be well in excess of the inertia pressures. As these increase with the square of the piston speed we soon arrive at a point where the inertia pressure is above the gas pressure. In a four-stroke engine we have the maximum pressure applied four times per cycle, with a cancellation on one occasion, and so this inertia pressure soon becomes serious.

Parts can be reduced in weight in very many ways, by the use of high tensile drop forgings for the connecting rods in place of mild steel, by correcting the design, and finally by the employment of such a material as forged "Y" alloy. Pistons can generally be greatly reduced in weight by design, and considerable further reductions can be made by using aluminium, with or without a steel or iron cap and with or without cast iron slippers. Pistons pins can be reduced by the employment of high tensile steel and boring the pin to perhaps 0·8D. By these methods it is quite possible to double the speed and yet maintain the same load and, incidentally, produce a better engine.

1,500lb. is a very reasonable maximum crank-pin load, but this can be greatly increased by design and materials. The big end can be claw ended, thus being lighter and far more rigid, but it should be fitted with four bolts. A high tensile bronze can be employed with a very thin lining of white metal, and then, with a nickel chrome shaft, pressures of 3,000lb. can be contemplated. Such a bearing must be correctly machined and the white metal must have perfect adhesion; the usual practice of cementing in the white metal with tin oxide will not suffice.

There is still another factor that can be made to contribute to this desired increase in piston speed and make still higher figures not only attainable but desirable.

600 f.p.m. may be considered slow, and 1,500 f.p.m. will closely approach the best we can do with the above methods in the class of engine under review. If, however, the principle of the engine is such that there is a cancellation of inertia pressures by gas pressure on every stroke of the cycle, then by increasing the gas pressures we can nearly double the 1,500 f.p.m. already suggested and leave the crank pin but lightly loaded. This can be done with the double-acting two-stroke, but it can also be accomplished by the Low system; the double-acting principle is hardly suitable for this class of engine owing to head room complications and want of stability, but the Low engine provides all that we may hope for in structural rigidity and is suitable for any size and speed.

Of all the ills suffered by the Diesel engine perhaps that of liner wear is the most important, but it is not even suggested that the high-speed engine will show to any disadvantage in this respect. Wear is not a function of speed—if this were the case the maximum wear would be at mid-stroke—but is the result of excessive gas pressure behind the rings, inadequate cooling of the upper part of the liner, and high ring temperatures. All these disabilities are subjects for modification, and when we have reached normal conditions we may then turn to liner materials. Messrs. W. H. Allen Sons & Co., Ltd., claim for their special liner metal a wear of ·0005in. per 1,000 hours, but perhaps it may be that nitralloy cast iron for rings and liners will make a better showing than the nitralloy steel; anyhow, this would appear to be commercially reasonable.

With valves we should have no trouble. Messrs.

Allen can furnish a record of 14,000 hours without grinding in, for a set of Jessop's steel valves in an engine having a piston speed of 1,200 f.p.m., though in this case the b.m.e.p. was quite light, namely, about 75lb. per sq. in.

Auxiliaries.

Auxiliaries are of the utmost importance to all marine engines, especially those of low power. Circulating pumps must be really adequate for their work. Bilge pumps are essential, fuel filters should be in every way suitable for the job and should be supplied with the engine. In engines up to quite large sizes provision should be made for flange mounting of dynamos; this is essential where electric starting is employed. It is also necessary to provide a power take off that can be utilised for any drive up to its limit.

This prologue may be closed by calling attention to one detail, namely, the exhaust. This must be clean, free from smoke, soot, or lubricating oil in a liquid form. Where the terminal is a funnel, it must be dry, otherwise there will be discomfort to passengers and general depreciation of deck and deck fittings. It is in this respect that the marine installation differs greatly from an engine used for land purposes.

Some Examples of High-Speed Diesels.

The author has selected as the first example an engine that is not yet on the market, but which is far enough advanced in preparation and so well established as a power unit from a technical point of view that its employment as an example may be justified.

This engine is a Beardmore high-speed marine Diesel and it is a 6-cylinder, 4¼in. bore, four-stroke unit having an output of 90 h.p. at 1,800 r.p.m., with a consumption of 0·42lb. per b.h.p. per hr. With reverse and reduction gear the dimensions are 7ft. 0in. overall length, 13in. below shaft line and 2ft. 8in. above, with a total width of 2ft. 1in. over the rear mounting brackets. The weight, with reverse and reduction gear, is 2,200lb. in iron with steel connecting rods. This is just under 25lb. per h.p.; there would be a considerable reduction in this weight if aluminium construction were employed, but the engine has been designed for commercial work.

As far as weight and dimensions are concerned it can be accepted as a reasonable example, so we can proceed to examine this unit with a view to ascertaining in what manner, and how far, it complies with the conditions that have been set out earlier in the paper. Here we have a piston speed of 1,800 f.p.m., well above our limit, and this is obtained quite satisfactorily with steel connecting rods. We can now turn to what may be considered as essential and ideal characteristics. First comes watertightness, and it may be stated that for the conditions of temporary immersion this engine can be flooded up to the top of the cylinder cowling, or just below the pan-shaped air intake on the top of the hood. This air intake also serves as a crank-chamber vent, and fumes from the latter are drawn into the cylinders. This water-tightness does not apply to the dynamo or electric starter, as they are only splash proof, but then we hardly expect the electrical people to devote any attention to such a feature owing to the comparatively small demand.

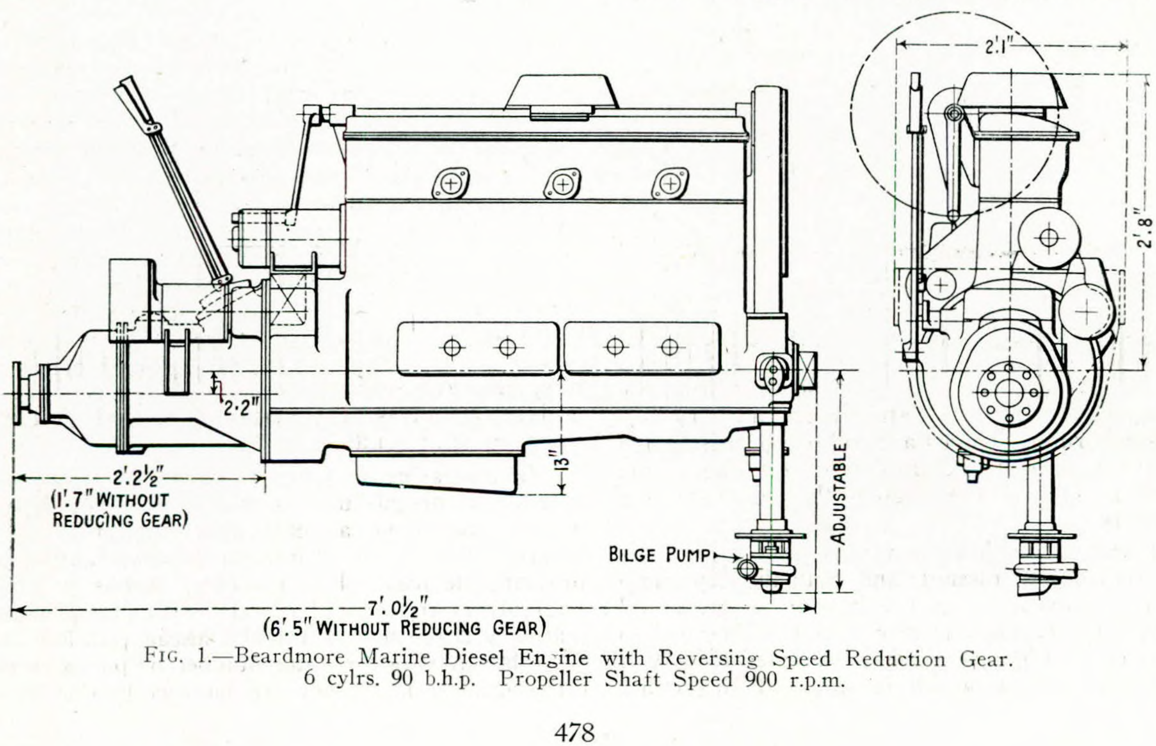


FIG. 1.—Beardmore Marine Diesel Engine with Reversing Speed Reduction Gear.
6 cylrs. 90 b.h.p. Propeller Shaft Speed 900 r.p.m.

However, this would not prevent the engine from functioning. There is also hand starting provided with decompression gear inside the hood, should this be required.

In regard to the matter of dust, the form of the intake hood allows dust to impinge upon and adhere to the wet surfaces, though it is quite exceptional for this class of engine to be subject to dust.

Rigidity of structure is obtained by the continuity of the main casting from a point well below the shaft line to the top of the cylinders, also by the provision of a substantial flywheel housing on which the reverse gear bell housing is mounted. One may digress at this juncture to point out the great advantage, in general convenience and rigidity, of an enclosed flywheel and the general facilities this offers to the designer.

Three point suspension is employed for mounting, there is a trunnion on the shaft line at the fore end, and there are two brackets in the way of the flywheel housing; these are formed on a banjo plate and thus the whole weight is distributed to a steel plate and not localised on the main casting. One must always bear in mind that a small vessel in a relatively heavy sea will, if she is travelling at any speed, impose some formidable loads on the bearers. The attachment can very well be through rubber blocks and rubber bushes which will give a flexible and insulated mounting to the general benefit of the engine, the boat and the passengers.

It will be obvious that with this engine the oil is cooled and filtered, and that the dry sump system is employed. In the lay-out design an oil tank of large capacity is shown and is intended to be carried as high as possible in order to give a head to the suction which is beneficial in starting up cold. Provision has been made for an enclosed fresh water cooling system with tubular coolers and scoops leading fore and aft, and for the usual header tank.

With regard to that important item—controls, these are not shown in the illustration, except for a conventional lever; a system has been elaborated, however, both for direct and distant operation, where the conditions outlined have been met.

The engine is provided with a slow-running governor which can be set to any desired idling speed. There is an inter-connection with the reverse gear that negatives this governor when in "astern" or "ahead", and automatically brings it into action when the gear is in "neutral". The hand throttle simply acts as a maximum stop to the pump control. For instance, if the throttle is set for "half speed" this will have no effect on the idling speed, but when the gear is put "ahead" the engine will run at "half speed"; the same applies to "astern". Thus any number of manœuvres can be carried out with the one reverse lever without any danger of the engine racing, or what is worse, stopping through being suddenly loaded when idling. The author would prefer to have seen complete governor control, but it is certainly a problem to adjust a governor from 250 to 1,800 r.p.m. without hunting.

The pleasing feature of the reverse gear that forms part of this unit is that it does not depart in any way from a reasonable conception of a reverse gear by the introduction of automatic pressure devices. For instance, it has a plain straightforward bevel, epicyclic with two identical plate clutches; one is for the ahead position and the other, having a greater number of plates, is the differential brake. They are operated by one lever,

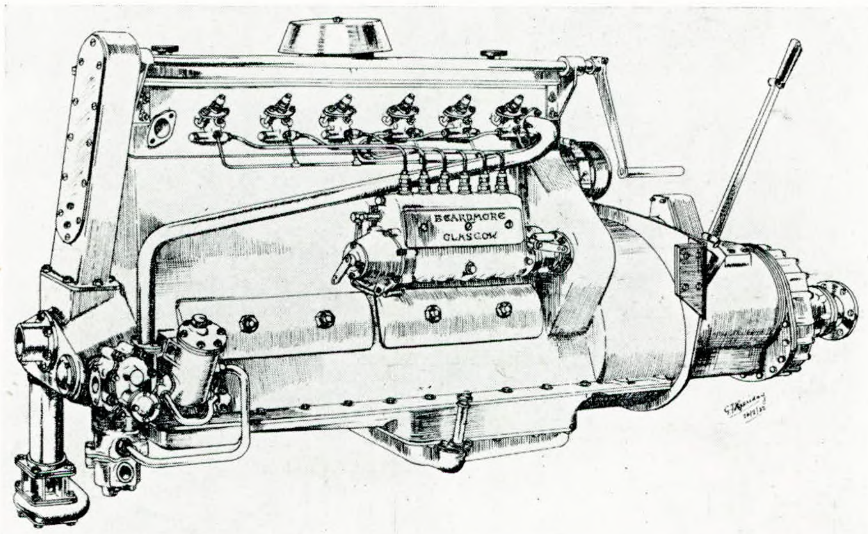


FIG. 2.—Sketch View of Beardmore 90 b.h.p. Marine Engine.

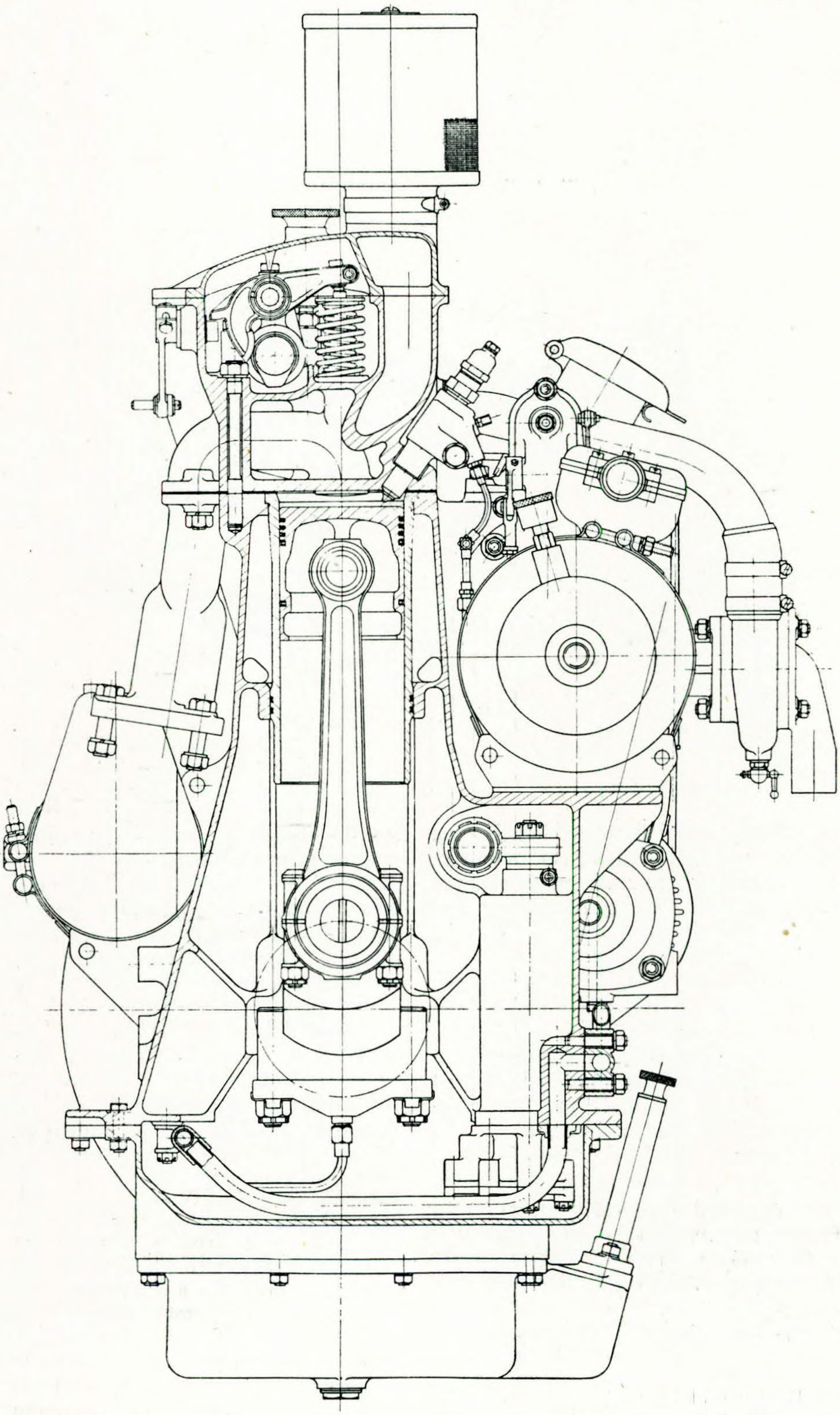


FIG. 3.—Sectional Drawing of Beardmore 6 cylr., 4¼in. × 6in., 90 b.h.p. Marine Diesel Engine.

and the adjustment for wear is quite simple and is manipulated from the outside. Ball thrusts, journal, and spigot bearings are employed, and the gear is built up from the flywheel and finally located by the bell housing. The shaft is drilled, the oil is fed from the engine, and the housing is drained to the sump.

The reduction gear selected for this unit is perhaps the best form of tooth gear one could use, though for marine work it is considered to be inferior to the crosshead and crankpin type.

This gear is really an old aeronautical scheme and it consists of an internal cut sprocket and enclosed pinion. So far, we have nothing new, but as this form of gear suffers (in the usual application) from the grave disability of overhang of both pinion and sprocket, the distinctive feature of this application is that the pinion is carried on two ball bearings by enclosing the pinion in a snout which is cut away to pass the sprocket, while the latter is supported by Michell slippers placed in the line of tooth reaction. In this gear there are no less than four teeth in contact at the same time, and as the lubrication is more effective and the tooth load less, not only is the efficiency of this gear very high, 97 per cent. at least, but there is very little noise.

It may be suggested that 1,800 f.p.m. piston speed is sufficient; that may be so in the majority of cases, but the minority are very important and it is doubtful whether an engine of this type could sustain a speed of 2,500 f.p.m. with security, even if combustion factors allowed the b.m.e.p. to be held.

The maximum load per sq. inch on the crank pin bearing at 1,800 f.p.m. is 1,530lb. This has been well legislated for, and we can only hope that in due course the designers will proceed somewhat further in this direction.

In the instance just given the makers had the advantage of being able to concentrate upon application details, factors concerning the power unit having been previously dealt with and settled, thereby leaving a clear field for the production of a high-speed marine unit. If they have failed in any direction there can be no excuse, while in the instance that now follows there would be every excuse, for not only are the designers taking the very bold step of producing a really high-speed two-stroke cycle engine, but they are utilising a design that has been subject to considerable doubt in the past, and with this new material they have endeavoured to build up a structure that can be accepted by academic as well as practical interests.

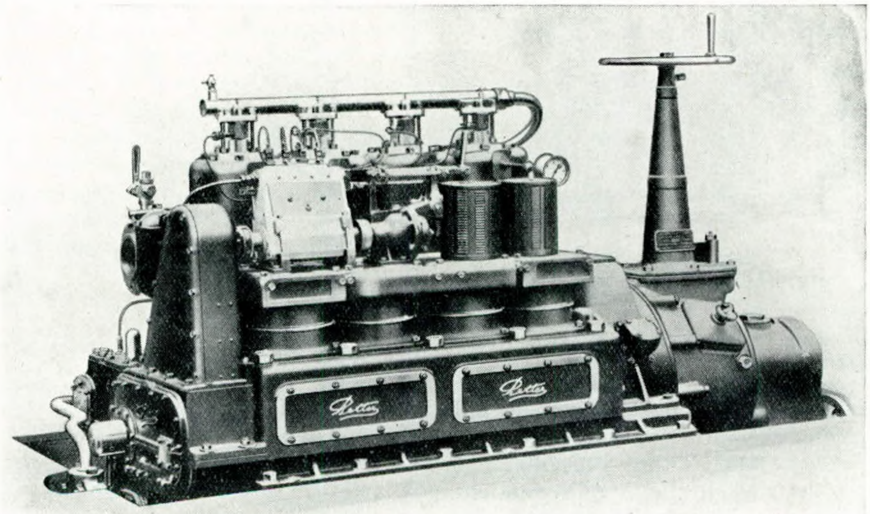


FIG. 4.—Petter Two-Stroke Cycle Marine Engine Developing 60 b.h.p. at 1,600 r.p.m.

The Petter high-speed two-stroke marine engine is referred to, an engine which may be briefly described as follows:—

A conventional two-port cylinder, piston and connecting rod are used, and a straightforward combustion chamber is formed without any attempt to provide more than the normal turbulence. Steel is used for the cover, and the crankshaft follows normal automobile practice, including a claw-ended rod.

In order to provide a full measure of scavenging a further light crankshaft is carried alongside the main shaft from which it is driven by a chain, and this shaft, which has a crank for each working cylinder, operates a scavenge pump for each line. This pump is of ample excess displacement, but as it is dealing with such low air pressures it can be, and is, very light. Apart from any possible trouble with air valves this pump will not give any cause for anxiety, whilst the remainder of the unit is quite conventional.

The economic factor is but a question of piston speed and brake mean effective pressure. The designers are proceeding with caution in both directions and although from observation this engine appears to be in every way satisfactory when running at 1,800 r.p.m. they have adopted 1,000 r.p.m. as the most desirable speed.

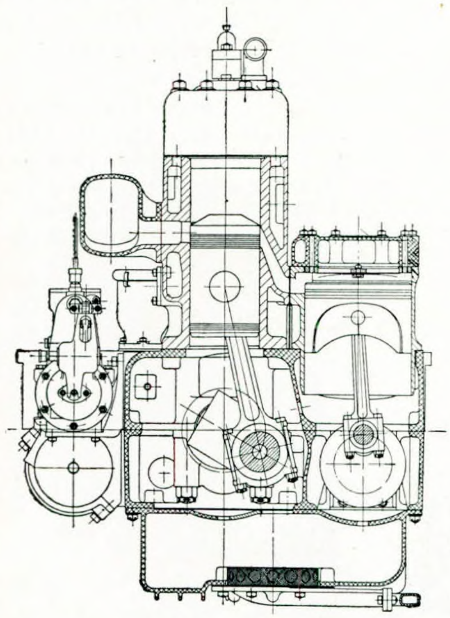


FIG. 5.—Sectional Drawing of Petter 60 b.h.p., Two-Stroke Cycle Marine Engine.

Also, in the matter of b.m.e.p. they would appear to be employing excessive caution, the engine being rated at the very low output of 50lb., but there is no doubt that when they feel confident that this can be done they will raise this pressure nearer to 75lb., which, together with an increase of revolutions to 1,500, for instance, will result in 50 per cent. reductions in weight and cost, both of which are desirable features.

In the marine engine the unit can be "handed" for port or starboard, and the arrangement is to mount the fuel pump on the top of two of the scavenge cylinders and to utilise the other two for the mounting of an air muffler.

Here we have a difficulty: there is a certain amount of noise from the air intake—there always is from the class of valve employed—and two-stroke engine designers will have to see to it that some different form of valve arrangement is used which does not suffer from this grave defect. The noise is harmless; it does not signify that there is anything wrong, and it cannot be heard about the ship, like water-hammer in a circulating pipe, for instance, but it is somewhat overpowering in a small engine room and cannot be considered as good business propaganda.

The reverse gear is mounted on the flywheel housing and is enclosed, but as finality has not been reached in the matter of reverse gears it will suffice to say that the gear employed is robust and "honest", and a reasonable amount of attention has been paid to the lubrication.

Circulating and bilge pumps are carried at the fore end; the lubrication is the conventional high-pressure dry sump system. In general the engine incorporates all the essentials of automobile practice that are necessary in this class of engine.

This engine is also made as an automobile unit, and in this case three-point suspension is employed, but the marine unit is arranged in the conventional manner with an angle bearer plate reaching the length of the engine proper. It is true that the designers have refrained from extending this aft and picking up the reverse and reduction gear, and they have allowed the chain gear-box forward to overhang, but one cannot help expressing regret that they did not adapt the three-point suspension to suit the circumstances of this case, for does not a broad stiff engine of this kind definitely call for such treatment?

It may be contended that an engine having a stroke of 5⅝in. does not come under the category of a high-speed engine, which would be the case if 1,000 r.p.m. were the ultimate piston speed; this, however, is not the case here, and the 4½in.×5⅝in. design may be given a very liberal measure of praise, not only for what it is, up to the present, but because it has opened a road that will eventually become the recognised highway of Diesel engine development.

The fact that it has a chain-driven pump shaft is but incidental, and now that designers are satisfied with the roller chain in place of the silent variety, we need have no fear in this connection; what is of importance is that we have a comparatively small pump for each cylinder, a plain straightforward piston, and a combustion chamber of any required design, this being formed with a steel cover that is free from valve pockets, thereby presenting a simple problem for the manufacturer.

It is true that there are a certain number of exposed "gadgets", that the circulating water pipe arrangements are far from ideal, and that a cowl over the cylinders, such as is employed in the automobile model, would be an improvement, while the controls do not appear to have been given just that amount of attention that they should have.

As previously explained, the designers have had two problems to deal with, to produce a power unit and to give a marine engine at the same time. We know that much patience is required to accomplish the former; the latter is more a matter of clear thinking and a clean sheet of paper. It is to be hoped that in due course, after the accumulation of a further measure of actual operating experience, the designers will finish off in the same excellent manner a job of such creditable and enterprising conception.

The Ruston-Lister four-stroke engine is a very interesting example of a marine engine built up on a good power unit foundation. This engine gives such a good practical performance, and it is so healthy and robust and so widely used that the author feels that it is desirable to search out the imperfections and point out where this engine fails to comply with the standard that he has set out. It will be understood that this is the smaller engine of the Ruston-Lister marine types, and that it is a Lister engine with the double combustion chamber.

It is just within the limit of our definition of the high-speed engine, but it does not come up to specification as regards water-tightness as, for one thing, the exposed flywheel very soon produces disorganisation in a partly flooded engine room. Now this exposed flywheel at the fore end is one of the penalties of moderate or slow speed and the curtailment of cylinders. This introduces another factor which has not been dealt with, i.e., multi-cylinders. It may as well be stated that there is only one way to escape the employment of four cylinders, that is by the use of the horizontal opposed construction, and then two can be tolerated.

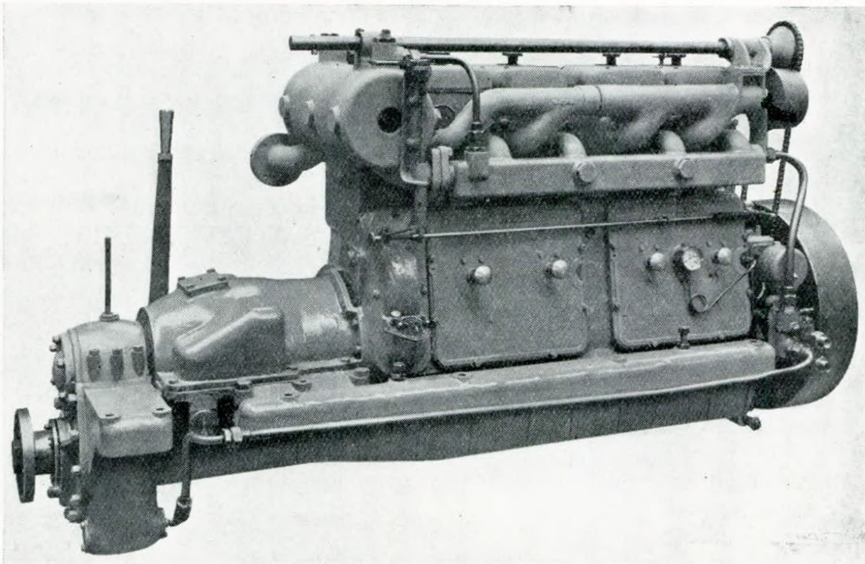


FIG. 6.—Ruston Lister $4\frac{1}{2}$in.×$5\frac{1}{2}$in., 4 cylr. Marine Diesel Engine Developing 36 b.p.h. at 1,000 r.p.m.

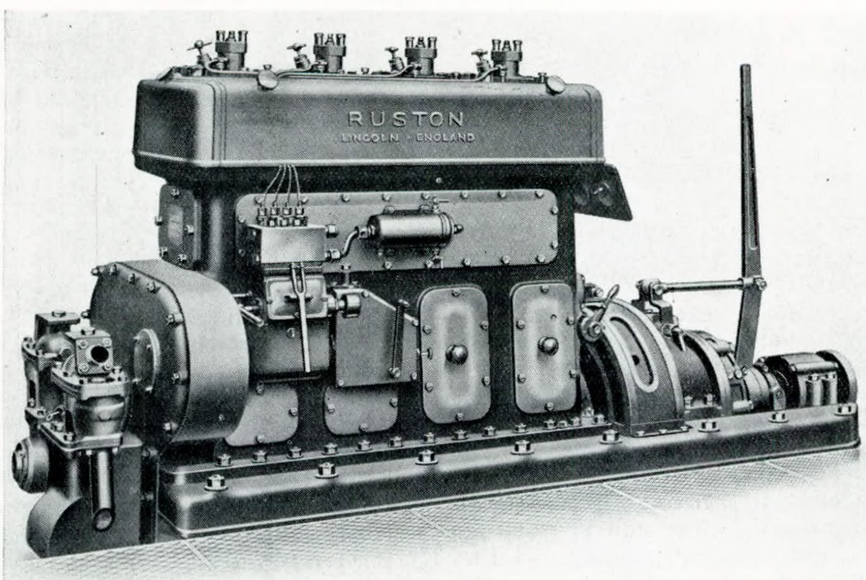


FIG. 7.—Ruston $5\frac{3}{4}$in.×8in., 4 cylr. Marine Engine giving 70 b.h.p. at 1,000 r.p.m.

A four-cylinder high-speed engine can conveniently house the flywheel necessary in the reverse gear housing; the reverse gear can spigot into this flywheel and the bell housing into the flywheel housing, as has already been shown. When it comes to a large flywheel to serve a comparatively slow-speed three- or two-cylinder engine, the wheel becomes too large for the after end; in consequence it for ever constitutes a menace and a general nuisance in the boat. Many years ago the author fitted cowling round the flywheel of a racing boat and used this for keeping down the bilge water, and it may be that the cowling part of this scheme, at least, will appeal to our designers. Everything is well covered up; there are holes in the cylinder hood, but there is no doubt that the latter would effectively keep out the bilge water thrown up by the flywheel and that the engine would continue to run till the water reached the air intake.

The details of the engine show that automobile practice has been adopted for practically all essentials, and one may venture to suggest that this has been subconsciously adopted because of rather, than in spite of, exceptional traditions in gas and oil engine lore. Traces of this lore can be seen in the spacious water jackets, the liner and entablature landing, and many other details, but we may perhaps suggest that in the matter of general rigidity the unfortunate experience of others appears to have received an immediate response from some logical mind. Unfortunately this rigidity has been carried literally too far, as it has extended to the engine bearers, but enough has been said upon this subject to allow any further ventilation to be dealt with later.

The reverse gear in this case is of the Widdop type—an honest, straightforward gear, well set out and made, and arranged with centre shaft oiling. The reverse gear case is split horizontally, the upper half forming a lid that is also bolted to a facing on the engine. This is really not such a good job as the bell-housing, though the claim is made that it provides greater accessibility.

The oil circuit is quite satisfactory; the pumping gear is good and the fuel is well looked after by a filter permanently fixed on the engine and coupled to the pump.

The control is by governor, and therefore the want of automatic control is not so badly felt; in fact, unless the operator had had previous experience with automatic throttle control, automatic governor control being identical in principle, it is doubtful whether he would agree that the latter could offer any improvement.

The author's main criticism of this engine is in connection with the reduction gear shown, which would appear to depend upon the skill of the boatbuilder to get it bolted down in line, and upon the rigidity of the vessel to keep it so.

If we now examine the larger Ruston-Lister engine, which is a Lincoln product and embodies the usual Ruston design for the cylinder head, i.e., with horizontal valves and axial injection, we shall find a great deal that is of interest. Again, it may be suggested that the best of automobile practice has been adopted subconsciously and used in a judicious manner. Valve rocker levers are mounted on lay shafts that are lubricated from the forced lubrication system and the oil is carried to the ends of the levers. This oil is caught by properly arranged trough-ways cast on the head and drains back to the crank-case. The camshafts are but large example of first-class automobile practice and perhaps more than usual attention has been given to, and progress made, with liners, pistons and rings.

This four-cylinder engine gives 70h.p. at 1,000 r.p.m. It has a bore of $5\frac{3}{8}$in. and a stroke of 8in., so that we are well above our 1,000 f.p.m. piston speed limit, but the b.m.e.p. rating is somewhat low. The engine is arranged with governor control, though the speed range is somewhat less than might be expected.

The water pumps, both circulating and bilge, are a very sound workmanlike job and here again we have the dry sump system for lubrication with an Auto-klean filter in circuit and provision for an oil cooler. This apparatus does not appear to be considered as standard equipment, neither is enclosed fresh water cooling included, but this is really a fault of the customers who object to the extra cost. If makers would only take a firm stand on this vexed question everyone would benefit, but concerted action is essential, otherwise the desired benefit cannot materialise.

This engine is a very pleasing job as far as the running is concerned, but it is open to a considerable amount of criticism in respect to the mounting of the reduction gear, as the mounting does not possess the rigidity that is required, neither is it rigid enough in its attachment to allow anything approaching three-point suspension.

Again, an open reverse gear is at present employed; it certainly is a well made gear, far beyond comparison with some of the examples we see from abroad and obviously it functions well. It is to be hoped that the makers will adopt an enclosed gear, with rigid mounting for both reverse and reduction gear, as soon as possible.

With this accomplished it will no doubt be possible to effect a compromise and shorten the bearer length to embrace Nos. 3 and 4 cylinders and the flywheel housing, and give the fore end of the engine some kind of flexible support. The designers should also pay some attention to the question of distant control, at least for the actual controls, apart from the starting gear.

Open reverse gears are a source of possible trouble through neglect; they throw oil about, are generally somewhat inefficient through inadequate lubrication, and are too efficient in the matter of noise production, which is a serious commercial fault.

The Gleniffer engine is an example of considerable merit and interest that has been on the market for some time with such excellent results that criticism is allowable. In this instance the designers obviated the fault of passing high pressure compressed air into the working cylinder for starting purposes by mounting a fixed radial air engine at the fore end and making use of a form of bendix drive for starting, via a gear ring on the flywheel, in accordance with conventional automobile practice.

The engine has horizontal valves and the reverse and reduction gears are well enclosed; albeit that the said reverse gear is of the jamming clutch type the introduction of a slipping ring allows this gear to function quite well, and as automobile practice has been incorporated in the engine details to a very considerable extent this engine can be cited as a very good example of the moderate high-speed type. In due course the designers will no doubt increase the rigidity of the reverse gear housing attachment, and if they cannot shift the flywheel aft they may decide entirely to enclose it and the starting engine pinion in a substantial housing at the fore end.

There is a certain amount of vulnerability in the cylinder cowling; the controls straggle more than is necessary and it will perhaps be agreed that the keynote to the suggested improvements is an increase of piston speed. Certainly this increase would make the execution of the above suggestions a comparatively easy task and at the same time decrease the weight and price of the engine. The Wiseman engine is a 4ft. × 6in. high speed example of considerable merit. It has a b.m.e.p. peak of 104lb. at 1,200 f.p.m. piston speed and a torque peak at 1,850 f.p.m., the fuel consumption at the higher figure being just under ·44lb. per b.h.p.

The engine is exceptionally rigid in construction and while it does not comply with our requirements for watertightness its failure to do so is accidental rather than fundamental.

Automobile practice has been followed to a considerable extent in the details, but the crankshaft is bedded in the base and not slung, and horizontal valves are employed. The liner is made of hard nickel cast iron having a Brinell figure of 450, and here we have to record a very progressive move. The liner, however, suffers from the usual fault of curtailed cooling at the upper end.

This engine is served by a pump and injectors made by Wisemans, who have been engaged upon this work for some time with excellent results, and one need only draw attention to the revolutions and the output, for even at 2,000 r.p.m., which is 2,000 f.p.m. piston speed, the b.m.e.p is above 80lb.

The main criticism of this engine is that the designers have concentrated on the power unit, the marine engine features tending to take the form of an addendum, but there is no doubt that when the makers have had time to apply the "clean sheet of paper" principle to their design of a *marine engine* we shall have something of considerable technical merit and commercial value.

H. Widdop & Co., Ltd., of Keighley, are well known as makers of a very progressive moderate power, slow-speed, two-stroke marine engine, a production that was lifted out of the rut of mediocre design at a very early date. It is therefore of considerable interest to find this concern turning to high speed, designing such an engine themselves, and adopting automobile practice to a very great extent, including the slinging of the crankshaft.

They have given watertightness much attention; at first glance one might say that the engine was submersible, but on looking very closely it will be found that there is no static water seal at the fore end of the shaft and it will also be discovered that the flywheel is not enclosed. Otherwise the engine is rigid and snug; the reverse gear is their own, as has already been mentioned, and this gear is being generally used as it is a very straight-

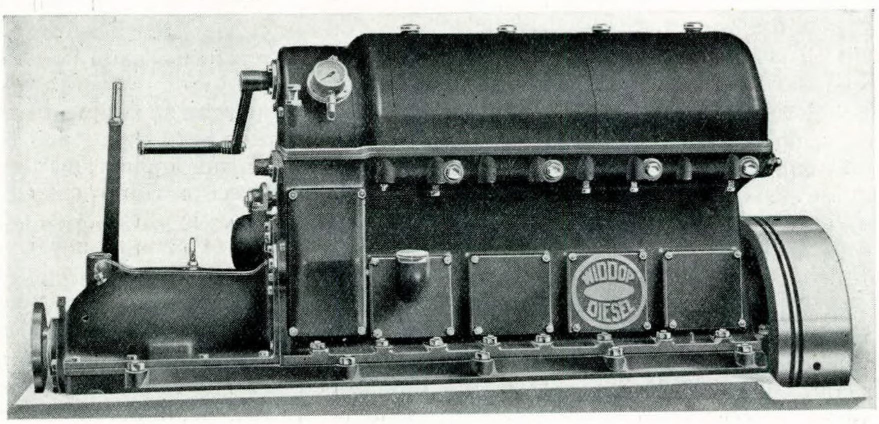


FIG. 8.—Widdop 48 b.h.p. 4 cylr. Marine Engine.

forward job. The water pumping arrangements are excellent, but the controls have very little merit, and previous remarks that have been made will apply to the attachment to the hull.

As the engine is more or less conventional with horizontal valves arranged in a very thoughtful manner, and liners that have been given the usual amount of consideration, time will not allow of further detailing of this example, but it should be pointed out that there must have been some very definite and logical urge for a firm of such standing and experience to devote the attention necessary to produce a high-speed engine of this merit.

speeds are not only to be tolerated but they become normalised.

There are other examples but these should suffice for the purpose and the author will now refer to an entirely different category by making reference to such engines as the Mirrlees-Ricardo, the Allen, and others of this type which are intended for somewhat higher powers.

Messrs. Allen have recognised the limitations of cast iron and cast steel and they have developed a moderately high-speed engine for locomotive work, the frame of which is constructed of welded steel. This is so arranged that the whole front of

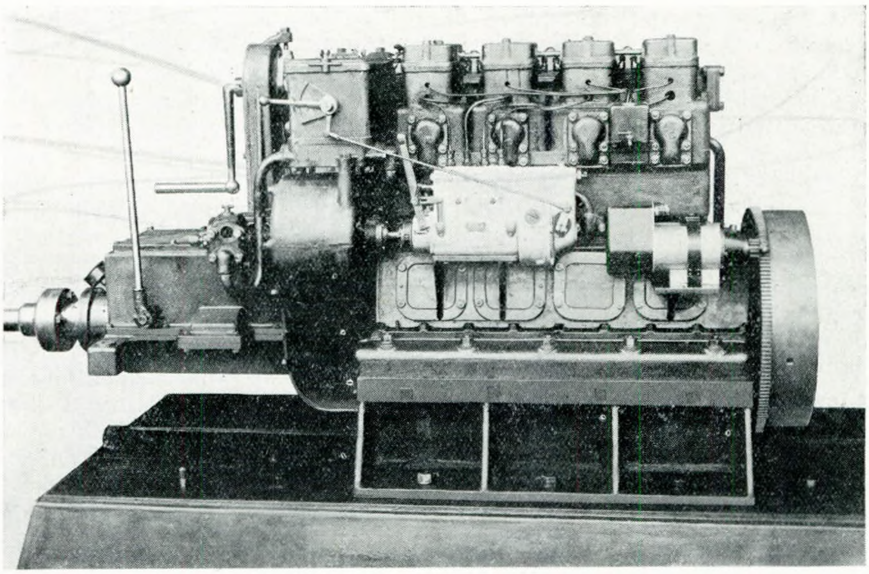


FIG. 9.—Atlantic 4 cylr., $4\frac{1}{4}$in.×6in., 35 b.h.p. Marine Diesel Engine.

the engine comes away for access to the crank shaft, or for its removal.

The Atlantic engine departs from the usual practice adopted for the marine engines that have been reviewed and adheres to the overhead valve; conventional electric starting is employed. There is very little that can be said about this engine because it fails to comply with our "exact and exacting" specification for watertightness, rigidity, etc., which relegates it to the category of a first-class, high-speed, Diesel power unit, and that will not suffice *for the purpose of this paper.*

We have a very good example of the mounting of reverse gear and flange-mounted starter motors in the Dorman engine. The Dorman reverse gear is of considerable value as the whole of the lateral stress due to the pressure of the brake band has been eliminated by the use of a plate clutch type of brake. It is an excellent gear in many respects, and as the engine is a standard automobile power unit adapted for marine work in a very neat and workmanlike manner, this engine will serve to prove that, provided the correct practice, materials, and details of design are employed, high piston

The steel construction will no doubt prove the turning point in high-speed Diesel design. It is not the author's intention to enlarge upon this as, for one thing, a paper is shortly to be read on this subject elsewhere; and therefore it will suffice if the broad statement is made that the weight of the frame can be reduced to two-thirds or one-half of the cast iron weight according to the design. The Allen engine has been mentioned because this firm is making a marine engine and the author may be able to give some particulars of this later.

The Mirrlees-Ricardo high-speed engine is very interesting from the point of view of practice, design and materials, and really requires a paper devoted entirely to its construction. From the marine lay-out standpoint it is of less interest; the reverse gear straggles somewhat and the overall dimensions are excessive, but if we consider this engine from the piston-speed aspect there is much to be learned. The $7\frac{1}{2}$in. bore by 12in. stroke engine turns at 900 r.p.m., which gives a piston speed of 1,800 f.p.m.

The piston is of cast iron and the connecting rod is made of 40 ton steel, but the crankshaft is of nitralloy. Whether this extra cost for the crankshaft is to save the cost of forged aluminium rods we do not know, but the fact that the speed can be sustained with every success in this manner is of value. Certainly the bearing shells are of steel centrifugally lined with white metal and this greatly increases the load carrying capacity, and the engine, which is of the single-sleeve type and has a built up crankshaft has clearly demonstrated that loads of 90lb. b.m.e.p. can be sustained at 1,800 f.p.m. piston speed.

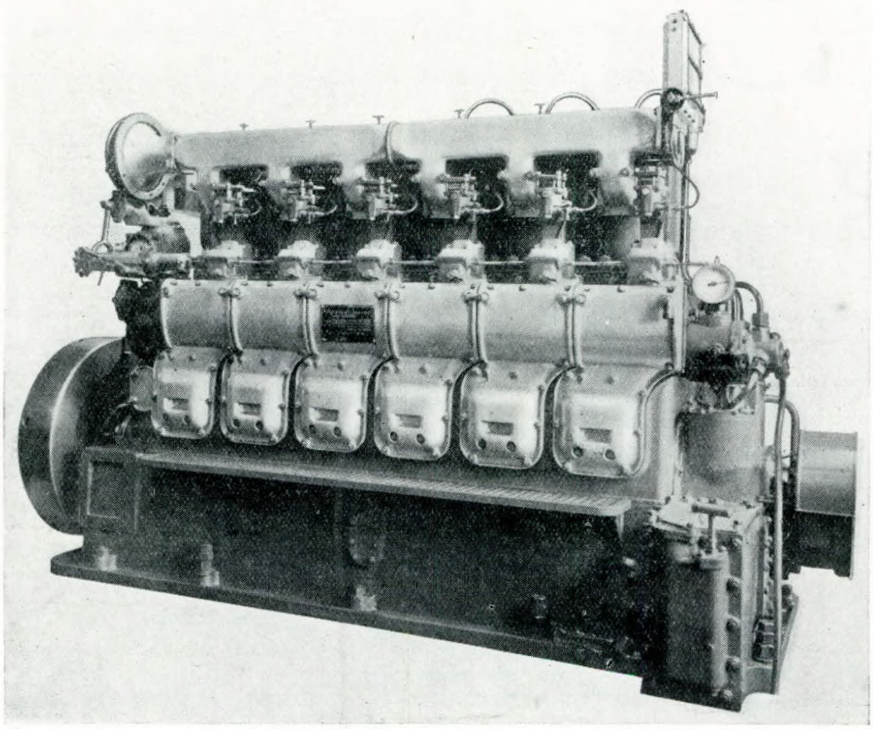


FIG. 10.—Mirrlees-Ricardo Marine Diesel Engine giving 300 b.h.p. at 900 r.p.m.

As regards weights and dimensions, a six cylinder engine giving 300 h.p. at 900 r.p.m., with a bore of 7½in. and a stroke of 12in., has an engine length of 9ft. 9in. and a weight of about 5 tons, or approximately 40lb. per h.p.

High Speed Ships' Engines.

We can select the "Deutschland" as the first example of a large vessel propelled by high-speed heavy-oil engines. In this vessel there are eight 7,100 b.h.p. M.A.N. propelling engines driving two shafts through Vulcan couplings and reduction gearing, and for scavenging there are four engines which have identical cylinders, but with five instead of nine, as in the case of the main engines.

The cylinders are 16½in. bore with a stroke of 22$\frac{13}{16}$in. and therefore at 450 r.p.m. the piston speed is 1,700 f.p.m. We thus have engines working at an exceptional piston speed and a high b.m.e.p. with a weight, including scavenge blower and engine, oil and water pumps, of 17·6lb. per shaft horse power, or a total weight including propellers, shafting, piping, gratings, floor plates, etc., of 48·5lb. per h.p. This is a very great achievement, but if we begin to count up the number of cylinders it will be found that there are no less than 92 required for the propelling machinery of 54,000 shaft horse power.

These engines are double-acting two-stroke units with airless injection, and they are arranged with a supercharge system which consists of a valve in the exhaust port which closes and allows the pressure to build up to that of the scavenge air, a somewhat brutal but very effective method of obtaining supercharge. The author has no authentic information relative to the running of this machinery. Germany proposes building another such vessel; if this vessel is laid down the inference will be that a success has been made of this most enterprising and progressive experiment. We must bear in mind that this group driving through reduction gear is far from novel in German practice. For instance, Blohm and Voss have built several ships with two engines per shaft, and it was their expressed opinion that the system would be developed to its logical conclusion, which is four engines per shaft.

In the case of the "Bremse" we have a smaller example, a vessel 318ft. long with a beam of 31ft., in which are installed propelling engines totalling 26,000 h.p. in eight units with two shafts as arranged in the "Deutschland". They are M.A.N. double-acting two-stroke engines and the revolutions in this case are 600. The eight cylinders have a bore of nearly 12in. and a stroke of $17\frac{1}{4}$in., and therefore the piston speed is about 1,700 f.p.m. The b.m.e.p. is high, as when developing 3,550 h.p. at 600 r.p.m. it is 91lb. The consumption is low and the overall thermal efficiency at overload is 39·6 per cent.

A number of tests have been carried out with these engines and those of the "Deutschland" (see "The Motor Ship", July, 1932) and it is very interesting to note that the results are superior to those of the 12,000 h.p. double-acting two-stroke slow-speed engine of the same make operating with blast injection.

There is a somewhat smaller, but excellent example in the FIAT engines, which were installed

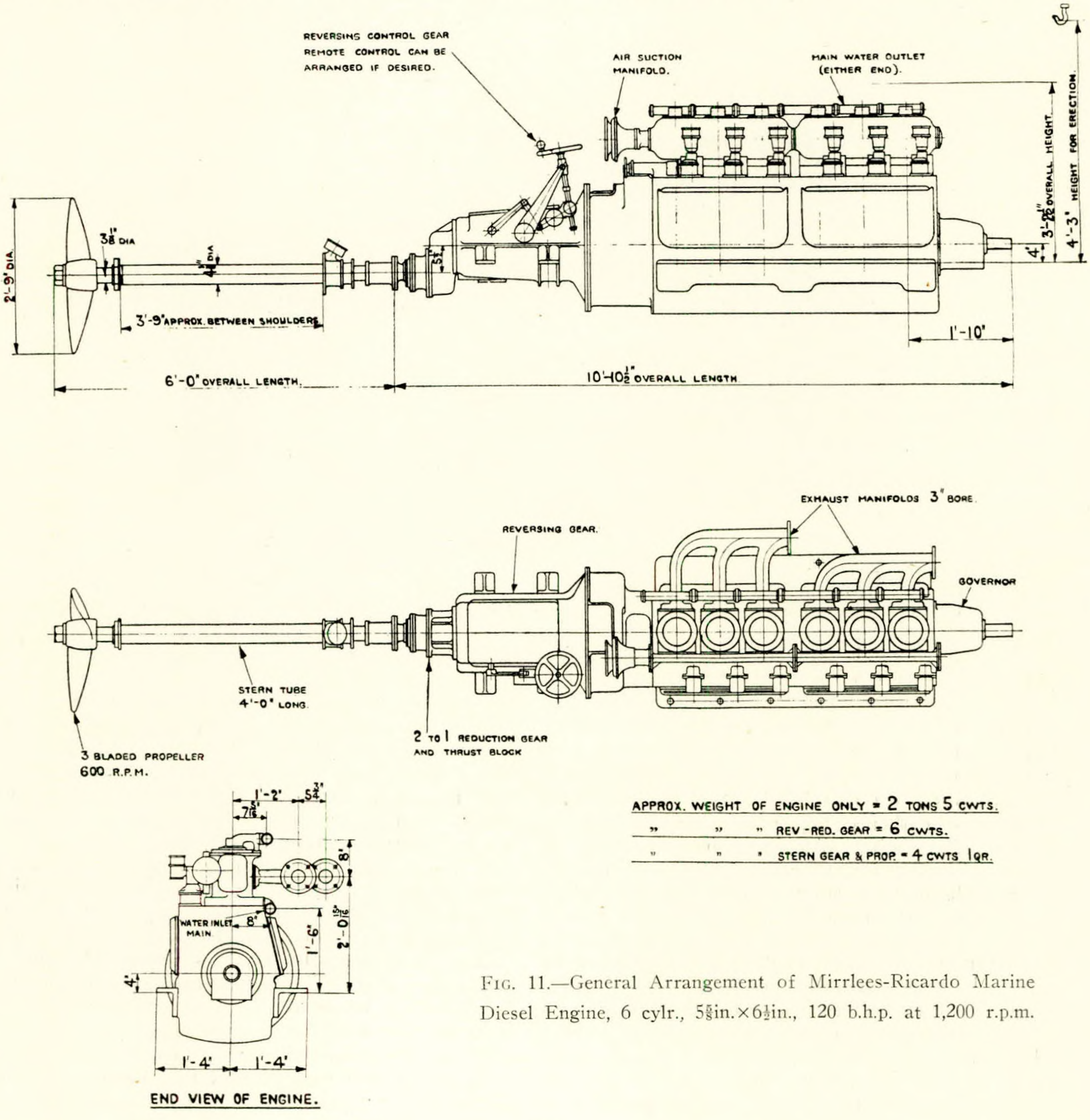


FIG. 11.—General Arrangement of Mirrlees-Ricardo Marine Diesel Engine, 6 cylr., $5\frac{5}{8}$in.$\times6\frac{1}{2}$in., 120 b.h.p. at 1,200 r.p.m.

in two Persian Naval vessels of 900 tons displacement. These engines are 1,250 h.p. each; they are on the two-stroke cycle and have a speed of 330 r.p.m., a bore of 16½in., but quite a moderate piston speed of just over 1,000 f.p.m. However, there are a number of small warships building, in service, or projected, and a very interesting account of these applications is contained in "The Motor Ship" of February, 1932.

The first example of a cross-channel boat propelled by high-speed engines is the "Prince Baudouin", which will not only be the first cross-channel motorship but also the fastest vessel of this type. The engines are of Sulzer design and were made by Cockerill, the particulars being as follows:—

Single-acting, two-stroke, crosshead type.

Twelve cylinders, 580 by 840mm., or 23in.×33in. approx.

Revolutions 258p.m., and a piston speed of about 1,400 f.p.m.

The brake horse power of each engine is 7,500 and as there are twin screws the total shaft h.p. is 15,000.

The overall length of the engine is 45·4ft., the height is 16ft., and the weight of the engine and accessories is 355 tons, which represents 53lb. per h.p.

The total weight of machinery, including auxiliaries is equal to 6·0 brake horse power per ton of displacement.

The consumption is low, about 0·38lb. per b.h.p. per hour, and therefore the propelling horse power of 15,000 will require 2½ tons of oil per hour.

Sulzers are very rapidly developing the high-speed light engine, using welded steel construction, and perhaps the most interesting example is their three-cylinder engine developing 6,000 b.h.p. at 265 r.p.m. This engine has a bore of nearly 27in. and a specific weight of approximately 24lb. per b.h.p., and as a twelve cylinder unit would give perhaps 25,000 h.p., it will be seen that 100,000 h.p. could readily be installed in a vessel at even a less weight than the figure given, which would total approximately 900 tons for the propelling engines.

It is possible that as experience is gained with welded steel construction, weights may be reduced and there is no doubt that many parts such as air trunks, scavenge blowers, cover plates, and the like can be made of magnesium alloy and further reductions made; the greatest field of all for weight reduction, however, is in the increase of b.m.e.p., and piston speed. The piston speed of this engine is not very high and the b.m.e.p. is low, no doubt purposely so, and when both of these factors can be increased and weight reductions made in the structure, it is quite possible that we may have engines of 10,000 h.p. with a weight of 15lb. per h.p.

The author would now like to refer back to the ideal characteristics of the marine engine, as set out in the early part of the paper, and to review some of these high power engines, as far as possible, in order to ascertain how far they comply with these requirements, though the absence of detailed information and drawings makes this somewhat difficult.

We will take watertightness. Do the M.A.N. engines of the "Deutschland" comply? Would they function if the engine room were flooded? Would they allow her to be beached, for instance? It is quite possible that they would, or that they could be readily made to comply, but one would not expect to go down and start up the engines with a flooded engine room. The accessories would no doubt prove the obstacle, and if the engines failed to continue running the cause, apart from accessories, would be one that could readily be rectified in design—if it were thought worth while.

Rigidity of structure is the next factor and one may say off hand that the engine is rigid, though the double-acting system, with the bottom cover and distance piece, has reduced this rigidity to a very great extent.

Three point suspension has not been legislated for, the engines being part and parcel of the ship's structure. This is no doubt essential owing to the gear drive, but for single unit per shaft such an engine could be isolated from ship movement and the ship insulated from engine vibration, with very little alteration in design.

With these large engines we need not question the lubricating service; this has been carried out progressively until it has reached a stage when it is very difficult to select improvements. The engines are oil-tight, and in the evolution of this oil-tightness they have automatically become watertight, though it does not always follow that an arrangement which will keep in oil will keep water out.

One hears very little of the cooling arrangements of these large engines, and the author will venture to suggest that fresh water circuits and coolers are either incorporated in the design or are being given very full consideration. Here again this has evolved; the cooling of pistons initiated the practice in ships' engines and from this it has grown in esteem until it is now being recognised as essentia for cylinder cooling.

Distant control has hardly been considered for large engines. As yet there is no need, there being an adequate staff in the engine room, but as there is generally a junior deck officer at the telegraph, and as bridge control allows for immediate response in the case of emergency, this can very well be left to the future and to the time when the reversing is simplified and made more positive.

We must now depart from the review of engines which are in existence to consider a project of an engine which, on paper, complies very

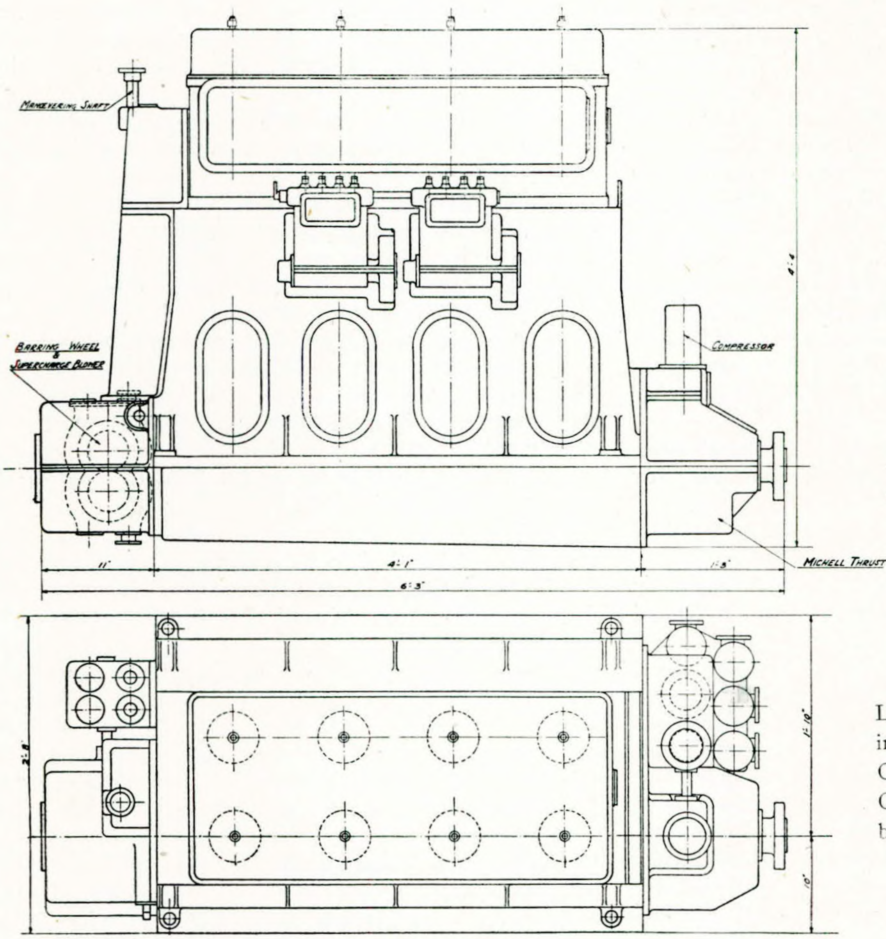


FIG. 12.
Low 4 Crank Direct Coupled Reversing Engine. Manganese-Aluminium Construction (Stevens System) 8 Cylinders $5\frac{1}{4}$in. $\times$ $7\frac{1}{2}$in. Stroke. 600 b.h.p. at 2,400 r.p.m. (Without Supercharging).

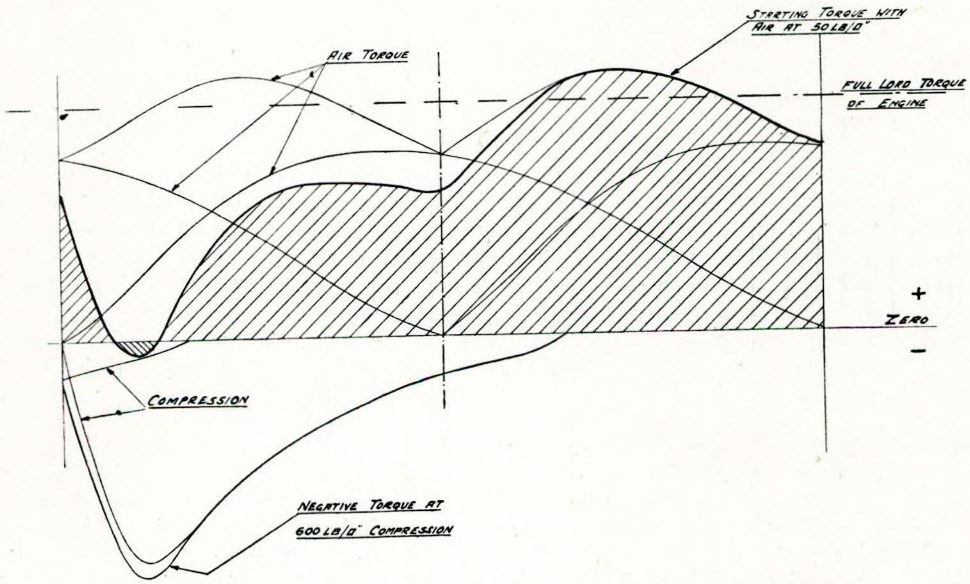


FIG. 13.—Starting Torque of 2 or 4 Crank Low Engine.

generally with our specification and has assumed some virtues of its own. The author refers to the Low engine, and to a projected example that is intended to cater for the small high-speed vessel. This engine is a two-stroke, rocking-beam type, with the connecting rod actuated from one end of the rocking beam and the scavenge pump-cum-

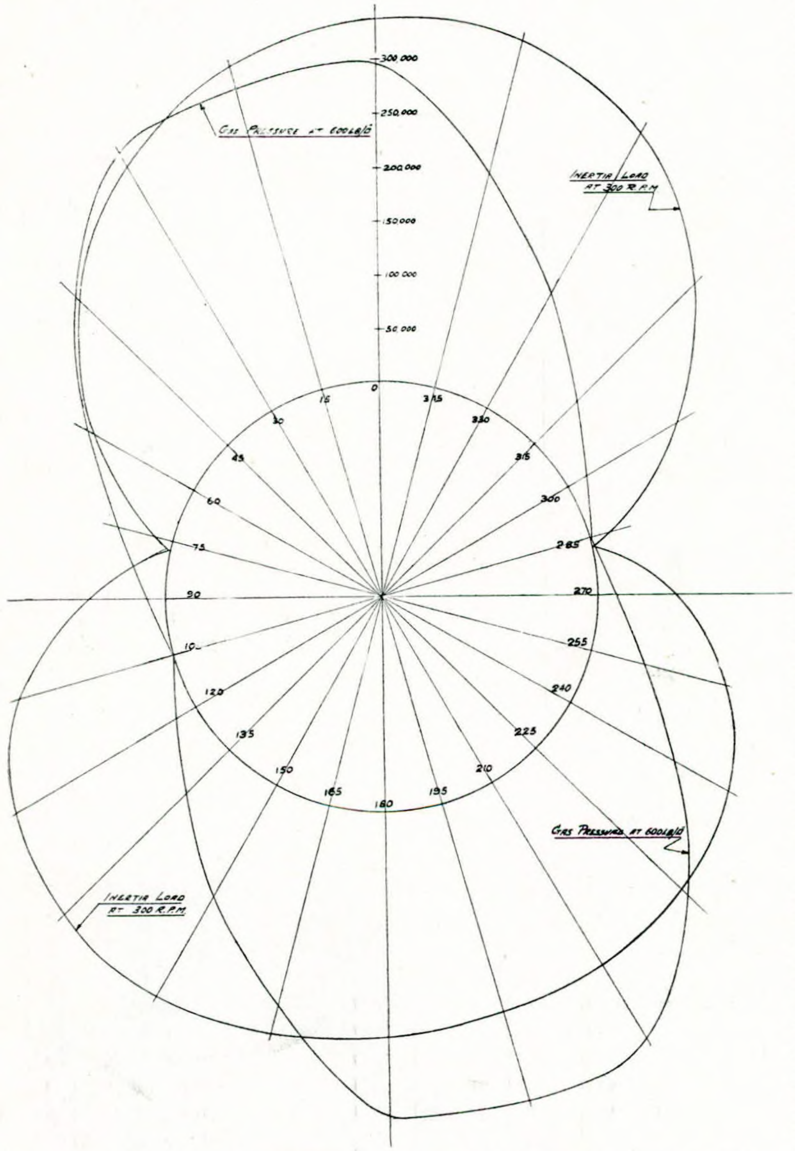


FIG. 14.—Inertia and Gas Load Diagrams of Low Engine.

starting engine driven from the other end, above the beam being mounted two single-acting cylinders with the pistons linked to the ends of the beam.

The project shown is for a cast magnesium-aluminium crankcase, though this has been entirely abandoned in favour of one made on the Stevens welded-steel system, and this modification has actually resulted in a saving in weight.

This engine has four cranks and eight cylinders $5\frac{1}{4}$in. in diameter and the stroke is $7\frac{1}{2}$in. The revolutions are 2,400 per minute, which is equal to a piston speed of 3,000 f.p.m. and the b.h.p. is 600 without superchange. The overall length of this engine is 6ft. 3in., including Michell thrust, pumps and supercharger at the end; the height is 4ft. 4in. overall; the width 1ft. 10in.; and the weight approximately 4lb. per h.p. In regard to this weight, it is interesting to note that the welded steel frame only weighs 0·326lb. per h.p.

We can now ascertain how this engine complies with our specification and whether the figures given are reasonable. Why, for instance, can a piston speed of 3,000 f.p.m. be projected when this appears to be limited to 1,800 or so? Also, what are the limitations to piston speed?—is it pressure on the big end bearings in terms of pounds per sq. inch of bearing surface, or is there some overriding factor?

The first query is answered by the statement that the engine was designed as a submersible unit. Obviously the project drawing is lacking in many details; in consequence the methods employed cannot be illustrated, but it is intended to be capable of remaining at rest under water and of starting up and running under these conditions. The engine is certainly rigid. It is a short wide box construction that lends itself to this feature, and while it is not shown with three point suspension there is a very good reason for this, in this instance.

Lubrication and cooling may be taken as read and we therefore come to the "distant control". This is a direct-coupled reversing engine, and this reversing is effected by treating the scavenge pumps, which are arranged with sleeve valves, as air engines and providing them with air at 50lb. or less. There is an air pump for each crank, and as it is double-acting and about 1·5 displacement ratio, it follows that the m.e.p. of the air engine is approximately 75lb. when referred to the working cylinders, or very nearly the full load torque. There is, therefore, ample power to start, and also to reverse against propeller drag, for every turn that the engine makes contrary to the gear setting, the air pumps are moving against full receiver pressure for the whole of the stroke.

In the case of a two-crank engine there is ample torque to overcome the first compression, in

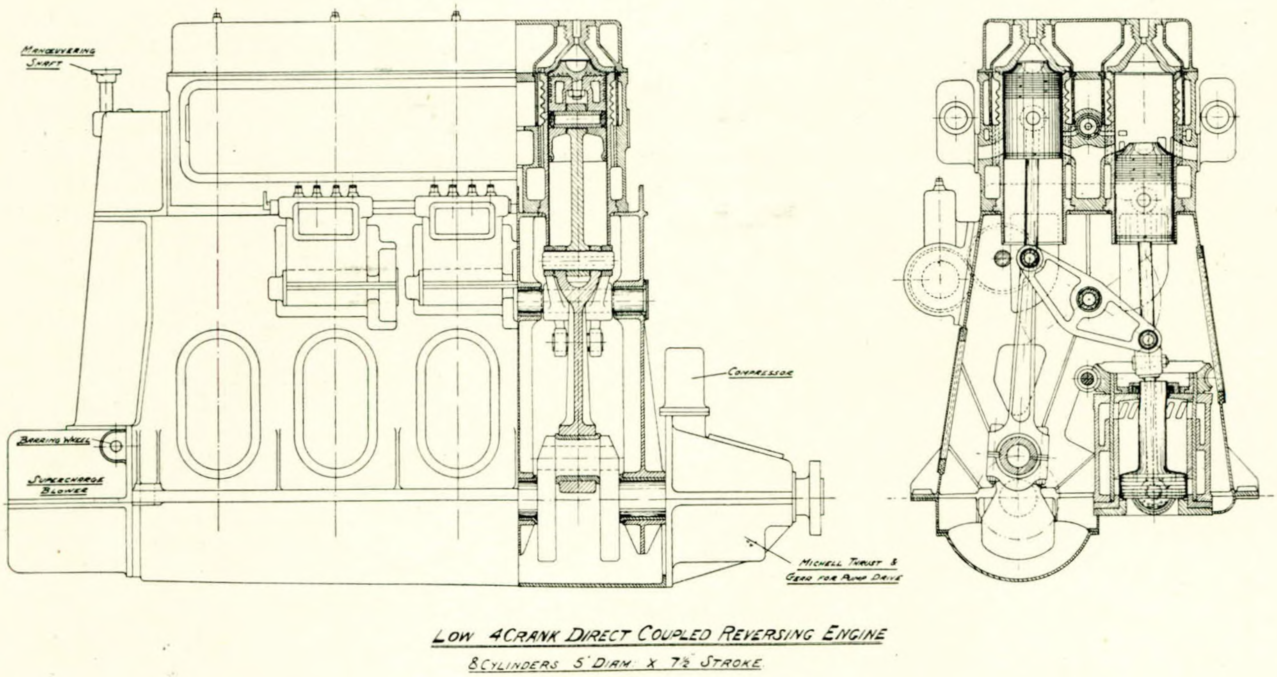


FIG. 15.

consequence we have that certainty of mechanical movement that makes distant control reasonable. Again, there is no cold air admitted into the working cylinders and therefore injection can take place at the first compression *in the desired direction,* the sum of all this being that the amount of air used is either very small, or a minus quantity.

A polar diagram of the inertia and pressure forces on the crank pin shows that at some revolution speed this engine, or any of its type, arrives at an approximation of balance between inertia force and gas pressure and at this balance speed the crank pin is lightly loaded, just as is the case with the double-acting two-stroke. The balance speed is 3,000 r.p.m. in this case, due mainly to the employment of automobile practice, such as forged RR alloy connecting rods, aluminium pistons with valve steel caps, valve steel cylinder heads with submerged joints, Nitricast iron liners, nickel chrome crankshaft and the usual first-class practice in bearings. Piston slap from the aluminium pistons is averted as the pistons are always pressed in one direction on to the cylinder walls and so on, but time does not permit any further amplification of the details of this engine.

The author's contention is that still higher speeds and pressures, in conjunction with weight reduction, are quite possible, and the main objective of showing this engine is to illustrate that, if only one dares to depart from the conventional, many things are possible.

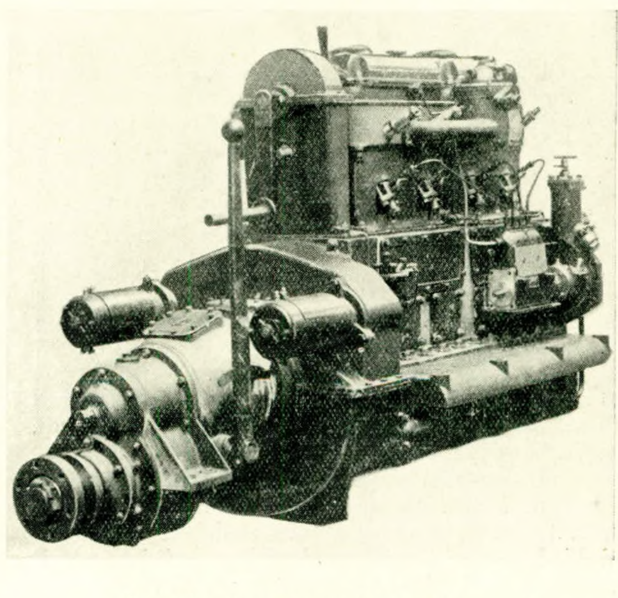


FIG. 16. Dorman marine engine.

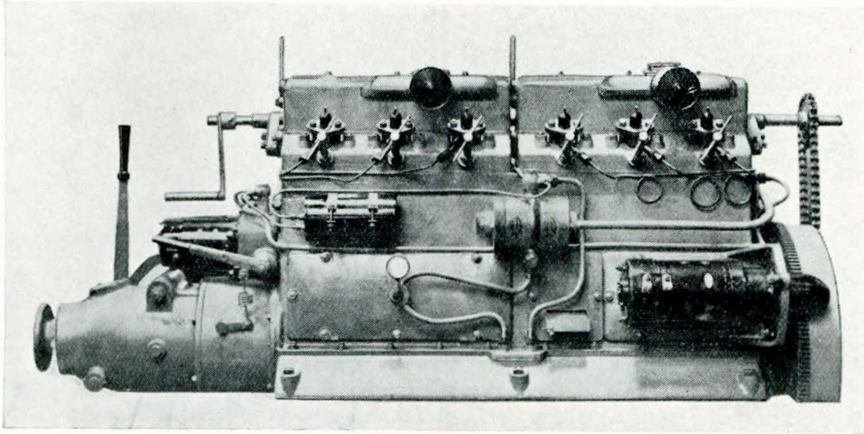


FIG. 17. Ailsa Craig Diesel engine.

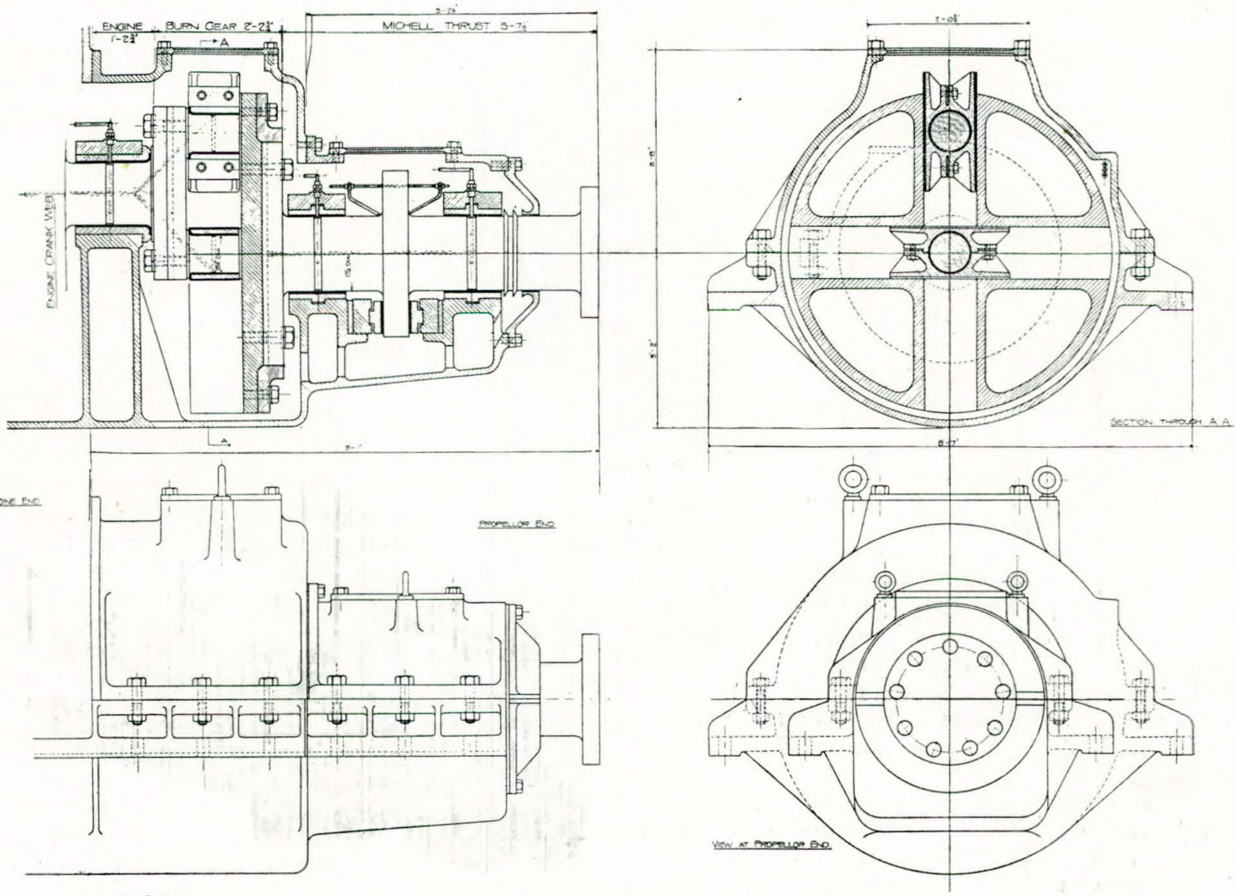


FIG. 18. Burn silent marine reducing gear with Michell thrust. Ratio 2 to 1. 2,400 h.p. at 160 r.p.m.

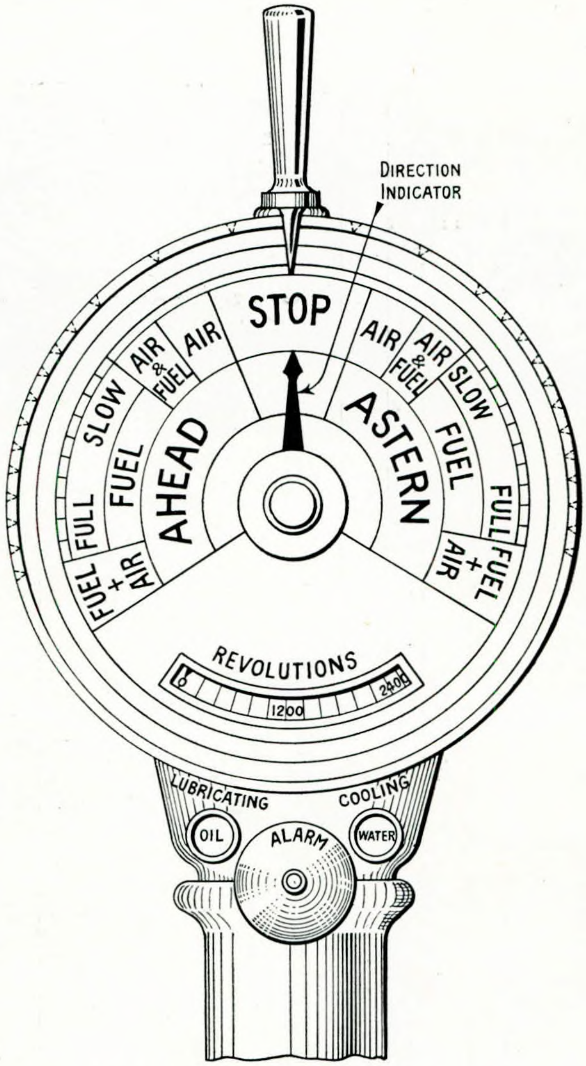


FIG. 19. Remote control for manœuvring.

DISCUSSION.

MR. J. CARNAGHAN (Chairman of Council) said that for the purpose of introducing Mr. Evans to them that evening he had, in the absence of personal information, consulted an unquestionable authority respecting his career. From this source of information it would appear that he was born sometime prior to 1894, because at that date he obtained some experience with a Daimler motor launch.

About 20 years ago Mr. Evans was actively interested in motor-boat racing, and subsequently carried out experimental work on two-stroke cycle oil engines. After twelve years service as Engineer Superintendent of the Royal National Lifeboat Institution, he had for some years practised as a Consulting Engineer in connection with heavy-oil engines, yachts, etc.

He might add that as Mr. Evans was successful in obtaining the Institute's "Akroyd Stuart" Award in 1929 for a paper entitled "The Origin and Development of Heavy-Oil Engines", it was hardly necessary for him to be introduced.

He would now call upon Mr. Evans to read his paper, which he was sure would prove most interesting to them all.

At the conclusion of Mr. Evans' reading of the paper the Chairman said that he felt sure they had all appreciated the manner in which the author had treated his subject.

It was a controversial subject, and as he was confident that Mr. Evans had provoked a keen discussion he would now throw the meeting open for that purpose.

MR. J. CALDERWOOD, M.Sc. (Member of Council) said that, although many nice things could be said about Mr. Evans' paper, he would confine his remarks principally to criticism, as he felt sure that this was in accordance with the wishes of the author.

The paper had given him rather a shock—the kind that one would get on reading that Mr. Maxton had turned Conservative. They had so often had from the author rather extreme opinions on the question of the rating of engines, whereas in the paper he treated as high-speed engines some which many people would almost designate low-speed.

The author had previously given definite expressions of opinion as to the name of the heavy-oil engine, yet in his paper he had adopted the name "Diesel" engine. The speaker's opinion on this question was quite open—he did not mind what name was used—but he had anticipated that, in view of past remarks, Mr. Evans would have had some more general and non-controversial term such as heavy-oil engine.

The part of the paper referring to essential characteristics was that which he proposed chiefly to criticise. The author stated that rigidity of structure was essential, a question on which he quite agreed with the author. In the case of the small engine it was possible to adopt three point suspension, so that no stresses were imparted to the engine from the hull, but for the really big engine this arrangement did not appear to be practicable.

The author had not mentioned a much more important reason for rigidity, namely, that it was not possible to ensure freedom from vibration unless the engine frame was rigid both in longitudinal and transverse bending and in torsion.

Mr. Evans stated that "our high-speed engine will, in all probability, be provided with constricted waterways". A good deal could, however, be said against as well as for this feature. If little water was in the cylinder jackets and the circulation stopped for any reason, there was little time available before trouble arose due to overheating. It was, perhaps, better to have ample passages with water flow arranged to give the highest possible speed through them.

He quite agreed with the author that for many types of vessel bridge control was both desirable and practicable, but the author had suggested that in addition to the controls, the tachometer, oil and water pressure gauges and distant thermometers, etc., should all be on the bridge, so that the quartermaster might look after these whilst he was also steering the ship. He considered that it was quite beyond the bounds of possibility that one man could pay proper attention to both the ship and the engine gauges at the same time, and thought that where bridge control was used the engine services must be sufficiently automatic and reliable to require no gauges on the bridge, or at most should be provided only with a warning bell or light.

On the question of engine speed, Mr. Evans appeared to think that the engines should run at just about twice the speed that would be ideal for the propeller. The speaker thought that the views on propeller speeds had changed somewhat, and that it was being realized that considerably higher speeds could be adopted without any great loss of efficiency. Rather than advise the use of gears, he thought it would be better to suggest further propeller research with the object of attaining better efficiency at high revolution speeds. Gears were adding to the complications of the plant, whereas the aim should be further simplification.

Throughout his paper, in discussing high speeds, the author had treated piston speed as the vital factor in this connection. He referred to inertia pressures increasing as the square of the piston speed, but that was only correct for a particular engine, because they actually increased as the piston speed square divided by the stroke, so that in the case of two engines running at the same revolution speed, one double the stroke of the other, the inertia forces in the former were not four times but twice as great, and with the same weight of reciprocating parts the former engine could run at $\sqrt{2}$ times the piston speed with the same inertia forces as the latter. This factor must be taken into consideration when comparing high-speed engines.

The author appeared to consider that bearing loads and mechanical stress due to inertia forces were the limiting factors in determining speed; this might be so when small-engines at very high speeds were considered, but for moderate or large engines the main difficulty was to get the air into the cylinder and to ensure good combustion with a commercially practicable arrangement of valves and valve gear in the four-stroke, or of scavenge pump and ports in the two-stroke engine.

Mr. Evans had stated, after detailing various improvements, that 1,500 f.p.m. would closely approach the best they could do. He could assure the author that there was plenty of engines in service which would run at this speed, and would do so without the use of any special methods of construction, although, of course, the workmanship must be first-class. General experience now was showing that piston speeds could be raised to about 1,500 f.p.m. with safety. An increase of engine output by raising the mean pressure was much more difficult and liable to give rise to trouble.

The author's comments upon the metalling of the bottom end bearing were very interesting. He believed this suggestion was in line with all modern aeroplane practice, and that very satisfactory results were obtained, much higher bearing loads being safely carried with bearings treated in this way.

He thought that all present who had anything to do with Diesel engines would wish that the problem of liner wear were as simple as Mr. Evans stated, i.e., that it was simply the result of excessive gas pressure behind the rings and the top of the liner becoming too hot. A great many tests by various engine makers seemed to be purely negative in that respect; whatever was done seemed to be ineffective. It would almost seem that the cause of wear was chemical rather than mechanical, as no mehanical alteration in the design of the rings appeared to have any noticeable influence. Rings had been designed to allow and others to prevent the gas pressure getting behind, others had been tried low down in the cooler part of the liner, and still others up in the hotter part. All this had been done without any appreciable effect on the liner wear, which (so long as quantity and quality of lubricant was reasonable) appeared to depend entirely upon the fuel that was used and the service on which the engine was running. If the real cause of the wear could be discovered, there was no doubt that cases of excessive wear would soon be eliminated altogether, but no one had yet put forward a suggestion that held water.

He would now refer for a moment to the engine which was shown at the end of the paper. The author made a great point of the crank pin being lightly loaded with this particular arrangement, but common experience with low- and moderate-speed marine engines, whether steam or Diesel, gave little reason to fear trouble from any bearing with complete rotating motion, whereas bearings with an oscillating motion such as top ends were a more difficult problem. In this engine the author had shown three bearings per pair of cylinders, which had oscillating motion and which were subject to the full inertia and pressure stresses as in an engine of normal design, and so must be subject to much higher loads than the bottom end bearing. The speaker thought that the trouble from these bearings would be much worse than from the bottom end of an engine of normal design.

Another point in regard to this engine was that he did not see how the air could be got into the cylinder when running at the speed the author had indicated with the ports as shown. It would be very difficult to get this engine to run at 2,400 r.p.m. without absorbing so much power in the scavenge pump that the mechanical efficiency would be completely hopeless, unless the height of the ports was 40 to 50 per cent. of the stroke.

Referring to his previous comment that Mr. Evans had turned "Conservative", the author had included almost any engine over 1,000 f.p.m. as a high-speed engine. The speaker had a table of all the published particulars of engines that had appeared recently, and he could only find one engine with a piston speed of less than 1,000 f.p.m. If piston speed were to be the basis, he would not consider an engine to be of the high-speed type unless its piston speed were 1,500 to 1,800 f.p.m. and this cut out most of the engines Mr. Evans had described. The b.h.p./litre and the r.p.m. of engines might be expected to vary inversely as the square root of the b.h.p. per cylinder, so that $\frac{\text{constant}}{\sqrt{\text{b.h.p. per cylinder}}}$ can be used as an expression for engine rating either in speed or output per litre. On the r.p.m. rating for a Diesel engine this constant would be over 6,000 for a high-speed, about 4,000 for a moderate-speed, and about 2,500 for a low-speed engine. On the b.h.p./litre the constant would be over 33 for a high engine rating, about 23 for a moderate rating and about 15 for a low rating. All of these figures referred to four-stroke single-acting engines and the constants would be higher for two-stroke or for double-acting engines of either type.

Incidentally for the Rolls-Royce Schneider Trophy engine the b.h.p./litre constant was 815 and the r.p.m. constant 43,400. A rating such as this, the speaker suggested, was the object at which they had to aim. There they had an engine infinitely above the rating of any Diesel engine that had yet been built; they must try to get an engine of that rating which would run continuously.

Dr. S. J. Davies, M.Sc., Ph.D. (King's College, London University) said that he sometimes found himself differing from Mr. Evans, but he had found that evening that he accorded with most of the views expressed by the author in his paper. There were, however, several points he would like to raise.

He imagined that the author's intention was rather to stimulate thought in new directions, and higher speeds of revolution was one direction in which they could look for somewhat better utilisation of the materials of construction.

The last engine referred to in the paper promised, to his (the speaker's) mind, a good deal in the direction of this better use of their materials. He thought that, as mechanical engineers looking impartially at the matter, they all recognised that they did not by any means utilize the materials in their engines to the best advantage. Only for a very short period of the cycle of the engine did high stresses come into account, while in the greater part of the cycle they were moderately low. Their aim was to get more uniform stresses over the complete cycle, and the engine detailed by the author had in its mechanical arrangement—if this mechanical arrangement proved satisfactory—something which was an improvement in this respect.

He differed from Mr. Calderwood's ideas concerning the relative loading of the crank pin and gudgeon pin bearings. On high-speed engines he considered that it was the crank pin bearings which gave the most trouble. This was certainly the case in aircraft practice.

He had noticed that no reference at all had been made to difficulties with lubrication. Did marine engineers have no difficulty with their lubricating oils? This would also appear to be so from the author's statement on the last page of the paper that "lubrication and cooling may be taken as read". He (the speaker) would certainly not like to take lubrication "as read" in the case of the high-speed engine.

Another point in the high-speed engine was that one was liable to get unequal heating and cooling of the piston. One of the biggest difficulties in connection with aircraft engines was to keep the pistons from distorting at the high temperatures they had to undergo. A good deal of the trouble was due to piston distortion, which was linked up with the cooling question.

He would also be interested to know how the piston rings of this high-speed two-stroke engine behaved over long periods. This was a difficult point in connection with the two-stroke engine.

MR. JAQUES DU BOIS (M.A.N. Engine Co.) said that while the educational value of Mr. Evans' paper was undoubted, it would have been enhanced if he had suggested some direction in which the research for the most successful type of high-speed Diesel engine should be carried on. Interesting comments were made, for instance, both on four- and two-stroke engines, but without the author's opinion as to which of the designs was to be preferred.

The important question of rigidity was raised many times, and the author reviewed in the course of his paper all the desirable features for a satisfactory longitudinal rigidity of the engine and/or of the combined engine and reversing gear. He advocated a design with continuous longitudinal beams over the engine and gear, whilst the diagonal strength was obtained by dropping the engine casing as low as possible below the crankshaft centre line. The transverse rigidity, not only of the engine itself, but over the engine room as a whole, was also of vital importance. Above the engine room an opening was generally provided in the deck for lowering down the driving unit, thus further weakening the frames. The engine seatings themselves demanded further interruption of the frames, and it seemed, therefore, desirable that as few frames as possible should be involved by the hatch and the seatings. For this reason continental makers had gone away from the amalgamation of the reversing gear to the engine and had provided for a distinct reversing gear, thereby enabling (as well as a shorter hatch) at least one frame to be kept continuous immediately aft or forward of the flywheel.

The dismantling of a built-in reversing gear also presented many difficulties. The reverse gear was always an intricate mechanism, and, particularly with ball bearings, where any wear had the most disastrous consequences, easy inspection should be provided for. This condition could not be fulfilled so well with a built-in reverse gear. Generally speaking he (the speaker) objected to the use of ball bearings for continuous marine service.

No mention had been made of lubrication problems, which, particularly in high-speed engines, were of a very serious nature.

Also, no reference had been made in the case of the four-stroke engine, to the transmission from the crankshaft to the camshaft. Some makers used chain drive, others gearing, while others adopted a combination of both, but there still seemed to be some field for research to find a final solution of this problem.

Strong criticism was made when the slide of the Allen engine was shown. It was only fair to say that this engine was required to be erected on a barge working in smooth water, so that the question of the movement of the ship did not arise; the formation of the vessel was such that the engine maker had no choice, and, to his knowledge, these engines had run extremely well.

A slide was also shown of the main Diesel engines of the "Deutschland" and the author's brief remarks on these engines were not laudatory. He (the speaker) would confine his remarks that evening to saying that it was irrelevant to compare the "Deutschland's" engines with those of the "Prince Baudouin", as the former were designed for a very special purpose. It was also not correct to say that the ship was out of action as soon as one Diesel-driven blower stopped. There were four Diesel-driven scavenge blowers installed, and if one was cut out the others would still enable the vessel to proceed.

MR. R. E. STRUB (Messrs. W. H. Allen, Sons & Co., Ltd.) said that many of the points he had in mind had been dealt with in the discussion. However, there were other features with which he would like to deal.

He had been impressed by much of the criticism of details contained in the paper which occupied their attention daily, and in these matters the fuller the criticism, the more valuable they became.

The paper as a whole, however, lacked the main constructive idea of the author's thoughts on the main questions of the development of the high-speed marine propulsion engine. It was important that the author should decide upon the lines on which the high-speed marine engine should develop.

Fundamental questions such as the choice beween two- and four-stroke, with their subsidiary problems of scavenging and systems of injection, had not, he thought, been touched upon; these were the great points around which hinged the development of the high-speed marine Diesel engine.

Reverting to the points of particular interest referred to in the discussion, the question of rigidity had been treated on somewhat one-sided lines, and in his opinion this required more thought in regard to the particular application of each engine criticised, and it seemed obvious that a propulsion engine designed for a coal barge on the

Nile could not be compared from the same points of view as the layout of an engine for the lifeboat service. Strictly speaking, the installation criticised did not really come within the scope of this paper on high-speed marine propulsion.

The author did not appear to be in favour of installations in which the reverse gear was not in unit construction with the engine. Whilst this was perfectly satisfactory for small units, for large units there were many difficulties to be overcome. One perfectly practical solution for larger units had been successfully carried out on the Continent where the problem had been tackled from a new angle by inserting a flexible clutch between the engine and reversing gear, thus obviating the necessity of having a long and comparatively narrow unit erected on the relatively flexible foundation available in small craft.

The remarks regarding the details of the bearings, and particularly the white metalling of the shells, were of the greatest value to designers. It must be realised that the bearings of the high-speed Diesel engine were the most stressed of any class of machinery, and all experience which had been gained and was being discussed was of primary importance.

The subject of liner wear had been raised in the discussion, but there were so many contributory factors that a discussion on one isolated point could not lead to any definite conclusions. The degree of liner wear—or its absence—could not be attributed to one particular feature, as, for instance, the one mentioned where the top piston ring worked at the level of the water space. The crux of the whole matter depended very largely on the design of engine generally.

In conclusion he would like to state that the paper would serve a useful purpose, and they were all very grateful to the author for the information he had given them.

Mr. A. C. Hardy, B.Sc. (Associate Member) said that the author had usually something constructive to tell them, and he believed that the paper had been prepared with the deliberate object of provoking them to make the remarks that they had, in order that the sum total of knowledge might be definitely added to.

He would like, however, to have seen something more definite about the application of the high-speed engine to big ships.

One objection to the Diesel engine for marine purposes had been its weight, and it was in this respect that the high-speed engine offered definite advantages. The adoption of high-speed units, however, involved some form of indirect drive. Two big German shipowning companies had taken the initiative in this direction and had gone to fairly high piston speeds; they had been able to make remarkably compact machinery spaces. A firm in Holland had fitted geared Diesels in a cargo ship in order to get in an extra 'tween deck space, and a big Dutch tug with this type of propulsion was now building.

The question of gearing big Diesels was one which would have to be treated more seriously in this country. It would be interesting to hear if Mr. Evans could deduce any lessons from his experience with the motor-boat-type of engine, which could be applied to big ships.

The author had not set out to deal with the questions of electric propulsion, but surely the time was now imminent when it should be considered. These reverse gears might be a source of trouble, and electric propulsion got over the difficulty very satisfactorily. Electric propulsion was expensive at present, but that was the fault of the manufacturers.

Eng. Lt.-Com'r. H. J. Nicholson, S.R., R.N. (Member) said that he felt sure they would agree that Mr. Evans must have gone to a vast amount of trouble in order to produce such an interesting paper. He had analysed a large number of engines, pointing out their respective advantages and disadvantages, and this should be of no small value both to the designer and operator.

Mr. Evans had drawn attention to the necessity for an entirely enclosed engine, even to the extent of making it submersible in water. It was agreed that there was every necessity for thoroughly efficient casings capable of resisting ingress of water and impurities, both to the crank chamber and running gear. Under normal running conditions it was a comparatively easy matter to prevent impurities gaining access to these parts, but it was quite another question to prevent leakage of oil from the engine. There was still much to be desired in this direction. The pools of oil so frequently seen round the base of an engine seemed to suggest that either more attention was necessary to the finishing of joint faces, or that a complete oil-resisting jointing material had yet to be found.

If an engine was to be enclosed to the extent of resisting submersion, difficulty with efficient crank chamber ventilation seemed inevitable. That the automotive engineer had become fully alive to the necessity of adequate ventilation was evidenced by the arrangements for extracting crank chamber gases by way of the air induction system, now fitted to a large number of car engines. Probably the most serious result of a badly-ventilated crank chamber was the contamination of the lubricating oil by gases escaping past pistons. A certain portion of these gases would be soluble in the oil, thus having a tendency to increase or decrease its viscosity.

Mr. Evans very wisely drew attention to the necessity of automatic lubrication in the smaller engine. He also advocated cooling of the oil. This, however, was a debatable point, and might result in maintaining the oil in a viscous condition owing to over cooling, a condition which was not desirable in a small high-speed engine. A much more satisfactory arrangement was to provide an ample quantity of oil in the system, which would permit of a period of comparative rest and natural cooling.

The advocation of oil filters was to be commended. Many engines were fitted with very efficient oil strainers. Few, however, had filters capable of removing colloidal matter or the finely divided particles of solid impurities which collected in the oil after a period of service.

While dealing with the subject of lubrication, Mr. Evans suggested an amplified form of automatic lubrication for engines of larger power, and his reference to auxiliaries was assumed to apply to auxiliary engines, such as generators, to be found in the engine room of a large ship. The system suggested amounted to a common gravity supply to all these engines. For the main engine lubrication with possibly oil cooling of the piston, the gravity system had much to commend its use, although in the majority of large installations a pressure system was employed. A common system for main engines and auxiliaries had decided disadvantages.

The majority of auxiliary engines were of the enclosed type, having their own forced feed lubrication system. Leakage of cooling water from lines or coolers, or sudden extensive contamination by fuel affected only a relatively small quantity of oil with the possible stoppage of one engine only. With a common system for all engines, a large volume of oil would be affected with possible stoppage of all engines.

In the case of the larger main engines where the cylinders were usually isolated from the crank chambers, there was not the risk of water from leaky liners, or fuel and other impurities from the cylinders finding their way into the crank chambers, but there was, of course, the risk from leaky coolers. In general practice, however, the main engine lubricating oil received much more regular and frequent treatment by centrifgue or other purification apparatus, than the oil in the auxiliary engines.

With regard to high piston speeds, Mr. Evans had quoted 1,500lb. as a very reasonable crank pin load, and that a load of 3,000lb. could be contemplated. It was interesting to note that three or four years ago Messrs. Beardmore were running high-speed oil engines quite successfully with crank pin loads up to 3,600lb. maximum pressure per square inch of projected surface.

In connection with high-speed ships' engines, the author stated that "with these large engines we need not question the lubricating service; that this has been carried out progressively until it has reached a stage when it is very difficult to select improvements". With this he could not agree. There seemed to be a prevailing idea that so long as bearings ran cool and a good lubricating oil consumption figure was maintained, this was all that was necessary, whereas the vital factor of introducing a system that definitely prolonged the useful life of the oil in service was often overlooked.

Experience had shown that due to unsuitable pipe arrangements aeration of the oil was produced; large flat-bottomed tanks definitely retarded the separation of impurities in the oil; it was frequently impossible to clean the tanks thoroughly; and heated settling tanks were often omitted. Briefly, arrangements were such as to make it impossible to draw off oil in its worst condition from the system. Even in some recent installations these points had been given little or no consideration, whereas attention to them in detail when planning the circulation system would effect a marked improvement both in regard to working and to the length of service obtained from the oil.

Mr. S. N. Kent (Vice-Chairman of Council) said that it gave him extreme pleasure to propose the vote of thanks to the author for his exceptionally interesting paper.

He was sure they were all looking forward to the time when they could see the Diesel engine Mr. Evans had described to them that evening. He had certainly been looking for one which they could box up and run for years.

He had appreciated what Mr. Evans had said, and he was sure they would all agree they had been given something to think about.

The vote of thanks was most heartily accorded, and Mr. Evans suitably responded.

By Correspondence.

Mr. Wm. McLaren (Member) said that on the question of watertightness which the author had suggested could be secured by entirely enclosing the engine, he quite agreed with the desirability of keeping dust, dirt and bilge water from the working parts. To provide against spray or the flooding of the engine space, however, he would suggest fitting trunking above the cylinder tops, with a ventilated hatch cover to form an air inlet and a heat outlet. This could easily be constructed to the overall dimensions given, and made efficient and portable when required for overhaul or repairs.

He agreed with the author's very emphatic statement regarding lubrication of the smaller oil engines. One would, however, have liked to have heard that provision was being made to free bilge water from oil before pumping it overboard. The omission to do this and the consequent comparatively large quantities of oil floating around the seaside resorts was provoking strong criticism.

The author had underestimated the conditions when he suggested that the quartermaster could control oil-engine driven craft with the ease and facility experienced in a motor car; in his opinion the two tasks were not comparable, and, further, the unstable platform while pitching and rolling must be borne in mind.

He recollected that a few years ago (before 1914), about six oil-engined motor boats, 30 to 40 feet long, engined with 20/30 b.h.p. oil engines of the hot-bulb type, were used as market boats between Plymouth and Harwich for the purpose of provisioning some of the naval vessels—this was before the authorities took over the furnishing of supplies themselves. These boats were manned by a mechanic, who was, with the assistance of a super cargo man, steersman, engineer and skipper. There was no bridge and no wheelhouse; the steering wheel and engine controls were abaft the engine housings, the man controlling having the machine directly under his observation. He hoped, however, that outside home waters, the Institute would not endorse such a practice, especially with any larger vessels.

Mr. W. Hamilton Martin (Member) said that the author referred to the fact that of all ills suffered by the Diesel engine, liner wear was the most important. In view of this statement he would like to contribute some observations on this matter.

The wear of cast iron liners of normal hardness, after 1,000 hours service in a recent motorship burning Diesel fuel oil, was about 0·47 m.m. Similarly, in the Sulzer engine after 1,000 hours service, the cast iron liner wear, according to an engineer well-acquainted with this type of engine, when burning clean Diesel fuel oil, was about 0·03 m.m., while when burning Pakura oil (with a 4 per cent. ash content) it varied from 0·3 to 0·8 m.m.

On the third page of the paper the author stated that Messrs. W. H. Allen Sons & Co., Ltd. found that when using their hard liners with Diesel fuel oil a wear took place, after 1,000 hours service, of 0·0005in., or about 0·013 m.m.

It was of interest to compare these wear results with those recently obtained on the "Rupa" Coal Dust Diesel Engine No. 8. This engine had three cylinders of 320 m.m. bore by 520 m.m. stroke and ran at 220 r.p.m. Each cylinder had a different material in its liner. After operating this engine for 1,000 hours burning brown coal of 8 to 10 per cent. ash content, the following wears were measured, viz.:—

In cylinder No. 1 having a normal cast iron liner, the wear was about 2·00 m.m.

In cylinder No. 2 having a cast steel liner, the wear was about 0·50 m.m.

In cylinder No. 3 having a nitrided steel liner, the wear was about 0·18 m.m.

The greatly decreased wear in cylinder No. 3 seemed to point to the advantage of using nitrided steel liners. How much Nitralloy cast iron might be better was still a matter of interesting conjecture. The author might be able to give some further information on this point. Incidentally, the small wear obtained in cylinder No. 3 of the Rupa coal dust engine would seem to augur well for its early entry into the field of high-speed marine units, and traction and even motor car engines, especially considering the fact that the fuel consumed only cost from one quarter to one third of that used in a Diesel engine; this would far outweigh the cost of extra liner replacements if such proved necessary.

The first Rupa engine, an 80 h.p. single cylinder M.A.N. unit, had now run about 10,000 hours on its original cast iron liner of 1912, which had worn out at its top end from 420 m.m. to 427 m.m. Although this 7 m.m. might be considered as excessive and no doubt materially affected its compression, the engine, nevertheless, still started up from cold on coal, or as a Diesel on oil. If, then, this engine were fitted with such a nitrided steel liner with a wear of 0·18 m.m per 1,000 hours, it could operate for $(\frac{7}{0{\cdot}18}\times 1{,}000)$ 39,000 hours before it got in a condition similar to its present state, and even then it would still start up cold on coal.

With reference to the effect of ashes on the walls and rings, it was of interest to note that the size of ash particles existing in this engine had been found to vary from 1/10th to 1/40th of a millimetre; the wearing effect of particles of this size was insignificant.

His reason for drawing attention to this question of liner wear, which no doubt was manifested at its worst in the coal dust engine but was a matter of no less concern to every Diesel and oil-engine designer, was to impress upon them all that, as present-day operating pressures and temperatures rose due to the desire for higher speeds and lighter engines, and as the double-acting principle with its even greater heat and pressure stresses tended to aggravate matters, it was becoming of vital importance that a systematic research be carried out to find the best abrasion-resisting material for cylinder walls and piston rings. This could be done more quickly in a specially-designed abrasion testing machine than in an actual working cylinder. A modified machine of the type used by Messrs. Livingstone, Smith & Glaister for determining the effects of used lubricating oils on motor car engine cylinder walls (described in "The Engineer" last year), by which definite data could be obtained as to the influence and limits of temperatures, rubbing pressures, piston speeds, etc., was required to enable the most suitable materials (and for that matter the best lubricating media) to meet the arduous operating conditions in future internal combustion engines to be determined.

The value of such an investigation could not, in his opinion, be too highly emphasised and ought to prove a very useful subject for research work at one of the leading engineering colleges. If there were any funds available for this work, or the Fuel

Research Committee, the Institute of Fuel, the Air Ministry or the Admiralty, the Diesel Engine Users Association, or even one or more of the private firms building internal combustion engines, could be induced to interest themselves in this question, one of the greatest problems (or "ills" as the author aptly described it) of the internal combustion engine could, in all likelihood, be effectively overcome.

He would like to add that he was pleased to hear Mr. Calderwood now supporting the view that he had always upheld and propagated at several meetings of this and other Societies, i.e., that more efficient propellers were necessary for higher speeds to allow of direct driving by Diesel engines, not only to take advantage of a more efficient engine but, equally, to ensure to a greater extent vibrationless operation. Special multi-bladed propellers designed by his (the writer's) father some 40 years ago for high-speed restricted-draft patrol vessels of light scantlings (comparable with modern high-speed motor-driven craft) proved very successful, so much so that the captain of one of these ships was known to have remarked: "With these propellers it seems as if my ship when travelling at full speed is passing through syrup instead of water, so smooth has her motion become, no matter at what point of the ship I happen to stand". Trial results had since been examined by Mr. Baker, of the Alfred Yarrow Tank, due reference to which was made in his paper on propellers in the current issue of the Transactions of the Institution of Naval Architects. Mr. Baker found them to be very accurately measured, decisive on certain points, and holding out definite promise for higher propeller speeds.

The Low engine referred to had certainly some highly attractive features to recommend it, even if at first sight the multiplicity of moving parts and wearing points demanded one's closer attention to appreciate their *raison d'être*.

The originality of its design and the objects achieved would seem to hold out promise. Modifications might still prove necessary in its further development. The designer was most certainly to be congratulated on his achievement, and it was to be hoped they would hear of a Low engine on test before very long.

He would conclude by expressing his appreciation to the author for his most informative and interesting paper.

MR. G. J. WELLS (Vice-President) stated that in the second paragraph and also in several other places in the paper, the effect of high piston speed was emphasised, whilst that of quick revolutions was passed over as if of but little importance. Surely this was not strictly the case! In the section headed "High Piston Speeds", it was stated that the inertia pressures "increase as the square of the piston speed". The most convenient formula for the inertia pressure was that published by Mr. Macalpine in "Engineering", October 22nd, 1897, and it might be written thus:—

$$M\omega^2 r \{\cos(\theta+\alpha) + A\cos 2(\theta+\alpha) + B\cos 4(\theta+\alpha) + C\cos 6(\theta+\alpha) + \ldots\ldots\}$$

In this formula ω was the angular velocity in radians per second, the mathematician's symbol for revolutions. The constants A, B, C, etc., were functions of the ratio of stroke to connecting rod length. The crank angle θ was, of course, $=\omega t$. Each successive term within the brackets represented a crank moving with an angular speed exceeding the preceding by 2θ; thus the all-important factor was r.p.m.

A numerical example would make this matter quite clear. Take the case of four engines having strokes of 6, 8, 10 and 12 inches respectively, and in each case running so that each engine's mean piston speed in feet per minute was 600. For each unit of the reciprocating mass, the corresponding inertia force would, neglecting the effects due to the connecting rod, be as shown below, viz:—

Stroke in inches (=2r)	6	8	10	12
R.p.m.	600	450	360	300
Angular velocity radians per sec. $=\omega$	62·8	47·12	37·7	31·4
(Angular velocity)$^2=\omega^2$	3,940	2,220	1,420	985
Force required to overcome the inertia of each lb. of M.) lb.	30·6	23·0	18·4	15·3

It was clear, therefore, that the revolutions per unit of time were the all-important factor in determining the inertia forces to be overcome.

The writer was interested to note the author's insistence upon the complete enclosure of the engines, as he could recollect the criticisms of the Willans engine, in its early days, because no one could *see* what was going on inside.

Another good point was the author's insistence upon rigidity of the engine frame and its supports, as this lack of rigidity had been a source of trouble ever since engines were first built.

What did the author mean in the fifth paragraph under the heading "High Piston Speeds" where he stated that if "there is a cancellation of inertia pressures by gas pressures . . . and leave the crank pin but lightly loaded"? It was not clear what this meant. For balancing purposes, the problem was to introduce an equal and opposite force to the unwanted force. and this was not cancellation but an additional force. Now the engine rotated by reason of the torque, due to the resultant tangential force acting at the crank pin centre. and if there was any cancellation or "wiping out" of forces, the resultants must become less and the power delivered would surely also become less. Accordingly, it would be most interesting to learn more definitely what the author had in mind at this point of the paper.

He would like to know how the Low engine differed from the Wigzell engine, described in

"Engineering", 7th September, 1900, and if the author knew if the Wigzell engine was still being built? There had been other engines of the same type as the Wigzell, but for some reason or other they had not been adopted generally. Did the author think that the Low engine was such an advance upon the earlier designs that it would come into general use?

ENG. LIEUT. D. BASTIANINI, D.Sc., R.I.N., (Member) stated that Mr. Evans' very interesting paper undoubtedly contained many valuable particulars and considerations; however, with very few exceptions, it dealt only with high-speed Diesel engines of limited power. He thought it would be very interesting to know the results of the latest endeavours on the part of specialised firms to reach high powers with this particular type of internal combustion engine. Success in this direction would naturally widen the applications of such engines on board big ships, a point of great interest in the progress of shipbuilding. In this respect he completely agreed with Mr. Hardy that it would be particularly interesting to have all possible details of what had been done, and Mr. Evans' opinion regarding further developments which might be expected in the near future. The comparison between high-speed Diesel engine plants and up-to-date steam installations was naturally the principal point, chiefly with regard to the weight per s.h.p. As a matter of fact, some of the known details of weights of high-speed Diesel engines installed in ships were not very encouraging in comparison with the low weight reached by the modern high-pressure and high-temperature steam installation. Was it possible, on the basis of the progress already made, to foresee such a reduction in weight, particularly of high-speed engines of high power, to be at par with, or even to better the results obtained by the up-to-date steam installations? If so, the future of Diesel engines for marine propulsion would promise the best results, in view of the very low figures of fuel consumption.

Right from the start Mr. Evans had excluded from consideration the engines which were not coupled mechanically with the propeller shaft; therefore, while in the author's reply he could not expect considerations regarding the interesting point of Diesel-electric propulsion with the application of high-speed engines, might he (the writer) perhaps, notwithstanding the reserve made by Mr. Evans, draw attention to another point which, he thought, was of considerable importance for the progress of high-speed Diesel engines, and that was the ships' electric generating plants consisting of dynamos driven by high-speed Diesel engines. As far as he was aware this application was so far limited to auxiliary sets of low power. Therefore, Mr. Evans' opinion on the possibility of its being extended to the main generator sets would be very much appreciated, in view of the advantages that could be derived if the perfect running of the motors were assured.

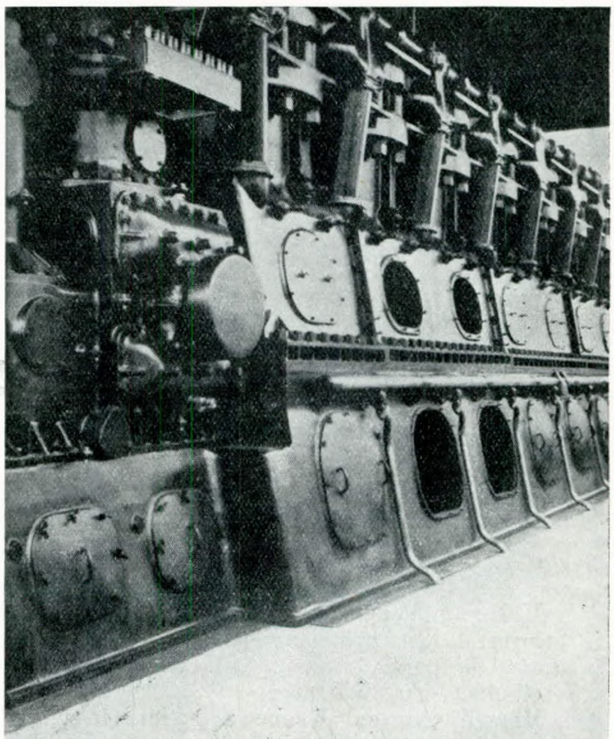
MR. F. A. PUDNEY (Member) stated that the author had dealt with the problems of high-speed engines having in mind apparently such craft as fishing vessels, coast patrol, life boats, etc., the duties of which call for special protective devices for running parts against the effects of sea water, and general neglect due to lack of a real engine room staff.

The real marine engineer, as understood today, would not be greatly attracted, one would imagine, by any "boxed in" arrangement of main machinery, certainly not to the extent of actual watertightness indicated in the paper.

Open crankcase working, and the like, even for low-speed Diesel machinery was practically impossible due to forced lubrication, etc.; also, the construction of crankcases carried right up to the cylinder head joints seemed only possible with units of comparatively small power.

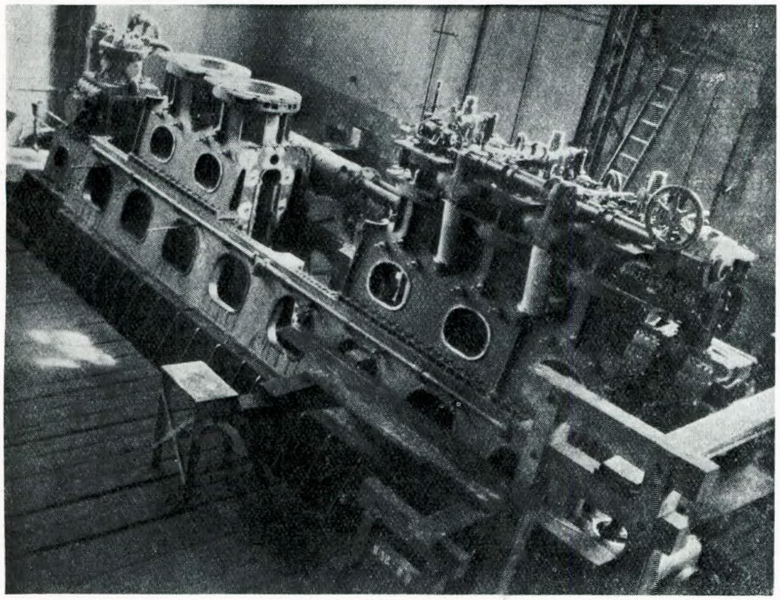
There were, of course, two distinct schools of thought on these matters, one asking for simplicity in design and construction, and the other seeing the possibilities of making "everything in one piece", in fact it was the old battle of the "cycles", but in another form.

The following views and comments were put forward as indicating some actual examples of Diesel machinery, etc., and special cases. An Italian lake public service motor vessel (to carry



VIEW 1.

up to 200 passengers in two classes) a number of which were put into service to obviate operating uneconomical steam paddle vessels, was fitted with



View 2.

engines of the three-cylinder air-injection type, 150 b.h.p. at 230 r.p.m., direct-coupled to a reversing propeller. The design and operation of this gear was very satisfactory as it allowed of a non-reversing engine, and, at the same time, it was not necessary to have clutches at all, as the blades of the propeller were moved to the neutral position by the engine itself, after which the engine continued to "idle round" on the governor, an excellent feature as it avoided the admittance of cold starting air to the combustion chamber at the numerous landing stages on the lakes. Similar vessels were fitted with hot-bulb type engines running at 500 r.p.m. but they were not a success either from the engineering point of view or that of the passengers.

View 1 indicated a four-cycle air-injection marine Diesel engine of 2,500 b.h.p. at 400 r.p.m. entirely suitable for cross-channel purposes and large ships in which 4, 6 or 8 such units could be coupled up to the propellers direct or through gearing. The engine in question presented all the features of rigidity and accessibility asked for by the author.

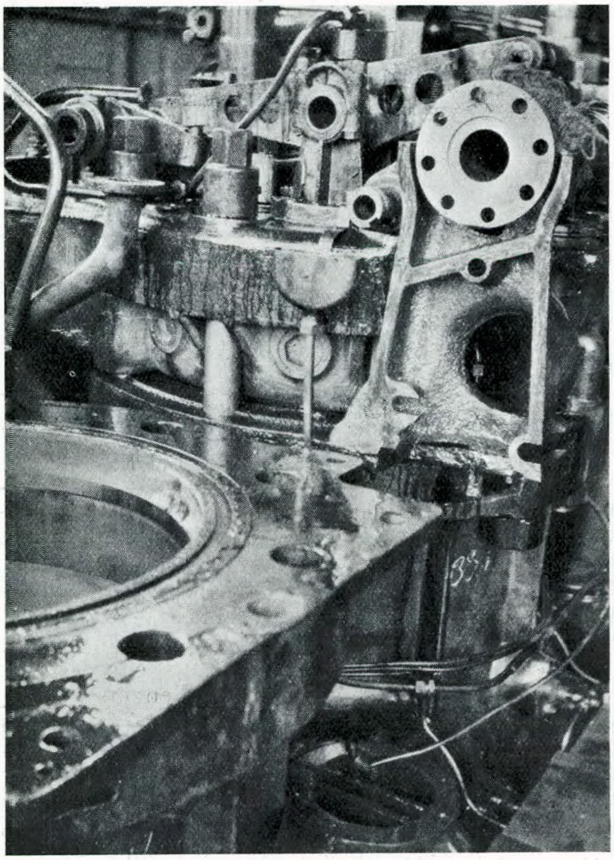
View 2 showed the engine in assembly, indicating clearly the unit construction of various parts which, from a true marine point of view, offered many advantages.

View 3 indicated the special feature of cylinder head construction with overhead cam shaft, the various components of which, due to sectional design, were so suitable for examination and overhaul. It should be pointed out that induction air could be and was arranged to be drawn from the upper crankcase, thus avoiding any trace of oil fumes reaching the engine room and passengers' quarters.

View 4 was of the control station, with which the author could be entirely satisfied as remote control was applicable; all movements of starting air to a separate air starting motor geared to flywheel, r.p.m. and power output were controlled from this wheel, with all engine gauges grouped at this point.

View 5 indicated the built-up piston, with crosshead integral with the piston rod. The crown part of the piston carrying some of the piston rings, was of forged steel, and was provided with oil cooling ribs; the lower part of the piston, carrying the remaining rings, was in cast iron. The skirt, which was merely used to cut down oil consumption, was made in aluminium.

The author referred to three point suspension, but an idea such as this could have no meaning where engines of 500 h.p. were concerned,

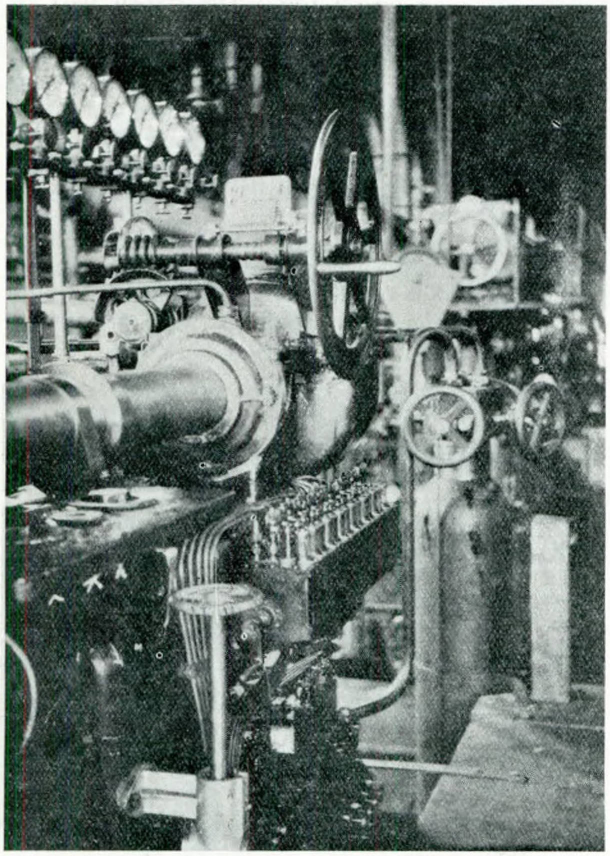


View 3.

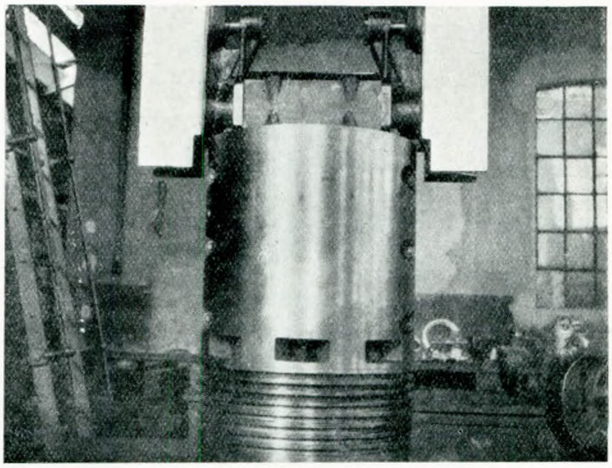
unless an era of light-weight machinery, acceptable to owners, builders and registration societies, was opening out before them, but possibly the author had in mind the last two lines of his paper "that if one dared to depart from the conventional many things were possible".

Apart from fresh water cooling now carried out for piston heads of quite large Diesel engines in service at sea, surely *closed* fresh water cooling could only apply to quite small units.

The form of suggested control from the bridge of large power marine sets, while interesting, was not entirely new. There were, however, practical considerations concerning the operation of Diesel sets which appeared to be insurmountable for this type of remote control. As an alternative why not suggest having the navigating folk down in the engine room to guide the ship, etc., by means of a periscope or similar device.



VIEW 4.



VIEW 5.

Unless an actual example of the Low engine had been in operation under marine conditions for some time, it was not fair to criticise the design except to say that the lubricating oil consumption of the cylinders would be enormous. He had had some experience with the novel piston cap with nut fixing; it was splendid, *on paper,* but the author would be surprised how soon it cracked, became burnt through or got loose.

One must compliment the author on breaking new ground, and it only remained to get financial support in order to have one or more vessels built with the high-piston-speed engines (Diesels) which would claim attention as they deserved to do.

The only example, as far as the contributor was aware, of control of the main engines from the bridge was now in operation in Venice for public service vessels, and operated quite satisfactorily, but the engines were of the steam reciprocating type and were fitted with poppet valves and rotary cam gear.

THE AUTHOR'S REPLY TO THE DISCUSSION.

The author, in reply, said that he was thankful that Mr. Calderwood had let him down so lightly. Mr. Calderwood had such a wealth of experience (acquired by his firm) at his disposal, that there must have been many things he could have said. One felt that there could be no problem in connection with the Diesel engine that he could not solve; in consequence it was somewhat difficult to argue with him. There were, however, one or two points on which he, the author, would have to differ.

He did not feel disposed to be drawn into a discussion about Dr. Diesel; on several occasions the author had put forward the name "Injection Engine", but "Diesel" had the merit of being shorter.

On the question of rigidity, he was in agreement with Mr. Calderwood that this was essential for freeing the vessel from vibration imparted by the engine. He was once asked by a large maker of engines whether a certain example would be suitable as a basis for a marine engine. He had

had to point out that, although this was a six cylinder engine, as it consisted of six structures mounted on a shallow bed plate there was not sufficient rigidity, and it was readily demonstrated that the flexing of this bed was very considerable. Not only must they prevent the ship from bending the engine but they must also guard against the engine bending the ship.

He did not agree with Mr. Calderwood on the question of constricted waterways. In a small high-powered engine the waterways would have to be small, but there were no ill effects likely to arise from this, provided clean, de-aerated and neutralised water was employed. This was quite a simple arrangement consisting of a closed circuit passing through a cooler, which in turn could be fed by scoops or a centrifugal pump. The enclosed circuit had its own circulating pump, while a make-good tank carried at a convenient height fed the circuit at the correct point.

He would venture to suggest that the trouble experienced by the record-breaking boat, "Miss England", was not unconnected with the use of sea water for cooling. With this class of vessel, where the water was literally skimmed from the surface of the sea (or lake), not only was it saturated with air, but there was actually free air present. As for the reserve of water in the jackets provided by the conventional system, he could not see that this could provide sufficient margin of time to be of any practical value.

There had been a great deal said about "bridge control", and generally speaking it was not viewed with favour by the engineer. At one time a mechanic was carried on a motor car; this was not done now as the machinery of the car had reached a form that was in accordance with requirements. The driver of a car had need of far greater concentration than the helmsman. The owner of the small yacht considered pilot-house control essential. Some time ago there was considerable opposition to bridge control by the United States equivalent of the British Board of Trade. They refused to sanction a Diesel-electric ferry in San Francisco with bridge control—until they saw and handled the job. For the main opposition to this arrangement they could refer to the usual engine supplied for marine propulsion, where a process of nursing was usually required for almost every evolution.

With regard to propeller speeds, he agreed that they were increasing; so were engine speeds, speaking from the point of view of possibilities in both cases, but the engine speed still retained the ratio that was mentioned.

The valve of reduction gear was very obvious in the case of a cabin cruiser in a short head sea, but here they had many examples for comparison. When they arrived at extreme speeds, 9,000 r.p.m. for instance, the circumstances were entirely different and all propeller data went by the board. There was obviously some figure of peripheral speed which introduced this new set of conditions, but this figure was far above the instances that they had before them.

He could not quite follow Mr. Calderwood on the point of piston speed, as he based his criticism on the author's neglect of "r", and he assumed equal weight for his illustration. The author would prefer to leave the matter as it is, because it was one engine that they had to consider and they had to ascertain how it might be possible to obtain better output from some given bore and stroke that they had available.

Mr. Calderwood criticised the Low engine on the following grounds:—

(*a*) The limiting factor was not pressure on the big end bearings.

(*b*) The limiting factor was more probably the mean effective pressure that could be carried.

(*c*) The oscillating bearings of the rocker would be the weak point.

(*d*) The air velocity of the scavenge air would be so excessive that the engine would be very inefficient.

The author desired to state that he could not agree that the big end was not the limiting factor, and with the Low engine the full speed full power load on both big end and main bearings was, perhaps, one third the normal. The rocker arm bearings, as they were designed, were capable of standing a very high load indeed, far beyond the needs of the engine, and the piston pin, with its small angle of movement, had also been legislated for.

The author considered that the limiting factor of b.m.e.p. was from the production side, rather than that of the application. If they might assume 100lb. b.m.e.p. for that engine, there was no real reason why it should not be carried. The point at which the cast iron head cracked was the limiting factor at one time. If a combustion head was made of a K.E. 965 forging, this limit no longer applied.

In regard to air velocity, the author stated that he understood that Mr. Low had arranged an air velocity of 110 feet per second through the air valves, and he assumed that the port velocity would be consistent with this.

They must consider this rocker somewhat in the light of a crosshead guide. A conventional slipper guide could be loaded to perhaps 100lb. and even then it was not very efficient, while a correctly designed link bearing was highly efficient and 6,000lb. per sq. in. would be a reasonable load.

They had some experience with two-stroke engines running at quite high speeds, 4,000 r.p.m. for instance, which gave a torque curve that offered a considerable amount of encouragement.

In reply to the comments of Dr. Davies the author stated that he would like to say that their disagreements had always been of a friendly nature, and he was very grateful for his concurrence in his views regarding crank pins.

Dr. Davies had stated that he did not like to take lubrication as read. There was a slight misunderstanding there; it was because the subject of lubrication required a paper in itself that he had been obliged to take it as read.

Mr. Du Bois desired to know why he had not stated which was the better kind of engine, the two-stroke or the four-stroke. He would have been glad to have made this statement if he had been able to do so from information that was quite definite and beyond question.

As Dr. Davies had stated, their material was idle too much of the time with the four-stroke cycle engine and this, with other defects, turned their attention to some alternative. With the gas engine the two-stroke system had so many detrimental features that it had been discredited. With the Diesel these faults were, in the main, eliminated, but there remained one dominant factor, the cost of scavening. In the four-stroke engine this was obviously 50 per cent. of the cost of the engine. If they had to employ another engine room and another battery of engines for this purpose their doubts might be justified. If the cast iron jacketed heads became vulnerable owing to the increase of heat transfer they had another element of doubt, and if the b.m.e.p. fell to half that of a four-stroke engine, as was the case of the crank-chamber scavenge engine, they were again paying 50 per cent. for scavenging. On the other hand, whatever may be decided to be the ideal form of combustion chamber with the four-stroke engine, this form had to be distorted to accommodate the valves; this, the author stated was a very important factor, and it encouraged them to ascertain whether it was not possible to eliminate the other detrimental features for the sake of the combustion chamber and cylinder cover facilities which were offered. He would point out that there was an exception in the matter of combustion chamber design, in the case of the Ricardo sleeve valve engine, but it was possible that this arrangement was limited as to cylinder diameter.

He would also point out that the two-stroke cycle had actually given outputs somewhat beyond those that were generally obtained from highly-developed four-stroke Diesel engines; if they could do that surely it was worth while putting up with a great deal in the way of overcoming difficulties to make use of this cycle. The output from the whole cycle, and piston speed, inversely decided the cost of the engine, and this was the correct method of reducing the cost in contradistinction to economies in workmanship and material.

He agreed with Mr. Du Bois that continental practice was more towards the employment of a separate reverse. This was all to their good and to the commercial detriment of their continental friends, as the separate reverse occupied more room, cost more, and it was inferior from the technical point of view.

As regards the point made with reference to accessibility, the author would ask why should one wish to get at the reverse gear? If it were well made, enclosed, protected and lubricated, there should be no necessity for easy access. The fetish of accessibility caused more trouble than it saved, and he asserted that, given correct design, material and workmanship, if the gear was closed up to keep away water and dirt, and if it was well lubricated, undue wear and its consequent troubles would be eliminated. He would point out that at one time motor car gear boxes were left open; this was for the purpose of oiling the shafts and ascertaining whether all the teeth were still there, and no one would deny that present-day practice was better.

The separate scavenge engine appeared to be a source of weakness, and it added to the vulnerability if the scavenge air supply was from a separate engine room, as the vulnerable length of the vessel was increased; it did not matter how the scavenge engines were duplicated, as a larger target was offered for a torpedo or projectile.

The author regretted that Mr. Strub should have expected him to put forward any definite constructive policy in a concrete manner as this would have had to take the form of some engine project in detail. The title of the paper would then have become "A Proposed Marine Diesel Engine", and if the project had been of any merit and the subject given a full measure of attention, this paper and its discussion could then have occupied the rest of the Session. This (the submission of a project) would have been out of the question at this juncture; besides it was very easy to criticise but quite a different matter to construct, and all the author could hope to do was to point, sometimes in an ill-mannered way, he was afraid, to such faults or weaknesses as had been disclosed to him.

Mr. Strub, a designer who had advanced the intermediate-sized engine from the mediocre to a very high class indeed, had suggested that the author should dogmatise on the selection of cycle. This point had already been dealt with by him and, therefore, all he would venture to suggest to Mr. Strub was that he should very closely investigate the governing factor—the cost of scavenging—in this decision, and when this was completed he would be able to see what bearing the valves had on the design of his ideal combustion chamber.

The author, at the outset, stated that he would not deal with the combustion side, and as fuel injection was but part of this problem he would again suggest that Mr. Strub should get out the exact cost of the blast air apparatus, add to this the percentage cost of the engine in indicated power absorbed, and this would give him the cost per h.p. for the scavenge air. In the matter of airless injection he would ask him to think in terms of "degrees of crankshaft movement" rather than in fractions of a second, as the major portion of the trouble that had been experienced with airless injection had been due to the failure to properly equate "time", acceleration and degrees of crankshaft movement.

The author fully appreciated Mr. Strub's protest in regard to the barge engine shown and criticised by him (the author), but Mr. Strub had overlooked the fact that a barge was a very unstable structure; it was often badly loaded and frequently rested on an uneven bottom, and more than one instance had occurred within the author's knowledge of faults with such propelling machinery from this cause. On the other hand the engine might do so well in a barge that it was transferred to a fishing boat, for instance, and it was then accepted as the makers' conception of a marine engine.

The author assumed that Mr. Strub referred to bearing liners in his remarks on white metalling. There was one rule only, as far as the author knew—the white metal should be as thin as possible, in a bronze shell, the limiting factor being set by the commercial machining error in the shell before metalling. With a steel shell the thickness could be increased so as to ensure that the steel did not make contact with the shaft. For instance, with an 8in. shaft he would expect $\frac{1}{16}$in. thickness in a bronze shell, and $\frac{3}{32}$in. in steel would be a good compromise.

Mr. Strub's statement, which confirmed that of Mr. Calderwood, that liner wear was independent of the position of the piston rings in relation to the water space, was in opposition to the author's personal experience, and, what was more important, was tantamount to stating that this wear was independent of temperature. The author would like to suggest that if the rings were allowed to attain a very high temperature a comparatively small difference in the temperature of the upper part of the liner would not be noticed in the matter of wear. The author did agree that the secret of liner wear had yet to be found and, perhaps, Mr. Strub could state whether air compressor practice threw any light on the subject.

The author, in reply to Mr. Hardy, said he considered that he had already said a great deal about the application of high-speed engines to large vessels. So far, all that they had seen in this direction were adaptations and improvisions, while the requirements were a clean sheet of paper and the unbiased selection of such material as they had before them.

If they selected some of the ingredients of the M.A.N., Sulzer, Beardmore, Allen and other engines, seasoned them with some of the new ideas of which they were hearing, and poured them into a mould made of welded steel by Stevens on the Low principle, and if they interposed a Burn or Beardmore internal reduction gear, according to the ratio required, they could give a liner nearly 100,000 h.p. on four shafts, each with its direct-coupled reversing engine. They could do this and give the purser's department space for an ice-skating rink, should it so be desired and they could mount these balanced units in such a manner that they would not impart any vibration to the hull.

Practically the whole of the above suggestion arose from the experience that had been gained from the motor-boat, either direct or implied, and still following this experience they would carry the controls to the bridge in order to eliminate that minor delay and the slight risk of confusion of orders.

The author agreed that Diesel-electric propulsion should be seriously considered—as being quite unsuitable for the purpose. Its cost was high, and its weight was equal to the prime mover. The sole reason for its introduction was that at that time the Americans were not able to construct a Diesel engine that could be manœuvred with ease and absolute certainty.

The author stated that he was glad that Commander Nicholson had paid such attention in his remarks to the questions of enclosure and lubrication.

Coupled with enclosure was the problem of venting the crank chamber, and there they had one of those inexplicable things that sometimes occurred. Crank chamber venting to the induction system was very old; it was employed in the "A" type submarines and was now very often found in small marine Diesel engines, but in the interim it appeared to have been neglected. The modern design of marine Diesel incorporated the crank chamber vent and the air intake in the cylinder cover hood, and thereby effected silencing, air filtering and a certain amount of cooling, and this arrangement paved the way to an air pipe that would allow of submersibility.

He agreed that it was also necessary for the oil to be kept in the engine and would state that this was quite a simple matter, providing it was kept in mind from the commencement of the design. He assured Commander Nicholson that there were several packings, "Vellumoid" was one, that would effectively seal any reasonable joint against even fuel oil leak. The author could not agree with the suggestion that there was a reasonable danger of over-cooling. Oil was so difficult to cool that this trouble could hardly be anticipated. He also did not agree with the suggestion for a large bulk of oil with natural cooling. What was natural cooling might be asked?

He agreed that the fears expressed regarding the contamination of the oil in a general gravity system with common supply, were not entirely groundless. Nevertheless, if reasonable precautions were taken, such as a sight delivery from the auxiliary engine and a thermometer, and if all the precautions suggested by Commander Nicholson, including an effective centrifuge and filter system were employed, and if an oil having a minimum emulsifying factor were used, this common supply system, taking it all round, was to be preferred to a multitude of separate lubricating units.

The author was aware that Beardmores had employed the comparatively high crank pin loading of 3,600lb. and, moreover, that they had records of a Diesel train that ran for 2,500 miles without overhaul, under these conditions.

The author was very glad that Commander Nicholson had risen to the bait cast with reference to the lubrication of large engines, and he would amend his statement by saying that there was very little that could be suggested of value on the subject that was not already known, this being in place of the inference that there was very little that could be done that was not already common practice.

In order to summarise the suggestions that have been made the author submitted that the following appeared to be in accordance with Commander Nicholson's views, and in which he, the author, concurred :—

As regards the engine, the water and dirt must be kept out and the oil retained. A constant, definite feed at some designed pressure must be maintained, and the author would add that this should be applied for an appreciable time before the engine was moved.

The oil to be immediately collected from the engine, roughly filtered, passed to a heating tank and maintained at such a viscosity that water and heavy impurities could decant. The whole of this oil should then be centrifuged and delivered via a cooler to a running tank having a considerable capacity, and then either delivered by gravity or by a separate pump to the engines. Gravity or the separate pump allowed for the priming of the engine before starting, and, obviously, the above system should be in duplicate.

Mr. McLaren stated that the bilge should be freed from oil before it was pumped overboard. The author agreed and remarked that far too much oil went into the bilges; this neglect was perhaps inherited from steam, but there was every reason why some form of separating tank should be used, even on quite small vessels.

He assured Mr. McLaren that there was no difficulty at all in dealing with the controls of a small twin-screw vessel as well as the usual helmsman's duties, even in quite bad weather or other adverse circumstances, providing the controls were as they should be and the propelling machinery was satisfactory. There was a suggestion in Mr. McLaren's contribution that the author was instigating a movement for the abolition of the marine engineer. This was not the case, but on the other hand the author's views were that in small and moderate size vessels, from the small yacht to the 10,000 ton tramp steamer, the engineer could be better employed supervising his machinery, looking after his fuel and lubricating oil cleaning apparatus, electric light plant, and other jobs about the ship, than in standing by the gear for the whole of his watch. If he was there, or thereabouts, he was wasting his time; if he was away from the gear it would, in the case of an accident, have been better if there had been bridge control.

The author stated that he was very interested in the information given by Mr. Hamilton Martin concerning liner wear in the Rupa engine, as well as the interesting comparison showing the effect of oil impurities in a Sulzer engine. He considered that they should look upon liner and piston ring wear from several angles. First of all there was the wear set up through metallic contact at high pressures as so often occurred when the rings were at rest at the top of the stroke. In this case the film had broken down because of :—(*a*) decomposition of the oil owing to temperature rise; (*b*) undue fall in viscosity of oil; (*c*) excessive pressure at the back of the ring and (*d*) uneven contact between ring and liner. The factor (*a*) could be controlled by proper oil tests, though it would appear that these tests were seldom carried out. The value of an oil could also be determined by the weight per sq. inch which a film would support at the actual working temperature. This test did not appear to be in general use; it was quite a simple test, with the correct apparatus, and the author made some suggestions in this connection some years back (see Transactions of the Diesel Engine Users Association). The factor (*c*) was one that had been greatly neglected. Doxfords had made some progress, but there appeared to be several methods available that had not yet been tried. The factor (*d*) was generally an effect—not a cause—and it behoved them to see that it was never the latter.

Impurities in the fuel provided a further cause of wear, for instance, the mineral matter in the oil mentioned by Mr. Martin, the coal ash in the Rupa engine, dust from the atmosphere, iron oxide from the combustion chamber, and so on. With the oil engine there was no excuse for using an oil with an abrasive content, and if the oil companies were not able to supply an oil, at a reasonable figure, which complied with this qualification, the author was of the opinion that all vessels, of any size, should be arranged with fuel cleaning gear. This gear would no doubt pay for itself in two ways; it would allow a somewhat cheaper oil to be purchased and it would save liners and rings.

Last of all came the elusive question of materials. The author considered that ordinary soft cast iron, which did so well in the steam engine, was quite unsuitable for the Diesel. Mild steel also appeared to be out of the question, but they had very little information in regard to the properties of case hardened or cyanide hardened steel. Hard cast iron having a Brinell of about 500 gave good results. Nitralloy was far too costly at present, but nitrocast iron gave very great promise, as shown by Mr. Hamilton Martin.

The author pointed out that there still remained the question of ring material. Were these rings to be softer or harder than the liner? Were they to be of forged RR on nitro cast iron, or nitralloy on heat treated liners? They did not know, and it was here that the excellent proposals of Mr. Hamilton Martin for joint research were of such value. The Institute of Automobile Engineers Research Department were dealing with the subject as applied to automobile engines; who would tackle the 24in. liner?

The author reverted to Mr. Calderwood's remarks to the effect that the passing of the fire ring into the uncooled or shrouded part of the liner had no effect. If this was the case, one was led to conjecture why the aeronautical people who specialized in big outputs in the way of b.m.e.p., should take such care to cool that critical part of the cylinder.

Lieut. Bastianini very rightly pointed out that the development of the high-speed engine in the higher powers was of more interest than the work that was being done in connection with the smaller units that had been mentioned.

The author would state that it was a matter of very great regret that he was not able, for reasons that were entirely non-technical, to outline an engine that would, he felt sure, very greatly interest Lieut. Bastianini, as this example went far beyond anything that had been made public so far.

The collective position appeared to be that engines had been constructed in units just under ten thousand horse power, piston speeds with double-acting two-stroke engines had reached the limit which Mr. Calderwood admitted to the high-speed class, namely 1,800 f.m.p., weights were just below 25lb. per h.p. and brake mean effective pressures were round about 90lb.

On the authority of "Punch", and it was many years ago, a certain potentate on being informed that the British had a battleship mounting six twelve inch guns, immediately gave the order for a vessel to be built with twelve twenty-four inch weapons. This was a very good policy to follow. Did not Rudyard Kipling tell them to "set your light so shining, one in front of the next"? When, therefore, the designer came along and began doubling this and halving the other they must be patient, they must follow his reasoning, his deductions and his proofs, so that in due course they might go even part of the way with him.

Could they increase piston speeds? In the author's opinion, they undoubtedly could do so, right up to 3,000 f.p.m., without the dire results predicted by Mr. Calderwood, providing proper arrangements were made. Could they exceed 90lb. b.m.e.p.? This was quite possible; the author had recorded 150lb. mean indicated effective pressure at 1,200 r.p.m. and a piston speed of 2,000 f.p.m. with perfect combustion and a reasonable fuel economy. If they did so, they could reduce the weight, and if they could apply these conditions to a 600 mm. engine, they would accomplish that which was desired. If this was considered impossible the author would suggest that those who knew should state the limiting factors; it might be the cast iron cylinder heads, it might be piston cooling, or even scavenge air pressures; therefore, let them call for their "twelve twenty-four inch guns" with the object of disclosing the limitations.

Although Diesel-electric propulsion had been ruled out of the paper the author would state that in his opinion the limiting factor was the weight of the electrical transmission apparatus which, he was informed, could not be less than 20lb. per h.p. more than the weight of the prime movers they anticipated.

Merchant ships' generator sets had been somewhat of a disgrace to the profession for some time. They had failed to develop, though there were now definite signs in this direction. The main reason was that an ordinary land engine had been taken and dumped into the vessel with no thought or imagination. The author considered that generator sets could be one third of the present weight and quite free from vibration, should the purchasers so desire, and this could be accompanied by satisfactory running in every respect.

The author would state, in answer to Mr. Pudney's suggestion, that his remarks relating to total enclosure were intended to apply to all classes of propelling and auxiliary machinery. Mr. Pudney suggested that the main objective of this enclosure was to counteract the effect of general neglect and inefficiency on the part of the engine room staff. This was far from the case; it was a definite cleavage from the old steam practice where the design, machining and materials made it essential that every bearing, every working part had to be nursed with skill and close attention to ensure their continuing to function. The engineer's art had advanced beyond that stage, and, in consequence, a well-designed engine could be left to itself and the skilled engineer could devote his attention to some useful job of work, unless Mr. Pudney insisted that he should spend his time standing by the gear—" Steaming to bell for fourteen days o' snow and floe an' blow——". It was true that the old order of things died hard, but the author very much doubted whether even "Mr. M'Andrew", who said that "there was a glimmer left to cheer the Man—the Artifex and that by that light we'll build the perfect ship", would object. Whatever the engineer of to-day might think the engineer of to-morrow would demand rigidity and protection.

The author did not follow Mr. Pudney's reference to "making everything in one piece". Mr. Stevens would make his welded structure reach from the sump to the cylinder cover cowel level, even if it was thirty feet high. Into this he would weld or bolt all the components, and he would enclose everything with wrapper plates or covers as might be required. If it was desired to remove the crankshaft, this could be done with comparative ease; if it was the piston rings that needed inspection, head room of two feet above the cowel would suffice, while between such overhauls the engine would be closed up, the oil kept in, and the wet and dirt kept out.

The author did not consider a reversing propeller a reasonable appliance for normal engines, though it was a help when there was some difficulty in starting. Such a gear was not required in the case of a steam engine in which the retardation and reversal of motion was powerful, immediate and certain, as exemplified in a rolling mill engine for instance (incidentally, they had there an excellent example of control quite remote from the engine), and it only remained for them to produce a marine oil engine which incorporated these features and thereby eliminate any further consideration of reversing propellers or reversing gear. The author would like to point out that the reversing propeller had the grave defect that it had no real definite neutral position and in the larger powers it was slow and heavy to operate. A clutch was really an essential adjunct to a reversing propeller.

Space did not permit of an analysis of the engine submitted by Mr. Pudney, even if the drawings were available, but the illustrations, Views 1, 2 and 3, disclosed that the structure was far from rigid, and View 1 served to remind the author to ask what was the cost and weight of the apparatus employed for the compression, storage and distribution of blast air?

Mr. Pudney stated that he could not see how three point suspension could be applied to engines of 500 h.p. or over, unless one dared to depart from the conventional. The author considered that in the matter of the marine Diesel engine, large or small, high-speed or low-speed, they had arrived at the parting of the ways. Some of them would travel along the old, well-made road, while others would take the more difficult track and explore every new process, new material, new design, and new system, and would investigate these with an open mind and analyse them without prejudice. They would sort over their material as the diamond sorter works, selecting that which was of value and discarding the rest, and provided they welcomed any idea that had some actual potential merit and discarded mere aimless alternatives, placed no faith in reputations, and kept the main objective always before them, they would, after much toil, arrive at a very fertile and pleasant plateau and the old road would become but a happy memory.

In the matter of three point suspension for large engines for passenger ships, for instance, an engine room with two or perhaps three 15,000 h.p. engines direct-coupled and turning at 250 r.p.m., the author would consider it quite a reasonable project to locate the thrusts right aft and couple the engines to the propeller shaft proper by a comparatively long length of small diameter high tensile steel shaft. The engine, if it were on the Low system with a welded frame, would be so short and rigid that it could be mounted at three points, or even compound-mounted with four points. It would be insulated from the hull structure by springs and oil dash pots with radius rods to deal with lateral strains, these radius rods being, in turn, spring and dash pot mounted. With this arrangement, provided the propeller was balanced and correct, they could have a passenger vessel without vibration, and the author suggested that this would prove quite an attraction to those who had had some experience of modern ocean travel.

To refer again to remote control, Mr. Pudney suggested that there were practical considerations concerning the operation of Diesel sets which appeared to be insurmountable for this type of remote control. In the author's opinion these difficulties could be overcome.

Mr. Pudney criticised certain features of the Low engine, for instance, he suggested that the oil consumption of the cylinders would be enormous. This was not so. Mr. Pudney stated that he had had some experience with the novel piston cap; this could hardly be the case as he also stated that his piston cap burned and cracked and worked loose. The author thought that it must have been quite a different cap and of quite different materials, especially if there was any sign of burning. He had trouble many years ago with piston caps that had to be discarded, mainly through burning and scaling, but there was no need to use such materials nowadays.

Mr. Wells rightly pointed out that the piston speed squared law only applied to some given piston stroke. What the author had in mind was that there was a set of problems appertaining to periodicity that he did not propose to consider. Also, in small racing engines, motor-cycle engines and "outboards", where revolution speeds of five or six thousand were attained, 1,000 r.p.m. was considered but "ticking over", while a reciprocating steam engine turning at 200 would frighten an engineer from an engine room where 65 revs. was full speed. Again, their main problem was pressure per square inch on the crank pin bearings of the engine they were dealing with, and the fact that, with a longer stroke, higher piston speeds were possible only reflected upon those designers who had been dealing with the larger engines and had failed to take advantage of this fact.

In reference to the objections raised in connection with the Willans engine, the author would remind Mr. Wells of the advent of the Belliss engine when it was stated that it was impossible to expect a double-acting engine to run at those speeds. But this sort of thing was repeated at the advent of every innovation.

In regard to the cancellation of inertia pressures by gas pressures in the double-acting two-stroke and the Low engine, this would, perhaps, have been better put the other way. In Fig. 14 the polar diagram showed the gas pressure load on the pin, both on the compression and combustion strokes. This gas pressure curve remained approximately constant for all speeds. The inertia load varied with the square of the speed and as it was opposed to the gas pressure load it could be adjusted to more or less cancel out the gas load. An examination of this diagram would show that at one particular speed with the Low engine there was no work being transmitted to the crank shaft during the combustion stroke, as this was being stored up in the reciprocating parts for delivery during the latter half of the compression stroke.

Mr. Wells wished to know how the Low engine differed from the Wigzell engine. This latter engine was a modification of the Fleming and Ferguson system and a modification of no practical value. The objective of this engine was to employ one crank without that detrimental feature of a steam engine, the dead centre. With this engine a double-acting cylinder was essential and the dominating feature of the Low engine—the scavenge manœuvring cylinder—could not be so readily applied. The measure of advance in the Low engine was shown by the reduction in length, weight and cost of construction, and the exceptional manœuvring control provided by the air cylinders at a comparatively low air pressure, as illustrated in Fig. 13.

Final Remarks.

Mr. Strub, at the conclusion of his remarks said: "but everything must be right". That was so, but the difficulty was that they were so prone to assume that what they had accomplished was *ipso facto* correct. What they should do was to premise the exact requirements and then endeavour to comply exactly with them. For instance, no one would dispute that the exact requirements of a Diesel reversing system were as follows:—To apply without delay and without fear of contingencies, and by one simple arbitrary movement, a torque to the propeller shaft that was sufficient to rapidly bring the shaft to rest and rotate it in the opposite direction at the full load torque of the engine, and to do this with the vessel moving ahead at full speed. If this was accepted as a correct premise, then it was the designers duty to comply with it in an economic, practical and reasonable manner. Was it reasonable to spend another £3 per h.p. and add a weight of 20lb. for this purpose? Did it really comply when they had to apply a brake to the engine and then, when it had stopped moving ahead (and not before) move the lever to the astern position in stages, each having its psychological moment for application? The author suggested that this was not the case and that such gear carried to the bridge was really tantamount to a periscope taken to the engine room for the chief to "con." the ship.

Communicated later by the Author.

In the "Daily Mail" of November 1st was a short article written from Southampton on the repairing of the "Olympic" in which the statement of a sea-going engineer was set out as follows:—

"On the North Atlantic, in heavy weather, the engines are subjected to very unequal strains due to the labouring of the ship. . . . When the amidship section of a liner is caught on the crest of a wave, and the ends are not equally supported, a tremendous strain is imposed. . . ."

The article takes the usual form of technical articles in the daily press, but it did serve as an exemplification of the contentions that the author had made on the subject of rigidity and flexible mounting.

INSTITUTE NOTES.

OBITUARY.—Sir Dugald Clerk, K.B.E., F.R.S., Hon. Vice-President.

Sir Dugald Clerk, K.B.E., F.R.S., who died on Saturday, November 12th, at his home at Ewhurst, Surrey, in his seventy-ninth year, was an inventive genius who combined scientific theory with practical knowledge. He was known all over the world for his researches on internal combustion engines, the properties and possibilities of gaseous fuel and gas lighting and heating, in addition to his intimate knowledge of all industries in which chemical reactions are involved.

The son of Mr. Donald Clerk, machinist, of Glasgow, he was born on March 31st, 1854, and was educated at the West of Scotland Technical College, Anderson College, Glasgow, and the Yorkshire College, Leeds. He obtained technical training at his father's works, and in 1877 joined Thomson, Sterne and Co., the Crown iron works, Glasgow, when he began his experiments on the gas engine. From 1892 to 1899 he was scientific director of Kynoch's, Birmingham.

The discovery that he made in 1881 of an alternative to the Otto cycle, followed by the construction of a two-stroke engine, was in advance of his time, and it was not till some 30 years later that its full importance was realised and the Clerk cycle was generally adopted. His researches on the specific heat of gases and on explosive pressure led in 1908 to his election as a fellow of the Royal Society; he served on the Council and received a Royal medal in 1924.

Two years before, he was awarded the Albert medal of the Royal Society of Arts for his work on the development of the internal combustion engine, and was for two years chairman of council of the society. He was president of the Engineering Section of the British Association at the Dublin meeting in 1908. He was Watt medallist, Telford prizeman, and gold medallist of the Institution of Civil Engineers, and was elected president for this year, but ill-health prevented him from taking office. He was president's medallist of the Gas Institute, and past president of the Junior Institution of Engineers, the Society of British Gas Industries, the Institution of Gas Engineers, and the Incorporated Association of Automobile Engineers. In 1929 he was elected an honorary vice-president of the Institute of Marine Engineers in recognition of his personal adjudication of the first Herbert Akroyd-Stuart Award. He had been chairman of the delegacy of the City and Guilds Engineering College, was a member of the University Grants Committee, and a member of the Court of the Goldsmiths' Company, of which he had been Prime Warden. Clerk was a judge at the Automobile Club trials at Richmond in 1899 and the 1,000 miles trials in 1900, and at the reliability trials at Glasgow in 1901 and the Crystal Palace in 1903.

In the War, Clerk served as director of engineering research at the Admiralty, and as member of the Advisory Committee for Aeronautics at the Air Ministry and chairman of the internal combustion engine committee of that body, and member of the Air Inventions Committee and of the Panel Board of Invention and Research. He was the author of standard works on the gas and petrol engines, and of numerous papers and lectures. He was created K.B.E. in 1917, and had received honorary degrees from Manchester, Liverpool, Leeds, Glasgow, and St. Andrews Universities. Since 1888 he had been in partnership with the present Lord Marks as consulting engineer and patent expert, and was in active practice till shortly before his death. He was a member of the Athenaeum (Rule II.), the Reform, the Royal Automobile, and the Royal Clyde Yacht Clubs. Sir Dugald Clerk married in 1883 Margaret, daughter of Mr. Alexander Hannay, of Helensburgh; she died in 1930.

ELECTION OF MEMBERS.

List of those elected at Council Meeting held on Monday, November 7th, 1932.

Members.

Charles Albani, Coastguards & Fisheries Service, Alexandria, Egypt.

James Anderson, 16, Drumoyne Square, Glasgow, S.W.1.

James Cameron Baillie, 1, Shandon Street, Edinburgh.

Stanley Smith Cook, 94, St. Georges Terrace, Newcastle-on-Tyne.

Robert Livingstone Gillies, Union S.S. Co. of N.Z., Wellington, N.Z.

Joseph Edgar Francis Griggs, 89, Queen Street, Barry, Glam.

Arnot Hepburn Knox, 11, Springfield Park Road, Burnside, Rutherglen, Glasgow.

Robert Lang, 191 Boreland Drive, Knightswood, Glasgow.

David Cyril Leathley, 11, Russell Terrace, Bean Street, Hull.

Robert Charles Hermon Milne, Castle Rock, Mortehoe, N. Devon.

Walter Charles Wright, Oakfield Cottage, Overdale Road, Willaston, Wirral, Cheshire.

Francis Kildare Wynn, 94, St. Dunstans Avenue, Acton, W.3.

Associate Members.

Robert Alexander Hobson, 15, Denwick Terrace, Tynemouth.

Geoffrey Mann, c/o Lynwood, London Road, Ditton, Kent.

Robert McMurdo Wallace, 59, Dongola Road, Ayr.

Harold Napier Williams, Ravenscroft Flats "C", 20, Furzedown Road, Southampton.

Associates.

John Barclay Polland, 5, Clarence Lawn, Dover.

Edward Purvis, 332, Cherryhinton Road, Cambridge.

Transferred from Associate Member to Member.

Francis S. Grant, 28, Brisbane Road, Ilford, Essex.

James Shaw, 22, Kelburne Drive, Paisley.

ADDITIONS TO THE LIBRARY.

Purchased.

Kings Rules and A.I. Amendments (K.R. 8/32, K.R. 9/32 and K.R. 10/32). Published, 1932, by H.M. Stationery Office at 2d., 1d. and 3d. net. respectively.

Presented by the Publishers.

Nickel Bulletins, published by The Mond Nickel Co., Ltd., on :—

"Rolled Nickel in Composite Metal Products".
"'Ni-Resist' Valves for the Chemical Industry".

Report of the Advisory Committee of the William Froude Laboratory for the year ended 31st December, 1931 (for official use). Published by the National Physical Laboratory.

Advanced Proofs of the following papers from The American Society of Naval Architects and Marine Engineers :—

Pitre on "Trial Analysis Methods".
Kempf on "Measurements of the Propulsive and Structural Characteristics of Ships".
Eggert on "Propeller Cavitation".
Saunders on "Tests on Three Geometrically-Similar Ship Models".
Bibber on "Welding Longitudinal Seams of Shell Plating".
Rock on "Education of Naval Constructors and Naval Architects".
Niedermair on "Stability of Ships after Damage".
Norton on "Raising the s.s. 'Segovia'."
McComb on "Structural Hazards on Shipboard".
Schoenherr on "Resistance of Flat Surfaces Moving through a Fluid".
Roop on "Elastic Characteristics of a Naval Tank Vessel".
Smith on "Propulsion Turbines and Gears for Panama Mail Steamships".
Burkhardt on "Performance of the 'Mariposa' and 'Monterey'."

Hague on "Performance of Standard Oil Tankers".
Roe on "Modern Power Plant Practice and its Application to Marine Work".
King on "Machinery for Modern Cargo Ships".

Calendar for the Session, 1932-33, of the University of London.

British Standard Specifications as follows:—
No. 349-1932. Identification Colours for Gas Cylinders.
No. 461-1932. Bordeaux Connections for Wire Rope and Chain for General Engineering Purposes.
No. 462-1932. Bull Dog Grips for Wire Ropes for General Engineering Purposes.
No. 463-1932. Sockets for Wire Ropes for General Engineering Purposes.
No. 464-1932. Thimbles for Wire Ropes for General Engineering Purposes.
No. 465-1932. The Quality of Pitched or Calibrated Wrought Iron Load Chain for Hand Operated Pulley Blocks.
No. 466-1932. Electric Overhead Travelling Cranes (Power Driven in all Motions).
No. 467-1932. Marking and Colouring of Foundry Patterns.
No. 10-Part 5-1932. Pipe Flanges (For Land Use).

Bulletin No. 243 of the University of Illinois on "The Creep of Lead and Lead Alloys used for Cable Sheathing".

Rensselaer Polytechnic Institute Bulletin No. 37 on "Solution of Special Problems in Pipe Flow by Graphical Analysis".

Transactions of the Liverpool Engineering Society, Vol. LIII, 1931-32, containing the following papers:—
Bolt on "Oil Fuel for Steam Raising Purposes".
Duncanson and Malley on "An Automatically Operated Pumping Plant".
Willcox on "The Maintenance of a Dredging Fleet".
Harris on "Some Enquiries from the Manager to the Expert".
O'Brien on "Electrification of Main Line Railways".
Gregson on "Coal Fired Marine Boilers".
Herrod on "Piling as Applied to Foundations".
Rylands on 'A Discussion on Wages".
Scholes on "Carburettors".
McLeod on "Mechanical Gearing".
Bryant on "Depreciation in Special Reference to Merchant Tonnage".

Bulletin No. 36, Session 1932, of L'Association Technique Maritime et Aeronautique, containing the following papers:—
"La pêche frigorifique et les chalutiers congélateurs", by R. de Boysson.
"Moyens de sauvetage modernes", by Professeur L. Ghirardi.
"La propulsion Diesel électrique des bâtiments spéciaux", by A. Avril.
"Fatigue et mouvement des bâtiments sur l'eau", by L. Kahn.
"Les possibilités de fonctionnement du moteur Diesel aux huiles de goudron de houille sans utilisation d'huile spéciale pour l'allumage", by M. Gautier.
"Etude de la qualité antidétonante d'un combustible sur moteur à explosion basée sur les mesures des quantités de chaleur communiquées à l'eau de refroidissement", by R. Champsaur.
"Pièces biconiques ou galbées chargées debout", by J. Danis.
"Principes d'adaptation des groupes motopropulseurs des avions multimoteurs par la méthode graphique à échelles logarithmiques", by G. Bilbault.
"Remarques sur l'équilibrage des forces d'inertie dans les moteurs en étoile", by G. Lehr.
"Quelques aspects de la technique du dirigeable", by P. Jouglard.
"Etude sur un avion du fonctionnement du groupe motopropulseur et recherche de l'adaptation", by G. Bilbault.
"Contribution à l'étude expérimentale du sondage acoustique par échos à bord d'aéronefs bruyants", by G. Florisson.
"Note sur les hélices sustentatrices au point fixe et en mouvement de translation uniforme", by M. Œhmichen.
"Note sur la trempe à l'eau des lattes en bois de gaïac pour coussinets de lignes d'arbres", by A. Vaphides.
"Considérations sur le rouis", by A. Pommellet.
"Influence de la marche d'un navire sur l'amortissement du roulis", by R. Legendre.
"Stabilité des mâts de charge à bord des navires", by A. Pommellet.
"Sur la déformation et les tensions internes des tuyaux à ligne moyenne plane", by Thuloup.
"Note sur les principales averies par corrosion des tubes de condenseurs et réfrigérants en laiton", by J. Chaintreuil and H. de Leiris.
"Emploi de tubes non lisses sur les tuyautages de vapeur", by H. de Leiris.
"Sur un problème général de flambement des poutres droites à section constante", by A. Thuloup.
"Flambement des poutres droites par déformation gauche", by A. Thuloup.
"Note sur la vibration des périscopes sous-marins", by G. Cahen.
"Oscillations de torsion des arbres (calcul des amplitudes)", by J. Mancy.
"Note au sujet de calcul des vitesses critiques de flambement des lignes d'arbres de navires", by L. Doucet.
"Stabilité d'une enveloppe cylindrique à section circulaire soumise à une pression extérieure", by J. Mancy.
"Formes de carènes de moindre résistance", by V. Yourkevitch.
"Note sur lat théorie des hélices; calcul des couples et poussées; détermination des pressions locales; prévision de la cavitation", by R. Brard.
"La cavitation des carènes (étude expérimentale)", by R. Legras.
"Régimes d'ecoulement par tranches d'un gaz parfait dans une tuyère ou un diffuser", by M. Toy.
"Cavitation et changement de régime", by R. Legras.

"Industrial Microscopy", by Walter Garner, M.Sc., F.R.M.S. Published, 1932, by Sir Isaac Pitman & Sons, Ltd., London, W.C.2. 21s. net. 389pp.

A cursory study of this book, which is addressed to "all who use the microscope in industry", would indicate that the author has gone to very great pains to make his work thoroughly comprehensive and of value to those to whom it is intended to be of service.

It is a technical work designed for the service of a highly technical community, and is well worthy of a place in a marine engineer's library if for no other reason than that he will see in it examples of beautifully-designed apparatus, and will find born within him a deep respect for the research specialists who are skilled in the use of such apparatus, and in the extraordinary examples of types of work in which this book is rich.

So far as the book is concerned with microscopy, it seems safe to state that the author has not only covered the ground which he has set out to cover, but that he has, by the aid of a comprehensive bibliography at the end of each section, made it easy for those capable of appreciating the subject to delve further into special phases of the matters of which he treats.

It is to be regretted that the author did not devote a section or so to the science of microscopy as it has been brought to the aid of the metallurgist, instead of dealing only with such branches as interest the chemist, the biologist, the botanist and other experts not especially concerned with metals.

The book is excellently produced, and it leads one to hope that opportunity will be afforded later of reviewing a book more especially devoted to that branch of microscopy which could rightly be termed "Engineering Microscopy".

"Notes on Marine Insurance Practice", by "Clarus". Published, 1932, by Lloyd's List and Shipping Gazette. 2s. 6d. net.

Written by a man having intimate, everyday experience of and association with marine insurance and the delicate and complicated questions which arise in the course of settling and adjusting insurance claims, this book provides many examples, by study of which it is possible to get a sound basic idea of the principles which underlie the practice of marine insurance.

The book is one which can be heartily commended to the attention of marine engineers, for the reason that they will find it helpful in enabling them to appreciate the framework upon which the practice of insuring ships and cargoes has been built, and to follow fairly easily the trend of arguments in connection with claims and so on, with which they may occasionally be brought into contact.

This book cannot be regarded as a comprehensive treatise on every aspect of the subject, but those who read it carefully will certainly find themselves in a much better position to understand what is required in regard to marine insurance questions, than they would if they became involved in some problem without previous knowledge or experience.

We recommend this work to our Members as an exceedingly useful addition to a marine engineer's library; at its modest price it is excellent value.

Lloyd's Calendar, 1933. Published by the Corporation of Lloyd's, London, E.C.3. 3s. 6d. net.

This book is one which should be in the possession of every master and chief officer, as well as on the office bookshelf of all those who are concerned with the marine world on shore. It is a book which one finds, from personal experience, to be capable of providing information of value and food for thought throughout the whole of the year. It is at once a "dictionary" on matters of every day importance, and a work of interest and reference covering the most important of the many phases of affairs as they vary from year to year. One feature alone serves to illustrate the latter point—that entitled "Law Cases of Interest", while the numerous tables and other data which one naturally looks for in the Calendar ensure that the book will be well thumbed, as also does the international glossary of important technical terms.

It is impossible in a short review to give even an outline of the contents of the eleven sections into which the book is divided, but as the type is small, the number of pages of text, 777, and the whole book indexed carefully, the index itself running to eleven pages, it will be gathered that the work is well worth the relatively small sum at which it can be purchased.

"Theory of Electricity and Magnetism", "Theory of Light", "Theory of Heat", by Professor Max Planck. Translated by Professor Henry L. Brose. Published, 1932, by Macmillan & Co., Ltd., at 10s. 6d., 10s. 6d. and 12s. net. respectively.

These three volumes are a decided acquisition to the library. Professor Planck's work in the advancement of our knowledge of the fundamentals of physics is well known, and it was a happy thought that prompted Professor H. L. Brose to carry out the work of translation.

These three volumes form, with two others, the substance of Professor Planck's lectures to the students of physics at the University of Berlin. The students of to-day sometimes wonder exactly where they stand, as the result of the rapid advances made in the unravelling of the secrets of nature. The author's brilliant work will prove very helpful to such students.

The first two volumes of this series are "General Mechanics", and "Mechanics of Deformable Bodies", and, as references in the text of the above three volumes are repeatedly made to these earlier works, we recommend, although we have not had an opportunity to review them, those interested to buy these for study in conjunction with the three now being reviewed.

In the past the treatment of physics has been more or less based upon the "watertight compartment" system; this is a sound idea when applied to ship construction, but in the study of physics has resulted in leading to the belief that "heat" was one subject and "light" another. However, just as at sea, where openings are found necessary in the bulkheads, so in modern physics it is found that all the several manifestations of energy are necessarily linked together.

These books are of necessity written concisely but lucidly, and whilst the claim that the mathematical knowledge of any pass or honours university candidate will suffice to follow the author's statements and deductions is probably quite true, we think, that the ordinary reader may find that these volumes require careful reading.

The translator deserves the thanks of all English readers for the work he has accomplished in rendering generally available to English students Professor Planck's work. Professor Planck's brilliant researches are classics in physical thought, and have played a dominant part in the modern development of physical theory. Thanks to Professor Brose, we now have in these fine volumes the advantage of seeing generally over the whole field of physics without the limitations of "bulkheads".

It is to be hoped that we may soon have an opportunity to record our detailed opinion on the two earlier volumes of this invaluable series on theoretical physics.

"Some Experiments on Oil Films in Complete Cylindrical Bearings", by Guido H. Marx, Professor of Machine Design at Stanford University, California. Published, 1932, by Oxford University Press (Humphrey Milford), 9s. net.

The scope of the work is best described in the author's own introduction and summary, viz.:—"The purpose of this volume is to make available to students in the field of lubrication the results of a series of experimental investigations carried on in the laboratories of the Department of Mechanical Engineering at Stanford University on the initiative and under the general direction of the writer".

Engineers will sense immediately that the results herein recorded of the behaviour of a solid bearing only 3¼in. diameter by 7in. long running at various clearances, loads and revolutions, are more academical than practical; as a matter of fact similar investigations have been carried out in this country during recent years by Professors Goodman, Boswall and others, the results of their labours being duly enshrined in the Transactions of the Institution of Civil Engineers and of the Institution of Mechanical Engineers respectively.

Professor Marx and his eight collaborators have apparently traversed the same ground and arrived at generally similar conclusions as regards journal *center* displacements or "attitudes", film distributions and so forth. They include, however, 16 pages of interesting data resulting from the use of different brands of lubricating oils, which will no doubt be carefully scrutinized by our oil experts.

British engineers and physicists have long regarded

Osborne Reynolds as the pioneer of modern bearing practice, and are agreed that the Michell thrust, for example, was the direct outcome of his remarkable experimental work in the eighties of last century. But the author tells us that, "It should also be noted that a Russian, Petroff, developed the hydrodynamic theory of friction independently of and coincidentally with, *if not prior to,* Osborne Reynolds. He should at least receive joint credit". This is characteristic of the methods employed by some American writers to disparage anything British, and such statements must be accepted with reserve.

While, therefore, this book may prove useful to researchers as showing what has been done on a small scale by the author, it must be said quite frankly that it would be of little or no use to members who are concerned with full-size bearings doing the world's work.

One final criticism and recommendation: the book has only a short table of contents, and should have an index for easy reference.

"High Speed Oil Engine Design", by B. Reed and H. Tanaka. Published, 1932, by The Draughtsman Publishing Co., Ltd., 96, St. George's Square, London, S.W.1. 2s. net.

It would not be an exaggeration to state that this paper is one of exceptional merit, and because of this one may be allowed to criticise with greater freedom than is generally considered permissible. The thermo dynamics are sound and the technical deductions are, in the main, both logical and practical, though in certain cases the academical side of the question has been allowed to overshadow some obscure practical factor of importance.

The authors have fallen into the usual pitfall of nomenclature and they suggest that only such engines as conform to Dr. Diesel's cycle should bear his name, overlooking the fact that by this reasoning any departure from the horizontal combustion line is a departure from the Diesel principle as understood, while his specification gives the compression pressure as a maximum. In other words, as almost any mixed cycle engine can be made to conform with this specification by retarding the period of injection it is somewhat unfortunate that the authors have stressed this quite unimportant point.

On page 8 in the second paragraph we have a very valuable clarification of the subject of compression and efficiency and the remainder of the chapter deals with supercharging in an exemplary manner.

The authors appear to have fallen into the common error in connection with ignition lag, inasmuch as they give the reader the impression that this ignition lag is inseparable from the Diesel engine and there is no suggestion of its empiricism.

In one's search for subject matter for criticism there does appear to be more than a proper proportion of conservatism of the kind that reasons in terms of precedent rather than possibilities; this is shown very clearly on page 10 in connection with the two-stroke cycle and air injection.

On page 22 we have the indication of a misconception that would appear to be the only definite mistake that we have observed in the paper. The authors suggest, when speaking of lag in ignition, that an early injection can be arranged without harm, as the temperature of the air will be too low to ignite the oil.

The paper is copiously illustrated, and in the main the illustrations are quite good. Fig. 19 is somewhat misleading and appears to have been drawn on too small a scale, and this latter criticism can also be applied to Figs. 26 and 27.

We have another misconception on page 32 where it is stated that a fish tail jet suffers more from dribble than a plain hole. This indicates that the authors place the onus for dribble on the jet, and not on the pump which is the real source of the trouble.

Chapter IV deals with engine design, and it is to be regretted that there is not more of this, as it would appear that there is a need for a book on high-speed oil engine design. Plain, straight-forward drawing office technicalities, proportions of pistons, connecting rods, balancing matters and such like, are what is required. Possible loadings should be dealt with and referred back to aeronautical practice as a limit. This suggestion is prompted by the excellence of the work of the authors under this heading in their paper which, one may add, should be studied by all those interested in the subject.

"Physical Principles of Mechanics and Accoustics", by R. W. Pohl, Professor of Physics in the University of Göttingen. Authorized translation by Winifred M. Deans, M.A., B.Sc., late of Newham College, Cambridge. Published, 1932, by Blackie & Son. 17s. 6d. net.

The first part of this book, a German publication, contains what we in England usually include under experimental dynamics and fluids. The last part is the treatment of the so-called Cinderella subject "Sound" in a very fascinating experimental manner.

The subject matter of the book is of the order of mechanics to be found in the usual English physics laboratory. For example, the first eight chapters deal with dynamics, such as force producing acceleration, motion in a straight line and circle, harmonic motion work, energy and momentum, rotation of rigid bodies and accelerated systems of reference.

The next two chapters deal with liquids and gases at rest and in motion, leaving the last two chapters to acoustics.

Throughout the book there is an abundance of evidence of the excellent teaching ability of the author. The experiments are original and simple, but lack precision and detail. The personal error is apt to be a very deciding factor in the results obtained, causing the experiments to be rather unconvincing.

The photographs and silhouettes of apparatus throughout the book are excellent, but in the written matter there is evidence that the book is a translation. This may be due to the fact that the book is really a course of lectures on experimental physics.

Suitable reference is made, in many places, to the practical applications of the various principles explained, such as governors and speed counters, the gyroscopic compass for ships and aircraft when dealing with centrifugal force, hydraulic transmission, and fluid friction and stream lines in the fluid section.

Some very interesting work is described in the acoustic section, the Fraunhofer diffraction grating used for sound waves being particularly original.

The 60 miscellaneous examples given at the end of the book are hardly sufficient to cover adequately the matter treated in this publication.

The book generally gives us a good impression of the author's capability for teaching this subject, which by his originality and ingenuity he makes fascinating and informative. It is a publication which we can recommend to our members.

"The Electrical Age", by V. H. L. Searle, M.Sc. Published, 1932, by Ernest Benn, Ltd. 10s. 6d. net.

About a year ago the author produced a small work entitled "Everyday Marvels of Science". The present work is practically a continuation of that on a slightly advanced scale.

As its title might lead one to conjecture, it is not a book on electrical engineering. It is rather a book on general science in which the author shows how the study of electricity is woven into our present conception of matter and energy.

The first chapter deals with the fundamental considerations of matter, and shows how the theory gradually evolves itself into one of electrical energy. The various theories are, however, not accepted without some reserve.

The remaining chapters are devoted to the application of electricity to the measurement of pressures and temperatures and of time, and also to domestic purposes. The production of X-rays and their relative position in the spectrum are given in most concise form.

All mathematical considerations are omitted, and the fact that the book is written in light vein makes it most interesting reading. There is no ambiguity about any of the author's statements, all his descriptions being most lucid, and we venture to forecast that the book will prove very popular with those anxious to keep up-to-date without having recourse to theory and technicalities.

"The Testing of High-Speed Internal Combustion Engines", by A. W. Judge. Published, 1932, by Longmans Green & Co. 25s. net.

With the ever-growing use of high-speed internal combustion engines, this excellent book will be of great service to the increasing number of people interested in their use and development. The author has treated the whole subject in a very practical manner, making it possible for the average engineer to obtain a good working knowledge of both routine testing and special research testing of high-speed engines.

Whilst the book is written primarily to cover testing of automobile and aircraft petrol engines, and little mention is made of the high-speed Diesel engine, the methods of testing all these types of engines are very similar, and a great deal of the matter in the book will apply to both petrol and Diesel engines.

In the first two chapters the general principles of testing and test procedure are made clear. Reference is made to the Ricardo variable compression engine and to the extensive work which Ricardo carried out with it.

A chapter is given to every important factor in connection with testing, including fuel tests and exhaust gas analysis, measurement of air supply, water supply and heat measurements, measurement of b.h.p. and pressure, indicator diagrams and temperature measurements. In these chapters the author gives excellent descriptions, diagrams and illustrations of different types of apparatus available for both routine and research testing, including apparatus used on road vehicles and aircraft. The information regarding indicators, of which a large number of types, including mechanical and optical indicators, are described in the chapter headed "Pressure Measurements", is of especial value to internal combustion engineers.

The chapter on indicator diagrams can also be marked out as of great value, because it is well known that with high engine speeds, an accurate indicator diagram becomes a very difficult record to obtain, unless great care is taken in the choice of the indicator and the method of using it.

Further chapters cover automobile testing, both on the road and on car testing apparatus, aircraft testing, and the testing of the Schneider Trophy engines. Methods of testing the transmission, gear box, brakes and steering, as well as acceleration, deceleration, and general road performance tests of motor vehicles are included.

As a whole the book covers all the ground required for all tests, both routine and research, except, perhaps, research of a very special nature, and it will be found of great value to research students as well as the internal combustion engineer.

"The Seed of Fire", by E. F. Spanner. Published, 1932, by Sampson Low, Marston & Co., Ltd. 7s. 6d. net.

The author of this book, whose name is familiar to the majority of the members of this Institute, is a well-known consulting naval architect. Writing novels is no part of his ordinary professional existence, but is simply and solely a hobby—a hobby which he finds most interesting and amusing, besides being one which gives an opportunity to people, not at all interested in ships or shipping, to gain some slight appreciation of the problems which have to be faced in ships and ship repair work.

Mr. Spanner can certainly not be accused of plagiarism. There have been written quite a number of novels about fires on board ships, but to the reviewer this book was absolutely original and, of course, refreshingly free from the absurdities which the non-technical writer is apt to introduce. The author has woven his story around the lives of people intimately connected with ships, being one of the few writers who are qualified to do so.

Evidence of the alertness of the author's mind can be found in the fact that concurrently with the publishing of his novel a spate of literature has been released by the technical press on the subject of fires on board ship. As his novel must have taken considerably longer to write than the articles in question, it is clear that he anticipated the trend of thought on this subject.

The reviewer here hastens to dispel any impression that the book is a technical treatise. It is a very interesting and sometimes thrilling story of the partial destruction by fire of a large ship. A mystery which keeps the reader in suspense for most of the story is provided, and the whole yarn is excellently spiced with villainy, wholesome romance and humour.

The book will be quite readable by and enjoyable to the non-technical public, and will provide first-class light reading for those who are in any way connected with ships. We especially commend it to members of the profession seeking occasional mental recreation—they will find its perusal affords an excellent week-end's reading without savouring of "overtime".

ANNUAL CONVERSAZIONE.

The Annual Conversazione and Dance was held on Friday, November 4th, 1932, at Grosvenor House, Park Lane, W. Over 350 members and guests were present. A reception was held from 7.30 to 8 p.m. by the President, Commander C. W. Craven and Mrs. Craven. Dinner was served in the Ball Room immediately after the reception, and was followed by a concert in which the following artists rendered a delightful programme: Miss Garda Hall, soprano; Miss Enid Cruickshank, contralto; Mr. Walter Widdop, tenor, and Messrs. Murray Ashford and Edgar Sawyer, entertainers. The remainder of the evening was spent in dancing to music rendered by Mr. Harry Heap's "Superbe" Dance Orchestra, with an enjoyable interlude at 12.15 a.m. by Gordon Marsh's Cabaret.

The Conversazione, which, as regards the order of the programme, was a slight departure from the arrangements of recent years, was acknowledged to have been a complete success in the opinion of the President and all who participated. (*See photograph on page* 517).

Visit to the National Physical Laboratory, Teddington.

By the kind invitation of the Director, Sir Joseph Petavel, K.B.E., F.R.S., a party of over 50 members visited the National Physical Laboratory, Teddington, on the afternoon of Saturday, November 5th. On arrival at 2.30 p.m. the visitors were divided into two parties, which subsequently toured the Laboratory in charge of members of the staff who acted as guides and demonstrated the important features of the work of their departments. The tour comprised the Engineering, Metallurgy, and Aerodynamics Departments and the William Froude Laboratory. The following notes, kindly supplied by the Director, are descriptive of some of the more interesting experimental and research work which the visitors were privileged to witness and have described to them by their expert guides.

ENGINEERING DEPARTMENT.

The Effect of Surface Conditions on the Fatigue Strengths of Steels.—Previous work at the Laboratory has shown that the strength of certain steels, e.g., spring steels, when subjected to alternating or repeated stresses, is largely dependent on the surface conditions of the material. The present exhibit showed how the condition of the surface affects the strength of steels which are used for forgings of automobile parts such as axles, engine connecting rods, etc., and how advantageous it is to machine and polish these parts when at all possible.

THE ANNUAL CONVERSAZIONE 1932.

Corrosion Fatigue Tests on Single Crystals and on Crystalline Aggregates.—Many machine parts are subjected in service to stresses which fluctuate between certain limits, and a dangerous type of fracture, by a spreading crack, is apt to be produced: this is termed "fatigue". Work on fatigue of the first importance has been carried out in the Engineering Department during the past years. In some cases, machine parts are subjected to this type of stressing while immersed in a corrosive environment, such as sea-water, steam, or acid solutions. Under these conditions the destructive effect of fatigue is usually accelerated by corrosion—sometimes to a marked degree—the combined process being termed corrosion-fatigue. A research on this subject is in progress and representative exhibits were on view.

General Equipment for Investigating the Mechanical Properties of Materials at High Temperatures.—In view of the developments taking place in the use of higher temperatures and pressures in various branches of engineering, a general study of the combined effects of stress and temperature on metals is being undertaken at the Laboratory.

The prolonged application of a load to a metal maintained at a high temperature produces "flow" or "creep", and may lead to fracture. While a relatively large load may be necessary to cause fracture within a few minutes of its application, successively smaller loads may still cause fracture, due to continuous creep, after periods which lengthen as the loads are reduced. The stress-temperature conditions existing in many high temperature plants are such that the component parts of the structures are creeping slowly but continuously.

The testing equipment in use permits the measurement of creep down to the exceedingly small rate of one hundred millionth of an inch per inch per hour. Experiments are carried out to determine the stress-temperature conditions for various rates of creep, from which the amount of creep deformation at working stresses may be deduced. A study is being made of the phenomena of creep of different classes of metals, of the behaviour of metals in the cast, wrought and heat-treated conditions, and of the effect of small alloy additions to carbon steel.

Fatigue under Combined Bending and Torsional Stresses.—Many engineering parts, such as crankshafts, are in service subjected to the combined action of bending and torsional stresses, each of which is alternating or pulsating in character. To study the effects of such combinations of stresses, an ingenious new machine has been designed, and was shown in operation, which is capable of imposing upon a specimen 2,000 reversals per minute of any desired combination of bending and torsional stress. One valuable feature of the machine is that it is brought automatically to rest as soon as a crack is produced in the specimen, with the result that the surfaces of the fracture are not damaged by hammering. The principle of the machine is that a force due to an out-of-balance weight fixed to a rotating disc is transmitted as a couple to the specimen through an arm which can be arranged at any angle from 0° to 90° to the axis of the specimen. The inertia forces due to this arm and its attachments are balanced out by springs, and the resulting couple on the specimen is merely that due to the centrifugal force of the out-of-balance weight acting at the leverage of the arm.

Metallurgical Department.

The Technique of the preparation of metallic specimens for microscopic examination was described.

Then followed a short description of the principles of photomicrography of metals and illustrations of typical metal structures in the form of transparencies were given. Types of furnaces for the heat-treatment and melting of small quantities of metals and alloys were shown and particular attention was paid to high frequency induction heating.

General remarks were made on the measurement of high temperatures, and the thermo-electric method was fully described.

Refractory materials of special composition, form and purity are often required for research purposes. The methods of preparation of these materials were briefly dealt with, and examples of products prepared in the Laboratory were shown.

Types of metallographic research were commented on and work in progress on "creep" failure was cited as an example. Test pieces are subjected to prolonged stress at constant high temperatures for periods ranging from some hours to several weeks. The polished specimens are enclosed in an evacuated tube during test so that oxidation is practically negligible, and changes in structure can be observed after the test by microscopic examination.

High Pressure Cylinder used for Determining the Corrosive Attack on Steel at High Temperatures.—From time to time engineers in charge of large industrial plants have been startled by the formation of cracks in steam boilers under their supervision. Apart from the heavy cost of replacements and the stoppage of work during the renewal operation, there is the risk of serious boiler explosions. In some quarters it is believed that certain impurities in the boiler feed water are partly responsible for this peculiar form of corrosive attack on the steel. The experiments at the Laboratory are intended to ascertain the conditions under which these cracks are formed, with a view to their avoidance in practice. Small specimens of typical boiler plate steel were being tested under tension inside a seamless pressure cylinder heated electrically. Sufficient liquid is placed inside the bomb to cover the specimens under test and the heat is so regulated that desired steam pressures up to 500lb. per sq. in. may be attained. With this equipment it is possible to study at high temperatures and pressures the influence of different solutions on stressed steel specimens.

Corrosion tests on Steel in Superheated Steam.—Progress in the economical production of power by means of steam has led in recent times to a considerable increase in the temperatures and pressures employed. Still higher temperatures and pressures would be advantageous if metals were available having sufficient strength and power to resist corrosion. It is therefore very necessary to investigate the resistance to corrosion by superheated steam of materials which are in other respects suitable for use in power plant, and a new type of boiler has been devised for this purpose.

Although the steam output of the boiler is exceedingly small, a pressure of 1,000 lb. per sq. in. can be reached at the high temperature of 600° C., the pressure being maintained automatically at the required value. The steam is produced by pumping water through a long coiled tube of special stainless steel, also heated electrically, which contains the specimens of metal under test. By means of this apparatus it is hoped to obtain data of considerable value to steam engineers.

Aerodynamics Department.

General Introduction.—The principle of testing aeroplane and other models in the wind tunnels of the Aerodynamics Department depends on driving a current of air at, say, 75 miles per hour against the model suspended upside-down in the tunnel from wires. The wires lead to balances on top of the tunnel, and the force of the wind on the parts of the model is counteracted and measured by weights on the balance.

Spinning of Aeroplanes.—The spinning apparatus, which enables the motion of a spinning aeroplane to be reproduced in a wind tunnel, has been in use for about a year, and has enabled more precise information to be obtained upon the aerodymanic forces and moments which act upon a spinning machine. In conjunction with mathematical analysis of the motion, valuable progress is being made in the study of spinning, and in the development of methods of design t. eliminate danger of spinning.

Wing Tip Research.—Certain aeroplanes have exhibited very good characteristics in stalled flight without recourse to wing tip slots for stabilising purposes, and it is not yet known to what these good qualities are due. This research is being made to determine how far the shape of the wing tips may modify the behaviour of the machine in stalled flight. Comparative tests using tip slots and other stabilising devices are also being made.

Compressed Air Tunnel.—In this tunnel, compressed air at 25 atmospheres pressure can be circulated while an aeroplane model is in position. The reason for employing this high pressure is that model tests made under these conditions are directly comparable with those on a full-scale machine, i.e., the "scale effect" which exists when working with a model in a tunnel at atmospheric pressure is eliminated. The installation consists of the tunnel proper, a steel shell 50ft. long and 17ft. in internal diameter, capable of withstanding a working pressure of 25 atmospheres, and enclosing completely a return flow open-jet wind tunnel. Three 400 h.p. compressors are provided in an adjoining room, and can charge the tunnel to 25 atmospheres in about 80 minutes. The compressed air in the tunnel is circulated by a two bladed duralumin airscrew driven through a stuffing box by an external motor of 400 h.p. This will produce a wind speed of 90ft. per second at the full pressure and will give conditions corresponding to those of a full scale machine of average size flying at 150 miles per hour.

THE WILLIAM FROUDE LABORATORY.

The exhibits of the William Froude Laboratory are divided into two sections. The first section illustrates the industrial side of the work and includes experiments in which a high speed ship is driven by twin screws through rough water in the Yarrow Tank. These experiments are leading to the development of types of hull which give really seaworthy performance in all moderate weathers, and to the design of screw propellers which maintain their thrust and efficiency in rough water to a much greater extent than in many existing ships. The waves are created in the Tank by a specially designed wavemaker, and the amount of power required to propel the model, as well as her pitching and heaving motions, are recorded automatically during each experiment.

The second section comprises the different types of apparatus used in the test work of the Department. It illustrates the improvements made in recording, etc., during the last 20 years, and shows the scope of the experiment work carried out.

The New Tank is nearing completion and should be in use before the close of the present year.

At the conclusion of the tour tea was served in the Staff Canteen at 4.45 p.m. Before departing, Mr. James Carnaghan, Chairman of Council, expressed on behalf of the visitors and the Institute generally their keen appreciation of the courteous reception they had been accorded, and of the interest displayed by the demonstrators in explaining the details of their work and in replying to the numerous questions which had been raised. Mr. S. N. Kent, Vice-Chairman of Council, supported Mr. Carnaghan's remarks, and a hearty vote of thanks was thereupon accorded to the Director and particularly to the members of his Staff who were present, and who had contributed so effectively to the enjoyment and instruction of the visitors. The vote of thanks was gracefully acknowledged by Mr. J. W. Christlow, Assistant Secretary, and Mr. J. L. Kent of the William Froude Laboratory, thus terminating a memorable and profitable visit.

JUNIOR SECTION.

Some Aspects of Steam Turbine Design and Construction.

A paper under the above title was read before the Junior Section at the Institute on Thursday, October 13th, by Mr. J. D. Pearson, B.Sc., Wh.Sc. (Student). The chair was occupied by Mr. H. R. Tyrrell, B.Sc. (Associate), and there was a good attendance of Junior Members and visitors.

The author, who has already achieved distinction in his practical work, since completing the tenure of a Lloyd's Register Scholarship, presented a thorough survey of steam turbine design from the point of view of the operating engineer. The methods of construction and blading large rotors were described in full detail, and various problems arising from blade vibration and the devices adopted in solving them were clearly explained. Various delicate electrical appliances and their use in inspecting the wheels and shafts during construction were described, followed by an interesting account of the special provisions which have to be made in the design for the effects of unequal expansion and high temperatures generally. The author showed how the introduction of the factor of "creep" had entirely altered the designers' conception of the proportioning of parts to stand their loads at high temperatures, and he gave examples from practice showing how the time element entered into considerations of the behaviour of materials.

Reference was made to gland design and to the precautions necessary owing to the effects of unequal expansion in starting, shutting down, and operating on a changing load.

Finally, the author tendered acknowledgements to Messrs. Metropolitan-Vickers Electrical Co., Ltd., with which Company he was associated for some time after completion of his university training and to whom he was indebted for information and assistance afforded to him in preparing his paper.

On the proposal of Mr. E. R. Chamberlain (Student) a most hearty vote of thanks was accorded to Mr. Pearson, both for his valuable paper and the excellence of his delivery, the latter having been a notable feature of the lecture.

BOARD OF TRADE EXAMINATIONS.

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

Name.	Grade.	Port of Examination.
For Week Ended October 13th, 1932 :—		
James, E. T.	2.C.	Cardiff
Graham-Cumming, John C.	2.C.M.	„
Gandy, John	2.C.	Liverpool
Pemberton, Eric	2.C.	„
Barclay, William T.	2.C.	Glasgow
Hunter, John D.	2.C.	„
McBay, George D.	2.C.	„
Noble, John W.	2.C.	„
Blaker, Charles H. W.	2.C.	Newcastle
Gamlen, Denys	2.C.	„
Phillips, Robert	2.C.	„
Procter, Thomas W.	2.C.	„
Fleuret, Bernard C.	2.C.M.	„
Johnson, Thomas F. E.	2.C.M.	„
Wilson, George W.	2.C.M.	„
Wright, Thomas E.	2.C.M.	„
Smith, Edward I. McC.	2.C.	London
Strachan, Richard R.	2.C.M.	„
Winhall, Edwin K.	2.C.M.	„
Alexander, Stanley	2.C.M.E.	Newcastle
Neilson, Donald R.	2.C.M.E.	London
For Week Ended October 20th, 1932 :—		
Butcher, Roberts W.	1.C.	London
Hockaday, Edward A.	1.C.	„
Meech, Walter	1.C.	„
Tuck, Ernest St. J.	1.C.	„
Bates, Frederick A.	1.C.	Newcastle
Harbottle, Joseph	1.C.	„
Palmer, Guy M.	1.C.	„
Raeburn, Charles A.	1.C.	„
Stevens, William	1.C.	„
Comrie, David G.	1.C.	Glasgow
Lang, Robert	1.C.	„
Shaw, James	1.C.	„
Clark, James E. M.	1.C.	Cardiff
Griffiths, Trevor L.	1.C.	„
Griggs, Joseph E. F.	1.C.	„
Rees, Thomas F.	1.C.	„
Foley, Wilfrid C.	1.C.	Liverpool
Robinson, George F.	1.C.	„
Pinkerton, Robert A.	1.C.M.	„
Brownless, George	1.C.	Newcastle
Aitchison, James	1.C.M.E.	„
Scott, Robert N.	1.C.M.E.	„
Miller, Ferguson, A.	1.C.M.E.	Glasgow
Hamilton, John P.	1.C.M.E.	„
De La Mare, Edgar G.	1.C.M.E.	Cardiff
Walker, Harold V.	1.C.M.E.	Liverpool
Scarisbrick, Walter	1.C.M.E.	„
Lomax, George A.	1.C.M.E.	„
Guthrie, Andrew	1.C.M.E.	„
Wignall, Arthur E.	1.C.M.E.	„
Kerr, Andrew	1.C.M.E.	„
For Week Ended October 27th, 1932 :—		
Gibbeson, Thomas P.	2.C.	London
Dyson, Robert W.	2.C.M.	„
Burns, Francis L.	2.C.	Newcastle
Ashton, George	2.C.	„
Chambers, Robert	2.C.	„
Hodgson, John	2.C.	„
Hopper, William	2.C.	„
Shutt, Herbert T.	2.C.M.	„
Wilson, James B.	2.C.M.	„
Barker, John W.	2.C.	Glasgow
Brown, Angus P.	2.C.	„
Fraser, Charles F.	2.C.	„
Matthews, John A.	2.C.	Glasgow
Watt, John A. McH.	2.C.	„
Campbell, James McK.	2.C.M.	„
Giles, E. F.	2.C.	Liverpool
Irvine, John	2.C.	„
Smith, Albert	2.C.E.	„
For Week Ended November 3rd, 1932 :—		
Burns, John	1.C.	Glasgow
Caldwell, Thomas	1.C.	„
Macdonald, Arthur K.	1.C.	„
Robertson, David J.	1.C.	„
Walker, George S.	1.C.	„
Crawford, Edgar D.	1.C.M.E.	Newcastle
Davies, Ernest W.	1.C.M.E.	Liverpool
Lochhead, David McG.	1.C.M.E.	Glasgow
White, Thomas Y.	1.C.M.E.	Newcastle
Taylor, David P.	1.C.M.E.	Glasgow
Chapman, Harold A.	1.C.	London
Hurley, Alfred G.	1.C.	„
Lumb, Reginald	1.C.	„
Robins, Charles A.	1.C.	„
Henderson, Robert	1.C.M.E.	„
Anderson, Charles N.	1.C.	Newcastle
Ferdinands, Charles W. Van den D.	1.C.	„
Frost, Alfred	1.C.	„
Jefferson, John R.	1.C.	„
Lyons, John W.	1.C.	„
Miller, Thomas S.	1.C.	„
Stewart, John G.	1.C.	„
Bormond, Joseph	1.C.M.	„
Brown, Norman A.	1.C.M.	„
Bell, George K.	1.C.	Liverpool
Egan, John	1.C.	„
Stephenson, Alfred	1.C.	„
Kendal, James C.	1.C.	„
Swetenham, Stanley H.	1.C.	„
Ellis, Fred	1.C.M.	„
Hood, Robert	2.C.M.E.	London
Lyon, James	1.C.M.E.	„
Lambert, Walter H.	1.C.M.E.	„
For Week Ended November 10th, 1932 :—		
Kedzlie, John E.	Ex.1.C.	Cardiff
Brims, Donald	Ex.1.C.	London
Eyers, John	Ex.1.C.	„
McIntyre, Peter A.	Ex. 1.C.	„
Tippin, Thomas C. W.	Ex.1.C.	„
McBride, Reginald P.	Ex.1.C.	Liverpool
Dumble, Thomas R.	Ex.1.C.	Newcastle
Lorimer, Ian McK.	Ex.1.C.	„

Suggested Modifications in the Design of Aircraft.

The Editor has received from Mr. H. Coke Powel a short paper dealing with his suggestions for modifications in the design of aircraft. Mr. Powel, Member No. 1,084, is now 90 years of age, and the members of the Institute will no doubt agree that he is to be congratulated on being able and willing at this advanced age to tackle the very difficult problems associated with the design of aircraft.

While the Institute cannot associate itself with the opinions expressed, it is thought that members may be interested in the following extracts from Mr. Powel's paper and the comments on the questions raised which have been made by a member of the Institute interested in aviation, to whom the paper has been submitted.

In his communication Mr. H. Coke Powel

makes some interesting suggestions on the design and behaviour of the modern aeroplane. As many others have done, he has studied, as opportunity offered, the methods evidently employed by birds, not only to propel themselves through the air but to make use of wind pressure, to enable them to glide, to remain stationary in relation to the ground, and to alight slowly.

Arising out of his observations, Mr. Powel makes the following suggestion:—

"An aeroplane has a great advantage over a bird in one way: a bird cannot rise from the land or sea vertically at once, for it has to use its wings to move forward but an aeroplane, driven by its engine, its wings can be placed at any angle.

"The wings of aircraft could be made to form an angle to the line they are being driven by their engines without any mechanical difficulty, probably a smaller wing under the main wing, carried on a shaft, traversing the body of the aircraft, the wing built on a tube turning on the shaft some distance from its forward edge to partly balance it and so more easily worked like a ship's rudder would be found all that is necessary. This wing made to take the extreme angle of about 45° to prevent collision on earth or sea, and made of laths to open out to better hold the wind, as a bird when spreading its wings, or better and simpler to have holes, round or oblong, and possibly coned in the wings which would offer little or no resistance when the wing is in its normal position".

In the above Mr. Powel raises a question which has received much consideration from those interested in the design of aircraft. It would undoubtedly be of great advantage if some simple means could be devised for adjusting the lift of an aeroplane wing to meet the varying conditions of loading and speed. The famous designer, Mr. F. Handley Page, has, in fact, devised a modification which carries out Mr. Powel's suggestion. It is called "the slotted wing" and consists of a small wing, very much as Mr. Powel's description, carried at the leading edge of the main wing, and capable of angular variations through the operation of a shaft. The effect of the modification of the angular position of this small wing is to increase or decrease the lift of the main wing, and originally the movement was controllable by the pilot, although in the present form a small wing moves automatically and is controlled by the variation in the speed of the machine. When the angle of the small wing is large the effect is to produce a slot between the main wing and the small wing. Mr. Powel's reasoning appears to be perfectly correct, but his suggestion that an auxiliary wing should be fitted under the main wing is impracticable, if only on account of the very serious increase in resistance, caused thereby and the fact that the presence of such an auxiliary wing would, to a large extent, destroy the lifting power of the main wing.

Like many others interested in aviation, Mr. Powel has evidently been somewhat disturbed by the recent accidents which have shown that in bad weather gusts of wind, especially vertical gusts, may be so severe as to stress the wing structure, or its attachment to the body of the aeroplane, beyond the limit of its strength. Mr. Powel's comment in this connection and his suggested solution are as follows:—

"A sudden blow strikes a wing above or below, the wings either break and so ends the life, or if able to resist the wind blow it rolls the aircraft over, and she would take an inclined position which would run her down in an increasing speed before means could be taken to correct her inclination, and this would explain the mysterious loss of wings and aeroplanes at sea.

"What does Nature do in her bird's design to meet these wind-blows?

"A small bird has its wings attached to her body by an elastic muscle, the larger birds have a second joint in their wings, and the outer feathers are spread out to their full extent to let the pressure fall away".

Here Mr. Powel seems to call for an arrangement by which the attachment of the wing to the machine is not rigid and could give slightly under conditions of exceptional load.

The practical difficulties of an arrangement such as this are obvious, but a serious objection to such an arrangement would be in the alteration of the angle of the wing which might cause serious effects on the stability of the machine. The bird, no doubt by instinct, maintains perfect aerodynamical balance, but it is very doubtful whether the pilot of an aeroplane would be able to correct such serious alterations in the stability and behaviour of his aircraft as would be caused by a movable wing. In this connection it is interesting to note that the form of accident in which the wing breaks away from the machine appears to be confined to the monoplane. The structure of the biplane, in which the two planes are kept apart by struts and bracing wires, is probably inherently more elastic than the structure of the monoplane, and so possibly does, to some extent, meet the conditions suggested by Mr. Powel.

ABSTRACTS.

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

Good Model Form.

"The Burntisland Shipyard Journal", October, 1932.

There can be few objects more fascinating to a discerning ship designer than the balanced symmetry of a good model form. In some respects there may be a casual similarity of shape in every vessel, and yet someone will say this ship is too beamy, that too full, this too stumpy, such and such a ship a wonder. In fact so many expressions are used and criticisms made, each bound up in the other, that unless constant attention be given to the subject, it becomes enveloped in a veil of obscurity.

Besides being of technical interest, adequate consideration of model form can be one of the greatest sources of financial profit. This will be readily appreciated when it is declared that *one per cent. increase in propulsive efficiency can have a capitalised value of not less than* £2,000! while faulty design of model form can easily increase the necessary horse-power (and consequently the fuel consumption) by more than 50 per cent.

In the process of designing the most efficient form, that is, one which will require the least power and bunker coal to drive it at the desired speed and have the greatest freight-earning carrying capacity, there are generally three main lines of attack, model tank testing; adaptation of model experimental data in collaboration with full size work; and direct proportioning from the lines of some convenient vessel.

Tank Testing.

Experimental tanks are equipped for the testing of ship model forms. Large scale models are made of paraffin wax. They are then run at speeds in the tank, which correctly correspond to that of the full size ship, and the resistances recorded by special measuring apparatus. From these the probable horse powers for the full size vessels can be calculated by using suitable co-ordinating factors applicable between model and ship. In this manner it is possible, and desirable, to test variations of the proposed model with a view to arriving at the best form. Model propellers are also tested both in open water, i.e., separate from the model, and in association with the model hulls. Thus it is possible to determine by experiment what is likely to be the best combination of propeller design and model form.

Experimental Data.

The published results of model tank experimental research work provide a valuable fund of information from which many general conclusions can be drawn and which can materially assist in the design of a least resistful form. Yet too much care cannot be employed in translating general conclusions into practice. If, however, a careful study be made of published experimental research work and its teachings be applied with due discrimination, it is then not too difficult to produce a successful design of hull. Particularly is this so where it has been possible to analyse the actual sea service data of earlier designs in conjunction with those predicted by methodical tank tested model series.

Prototype Models.

Another line of attack usually takes the form of a general reference to the nearest set of model lines which may have been found by past experience to give good results. If the dimensions be different the form is then proportioned up or down, in or out, to give the required displacement. On odd occasions some surprisingly good performances are shown by this method. But, if the history of grossly uneconomical ships were probed, it would probably be found that the incurable fault, almost without exception, could be traced to this rough and ready method of determining one of the most vitally important features of ship design. Only in the hands of a skilled ship designer, versed in modern technique, whose continuous study of current productions in modern naval science and model experimental work enables him to diagnose and prescribe, is it possible to evolve a least resistful form without recourse to a practical tank test.

Block Co-efficient.

For a given speed and length of ship it is not nearly accurate enough to determine the degree of fullness or fineness of form by any empirically chosen block co-efficient. While this factor might give some general indication of the block characteristics, it must be remembered that it is easily possible to design a form of ·78 co-efficient which will show less resistance and require less horse power to drive the vessel than another of ·76.

For definite proportions of ships it is found that, even irrespective of speed, there is a limiting block co-efficient. To go beyond this limit would involve trouble with eddy making and also interference with the efficient working of the propeller. This is, in part, confirmation that the general tendency in recent years to adopt finer standards of form has been in the right direction.

An increase in beam will necessitate a smaller block co-efficient, if the mean angles of entrance and run are to be maintained. For example, 10 per cent. increase in beam or draft over standard proportions would necessitate about 2 per cent. reduction in the block co-efficient.

Features of Form.

An important point to appreciate is the desirability of securing a proper balance between the respective lengths of the entrance and run. It has been shown by experimental tank research, for example, that the length of the run in the after body in vessels of normal proportions should have a definite relationship to the area of the amidship section and speed. This fact has been confirmed by observations on trial trips, and when suitable modifications have been made in subsequent vessels the propulsive gain has been quite appreciable.

Even should the form be designed to comply with this desirable length of run, it is a distinct advantage to make the lower portions of the buttocks particularly easy, in order to assist in an easy flow from the bottom, when in the ballast condition and trimming by the stern.

Cruiser or canoe type sterns are, under certain conditions, worthy of serious development. Where the water line can be lengthened and a fair streamlined extension of the sectional area curve obtained, an appreciable improvement might result. There are limitations, however, to the extent to which a cruiser stern can be immersed in a single screw ship to obtain sufficient displacement to be of benefit; this being governed by the required diameter of the propeller and the height of the aperture necessary to give it sufficient clearance.

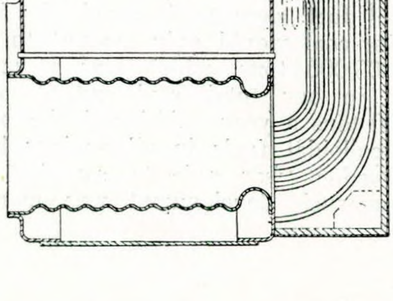
The steady improvement in model design technique is clearly seen in the increased Admiralty Co-efficients now associated with modern cargo vessels. An 8,000 tons d.w. 10 knot steamer at the present time can be produced to give an Admiralty Co-efficient of 400 on loaded trial basis, and 370 in sea service. These compare with corresponding factors of 300 and 250 which were acknowledged as good performances not many years ago.

Model form can be examined and checked by carefully watching the sea performances of any series of ships where systematic modification of form has been made. In two series of ships—eleven of 4,450 tons d.w. and twelve of 7,800 tons d.w.—a gradual and appreciable improvement in propulsive efficiency was shown as each new feature or amendment was introduced and survived the acid test of sea service. The prototype models, subsequent experience showed, were designed to good, sound practice, but the cumulative effect of each new and improved feature was proved to be quite substantial in the later vessels of the series, and it is not unlikely that still further improvements will be found possible.

A New Johnson Boiler.

"The Engineer", 11th November, 1932.

British Patent Specification, 381,112. April 21st, 1932.—Marine Boilers, J. Johnson, "Green Shutters", The Highway, Sutton, Surrey.



This marine boiler is put forward as being specially suitable for firing with oil or powdered coal. It is somewhat after the type of an ordinary Scotch boiler, but instead of having internal combustion chambers it has an exterior smoke-box lined with refractory material. Inside this box there are arranged water tubes, which more or less partition off the box into three compartments, one for each furnace. There is also a superheater in the upper part of the box.—*September 29th*, 1932.

Steam at 3,200lb. W.P.

Some Particulars of the Benson Boiler Installed in the S.S. "Uckermark".

"The Engineer", 28th October, 1932.

The second session of the Engineers' German Circle opened on Monday, October 10th, at the Institution of Mechanical Engineers, when a lecture was given by Dipl.-Ing. F. Ohlmüller, chief engineer of the Siemens Schuckertwerke, Berlin, on "Der Benson Hochdruckkessel (225 at.) als Land und Schiftskessel-Ausführungen und Erfahrungen". On October 20th, by invitation of the Hamburg-America Line, the members of the Circle, along with representatives of the Admiralty, the Board of Trade, Lloyd's Register of Shipping, and other interested parties, visited the cargo liner "Uckermark", on her arrival from the Dutch East Indies at Gravesend, and inspected for themselves the Benson boiler.

Dealing first with Herr Ohlmüller's lecture, it may be stated that it was a full and valuable account of the pioneer work on the Benson critical pressure boiler, which has been carried out by Siemens Schuckert since the early experimental work done at the English Electric Company's works at Rugby more than nine years ago. After describing the principle of the Benson system of steam generation, in which water passes from liquid to gas form at the critical pressure of about 3,200lb. per sq. in., and at about 707° F., the author went on to describe the test boiler of 10 tons per hour capacity built at the Nonnendam power station, Berlin-Siemensstadt. The No. 1 and No. 2 Benson boilers, of 25 and 40 tons per hour respectively, at the firm's Gartenfeld works, were then described, after which an account was given of the large 100 to 120 tons per hour Benson boiler at the Langerbrugge power station in Belgium. This part of the lecture was specially interesting, as it dealt with the difficulties which had been experienced in the early working of the plant and the means which have been adopted to overcome them. Before passing to the marine applications of the Benson boiler, a typical design for a stoker-fired boiler was illustrated.

The marine section of the paper, which described the 6,000 s.h.p. high-pressure Benson boiler and turbine installation on the s.s. "Uckermark", included details of the valves and steam pipe connections, and the experiments made which have shown the successful operation of the plant with salt water injection. Further interest was added to Thursday's visit by the fact that Dr.-Ing. E. Goos, the superinendent engineer of the Hamburg-American Line, and Herr Küntzel, chief engineer of Blohm and Voss, came over specially to demonstrate and describe the plant, which they did in excellent English, although naturally many members of the Circle asked supplementary questions which led to further conversations in German. A description of the "Uckermark" installation was published by Dr.-Ing. E. Goos in our contemporary the "Shipbuilding and Shipping Record" of November 26th last, and a translation of Herr Ohlmüller's lecture will appear, we understand, in an early issue of the "Steam Engineer".

The "Uckermark" has now been on service for about two years, and apart from some early troubles, the Benson boiler has, we were informed, functioned very satisfactorily. Its working pressure is about 3,200lb. per sq. in., and temperature of the steam is 707° to 752° F. At this critical pressure and temperature the steam exists only as a gas, and contains no molecules or drops of water. The importance of absolute steam-tightness will therefore be apparent. In length the Benson boiler takes up rather less space than the double-ended Scotch boiler alongside it, but its height is rather greater, being about 20ft.

The boiler is oil fired from both ends, and, as originally arranged, there were five furnace fronts or burners at each end, vertically one above the other. After the first voyage, in order to ensure more satisfactory combustion and a more even distribution of the stresses on the tubes, the burners were rearranged, and only four in each end are now used. Alterations in the groups of tubes were also made, as it was found that the original arrangement with the critical point of the water in the first radiating stage led to overheating and bursting of the tubes in which the transformation from water into gas took place. These alterations were made in October, 1930, since when no further trouble has been experienced.

In order to accommodate the higher pressure steam, a two-stage high-pressure turbine—each stage in a separate casing—was fitted, driving a separate pinion. Leaving the boiler at 3,200lb. pressure and 752° F., the steam is passed through a reducing valve and afterwards through a multi-coil superheater. Entering the special high-pressure turbine, the steam has a pressure of about 882lb. per sq. in.

Using the Benson boiler alone for propulsion purposes, a machinery output of 6,200 s.h.p. can be obtained, the corresponding ship speed being 14 knots loaded. With the Benson boiler shut down, and using only the three Scotch boilers, the speed of the ship is 12 knots. Whereas the weight of contained water in the double-ended Scotch boiler is about 35 tons, that in the Benson boiler is only about 1 ton. There is no water level, as such, nor are there any water gauge columns or glasses.

The weight of the Benson boiler alone is about 32 tons, or with all accessories, grids, insulation, furnace fronts, etc., about 100 tons. One of the most interesting of the boiler auxiliaries, and one which greatly interested the visitors, was the high-pressure feed pump. There are two such pumps, each of the ram type, with six single-acting pistons. The suction and delivery valves are placed about 5ft. away from the pump cylinders, so that the intervening column of water oscillates to and fro in synchronism with the displacement of the pump rams. In this way the feed water does not pass through the pump cylinders, but merely through the valves, and the water column may thus be regarded as the piston or ram. Although no material trouble has been experienced with these ram-feed pumps, we were given to understand that Blohm and Voss are meanwhile experimenting with a special type of centrifugal feed pump, which, if successful, will later be installed.

Based upon the actual voyage results during the past two years, the efficiency attained by the Benson boiler averages about 90 per cent., varying from 88·5 per cent. to as high as 92 per cent. This figure compares with an efficiency of about 65 per cent. from the Scotch boilers on board. The further development of the Benson system will be awaited with no little interest.

Colloidal Fuel for Marine Use.

"The Engineer", 21st October, 1932.

In the course of an address given to the Chemical Engineering Group of the Society of Chemical Industry in London on October 14th, Professor J. S. S. Brame, of the Royal Naval College, Greenwich, made reference to the coal-oil fuel which has been successfully tried out in the Cunard liner "Scythia", and said that many false hopes had been raised for a largely extended use of coal. For use on land it seemed unlikely, he continued, that coal-oil mixtures could compete, either with mechanical stokers or with pulverised coal. No opportunity ought, he thought, to be overlooked which might increase the use of home-produced fuel, but it was necessary, he felt, to guard against any exaggerated ideas of what the introduction of coal-oil fuel might mean to the coal industry. Any extended use of such fuel for the immediate future lay entirely in its application for steam raising aboard ship. Taking the merchant navy and the Royal Navy together, and assuming that nothing but coal-oil fuel were to be used, the increased demand for coal would only amount to approximately 1,000,000 tons, which was a very small increment in our total coal output of about 240,000,000 tons a year. Although the possibility of using colloidal fuels in oil engines had been foreshadowed, it was safe to say that for the present any such development was many years ahead.

Lubricating Oils in Boiler-Feed Water.

By J. S. Gander, M.I.Mech.E., etc.

"The Shipbuilder and Marine Engine Builder", Nov., 1932.

The marine engineer chiefly fears the presence of oil in boiler-feed water because oil retards the transfer of heat; and thus the heating surfaces of boilers, whether covered with scale or otherwise, are liable to become overheated. Again, with oil present in the boilers, foaming is liable to occur, and this may also be accompanied by severe priming. For these reasons, the use of internal lubricants is avoided as far as possible in engines using saturated steam; while in engines employing superheated steam and in turbine operation, where oil inevitably passes through with the exhaust, every effort is made to render the condensate as oil-free as possible. In cylindrical boilers, even up to the present pressure limit of 300lb. per sq. inch, there is actually little to fear from the amount of oil which passes proper separating arrangements; but in water-tube boilers, and especially as the higher ranges of pressure are approached, the danger is more apparent, although, due to the fact that such boilers are invariably associated with turbine working, one seldom hears of a collapse from this cause. The reason for this will appear from what follows.

Composition of Lubricating Oils.

The nature of a lubricant has a vital bearing on the subject; and the essence of the matter is that mineral oils do not tend to decompose under boiler conditions, whereas others do to a greater or lesser degree. Oils other than mineral may consist of animal oils or fats and vegetable oils, and in the presence of alkalis used for boiler-water conditioning they form soaps and other undesirable compounds. Hence it is that foaming occurs when compound oils, composed of mineral oils with animal and/or vegetable additions, are suddenly introduced into a boiler with the feed water. A pure mineral lubricant will not have this effect; and although the lighter constituents may be driven off in vapour, the residue is not harmful, except that an accumulation may interfere with the free passage of steam from the surface and so cause priming to some extent, although not of a serious nature. Obviously, where internal lubrication is necessary, or lubricants may be drawn inwards as in a turbine, it is desirable that only pure mineral oils should be used. This is more or less recognised in the case of turbine oils where some contamination of the condensate is unavoidable, and thus mineral oils which demulsify quickly are used in preference to other oils or compounds which have the opposite characteristic. There is no sufficient reason, however, why all oils for internal lubrication should be other than pure mineral oils. It is admitted that the addition of a small percentage of non-acid animal fat, for example, helps a cylinder oil to spread more evenly, and the addition of animal and vegetable lubricants usually renders an oil more stable under temperature changes; but these advantages are more than counterbalanced by the difficulty in properly separating them from the feed water under marine conditions, and they may do harm in the boilers. In brief, there is no condition of internal lubrication where steam is concerned which cannot be satisfactorily met by the use of a pure mineral oil, and for the sake of the boilers only mineral lubricants should be employed for all purposes where the oil used may find its way to the condensate.

Effect of Oils on Heating Surfaces.

The most dangerous condition, which is usually appreciated, is when oils or greases are spilt on heating surfaces in an empty boiler, but here, again, the mineral derivative is the least harmful. This is due to the fact that as a boiler is filled and then heated up the mineral oil or the mineral grease as it melts continually endeavours to rise to the surface, and even the part which is absorbed by scale also tends to rise as the action of steam bubbles clears a passage. Animal and vegetable oils and greases, however, have less tendency to rise when the water is alkaline in character, and what remains when steam is raised is quickly decomposed to leave an adherent residue. Tallow, in particular, is especially undesirable, because the acids formed under boiler conditions readily attack iron and steel. To some extent the same remarks apply when a clean boiler is filled with feed water which is contaminated with oil, but afterwards there is little tendency for wetted surfaces to absorb oils of any nature. Of course, the chief danger to be anticipated from the presence of oil in a boiler arises from failure to maintain a proper water-level, and even heavy rolling or pitching of the ship may cause oil floating at the water-level to come in contact with (and possibly attach itself to) heating surfaces, such as combustion-chamber tops. Naturally, there is little to choose between mineral or compond oils when heating surfaces are uncovered for any appreciable time; but for momentary exposures, which in heavy weather are often unavoidable with Scotch boilers, the contact of a mineral oil which tends to rise again is to be preferred to that of soapy compounds and residues which may adhere.

Foaming in Boilers.

This subject is now being exhaustively investigated, and especially at the Engineering Experimental Station of the Ohio State University; but up to the present not much appears to have been added to what practical marine engineers already know. Most consider that a boiler filled with fresh untreated water is more liable to prime than one containing conditioned water; but in the writer's opinion this sometimes happens because the filling water has contained organic traces liable to decompose and form a scum which may foam, and in a perfectly clean boiler the initial efficiency of the heating surfaces is liable to cause some slight priming when boilers are pushed to make steam for the final "full ahead" on leaving port. It is agreed, however, that with a normal boiler-water concentration there is no reason for either priming or foaming under ordinary weather conditions, although with the introduction of impurities in the feed water both may occur. Again, with the entry of animal and vegetable oils with the feed water, as already indicated, it is quite certain that with the inevitable decomposition of such in the presence of alkaline solutions, some foaming must take place, although with small amounts of oil the effect may not be apparent immediately. In the circumstances foaming may occur not only because soaps and other compounds are formed which tend to introduce bubbles, but also because other extracts which are soluble in the boiler water impart similar properties. Mineral oils have not this tendency; and one knows from experience that, whereas compound oils are a cumulative source of danger which may break out on entry into heavy weather as saponified residues pass over with wet steam and destroy lubrication, pure mineral oils, and even fuel oils, may be present at the water-level and may pass over without any serious effects on the working of an engine. One writes here of accidental intrusion, of course; but the knowledge is valuable.

Separation of Oils from Water.

In shore practice there is the choice of several efficient methods; but under marine conditions any involving the use of settling tanks, which must be still in operation, are practically inadmissible, nor in the average type of steamship is there the space or the opportunity to operate systems requiring special chemical treatments. It is therefore of little use to discuss these or electrical methods, which have latterly been developed. Consequently, what is generally termed "mechanical filtration" must be relied upon in any but the largest vessels, which are less affected by weather conditions. With turbine oils the problem is not a very difficult one; for in view of the fact that only pure mineral oils which demulsify quickly are used, and such must also resist tendencies to "sludge" formation and oxidation in service, the inappreciable residue which actually passes to the boilers is practically harmless in its effect on submerged surfaces, and it has no tendency to change or decompose under boiler conditions. With compound oils containing animal and vegetable ingredients, however the globules of oil formed in a mixture of oil and water, or an emulsion, have very much less tendency to separate. The finest may not separate in a mixture left standing for months, and cannot be caught by any filter, however fine. In fact, only by chemical coagulation and the somewhat similar electrical method can complete separation be effected, and these are impossible in general marine practice.

In spite, therefore, of the efficiencies of various types of mechanical separators and filters, such as are practicable in marine service for dealing with a large and continuous flow of feed water, it is impossible to properly separate oils of animal and vegetable origin which emulsify easily but separate with reluctance. Although with the use of final carbon or coke filters which may adsorb (not absorb) much of the remaining oil, some inevitably passes through to the boilers. The obvious remedy is the use of oils of pure mineral origin, not necessarily because they demulsify more quickly than others (although this is an added advantage), but chiefly because they do harm in boilers under normal conditions. From this generalisation, however, one would exclude water-tube boilers operating at the higher ranges of pressure such as are not yet used in marine practice, except for what are more or less experimental installations; for it is now recognised that, for extreme pressures, only a practically pure feed water will serve, although actually this is a state of perfection which cannot be maintained.