HOT BULB OIL ENGINES AND SUITABLE VESSELS

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BY

WALTER POLLOCK

M.I.N.A., M.I.MAR.E., M.I.MECH.E., M.I.M.

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PREFACE

In publishing the present volume the author expresses the hope that those interested in the progress of the Marine Oil Engine may find in it something of interest and help.

The experimental phase is past, and oil-engined craft, particularly commercial vessels with hot bulb engines, are now, and have been for some years, a sound paying proposition.

In the race for efficiency and world supremacy in water transport, oil-engined craft will play a rapidly increasing part and will, moreover, improve and simplify dock organisation and labour.

The author desires to thank the many firms who have supplied information and a large number of illustrations; also to acknowledge the assistance of Mr. R. A. Pelmore and others in bringing their experience to bear on various chapters.

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HOT BULB OIL ENGINES AND SUITABLE VESSELS

CHAPTER I

Scope of the Book.—The adoption of the hot bulb or low compression oil engine for marine propulsion introduces new possibilities in the design of vessels for many different purposes. The objects of this book are: (1) To popularise the engine, to explain what it has done and what it is capable of doing; (2) To enable those interested to appreciate the advantages and disadvantages of the various designs; (3) To facilitate the study, and add to the general knowledge of this form of prime mover and its application to vessels of various types. The portion of the book dealing with the profit-earning capabilities of vessels fitted with the hot bulb engine, and examples of its usefulness for marine work may be of assistance to intending purchasers of vessels, up to, say, two or three thousand tons, in selecting a suitable type of vessel and engine.

It is not intended to set out the detailed particulars of design found in the various engines on the market from the point of view of the draughtsman, but rather to present the characteristic features and the more important details for the interest and benefit of owners, superintendent engineers, and intending purchasers. By following this course it is hoped that not only will the natural reticence of manufacturers be respected, but also that the book will be free from much cumbersome matter which would only be of interest to a drawing office staff.

Engines of the high compression type, such as Diesel engines, and also paraffin and petrol engines, are only referred to by way of comparison, but all engines of the low compression type using heavy oils, and hot surface ignition of the injected spray are included under the title of hot bulb oil engines, although some makers use plates or discs, instead of bulbs.

The term "Hot Bulb" engine is intended to have reference to low compression oil engines, in which compression takes place before the fuel injection (*i.e.*, while the cylinder contains only air), and in which ignition is effected by a hot surface on to which the injected fuel is sprayed. The term is adopted on account of its familiarity rather than its merit. "Semi-Diesel" has also been proposed, but is misleading; and a more reasonable explanatory term, which would have been better if adopted in the first instance, is that suggested by Mr. P. W. Petter, namely, "Surface ignition engine."

Introductory Remarks.—Oil as a source of energy, with internal combustion engines to convert that energy into useful mechanical power, is a subject of increasing interest to shipowners, marine engineers, and naval architects throughout the world.

Much scientific research work, resulting in great practical developments, has been accomplished in recent years with a view to increase the efficiency of the steam plant, and to overcome the objections of weight, cost, and space occupied in small vessels. Quadruple expansion engines, steam turbines, higher pressures and superheated steam have all contributed their quota, but very large losses from a scientific and practical point of view are inherent in the engine-room plant as also in the boilers, whether fired by coal or oil; while the use of gas engines in conjunction with producer plants for generating gas direct from coal though it has effected large savings on land, has met with little success for marine work; and the expense of, and the danger of fire with, the low-flash point fuels used with the light petrol motor-car type engine and its modification for burning paraffin rule them out for practically all commercial marine work.

The employment of cheap or crude oil consumed direct in the cylinders is a natural alternative which has resulted in the appearance and development of numerous types of oil engines, which are to-day well tried and successfully earning good profits for their owners.

The problem was to design and manufacture an oil engine of simple construction, that would satisfactorily consume residual oils up to 0·95 specific gravity, that would not have excessive pressures, temperatures or stresses, and that would not require technical men for running it.

Previous to 1890, the only type of engines on the market which burnt heavier oils than paraffin, were the Priestman and Hornsby-Akroyd, which may be considered the pioneers for land work. They worked on the four-stroke cycle, the oil being vaporised in a separate chamber before entering the cylinder.

About the year 1890, progress was made along two different lines, in Germany, Scandinavia and America; stimulated in Germany and Scandinavia by the difficulty of obtaining a supply of cheap coal.

On the one hand Dr. Diesel and his associates in Germany worked on the lines of a high compression sufficient to ignite spontaneously the fuel injected into the cylinder. These researches have resulted in the Diesel engine, which is manufactured by many firms in many countries to-day. Though excessive pressures are naturally disliked by engineers, there can be little doubt but that this engine will, in its own sphere, continue to find favour, and will effect considerable economy in merchant shipping.

On the other hand, engineers in Sweden and America adhered to a lower compression and utilised a hot combustion chamber in direct communication with the cylinder to enable ignition to take place. Perhaps the foremost of these inventors was Mr. E. Rundlöf, in Sweden, who still directs the technical and research work for the firm of Messrs. Bolinders, of Stockholm.

Sweden may indeed be called the home of the hot bulb engine, and has produced men of marked mechanical ability and great ingenuity.

Messrs. Mietz and Weiss, of New York, were probably the first to place a hot bulb engine regularly on the market, which they did in 1898, though the **Avance** engine was produced at about the same time by Messrs. B. A. Hjorth & Co., Stockholm, Sweden.

The early trials of internal combustion engines with the wide variations of cylinder temperatures compared with those of steam engines caused many engineers to abandon their efforts, and the difficulty of designing and manufacturing an efficient hot bulb and cylinder that would scavenge well on the two-stroke principle further decreased the number of firms to achieve success.

Although probably about a hundred firms, who in the early days experimented with hot bulb engines, were obliged to abandon them, the number of manufacturers is to-day steadily, if not rapidly, increasing, and at the present time amounts to about a hundred and twenty in all parts of the world.

The British manufacturers did not take up this engine as quickly as those on the Continent, and although a launch was fitted with a Priestman engine in 1900, practically no headway had been made until 1909. In June of that year the launch **Alert** was fitted with a 12 B.H.P. Bolinder engine in Dartmouth, after which success followed success, and now the hot bulb engine is coming into its own, even in the conservative British Isles.

The first hot bulb engine of over 300 B.H.P. was made by the Bolinder Company, of Stockholm. This was a four-cylinder engine of 320 B.H.P. fitted in the *Isleford*, which was built in Glasgow in 1911. Two weeks' trials resulted in its purchase by the British Admiralty. This standard size engine has since been fitted in large numbers of vessels in the British Isles and other countries.

It will be convenient here to review the work done in the same field by other types of engines.

The Diesel engine, which is firmly established for land work, and as made by a few manufacturers, for marine work, has the advantages that it can more easily consume inferior fuel oil and can work at the lowest consumption per horse-power, that it dispenses with the hot bulb, and that it can be manufactured in larger powers per unit. On the other hand, the design, especially for small power, is more complicated, the pressures and stresses are much greater, the engine is more expensive and difficult to construct, and is not so reliable, especially for the powers in which the hot bulb engine is a competitor.

The hot bulb engine is not so heavy as the Diesel and, owing to the absence of high temperatures and pressures, it is safer, and subject to less wear and tear in the principal parts.

Some recent hot bulb engines are fitted with air compressors, though they can work at somewhat reduced power without the compressors, which is a very considerable advantage, as probably, apart from the pressure and temperature trouble, most of the difficulties of the Diesel engines are due to the air compressors. It is to be noted also that a hot bulb engine air compressor works at lower pressures, and is therefore simpler and more reliable than that part of the Diesel engine.

Paraffin and petrol engines have proved their reliability for marine work. They usually start quickly, are neat and compact, and can be driven by any good motor-car driver with very little additional practice.

Petrol engines find favour with owners for fast launches and especially for river launches, but the Admiralty and the Board of Trade dislike them because of fire danger.

Paraffin engines are still in considerable demand for Government launches and small craft, tenders for mail steamers, fishing vessels, etc. In the British Isles they have been much longer on the market than hot bulb engines and are generally cheaper per brake horse-power, although the higher revolutions do not allow a fair comparison. The reason why they have not obtained a great deal of success for commerical work is, because of the large number of small parts, of which the engine is comprised, the excessive fuel costs, and the large number of revolutions at which the engines run and the consequent inefficiency of the propeller. Regarding the latter the following comparison between two launches is not without interest :—

The wooden launch "A.A." fitted with a light four-cylinder 24 B.H.P. petrol-paraffin engine of a well-known make, running at 800 R.P.M. obtained a mean speed of ten miles per hour, while an exactly similar launch "B.B.," from the same lines and from the same yard, constructed shortly after, fitted with a 16 B.H.P. two-cylinder hot bulb oil engine, running at 550 R.P.M. obtained a speed of one-eighth of a mile per hour more than the petrol-paraffin engined boat, although the hot bulb oil engine was considerably heavier and of smaller power.

Some makers have fitted reducing gears to high-speed engines as, though for light high-speed craft a high peripheral speed for the propeller may be advantageous, for commercial craft it is not advisable if anything like efficiency is desired ; any form of mechanical or other reduction gear, however, carries with it many disadvantages.

Gas engines worked with a producer or suction generator have been tried for marine purposes, which is not surprising, as for land work they have had twenty years of successful trial, and are now made by many firms in very large quantities. They have greater flexibility than hot bulb oil engines and, theoretically, have many advantages, but up to the present the makers of marine gas engines have not produced a successful installation. The engines present no great difficulty except for reversing, but it is the generators or producers which have been at fault.

A successful suction gas installation appears only to be commercially possible by the use of bituminous or ordinary coal, on account of the price of anthracite ; this, however, calls for a lot of auxiliary machinery, such as cleaners or scrubbers, tar extractors, etc., and it is this which prevents the successful use of suction gas plant for marine work. There is also the question of dealing with any leakage of the heavy gas into the engine room, as ordinary methods of ventilation do not appear to have proved satisfactory.

As already mentioned, steam machinery which for so many years has had a monopoly, has received the attention of the greatest engineers in the world and, with continuous improvements, has attained a high degree of perfection. For large powers it will remain as the motive power for ships for many years to come, but as coal becomes dearer and oil fuel cheaper, it will have greater difficulty in maintaining its position. Steam machinery has the advantage of being specially reliable, of being easily handled by any marine engineer, of having great flexibility, and of developing a low percentage of power economically. On the other hand, the weight per horse-power is from two to two and a half times as much as for heavy oil engines, which is a serious matter, since every pound of weight on board ship requires the necessary displacement to be provided in the design of the hull ; the extra space required for steam machinery is for similar reasons another handicap.

The points in favour of the heavy oil engine as compared with coal-fired steam machinery might be summarised thus :—

*Simplicity in design and working parts.
*Economy in consumption.
*Elimination of the boiler and its attendant troubles, and consequent reduction in upkeep.
Elimination of the stokers and trimmers.
Reduction in the engine-room staff.
*Elimination of standby expenses.
*Reduction in space required for bunkers.
Quicker bunkering.
Greater radius of working without a reduction of power through smoky tubes, etc.
*Simplicity of installation.
Efficiency more independent of the engine-room staff.
*Reduced engine-room space and thus more cargo capacity.

A number of firms are experimenting with engines of a type between the hot bulb and the Diesel, having a compression

* Signifies that the advantage holds good over oil-fired steam plants.

pressure varying between 275 and 400 lbs., with a view to enable the engines to start up without the delay involved by the necessity of having pressure lamps to heat the bulbs, and also to do away with the very real objections to the high pressure and high temperatures of the Diesel type. In one instance this has been attempted without the necessity of "injection air" being employed, so that a lower compression can be used without any fear of mischief from the loss of heat which would take place if cold air was passed into the bulbs. Possibly this method may be satisfactory when oils having a low flash point, such as paraffin, are used for starting purposes, though they may not have a long lease of life.

The shipowner is usually chary of innovation, but sooner or later he will recognise the superiority of the hot bulb oil engine. Economy should be seriously considered in conjunction with all forms of expenditure; it is, indeed, the secret of success of many firms and businesses, particularly those appertaining to ships and shipowning; as years go on this will become more and more manifest and, in many cases, vital to those firms that not only wish to survive, but wish to progress.

Comparison for Power.—When once satisfied as to the need and advisability of adopting the hot bulb type of engine, the purchaser or his engineer must consider the powers and prices, and other details of the various proposals put before him.

Very few makers agree as to the method of calculation of the power, and, unfortunately, there is no standard basis; some have a large margin, some not; some specify a given cylinder volume as producing 20 per cent. more power than other makers at the same revolutions, which necessitates high mean pressures, whilst others have practically the same ratio of cylinder volume and mean effective pressure, but run at higher revolutions, which would appear to give a more powerful engine, although it may be actually the same size as one put forward by a more cautious maker as of less power, As there is no standard rule for the rating of the engine, it is difficult to make a fair comparison of the power, owing to the many different ideas; firstly, as to the revolutions of any given sized cylinder, secondly, as to the correct mean effective pressure and, thirdly, as to the margin between normal power and overload.

Another factor to be taken into consideration is the efficiency of the engine, and it must be remembered that experience and the production of thousands of engines nearly always result in greater efficiency for any given size of cylinder.

The weight of the engine should also be taken into consideration in dealing with the price.

Demand for Engines.—At the end of 1914 there were probably 300 vessels and barges in the British Isles, with a total of 11,500 brake horse-power of hot bulb low compression marine engines.

The progress during 1915 was enormous, due to Admiralty requirements, and the total number of vessels was possibly increased to 750 and the B.H.P. to 31,500. This ratio of increase is not likely to be maintained during the next few years, unless considerable numbers of engines are placed on the market at reasonable figures.

The demand for marine engines of, say, 500 B.H.P. might be expected to be three times as great as the demand for engines of 300 B.H.P., and for engines of 1,000 B.H.P. the demand would be five times as great as that for 300 B.H.P. as soon as the reliability of the sizes mentioned has been demonstrated ; economy has already been proved for almost any size, but reliability is of even greater importance.

For shallow draft and coasting vessels, where the dimensions are limited and the maximum hold space and cubic capacity for cargo are required, and for large case goods, the malt trade, etc., the demand for these engines will increase, and even at the present time, steam machinery has difficulty in competing, and in a few years will have greater difficulty still.

The demand should grow, too, for these engines for fitting on sailing vessels and converting them into auxiliaries, for Admiralty launches, river and harbour tugs, dredgers, and many other types of vessels, while the demand abroad will even be greater than in the older countries, as the prejudice against new forms of power is not so great. Countries with rivers and waterways near to the oil producing wells will have a proportionately greater demand. At one time the type of engine did not matter much, but with the increased cost of living, and the increase in wages of skilled men all over the world, the demand for the engine which is the most economical, even though it may be more costly in the first instance, is bound to grow.

Owners' Requirements.—Owners usually require a considerable amount of information before they adopt a practically new type of engine, and require to be satisfied as to its efficiency, economy and reliability; and all this it is necessary for makers to supply, including particulars of the economies shown in previous installations in regard to the reduction, both in working costs and in cost of upkeep. An owner of a sailing vessel, who is thinking of fitting a hot bulb engine as an auxiliary, will want to know besides all this, the names of similar vessels in which the engines have been fitted, what voyages they have done, how long they have taken, the saving of time on a round voyage, the cost of working the machinery including depreciation, the net gain to be expected and, finally, the disadvantages. No matter how nice the engine may appear from a theoretical point of view, it will be the actual accomplishments upon which success will ultimately depend, and practical results in a similar class of employment will be insisted upon.

It is therefore necessary for makers or their representatives to collect and tabulate this information and submit it in some such form as the examples given in this book. There would then not be much difficulty in supplying would-be purchasers with all the information they desire, especially in the case of coasters, lighters, canal barges, fishing and auxiliary vessels.

Makers cannot expect owners to adopt a new type of engine until its economy and all-round reliability can be proved over several years of working. Test bench results and low consumption figures of a few hours' duration will not convince an experienced owner, and a very low first cost quoted for an engine that he well knows is expensive to make will not attract him, but will be more likely to raise his suspicions.

A printed price list should be issued where possible, clearly specifying what is, and what is not, included. There are many difficulties in the way of doing this, such as the question of freights, the differences in the cost of the various forms of stern gear, whether bilge pumps are to be included or not, and whether or no the engine is to be classed with one of the classification societies, etc.; these, however, do not prevent the issue of a basis price list, packed and delivered f.o.r. at works, or f.o.b. at a given port.

CHAPTER II

Makes of Engines.—The following brief descriptions of the different makes of engines, arranged alphabetically, will enable a comparison to be made of the leading features adopted by various makers, though before dealing with individual makes, it may be well to give a brief description of how the ordinary two-stroke cycle engine works.

Cycle of Operations of the Hot Bulb Engine.

Most hot bulb engines work on what is known as the two-cycle principle, that is to say, there is one impulse in each revolution.

The general mode of operation is as follows :—

Outward Stroke.—Referring to Fig. 1, suppose the piston to be moving downwards after the ignition, and to uncover the exhaust port G, the pressure is released, and the exhaust gases begin to escape into the silencer L and thence to atmosphere. Shortly afterwards, and as the piston reaches nearly its outer dead centre, the scavenge port H is uncovered and air passes from the crank chamber C into the cylinder, striking the lip on the piston, which deflects it upwards through the hole (on the right) in the hot bulb E, and thence through the second hole, sweeping down the cylinder and expelling the spent gases, leaving fresh air in both bulb and cylinder.

Inward Stroke.—When the port G is again covered, the trapped air in the cylinder is compressed and, shortly before the top dead centre is reached, oil is forced by the fuel pump through the nozzle F as a fine jet into the bulb E, which has been previously heated by playing a blow lamp on the stud K, and as the jet impinges in the neighbourhood of this stud, combustion takes place and the cycle is repeated.

During the inward stroke air is drawn through the light flap valves B into the crank chamber, and here it is compressed on the outward stroke until the port H is uncovered and scavenging takes place.

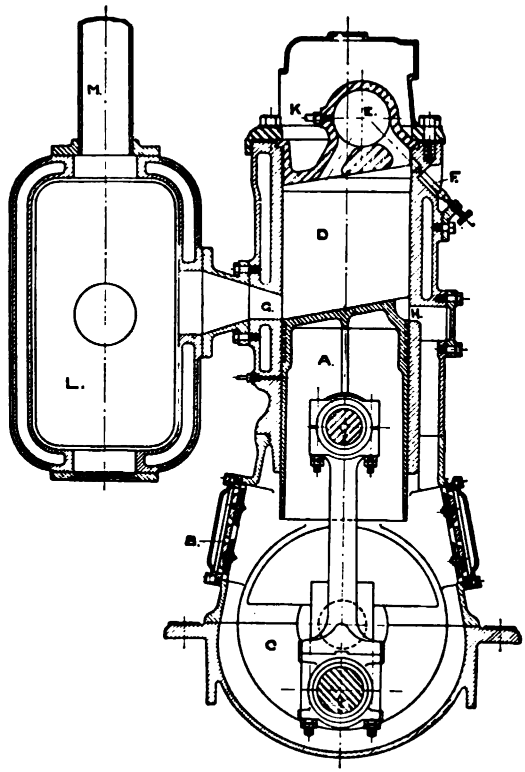


FIG. 1.—Section of the Bolinder Engine, "E" Type.

When once the engine is started up, the combustion itself maintains the bulb at a sufficient heat and the blow lamp is turned off.

Some thirty makes of engines are given in this chapter in rough outline with general illustrations, but in many instances details such as fuel pumps, governors, reverse gears, etc., will be found elsewhere by reference to the Index.

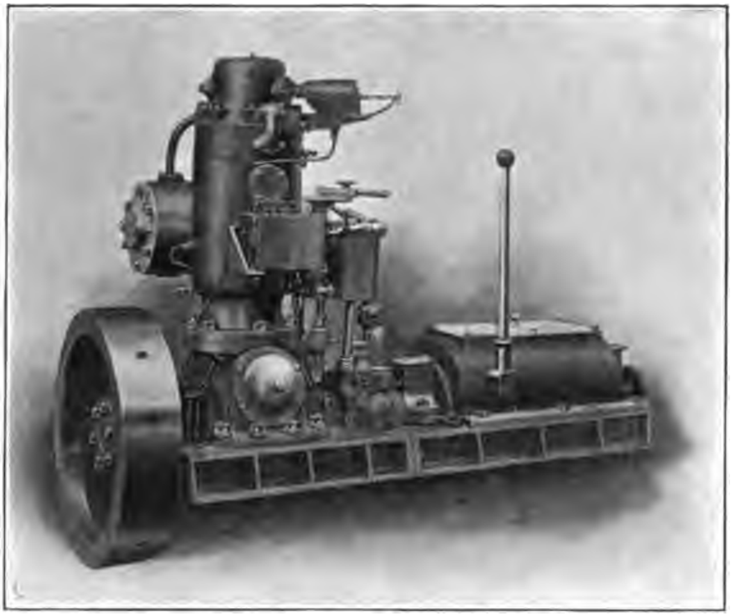


Fig. 2.—Ailsa Craig 10 H.P. Engine.

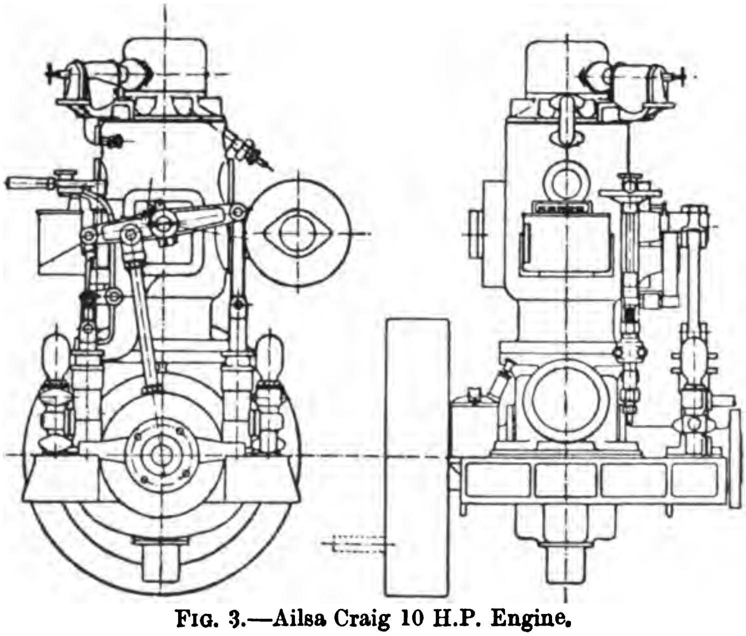


Fig. 3.—Ailsa Craig 10 H.P. Engine.

The Ailsa Craig.

The **Ailsa Craig** is a two-stroke cycle hot bulb engine, made in England by the Ailsa Craig Motor Co., Ltd.

The cylinder of the principal size is 7 in. diameter, 9 in. stroke, and develops 10 H.P. per cylinder at 400 revolutions per minute.

The crank case air valves are of leather.

The fuel pump, illustrated in Fig. 112, p. 135, is fitted with a gland. The fuel injection nozzle is illustrated on p. 143, Fig. 120.

Forced feed lubrication is fitted to the cylinders and to the main bearings.

A combined free clutch and reverse gear operated by one lever is fitted.

The Alpha.

The **Alpha** is a Danish four-stroke hot bulb engine. The first engine of 4 H.P. horizontal type was made in 1898, and was fitted on a fishing cutter for winch driving. The

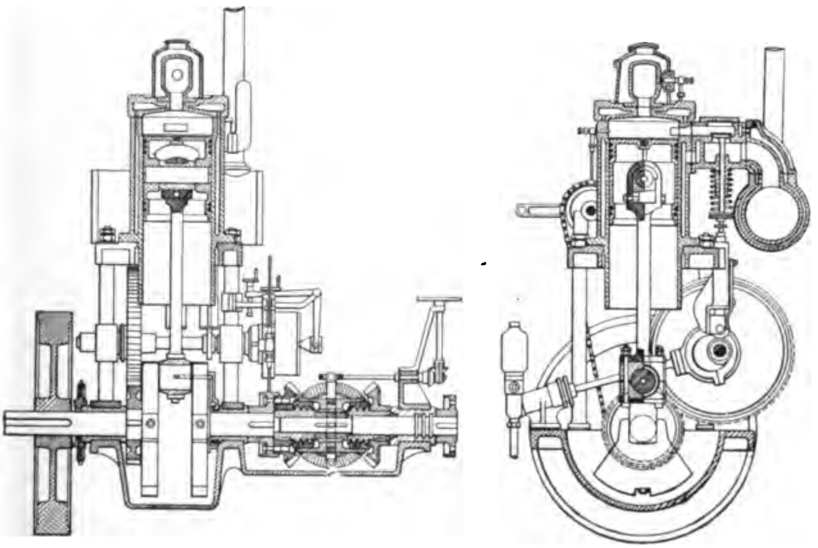


FIG. 4.—The Alpha 19 B.H.P. Engine.

owner, however, wanted it also to drive a propeller; a horizontal shaft was therefore fitted along the deck with a chain drive from the engine, the end of the shaft extended over the stern of the vessel and a vertical chain drove a cast-iron propeller, fitted in a frame which could be easily removed and lifted up out of the water if required—it was termed a "bicycle screw." The arrangement, however, was too complicated and not sufficiently reliable, as the chain sooner or later gave trouble, and it was only fitted in a few vessels.

The present four-stroke engine is illustrated in Fig. 4. The cylinders are supported on steel columns, which permits of an open crank case so that the bottom end bearings are easily accessible. A special feature is the fuel injection which has two nozzles or injectors, operated by one pump for the small engines and by two pumps for the large engines; these pumps are operated by a centrifugal governor which automatically shortens or lengthens the stroke of the pump or pumps, according to the load on the engine.

One jet is directed into the bulb or vaporiser and the other into the top of the cylinder, as will be seen by the drawings. The upper or hot bulb injection is sufficient to keep the engine running very slowly, the low number of revolutions being specially suitable for line fishing.

The engines are fitted with a reverse gear, and, in some instances, with reversible blade propellers.

Gravity or drip lubrication is fitted.

The engines are built for marine purposes in units of 1, 2, 3 and 4 cylinders, and in thirty-four different sizes, from 2½ to 96 B.H.P.

The Avance.

The **Avance** is a Swedish two-stroke hot bulb engine, and was one of the pioneers of this type.

It is manufactured in four distinct models:—

1. Direct reversible by compressed air.
2. Direct reversible by pre-ignition.
3. With reversing gear.
4. With reversible blade propellers.

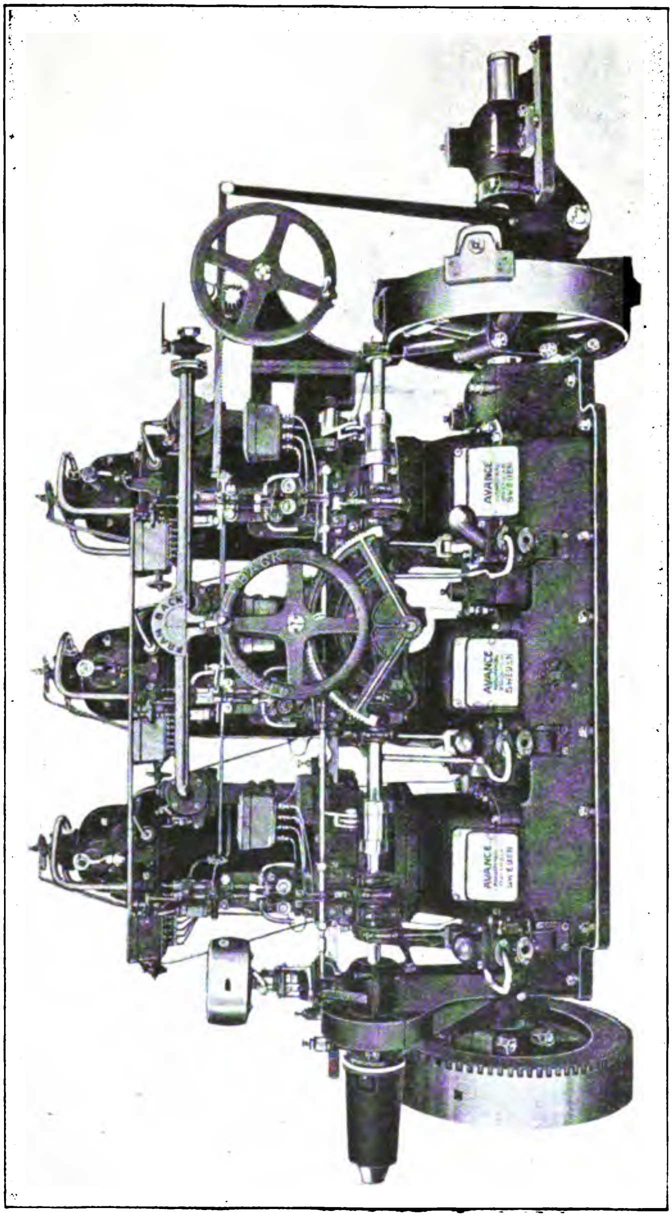


FIG. 5.—Avance 138 B.H.P. Oil Engine, direct reversible by compressed air.

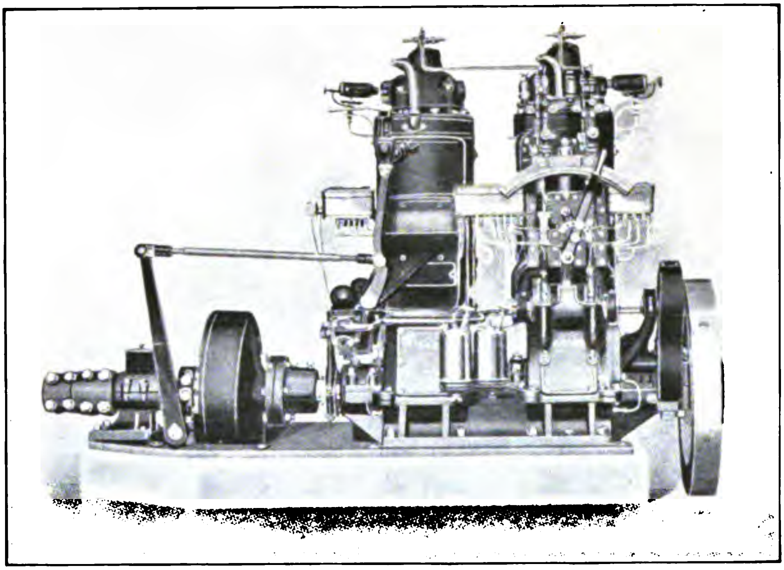


FIG. 6.—Avance 60 B.H.P. Oil Engine, direct reversible by pre-ignition.

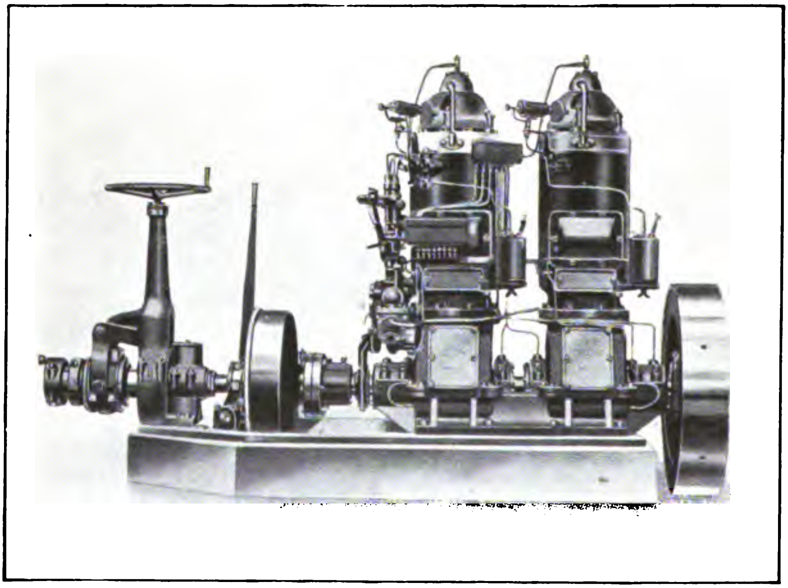


FIG. 7.—Avance 60 B.H.P. Oil Engine, with reversible propeller blades.

The direct reverse with compressed air, see Fig. 5, is only adopted for the larger engines, usually from 138 to 320 B.H.P. The weight of the 320 B.H.P. engine is about twenty-five tons.

The direct reverse by pre-ignition (see p. 106) is adopted for intermediate sizes, which are fitted with a clutch to take the load off the propeller shaft whilst reversing is taking place.

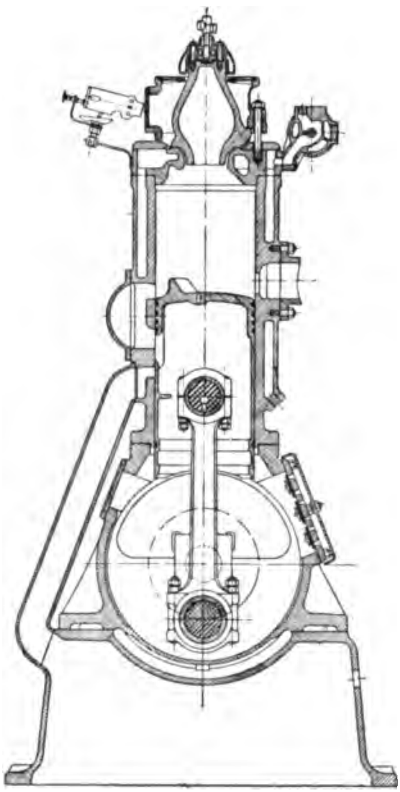


FIG. 8.—Avance Oil Engine.

All the models and types have water-cooled cylinder heads, hit-and-miss governors, vertical fuel pumps, mechanical lubrication to the cylinders and bottom ends, the latter by a banjo ring.

The scavenging air is arranged to cool the piston head before entering the cylinder. This is accomplished by means of two sets of ports arranged in the cylinder, connected with one another, and a set of ports cut in the piston. On the downward stroke the piston first uncovers the top set of ports and then the lower ports register with the ports in the piston, so that the air rushes up through the piston ports and into the cylinder through the upper cylinder ports.

The injection nozzles have a water-cooled cap, a ten-gallon tank being fitted above the cylinders (see p. 128), so that the water jacket is kept full when the engine is stopped. The nozzles contain valves and also an atomising and whirling device.

The fuel and water drip pumps are in the same casting and deliver into one passage in the injection nozzle. Both fuel and water pumps are packed with leather washers and a filter is fitted on the pump casting.

A circulating pump is fitted to each cylinder.

A number of details are illustrated and described in these pages, see Index.

The Beardmore.

The **Beardmore** is a two-stroke hot bulb engine of British make.

Like many other makers of hot bulb engines Beardmore's commenced their marine oil engine department with the

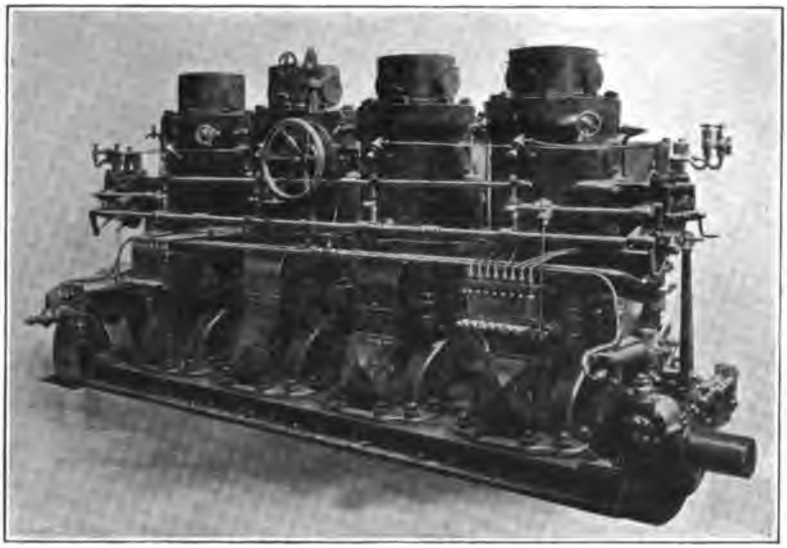


FIG. 9.—Beardmore 200 B.H.P. Direct Reversible Oil Engine.

electric ignition type of paraffin engine. After abandoning this in 1911, they experimented with hot bulb engines, both with force pump injection and with blast injection.

The latter did not warrant the extra complications, and was therefore not adopted as a standard.

The 200 B.H.P. engine, Figs. 9 to 11, has four cylinders, each 14 in. diameter and 14½ in. stroke, the power being developed at 280 revolutions per minute.

It is of the direct reversible type with a flywheel, but

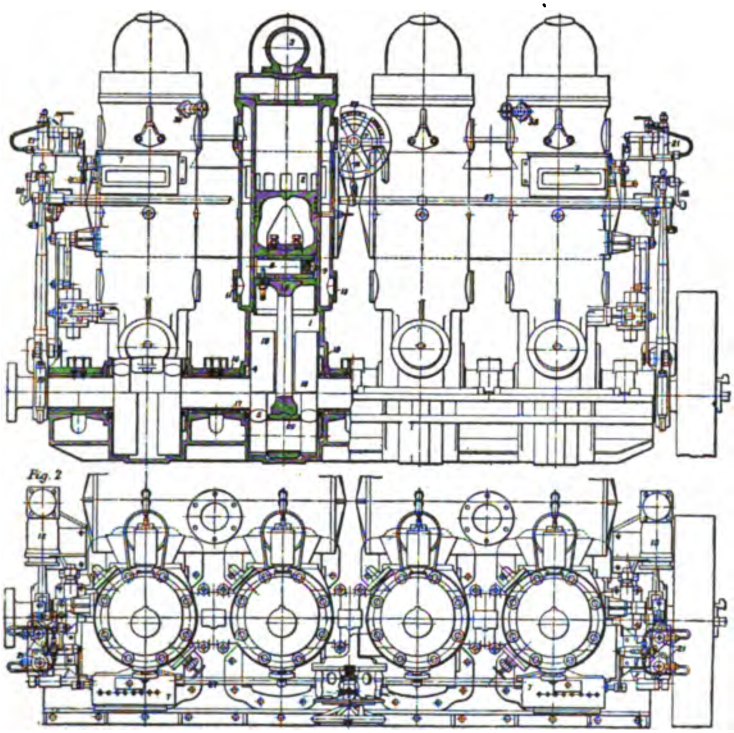


FIG. 10.—Beardmore 200 B.H.P. Oil Engine.

without a clutch. As will be seen by the illustrations, the cylinder head is water cooled but not the bulb, and crank case compression is adopted for scavenging purposes. Air tightness is secured round the journals by bronze rings which are fitted to the crank shaft and the crank webs, and kept together by springs.

A compression of about 150 lb. per square inch is employed, and the fuel is injected at the top dead centre directly into the bulb. A check valve is fitted close to the nozzle, and since this nozzle has to be drawn occasionally for inspection and for cleaning, it is made very accessible. Water-spraying was formerly fitted, and is indeed shown on the views of the engine, but it has been dispensed with in the later engines.

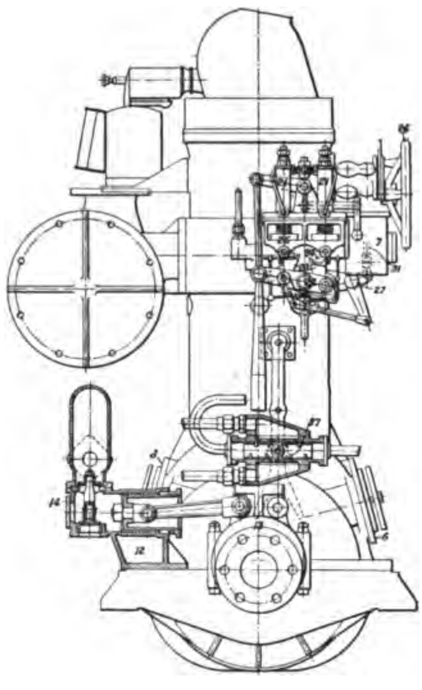


FIG. 11 —Beardmore 200 B H.P. Oil Engine.

For the cylinder lubrication, oil is carried to three points in the wall, one each at back and front and one at the side. The latter point is more particularly for the purpose of supplying lubrication to the gudgeon end of the connecting rod. Within one end of the hollow piston pin a box is secured, containing a scoop which is pressed outwards by a light spring. The scraper collects oil from the supply pipe in the cylinder wall, and it feeds the lubricant through holes in the box to the lining of the gudgeon bearing. The hollow pin has a relatively large clearance from the cylinder walls at each end, and is fixed by a short bolt. Five compression rings are fitted to the piston and a scraper ring is let into the skirt. An oil supply pipe is carried through the wall of each crank casing to feed the banjo ring which lubricates the crank pin. All these oil pipes are supplied from two mechanical oilers, one at each end of the engine, the motion for this purpose being obtained from the pump gear in a manner which can be easily traced in the drawings.

For the purpose of controlling the engine, a single wheel is used by means of which the engine can be started, reversed, and fully regulated, but the mechanism by means of which these operations are carried out is divided into two groups, mounted respectively on the forward and after cylinders. Each group serves an adjacent pair of cylinders, although the control wheel acts upon the four simultaneously. The upper position in each group is given to the fuel pumps, of which there is one for each cylinder, and the pump box is cast with the panel, by which it is bolted to the end of the cylinder.

A description of the Beardmore fuel pump, together with a description of the direct reversing gear, which should be studied in conjunction with that of the pump, will be found on pp. 97 to 100.

The Bolinder.

The **Bolinder** is a two-stroke hot bulb engine, made in Sweden. The first oil engines made by this firm in about

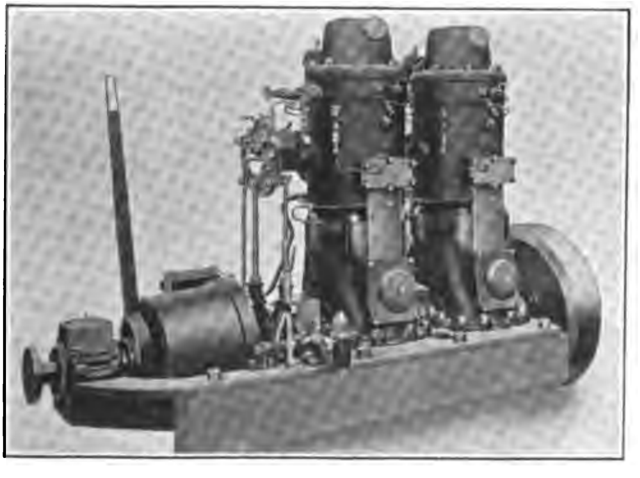


Fig. 12.—Bolinder Direct Reversible, "E" type.

1894 were of the four-stroke type, but experiments with the two-stroke engines very soon led to the abandonment of the former.

The operation of the engine is described on p. 12. All these model "E" engines need water injection or water

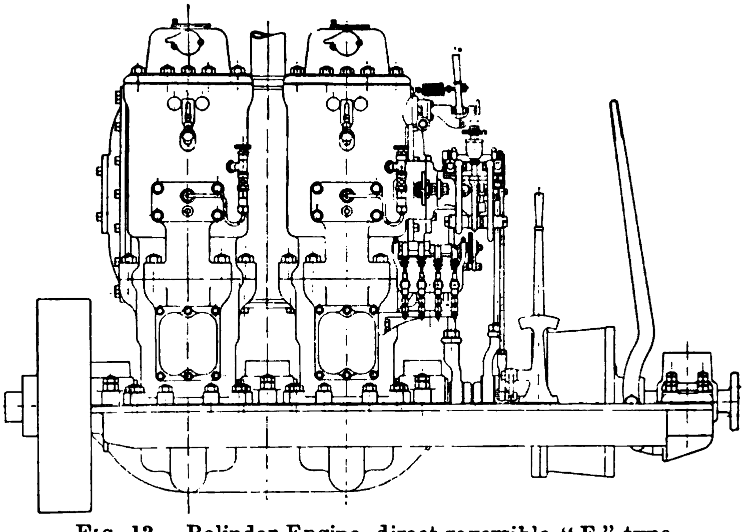


FIG. 13.—Bolinder Engine, direct reversible "E" type.

drip in the bulbs for the larger sizes when full power is required. Approximately, 600,000 B.H.P. of these engines were manufactured up to the year 1918, so that the makers can claim a very large experience in the production and

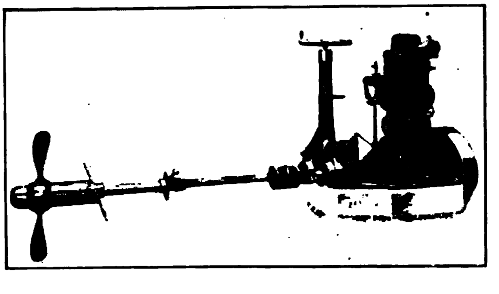


FIG. 14.—Bolinder Engine, with reversible blades.

perfection of this particular type. Engines of this type were manufactured as single-cylinder units from 5 to 80 B.H.P., as two-cylinder units from 10 to 160 B.H.P., and as four-cylinder units 80 to 320 B.H.P., but are now only made up to 80 B.H.P. in two cylinders.

The governor is of the "hit-and-miss" type, together with a hand adjustment of fuel pump stroke for economical running at cruising speeds.

A clutch is fitted between the engine and thrust block in all cases, whether direct reversible, or fitted with reversible blade propellers.

The arrangement of compressors and pumps for charging the air bottles for this type of engine will be found on Fig. 337.

From early years these makers have carefully avoided the manufacture of engines with reverse gears, adhering strictly to their patent direct reversible engines for the majority of their output, but building a number of engines from 5 to

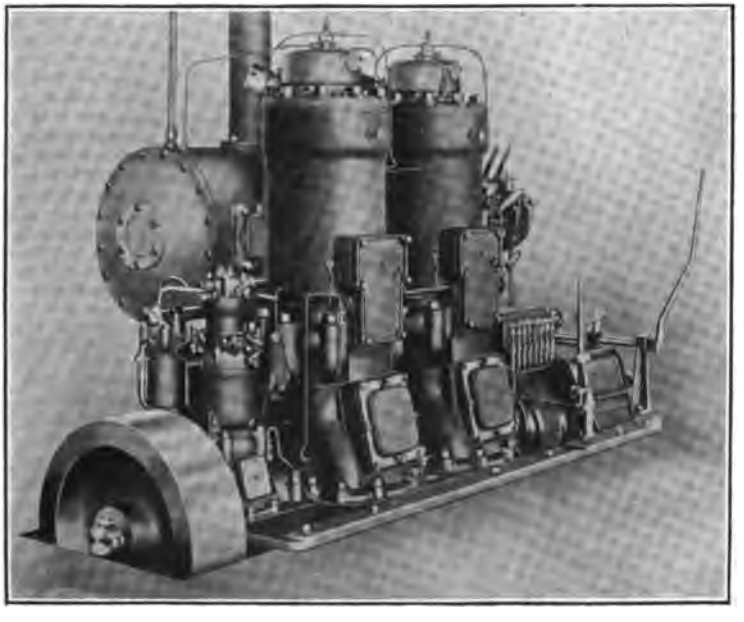


FIG. 15.—Bolinder, Model "M."

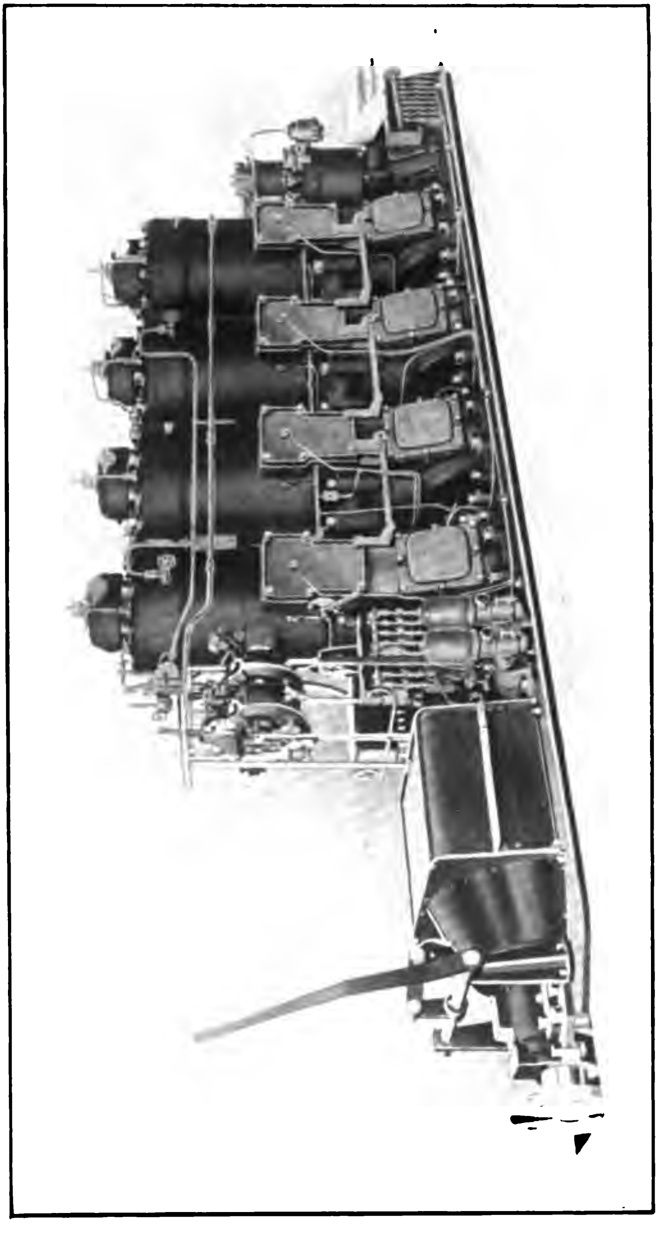


Fig. 16.—Bolinder, Model "M," 320 B.H.P.

65 B.H.P. with reversible blades, a model that was specially designed for fishing vessels, pilot boats, ferry boats, etc.

In 1912 Bolinders made trials with a new type of engine which they designate model " M " ; this they demonstrated on board ship in 1914 and placed on the market in 1915. This engine is made in sizes from 80 to 500 B.H.P.—about a dozen sets of the latter size being contracted for in 1915.

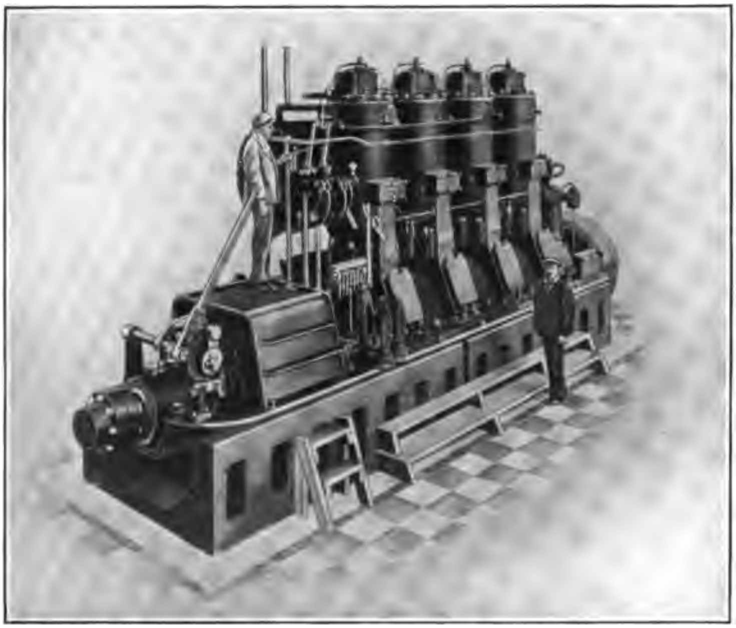


FIG. 17.—500 B.H.P. Bolinder, Model " M."

The chief alterations in this type are that a two stage air compressor is fitted between the forward cylinder and the flywheel for supplying air to the hot bulbs, that the cylinder heads are water cooled, and that forced feed lubrication is arranged to all parts. The claims for this engine include :—

(*a*) Complete combustion, resulting in very clean cylinders and, consequently, less wear.

(*b*) The ignition bulb, which is subject as a rule to great differences in temperature, never becomes more than just visibly red when running on an overload, and is quite black when running at normal load.

(*c*) Water drip is dispensed with entirely and, even should any trouble happen to the air compressor, the engine can still work at about two-thirds power while the compressor is out of action.

(*d*) As a result of the complete combustion, a good clean exhaust is obtained, which is a distinct gain, not only while in port or riverways, but also in keeping the exhaust pipes and secondary silencers free and also keeping the decks cleaner.

(*e*) The heat of the bulb can be accurately controlled by adjustment of the compressed air.

The 500 B.H.P. unit is interesting, as it is the first hot bulb engine to be constructed of that size. The revolutions are 160 per minute, weight 40 tons, length, including clutch and thrust block, 27 ft., the flywheel being 4 ft. 7 in. diameter. The first vessel to be fitted with an engine of this model was the *Hjalmar Sorensen*, see p. 271.

For other details refer to Index.

The Bolnes.

The **Bolnes** is a two-stroke hot bulb engine, which is in appearance something like an ordinary marine steam engine. It is made by a Dutch firm who have been working at it since 1909, when they first produced a four-stroke cycle oil engine.

As will be seen by the illustration, Fig. 18, this engine has the advantage of an open crank case, and an exposed connecting rod which is almost a unique feature for a low compression oil engine. The maker claims that by his "open" design, he dispenses with the difficulty of lubricating the connecting rod top and bottom ends, and that the engineer or driver in charge can always tell whether his crank-pin bearings are warming up, that the crosshead and guide eliminate the side pressures on the cylinder walls and the "oval-wearing" of the cylinder and piston are avoided; that the crosshead pin (connecting rod top end bearing) is not subject to high temperature, and that the engine is more easily taken to pieces for overhaul.

Undoubtedly, these are all improvements in the right

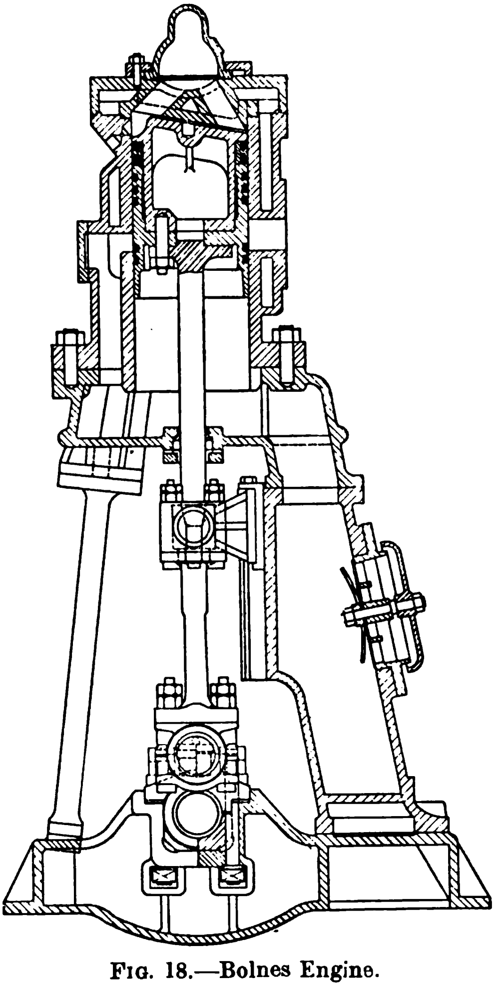


FIG. 18.—Bolnes Engine.

direction and the only disadvantage is that the engine is much higher, the centre of gravity is raised, and the weight is probably increased per brake horse-power.

A reverse gear is fitted for reversing the propeller.

The Brooke.

The **Brooke** is an English two-stroke hot bulb engine.

The engine, illustrated in Fig. 19, is nominally rated at 15 B.H.P., though actually it develops 21 H.P. when running at a speed of 485 revolutions per minute. Generally it presents no special departures from ordinary two-cycle hot bulb practice, and it has been designed for both marine

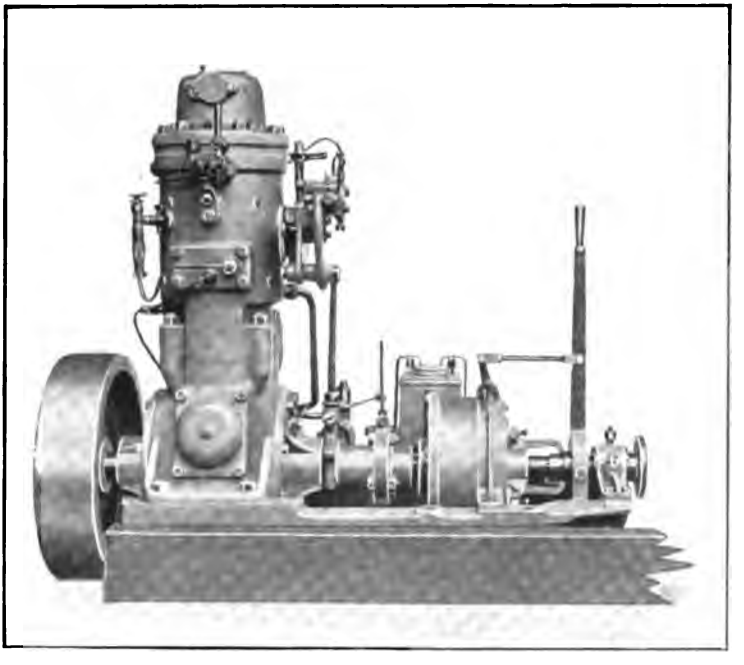


FIG. 19.—Brooke 15 B.H.P. Engine.

and stationary work, to run on the usual fuels employed with this type of engine at a moderate speed of revolution.

The fuel pump is operated from an eccentric through a bell crank lever, and the circulating water pump is arranged horizontally, driven off an eccentric.

As will be seen it is fitted with a reverse gear. The weight of the engine and reverse gear to the end of the thrust block is 12 cwt.

The governor is of the "hit-and-miss" type. Water injection is provided, and the makers state that it is only required when working on an overload.

The length of stroke of the fuel pump (see p. 145) is regulated by a quadrant, and the speed is governed by a spring engagement, working on the top of the striker.

The Capitaine.

The **Capitaine** engine is described in these pages because, like the **Priestman**, it was one of the early petroleum engines, and may have had something to do with the introduction of the hot bulb engine.

This engine is of the four-stroke type and was first made in France about 1889. As will be seen from Fig. 20, the cylinder head or combustion chamber was water cooled.

Originally an ignition tube was fitted, but in 1891 this was discarded, and the heat produced by the lamp was utilised exclusively in the vaporiser. This vaporiser (*c*) has the same function as a small hot bulb, with the difference that the fuel oil and air pass through it. The feed pump injected the oil into the valve (*a*) before the downstroke of the piston, or just before the period of suction commenced. On the downstroke of the piston rarefaction took place, so that the pressure of the outer atmosphere opened the valves (*a*) and (*b*). The petroleum previously injected into the spraying valve (*a*) was met by the incoming air and sprayed into the cherry-red walls of the vaporiser (*c*), where it was instantaneously vaporised, and admitted immediately into the cylinder in which the suction took place. The vaporised petroleum issued from the vaporiser long before the end of the period of suction, whereas the air was admitted by the valve (*a*) into the vaporiser as long as the process of suction continued. Consequently, when the period of suction was at an end, the vaporiser was filled with air, and as the inlet valve (*b*) was also open during that period, the upper part of the combustion chamber was likewise full of air. This column of air formed an insulator,

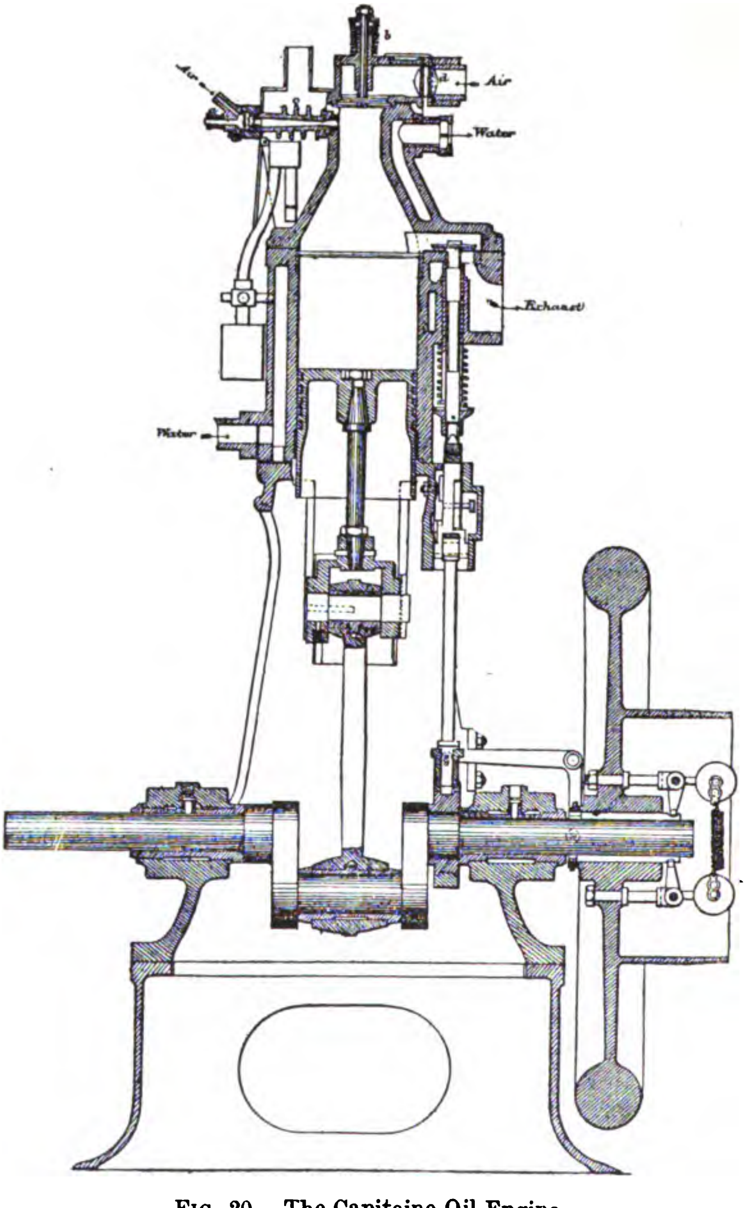


FIG. 20.—The Capitaine Oil Engine.

and prevented the inflammable mixture from coming in contact with the cherry-red walls of the vaporiser. By the upstroke of the piston, the inflammable mixture moved upwards until, at the dead point of the piston, it reached the interior of the vaporiser. Ignition took place, and a large flame spread with great rapidity from the vaporiser to the explosive charge in the compression chamber.

The precise action was dependent upon the sizes of the valves (*a*) and (*b*), upon their lift, and in some degree upon the tension of the springs, but as a further means of controlling the air admitted a throttle valve (*d*) was placed in the air supply inlet and arranged for accurate adjustment.

The Cross.

The **Cross** oil engine, Figs. 21, 22 and 23, is of the four-stroke type, made in England.

The combustion chamber immediately above the cylinder is water cooled and has screwed into it a small iron bulb, which is heated by a blow lamp before starting, and serves to ignite the charge for the first few working strokes, after which the ignition of the fuel is maintained by the heat of combustion.

The revolutions are high for marine work for the "BM" type, but for the "EM" type are only 350 per minute for engines giving 30 H.P. per cylinder.

The compression used is 160 lb.

A wide range of speed and flexibility is said to be obtained by dividing up the requisite air into two parts, the fuel being injected into that portion contained in the combustion chamber; thus smaller quantities of fuel can be ignited with greater regularity and with more complete combustion than would be possible if the fuel were injected into the whole of the air at one time. The second portion of compressed air is in an annular space uncovered by the piston early on the down stroke, allowing it then to mix with the burning fuel.

The flywheel placed between the engine and the reverse

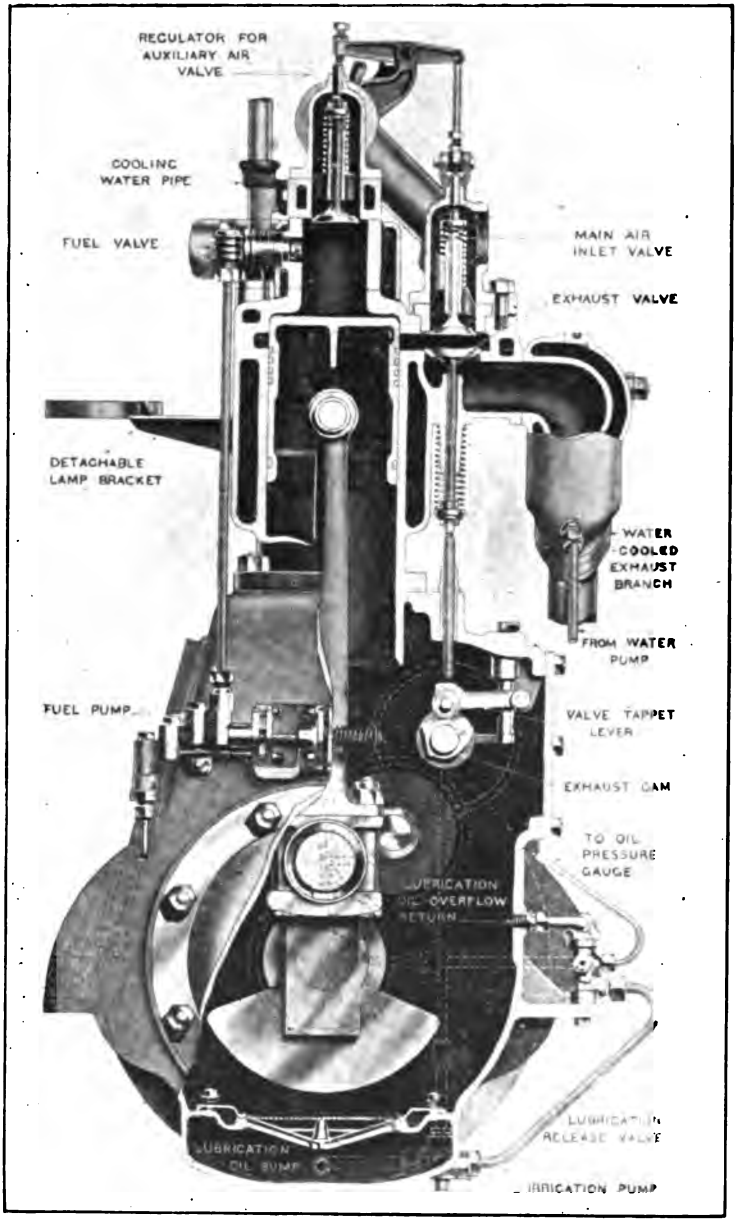


FIG. 21.—10 H.P. Cross Engine, end view.

gear is an unusual feature. The fuel pump is described on p. 139.

Crossley Bros., Ltd., who previously made some

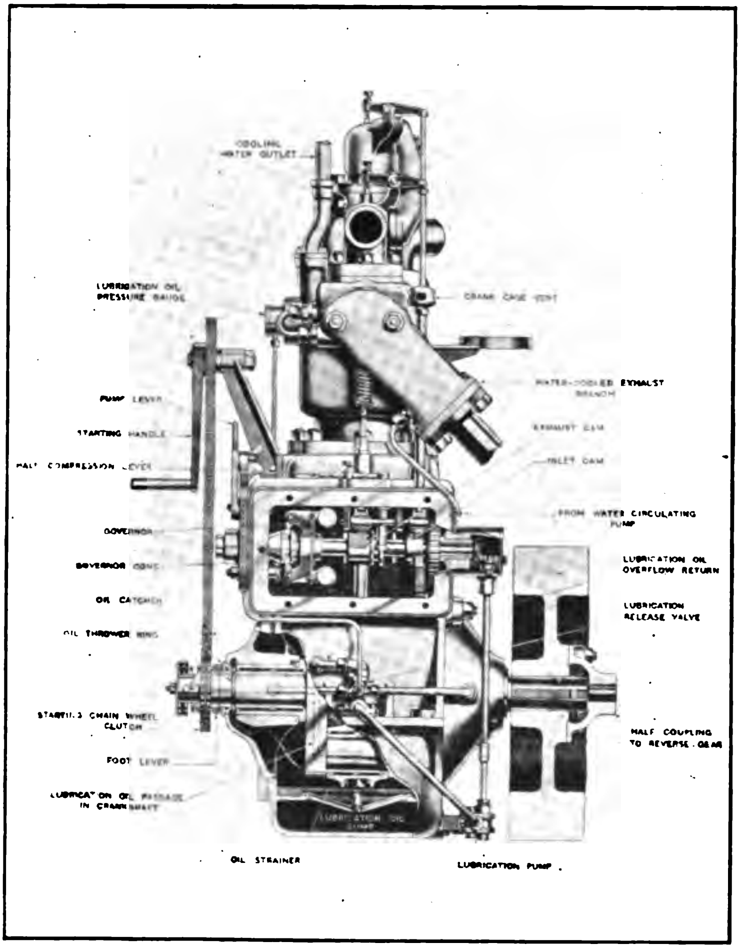


FIG. 22.—Cross Engine, front view.

paraffin marine engines, but abandoned them owing to pressure of work on their other well-known gas and oil engines, are developing a new simple type of low compression two-stroke cycle marine oil engine, designed to compete actively with the Diesel engine.

The engine is to start from "cold" without pressure lamps, to have a relatively low compression and high mean

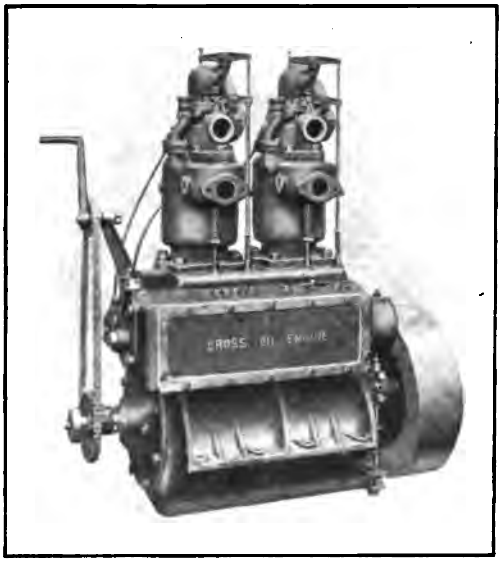


FIG. 23 —20 H.P. Cross Engine.

pressure, a low weight per horse-power, no hot bulb or water injection, and the fuel is to be injected by itself as spray without the aid of any injection air.

The Dan.

The **Dan** is a four-stroke hot bulb engine made in Denmark.

This engine has an open crank case, so that the crank-pin bearings are always accessible.

The fuel oil is injected by a pump into the chamber on the top of the cylinder; this chamber is kept at a sufficiently high temperature to vaporise the spray by the working of the engine, after it has, in the first instance, been heated by a pressure lamp.

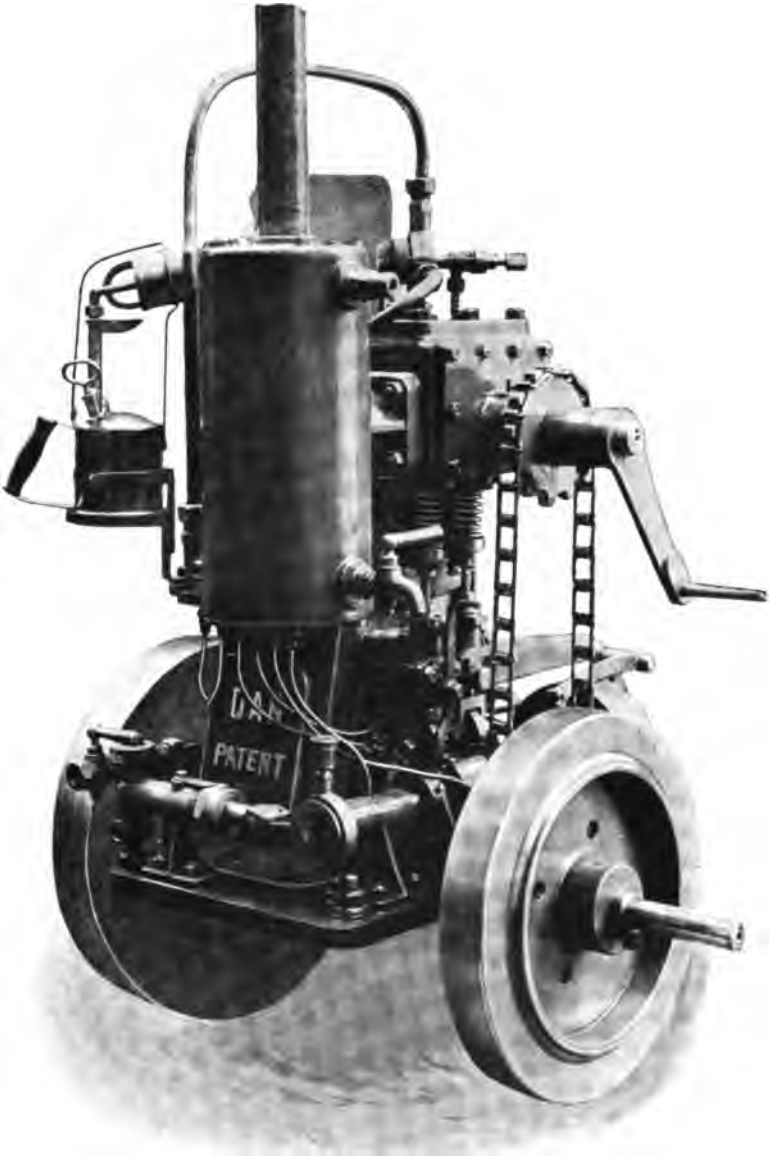


Fig. 24.—Dan Oil Engine, back view.

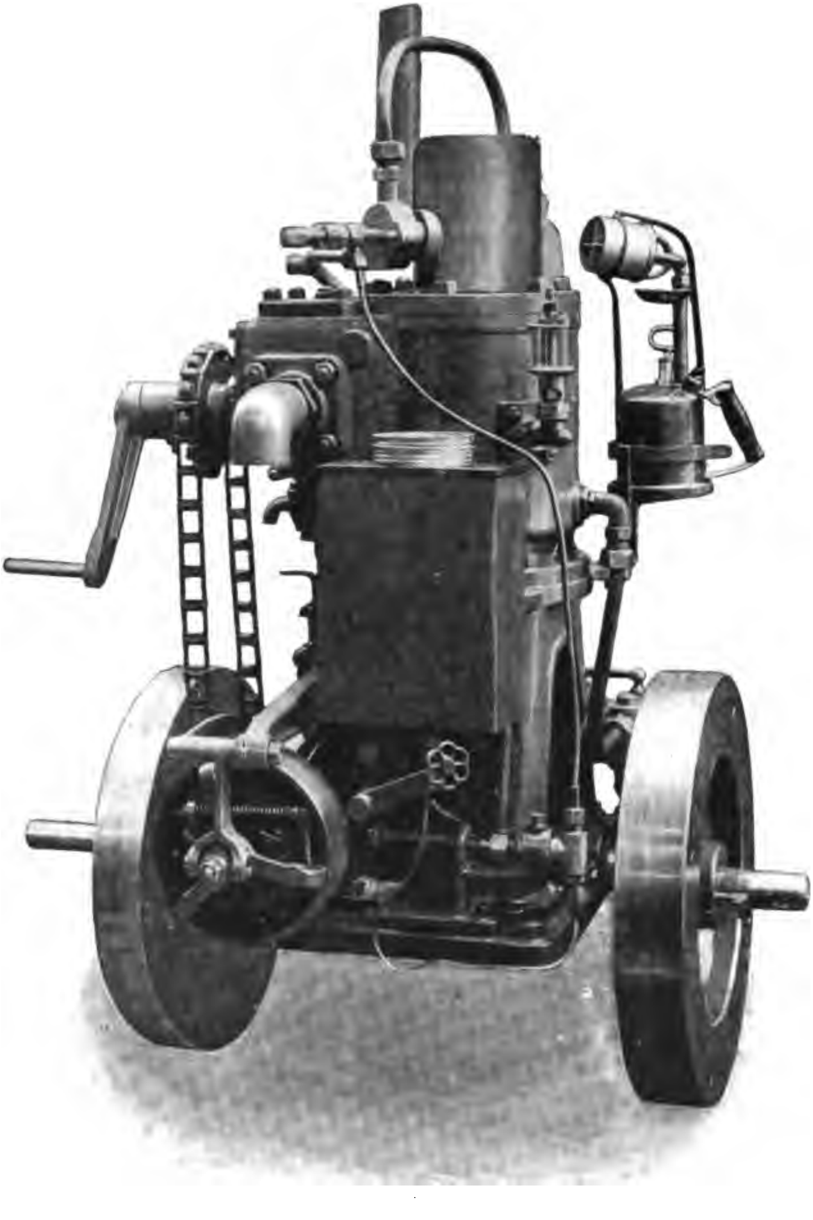


FIG. 25.—Dan Oil Engine, front view.

It will be seen that the vaporising chamber is well away from the air inlet valve, and the vapour is not mixed with air until the compression stroke.

The proper amount of air to make, with the paraffin vapour, an explosive mixture is not reached until the compression is at its maximum, and at that time the compression and the heat of the chamber unite to cause ignition, thus giving power for the working stroke of the piston. The exhaust is expelled on the return stroke through a mechanically operated valve.

The vaporiser has no mechanism or valves. The oil is injected into the vaporiser whilst the exhaust is being expelled, and in this way, it is said, both greater economy and more power are obtained than when the fuel is injected during the charging stroke of the Otto cycle.

In the early tests on one of these engines, in about 1905, with the original method of injection 9·58 H.P. was developed, but when the injection was made during the exhaust stroke the power of the same engine is said to have risen to 12·62.

Oil is injected into the vaporising chamber through a water-cooled nozzle, the amount being regulated, according to the load on the engine, by means of a governor which alters the stroke of the pump plunger. There is a hand adjustment which acts on the governor so that any required speed may be secured.

The Dux.

The **Dux** is a two-stroke hot bulb engine, made in Sweden, in single cylinder units up to 32 B.H.P., and two cylinder units up to 64 B.H.P.

The first installation in the British Isles were twin 8 B.H.P. engines fitted in a 40-ft. motor yacht in 1913.

The governor is of the centrifugal type, lubrication is by forced feed, no water drip is used or provided for, and the bulb is of cast iron.

The reversing gear is fitted with machine-cut wheels, which are always in mesh.

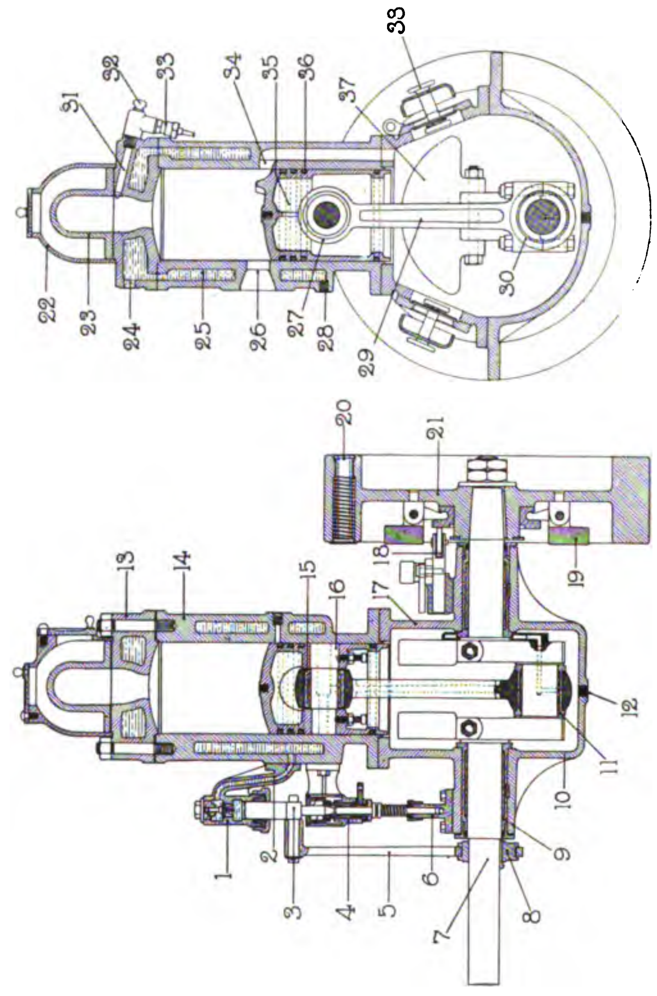


Fig. 26.—Dux Oil Engine.

The particulars of the various sizes of single cylinder engines are :—

Horse Power .	4	$6\frac{1}{2}$	10	$12\frac{1}{2}$	15	$18\frac{1}{2}$	25	32
Diar. cylrs. inches	4	5	6	7	8	9	10	11
Stroke, ,,	5	6	$6\frac{3}{4}$	8	9	10	12	15
Revolutions .	800	700	600	500	470	450	375	300

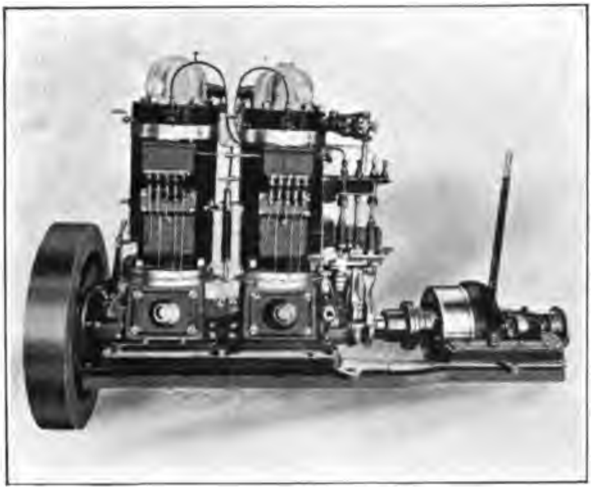


FIG. 27.—Dux Oil Engine.

The air starting valve is used for engines of 25 H.P. and above.

The fuel pump is gland packed.

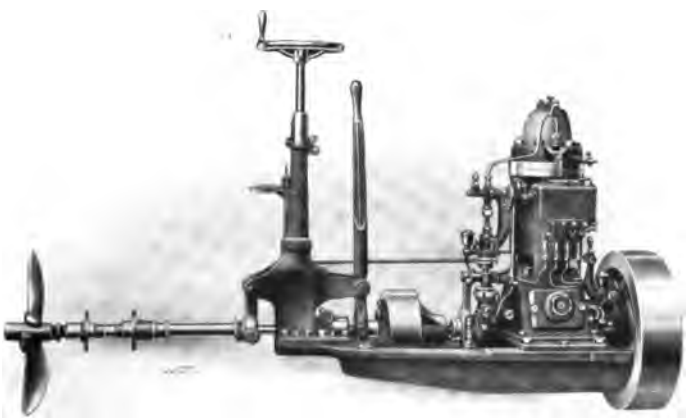


FIG. 28.—Dux Oil Engine, with reversible blades.

The Fairbanks-Morse.

The **Fairbanks-Morse** is a two-stroke hot bulb engine, made in America. The combustion chamber is water

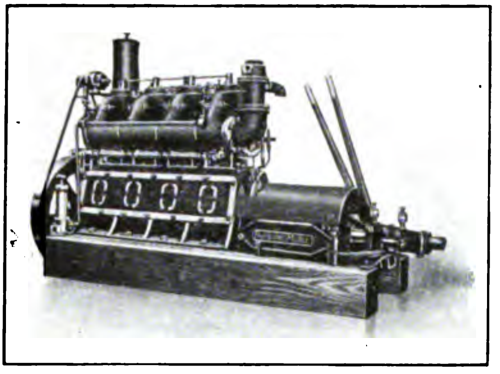


Fig. 29.—Fairbanks-Morse Oil Engine, front view.

jacketted, the amount of water supplied being regulated, so that the combustion chamber can be kept at the required

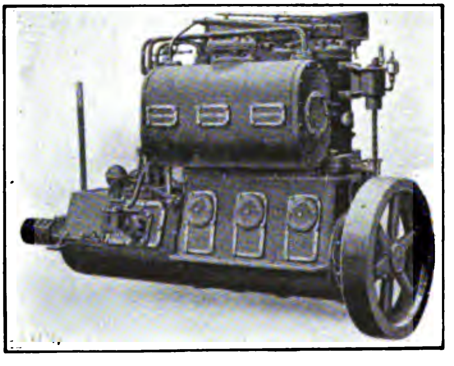


Fig. 30.—Fairbanks-Morse Oil Engine, back view.

temperature under all running conditions. Injection water or water drip is not used.

Multi-cylinder engines have the separate cylinders bolted to a common crank case cast in one piece.

The Grei.

The **Grei** is a two-stroke hot bulb engine, made in Norway.

Only a small uncooled bulb is used, and the remainder of the cylinder head is water-cooled. No water injection is used except for overload, and it is said to run indefinitely on no load without external heating. The governor is centrifugal and controls the effective fuel pump stroke.

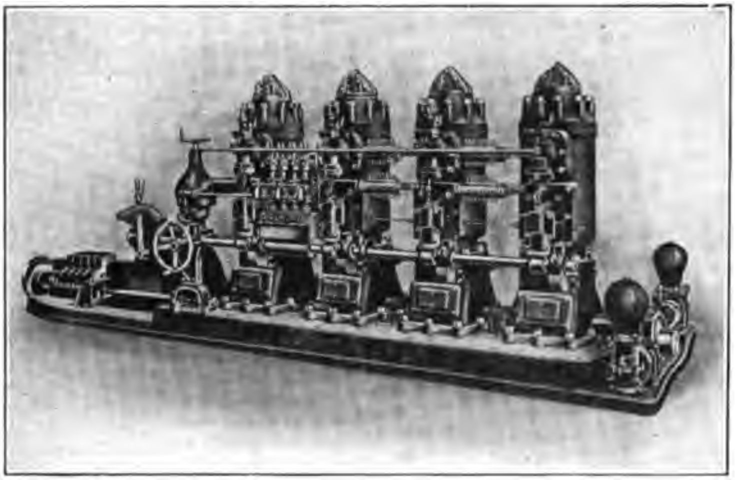


FIG 31.—Grei, 240 B.H.P.

The smaller engines have reversible propeller blades, and friction clutch and gear for reversing the propeller blades being mounted on the bedplate.

Air reversing is adopted on the 240 B.H.P. four-cylinder engine. Two sets of cams are used, one for ahead and one for astern, and reversing is accomplished by moving the camshaft axially, bringing the desired cams into operation. Particulars of this engine are:—Diameter of cylinder, 13½ inches; stroke, 15 inches; speed, 290 R.P.M. The engine will start from any position and only one handle is used for starting, stopping and reversing.

The thrust block follows marine steam practice with adjustable horse shoes.

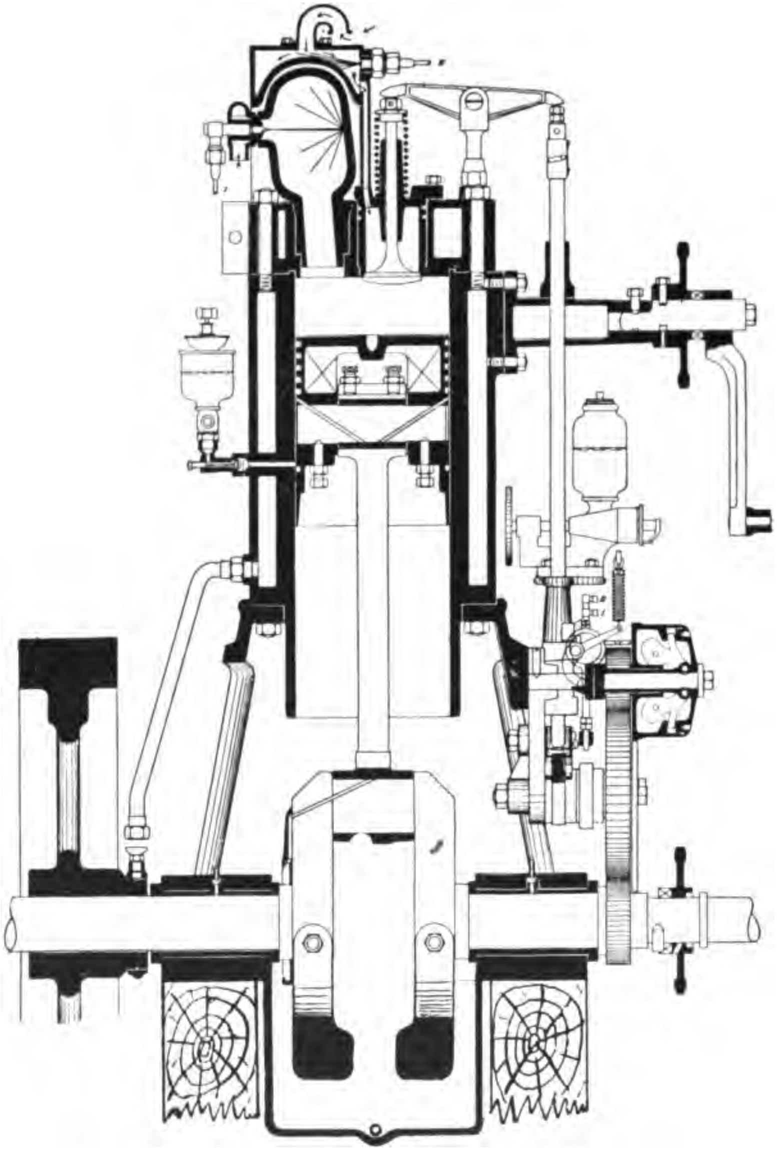


Fig. 32.—Hein Oil Engine.

The Hein.

The **Hein** is a four-stroke hot bulb engine, made in Denmark.

As will be seen by the illustrations it is of the open crank case type. A special feature of this engine is that the water-cooled silencer is cast in one with the cylinder (see Fig. 35).

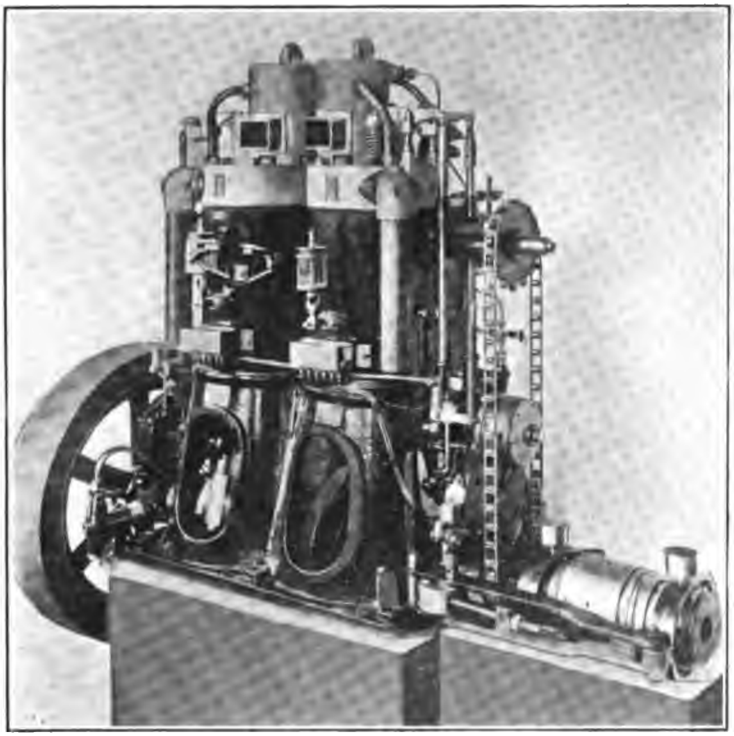


FIG. 33.—Hein Oil Engine.

The fuel is injected partly into the bulb and partly into the vaporising chamber, to improve combustion and produce even running.

The inlet and exhaust valves are arranged on the cylinder head, as will be seen by the several illustrations, and in that respect the engine is not unlike a Diesel. The valves open downwards, and are actuated by long levers from the cam shaft which is situated near the bottom of the cylinders.

The engine is non-reversible, and either a reversible blade

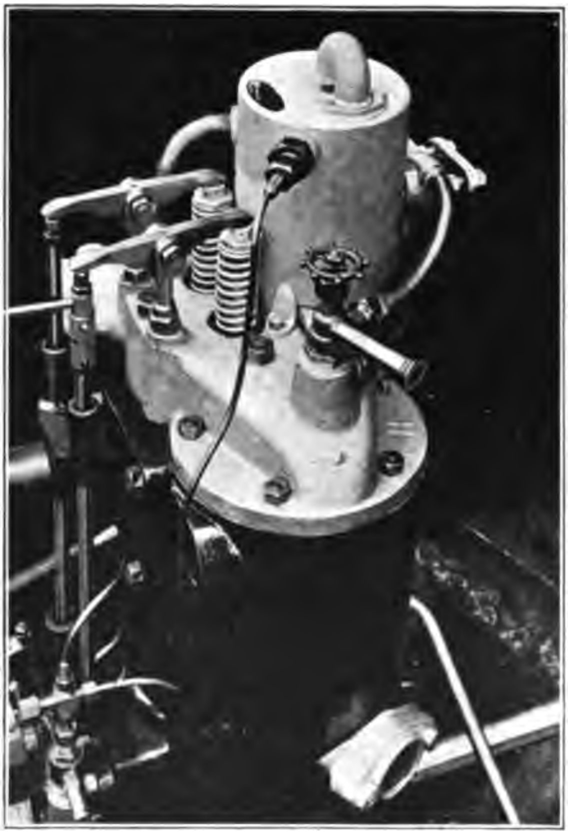


FIG 34.- Hein Oil Engine, valves and cylinder head.

propeller or reversing gear is fitted, the former being generally preferred in Scandinavia.

A double acting valve is used for fuel injection, rapidly to increase or decrease the supply to the vaporiser for variation in the power developed by the engine.

It is claimed that the mean effective pressure is very high even for this type of engine, and, in consequence, the machine is much lighter than other four-stroke engines of the same power.

The drive for the cam shafts and pumps is interesting

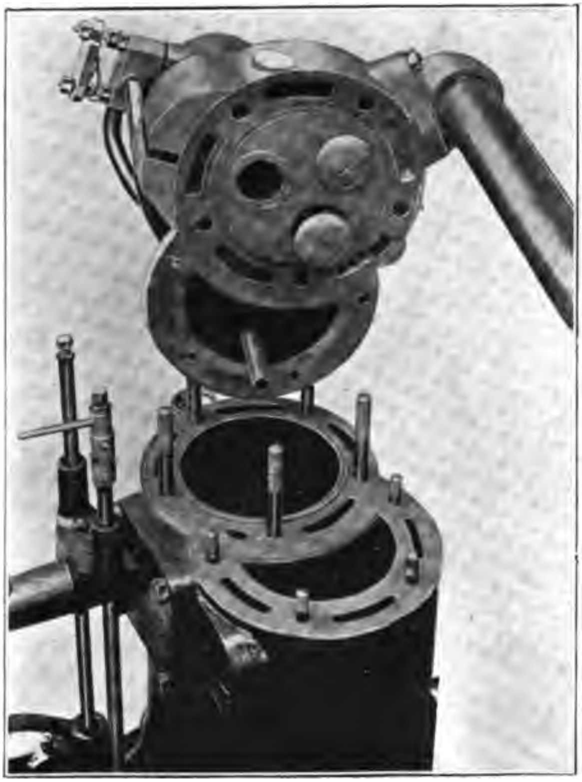


FIG. 35.—Hein Oil Engine, with cylinder head removed.

and is shown in Fig. 121, p. 143. The details of the governing are given on p. 146.

Lubrication is by a sight feed lubricator, both for the cylinders and for the main bearings.

Particulars of this firm's new "Thermo-motor" are given on p. 76.

The Hexa.

The **Hexa** is a two-stroke hot bulb engine, made in Sweden, in single cylinder units of from 6 to 20 B.H.P. and two cylinder units of from 12 to 40 B.H.P.

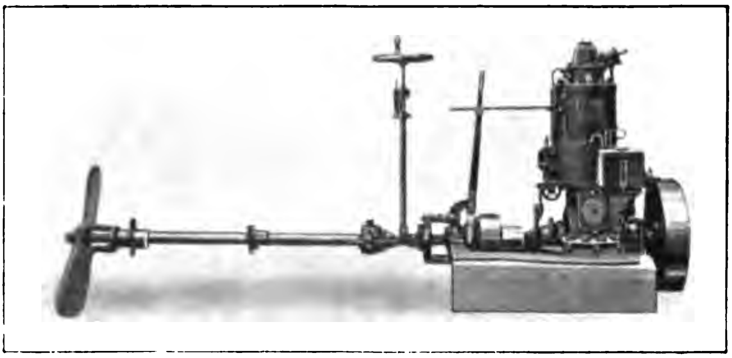


FIG. 36.—Hexa Oil Engine, 12 B H.P.

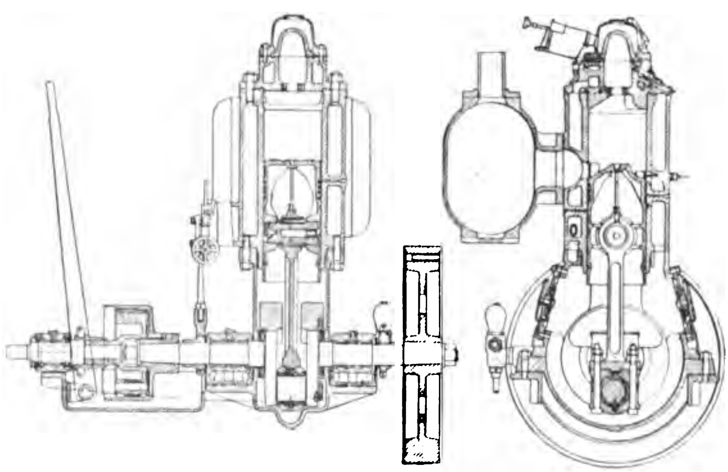


FIG. 37.—Hexa Engine.

The makers claim that the engine runs on crude and tar oils as well as petroleum.

The crank shaft air rings are described on p. 151.

A special feature of the **Hexa** motor is the patented arrangement for adjusting the motor to run on practically any grade of fuel oil available, by which means the maximum power is attained under varying conditions. This patented device may be briefly described as follows :—

Internally the cylinder cover, to which the hot bulb of the motor is bolted, serves as a special combustion chamber, separated from the cylinder itself by means of a portable screwed-in bottom, through small openings in which the piston forces air into the combustion chamber. It is claimed that by varying the size of the openings in the portable bottom the motor will run on any given fuel. This arrangement also renders it possible to regulate the temperature of the hot bulb and thus avoid overheating.

The main bearings are provided with chain lubrication, the other parts of the engine are supplied by a Bosch mechanical lubricator.

Water injection or water drip is used for overload, not usually for normal load.

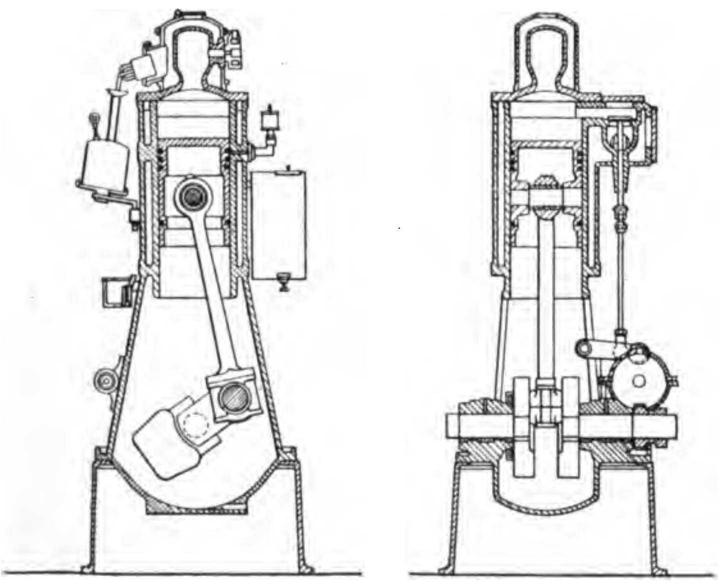


FIG. 38.—Holeby Oil Engine.

The smaller sizes are started by swinging the flywheel, and the larger sizes, as is the usual custom, by compressed air.

The Holeby.

The **Holeby** engine is a four-stroke hot bulb engine, made in Denmark, in sizes up to 20 H.P.

Lubrication is by means of a sight feed, and the governor is of the centrifugal type.

The Invincible.

The **Invincible** engine is made in England. It follows closely the accepted general construction of the two-stroke crank case compression design. The cylinder head is water-

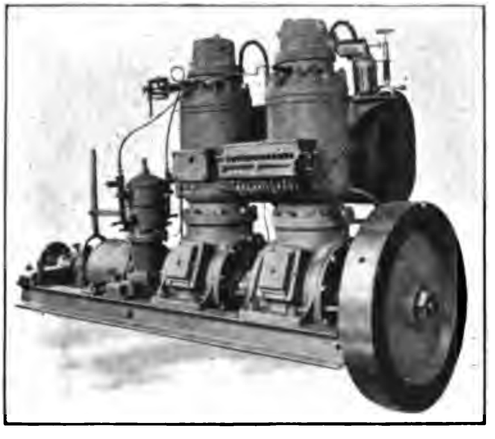


FIG. 39.—Invincible Engine.

cooled with an uncooled bulb above. The governor is of the " hit-and-miss " or centrifugal type, and the reversing is accomplished by a mechanical reverse gear designed and constructed by the makers. The most interesting feature appears to be the absence of the usual cast-iron bedplate, which is replaced by steel H-sections with a cast-iron distance piece at the after end. It will be seen that the crank chambers have bolted doors at each end.

The largest size is 50 B.H.P. per cylinder.

The Kromhout.

The **Kromhout** engine, which in general follows the typical two-stroke hot bulb engine practice with enclosed crank chamber, was originally made in Holland, but is now being manufactured as "The British Kromhout" in England.

There are two points in which it diverges from the

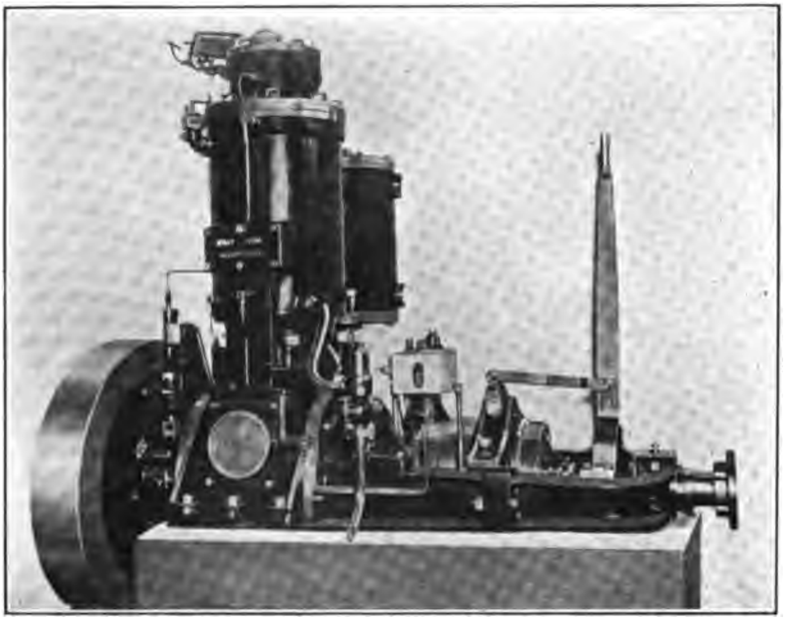


FIG. 40.—British Kromhout Engine.

typical: (1) the passing of the scavenge air round the gudgeon pin before it enters the cylinder port; (2) the design of cylinder head whereby it is claimed that no water drip is required at any load, while the engine will also run continuously with no load, without the lamps being alight. This latter is assisted by a baffle valve in the scavenge passage automatically controlled by the speed of the engine. The makers prefer not to publish details of the arrangement of the cylinder head.

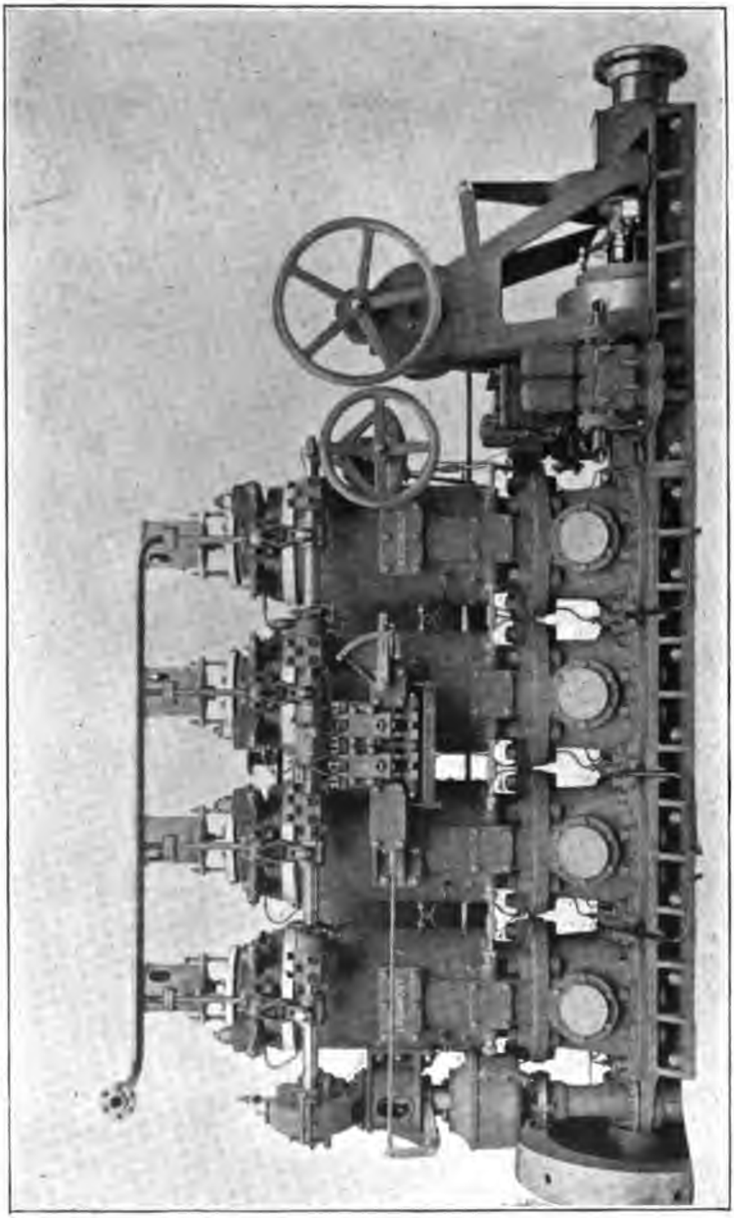


FIG. 41.—180 B.H.P. Kromhout Engine, with reverse by compressed air.

The small sizes are fitted with reversing gear and have a centrifugal governor fitted in the flywheel, which actuates a taper cam which controls the fuel pump stroke; while on

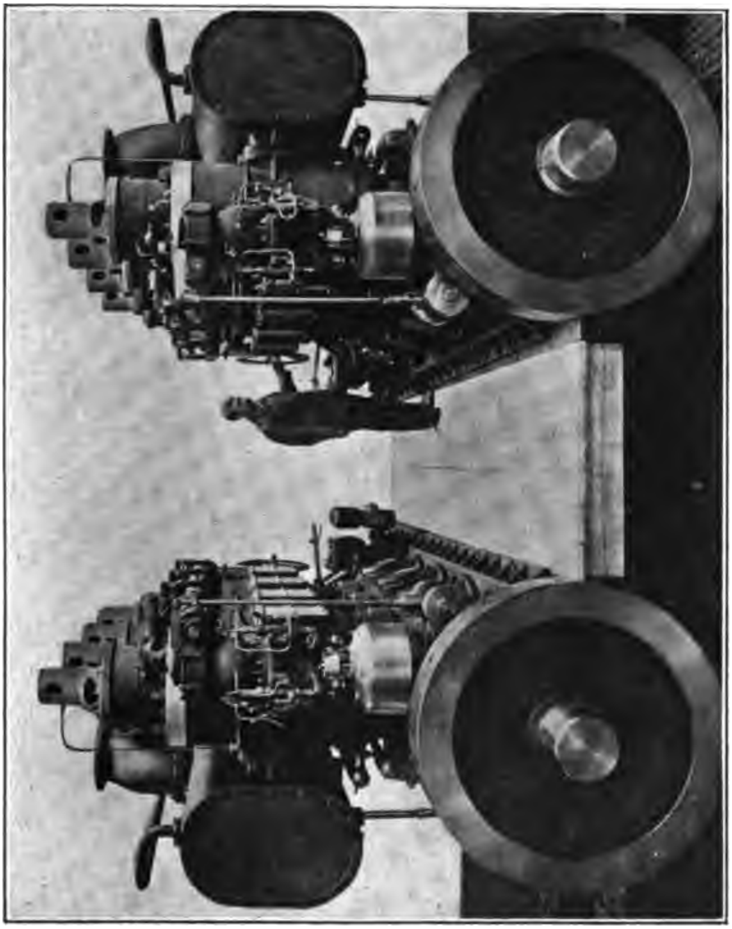


Fig. 42.—Two 275 B.H.P. Kromhout Engines, for twin-screw vessel.

the larger sizes, which are fitted with a clutch, the governor, which exercises control in the same way, is mounted on the vertical shaft which transmits the crank shaft motion to the horizontal lay shaft. This horizontal lay shaft, besides carrying cams to operate the fuel pumps, carries a pair of cams for operating the air valve on each cylinder, either

FIG. 43.—350 B.H.P. Kromhout Engine.

the ahead or the astern cam being brought into operation by lateral movement of the lay shaft.

The Mietz and Weiss.

The **Mietz and Weiss** oil engine is of the two-stroke type, made in America.

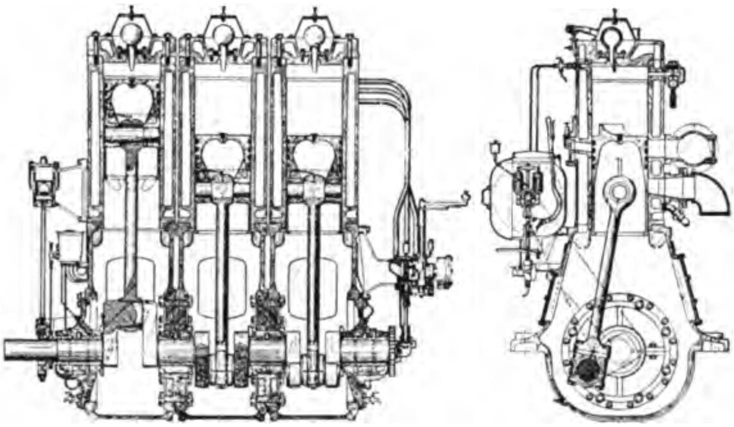


Fig. 44.—Mietz and Weiss Oil Engine.

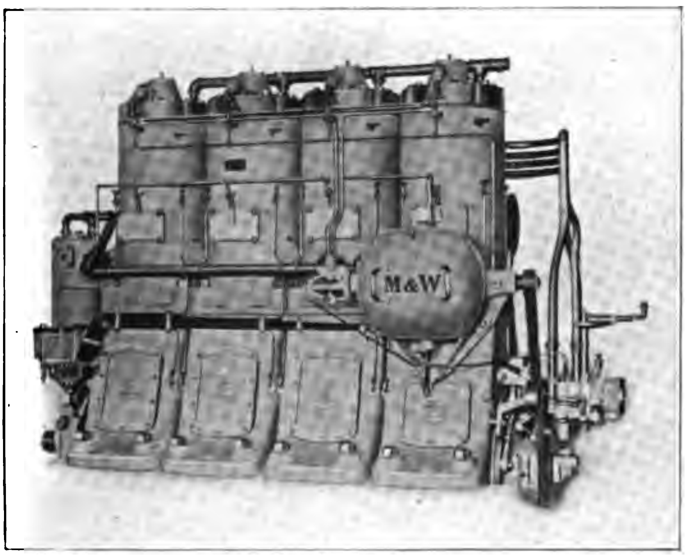


Fig. 45.—Mietz and Weiss 200 H.P. Direct Reversible Oil Engine.

For marine work these engines are made, either direct reversible by compressed air, Figs. 44 and 45, or with reverse gear, Fig. 46, the former in units of three to six cylinders, from 45 up to 600 B.H.P., the latter in units of one to four cylinders from 2 to 80 B.H.P.

The makers state that in 1895 they built the first successful two-cycle hot bulb oil engine, and that it is to-day at work where it was originally installed.

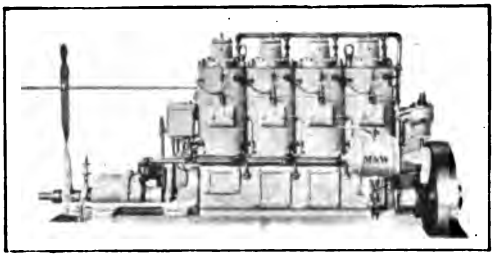


FIG. 46.—Mietz and Weiss Oil Engine, with reversing gear.

The lubrication is by a positively driven, valveless automatic force feed lubricator, for the pistons and bearings.

The thrust blocks are fitted with roller thrust collars.

The direct reversible engines are not fitted with a clutch or a flywheel, the engine and propeller shafts being coupled rigidly together.

Fuel is fed to the cylinders through a distributor by means of a single acting, plunger-type pump, which is operated by an eccentric on a chain driven shaft from the forward end of the crank shaft.

The Missouri.

The **Missouri** is a two-stroke hot bulb engine, made in America.

The engine is made in one, two, three and four cylinder units, giving 7, 14, 22 and 30 B.H.P. respectively, with cylinders 5 in. diameter by 6 in. stroke, all sizes being fitted with reverse gears (see Fig. 47). The fuel pumps are operated by a cam shaft driven by a silent chain, the centrifugal governor being connected to the after end of the cam shaft.

The connecting rod is of H-section drop forged steel with nickel steel bolts.

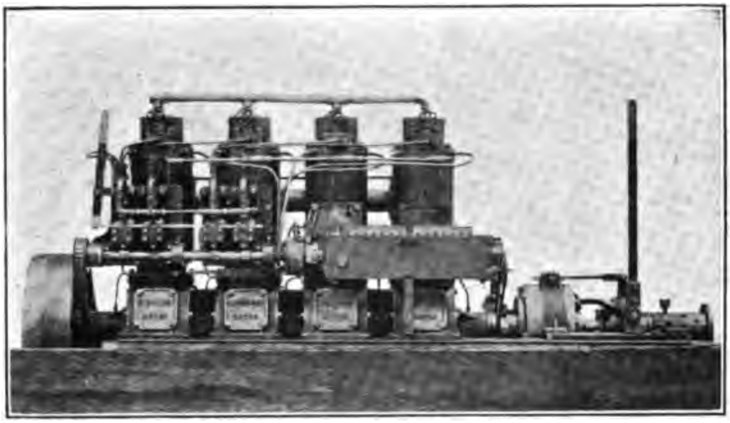


FIG. 47.—Missouri 30 H.P. Engine.

The crank pin bearings are lined with Parsons' white brass.

Water injection is used.

The fuel pump, which has double-ball check valves, is made specially long and well packed, so that it may seldom require repacking.

The Neptun.

The **Neptun**, a two-stroke hot bulb oil engine, made in Denmark, is fitted with water-cooled cylinder head. In the larger sizes of engines, which are fitted with water injection, the expansion of the hot bulb automatically controls the supply of injection water, as described under Hot Bulbs, p. 131.

Another type of **Neptun** hot bulb engine is shown on p. 129. In this case a "hit-and-miss" governor is fitted, while the larger engines have a compressed air starting

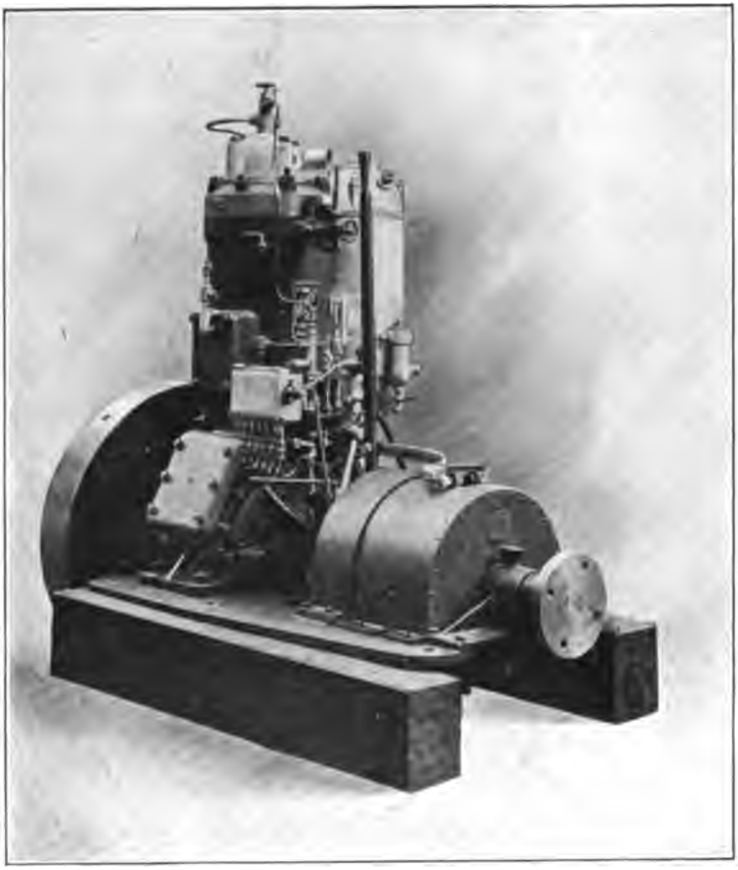


FIG. 48.—Neptun 25 H.P. Oil Engine.

device. The special form of ignition chamber is claimed to permit very quick starting up.

The Petter.

The **Petter** crude oil engine, which is of the two-stroke type, is made in England. The first engine of this type was made for land purposes in 1910, and the first marine engine, which was of 18 B.H.P., was fitted in 1915.

The scavenging air is taken into the crank case from below the bedplate for land engines, but through light suction valves on the side of the case for marine engines. The hot bulb is water cooled and no water injection is used.

Mechanical lubrication is adopted throughout. Each cylinder has four oil pipes, one for the crank pin, one for the connecting rod top end, and two for the cylinder wall, the latter being sub-divided to make four points of lubrication

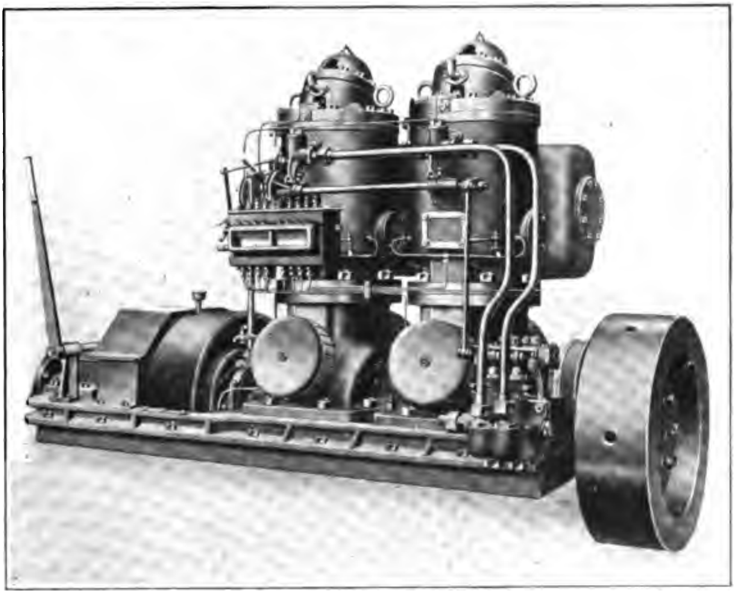


FIG. 49.—Petter Engine.

to each piston, and its four rings at the top and one at the bottom.

A hand lever regulates the stroke of all the fuel pumps of a multi-cylinder engine, and each pump can be separately regulated by adjusting nuts when the engine is standing, while the governor regulates the stroke independently of the hand control.

Reversing is accomplished by compressed air, for which a very small receiver, kept charged from the working cylinders during manœuvring, is apparently sufficient, as the engine can be disconnected from the shaft by a friction clutch. The operations are as follows :—

(1) The clutch is thrown out.
(2) The valve between the starting air receiver and the engine is opened.
(3) The fuel pumps are cut out by the hand lever and the engine slows down.
(4) The reversing lever is put over to "astern," allowing air to enter the cylinder on the up-stroke which cushions and reverses the piston.
(5) The fuel pumps are put in action again and the reversing lever returned to neutral.

It is claimed that this system is as positive in operation as a steam engine reverse, that reversal is effected in less than half a minute, and that it is equally effective on engines with one, two or four cylinders.

The Priestman.

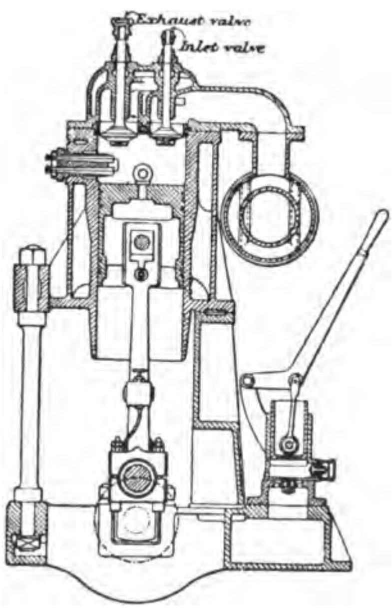


FIG. 50.—Priestman Oil Engine.

The **Priestman** oil engine, which is of the four-stroke or Otto cycle type, although not a hot bulb engine, is of interest, because it was probably the first oil engine used in this country specially for marine work, and it was the first engine in which safe lighting oils could be used successfully.

Experiments were begun in 1885, the engine was produced in 1888, and tested by Professor Unwin in 1889.

Air pressure, which can be regulated by a spring loaded escape valve, is initially obtained in the oil tank by the hand pump shown in Fig. 50, and maintained by an air pump driven by an eccentric.

The oil passes from the tank through a spray maker into the vaporiser or mixer, which is first heated by a lamp

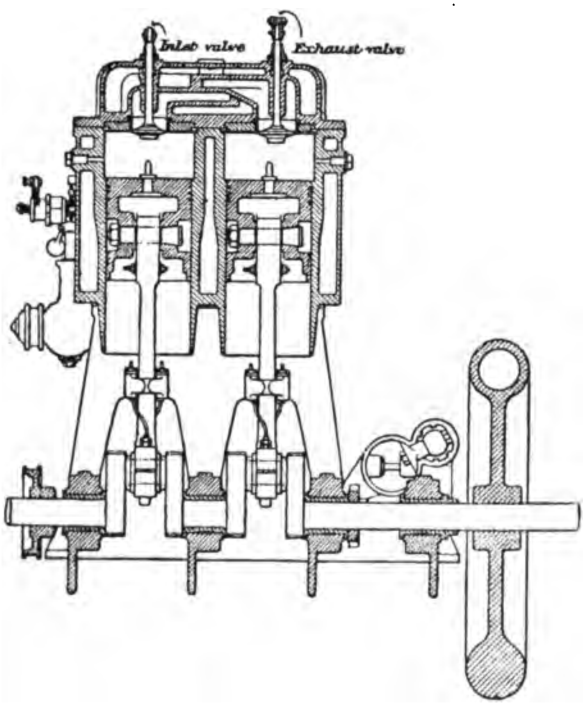


FIG. 51.—Priestman Oil Engine.

and afterwards by the exhaust gases, the charge being ignited by a battery and coil.

The 5 H.P. marine engine, Figs. 50 and 51, had cylinders 7 in. diameter and 7 in. stroke, working at 250 revolutions per minute.

The Rap.

The **Rap** is a Norwegian two-stroke hot bulb engine, made in single cylinder models from 5 up to 40 B.H.P.

It works without water injection in the cylinder by means of a patented arrangement in the bulb operated by a handle, by turning which the spray or paraffin can be diverted up

FIG. 52.—Rap Oil Engine.

or down the bulb, so that the temperature is regulated according to the speed and work of the motor.

The engine is fitted with a clutch and reversible blade propeller, a thrust of the ball bearing type, and a mechanical lubricator for the important parts.

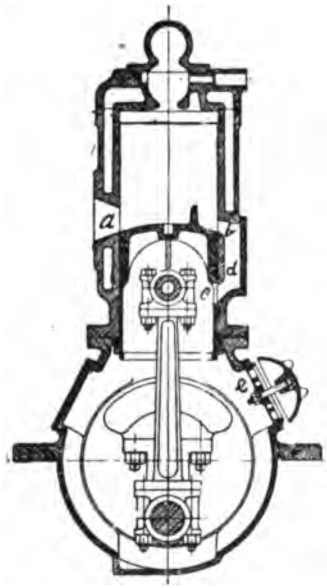


FIG. 53.—Rap Oil Engine, section.

The patented regulator is said to govern the speed from 200 to 500 revolutions per minute, and it is also stated that the engine can run for an indefinite period when de-clutched.

The Remington.

The **Remington** oil engine, manufactured in New York, is of the two-stroke type, with a small bulb and a nickel steel plug in the cylinder head for ignition, and is made with one, two, three and four cylinders from 7 to 75 H.P. The four-cylinder 75 H.P. engine, illustrated in Fig. 54, develops its power at 400 revolutions per minute.

The bulb formation and method of ignition are somewhat novel. The oil is atomised and sprayed through a hole near the end of the nozzle, on to the water-cooled nickel steel

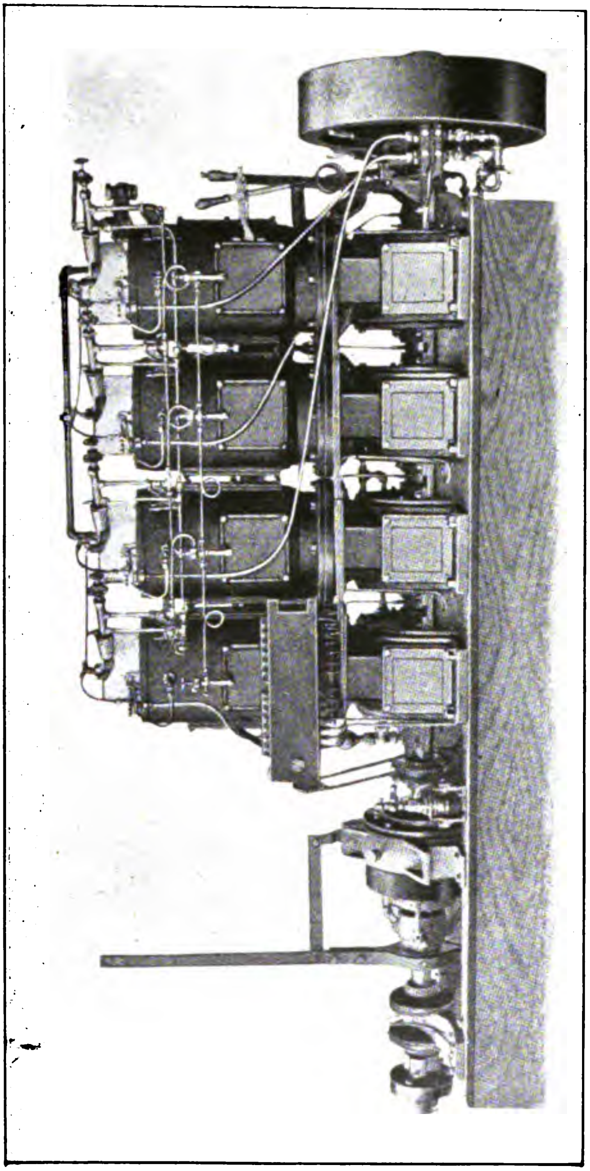


FIG. 54.—Remington Engine.

impinging plug for the crude oil type of cylinder head, for which type the ignition plug or tube is fitted.

The fuel pumps, one for each cylinder, are fitted horizontally and operated by a sleeve cam on the crank shaft. This sleeve is tapered, and is moved in a fore-and-aft direction by the governor or hand lever to increase or decrease the stroke of the pump.

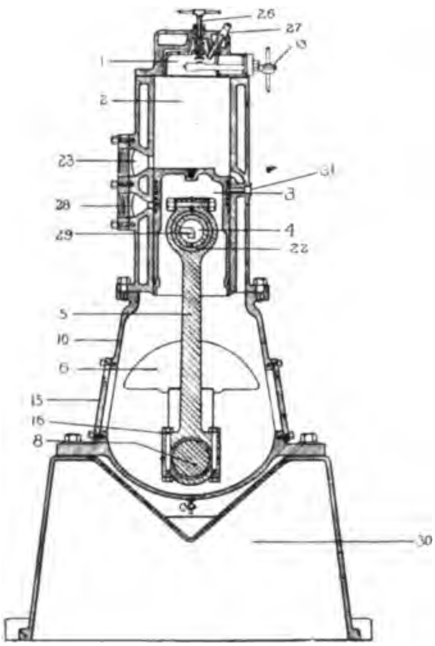


FIG. 55.—Remington Engine.

The governor is of the centrifugal type and is contained in the flywheel.

Water drip is provided for. Instead of air valves on the side of the crank case, the air inlet is immediately under the exhaust outlet, while the air passage to the cylinder is on the opposite side, the piston being shaped to deflect the air upwards.

A mechanical feed lubricator is fitted. The crank pin oil ring is made in two parts, so that the ring can be removed without removing the shaft, by taking out part of the crank case end plate of a multiple cylinder engine.

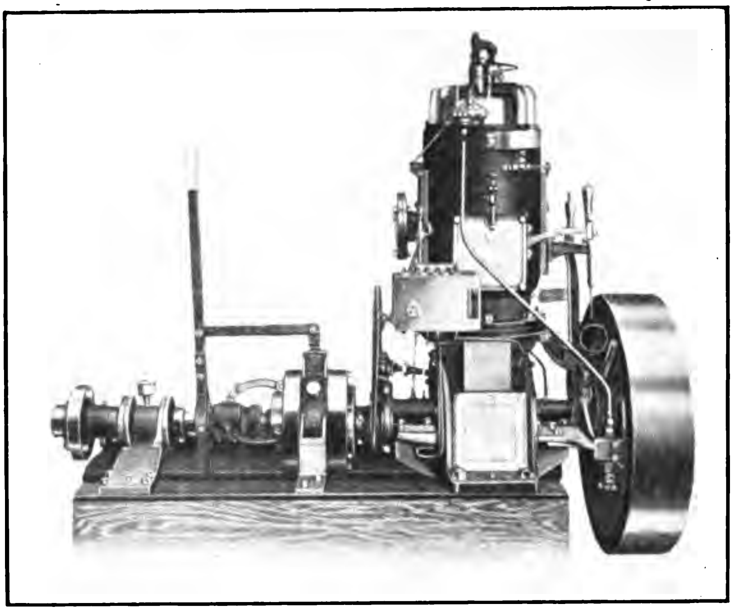


FIG. 56.—Remington Engine.

Pump levers and all parts liable to breakage are of malleable iron.

The Robey.

The **Robey** is a two-stroke hot bulb engine, having a water-cooled head, and is made in England, in powers varying from 8 to 100 B.H.P. for land work.

Although the makers are not catering for the shipbuilding trade at the present time, their engine, being of a vertical type, is of a design that is suitable for marine work and has some interesting features, and is therefore illustrated in these pages.

The fuel pump gear, arranged at the side of the cylinder at about half its height, is illustrated in detail on p. 140.

The centrifugal governor is illustrated on p. 148.

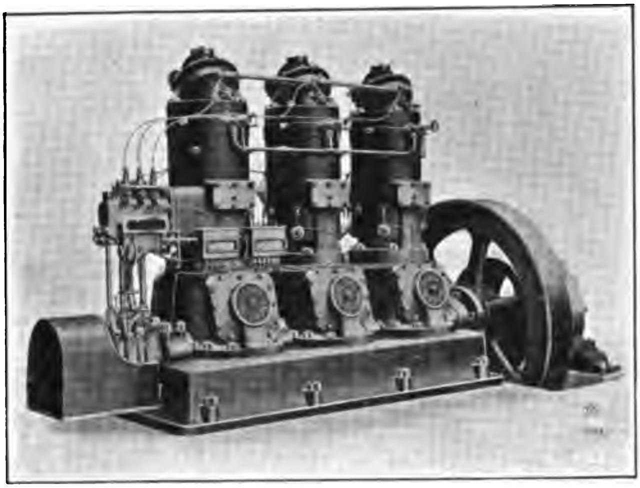


FIG. 57.—Robey Engine.

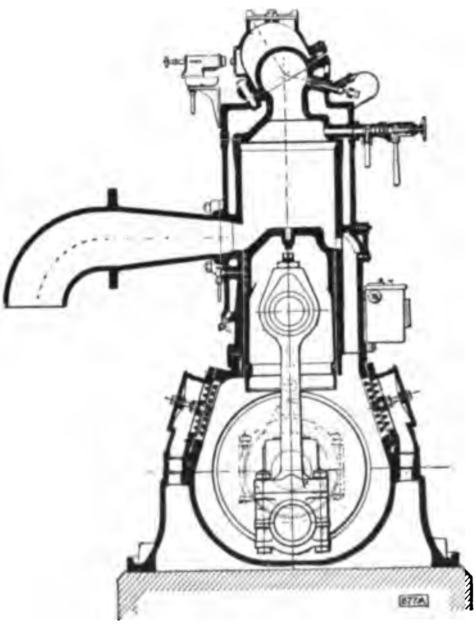


FIG. 58.—Robey Engine.

Forced feed lubrication is fitted.

The sprayer or fuel nozzle is illustrated on p. 144.

Further details of the **Robey** engine are illustrated and described in these pages, see Index.

The Seattle.

This engine, manufactured in America, differs in several respects from the usual hot bulb practice. The engine illustration shows an unusually large centrifugal governor which automatically controls the fuel pump stroke.

FIG. 59.—Seattle Direct Reversible Engine

The revolutions are low and the stroke long as compared with cylinder bore. The three cylinder 250 B.H.P. engine runs at 180 R.P.M., the cylinder bore being 16 in. and stroke 24 in., giving the usual piston speed of 720 F.P.M.

FIG. 60. Seattle valve gear and eccentrics.

The reversing is by compressed air, the air distributing mechanism being the invention of the engine's designer, who has fitted the gear with success to other oil engines. The valve gear is operated by the same eccentrics on the main shaft as operate the fuel pumps.

The cooling water passes from cylinder jacket to cylinder head by means of outside connection branches, thus avoiding

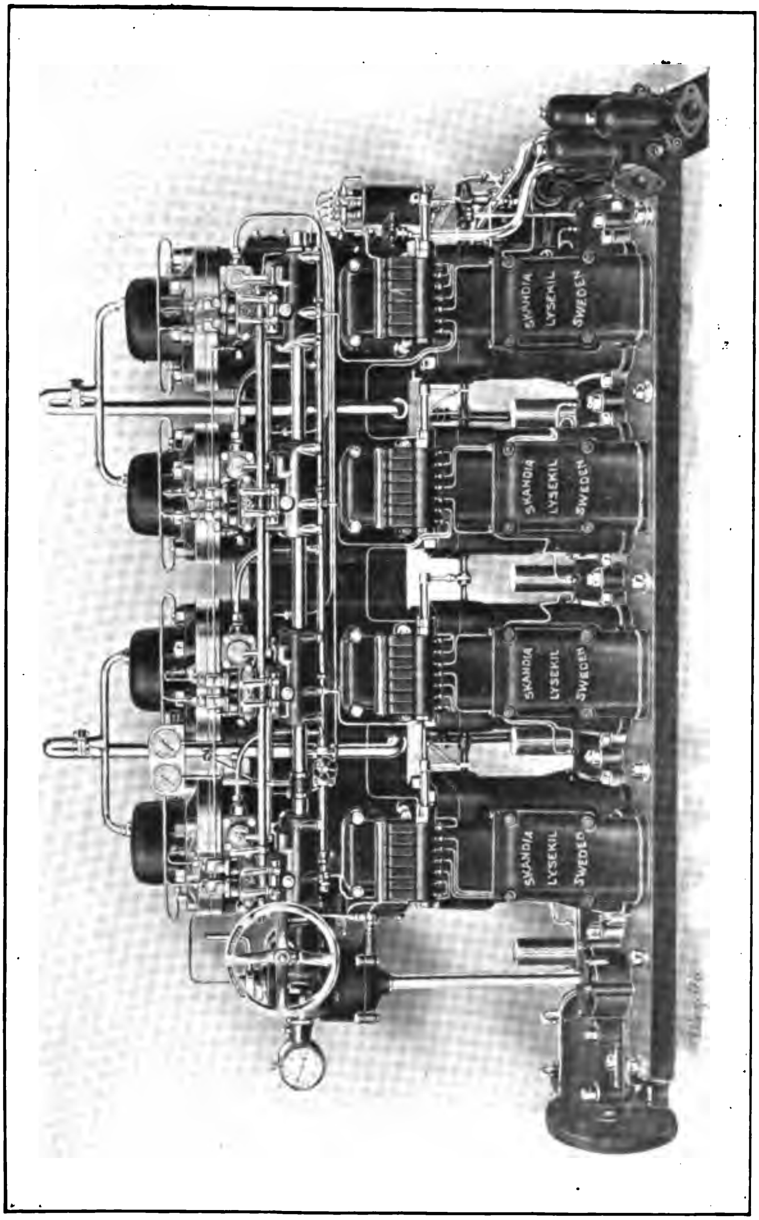


FIG. 61.—Skandia Direct Reversible Engine.

the possibility of water entering the cylinder through faulty joints, as may sometimes happen with engines adopting ports in cylinder head registering with ports at top of cylinder jacket.

The lubricating system avoids multiplication of copper pipes. A plunger pump feeds a pipe system, the pressure supply being indicated on a gauge, and sight feed regulating valves supply each bearing from the system.

The cylinder lubrication oil is carried by the piston and supplied by a plunger pump situated inside the crank case.

The Skandia.

The **Skandia** is a Swedish two-stroke hot bulb engine made in three types, direct reversible, with reversing gear and with reversible blade propellers.

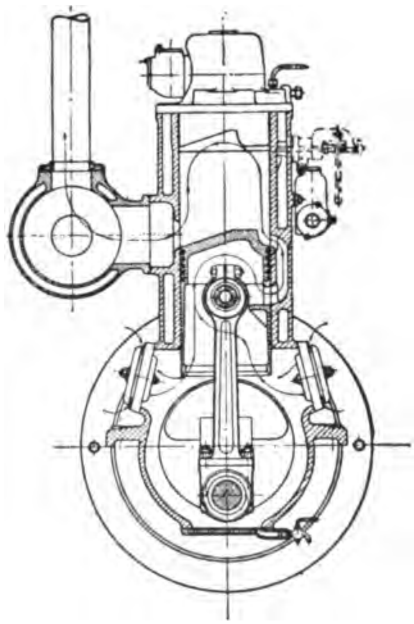


Fig. 62.—Skandia, section.

The direct reversible engines are made in four cylinder units, the smallest being 50 to 60 B.H.P. at 400 revolutions

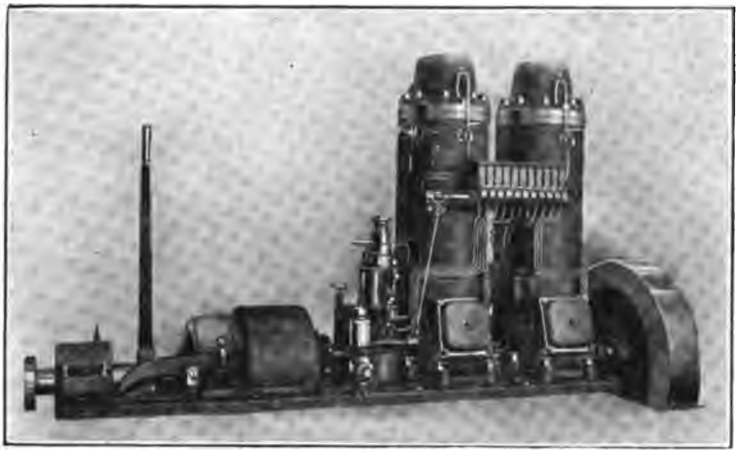


FIG. 63.—Skandia, with reversing gear.

per minute up to 320 to 385 B.H.P. running at 250 revolutions per minute, and weighing 21 tons.

The engine with reversing gear, illustrated in Fig. 63, is

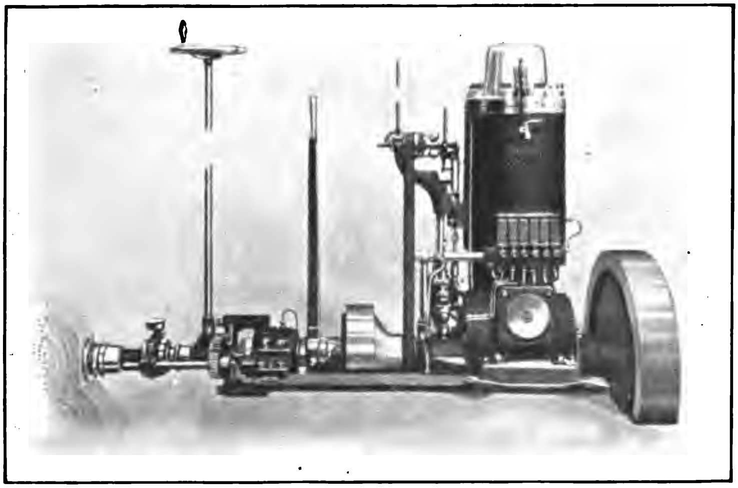


FIG. 64.—Skandia, with reversible blade propeller and centrifugal governor.

provided with a centrifugal governor fitted with skew gear, as illustrated on p. 149.

The engine with reversible blade propeller is shown in

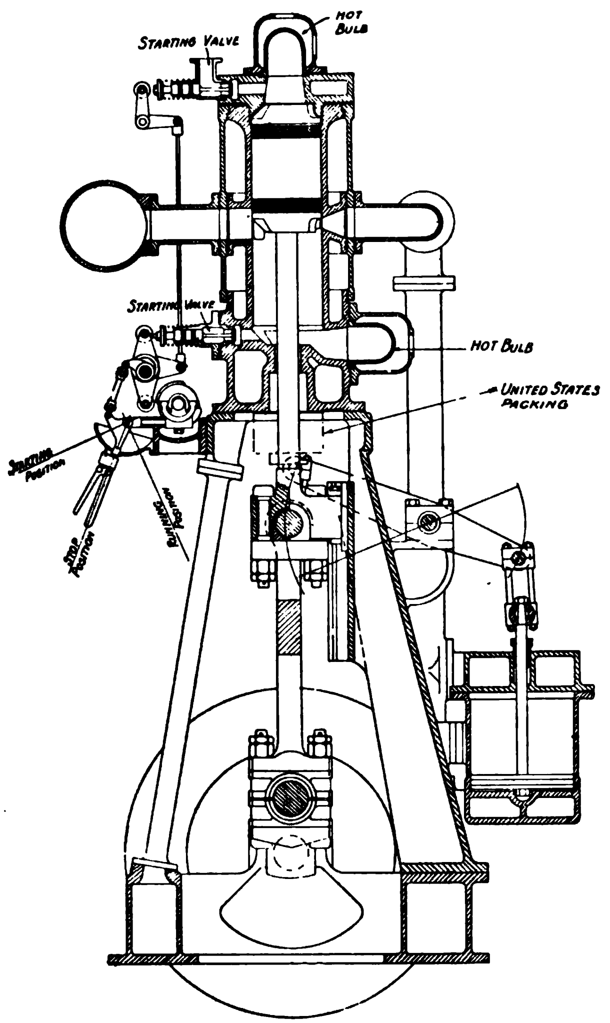


FIG. 65A.—Stallard Double-Acting Engine.

Fig. 64. It will be noticed that a clutch is fitted between the engine and the gear to reverse the blades.

The governor is of the centrifugal type, as illustrated on p. 141.

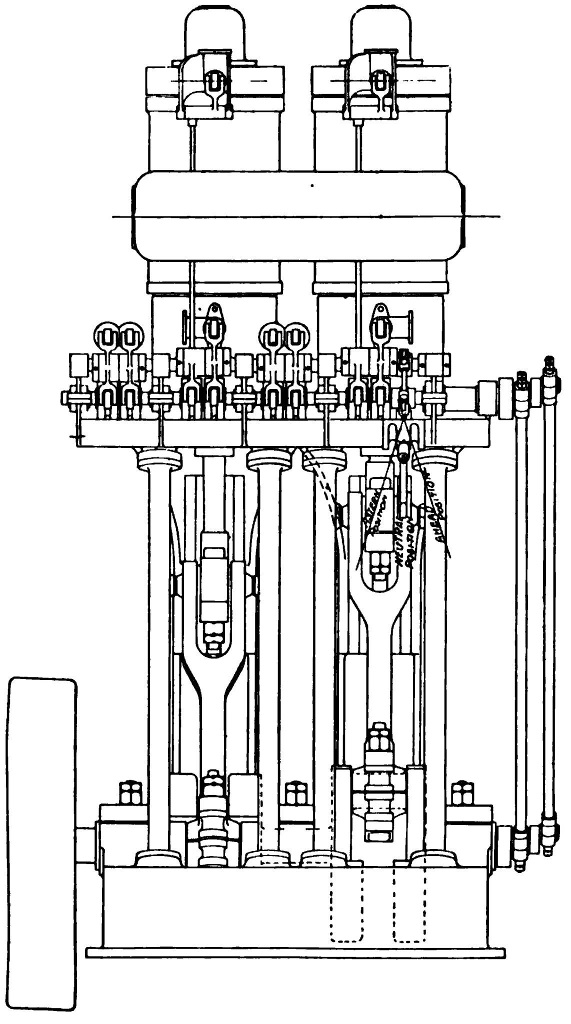


FIG. 65B.—Stallard Double-Acting Engine.

The Stallard.

The **Stallard** double-acting hot bulb engine, designed by Mr. G. W. Stallard, is illustrated in Figs. 65A, 66B.

The engine has a scavenge pump driven from the piston rod by a beam, in accordance with the usual marine steam-engine practice. The designer intends the scavenge pump to give a mean effective pressure of 80 lb. per square inch, as against 45 to 50 lb. per square inch, with the ordinary type of hot bulb oil engine fitted with crank case compression. The lower hot bulb is arranged on the port side of the cylinder wall. Both the cylinder covers and the piston rod gland are water cooled.

The double acting principle introduces two additional complications, namely, a water-cooled piston and a piston rod gland, but neither of these should present any insurmountable difficulty, as they have both already become essential factors in large gas-engine practice. The water for the piston would be taken in and discharged through the hollow piston rod, and there are several packings on the market suitable for high temperatures and pressures. On the other hand, the reversal of load that occurs every stroke in the case of the double-acting engine renders the lubrication of the gudgeon pin a far more certain matter. It must be admitted that in the two-cycle, single-acting engine, the "constant thrust" that is exerted on the reciprocating parts, while inducing smooth running, is not conducive to efficient lubrication, and that the gudgeon pin, in particular, may be thus handicapped even when forced lubrication is employed.

Up to the time of publication, we have not heard of an engine of this type having been manufactured.

The Sumner.

This engine, made in America, follows largely the general lines of marine steam engine design (see Fig. 66).

It is an open crank case low-compression two stroke type, the compression not exceeding 125 lbs. per square inch. The four-cylinder 350 B.H.P. size has a cylinder diameter of 16½ inches, and stroke of 22 inches, and runs at 210 R.P.M. The scavenge air is supplied by beam-driven double-acting pumps, each pump serving two cylinders.

The starting and reversing are accomplished by compressed air, distributed by a revolving cylindrical valve controlled by a lever at the engineer's platform.

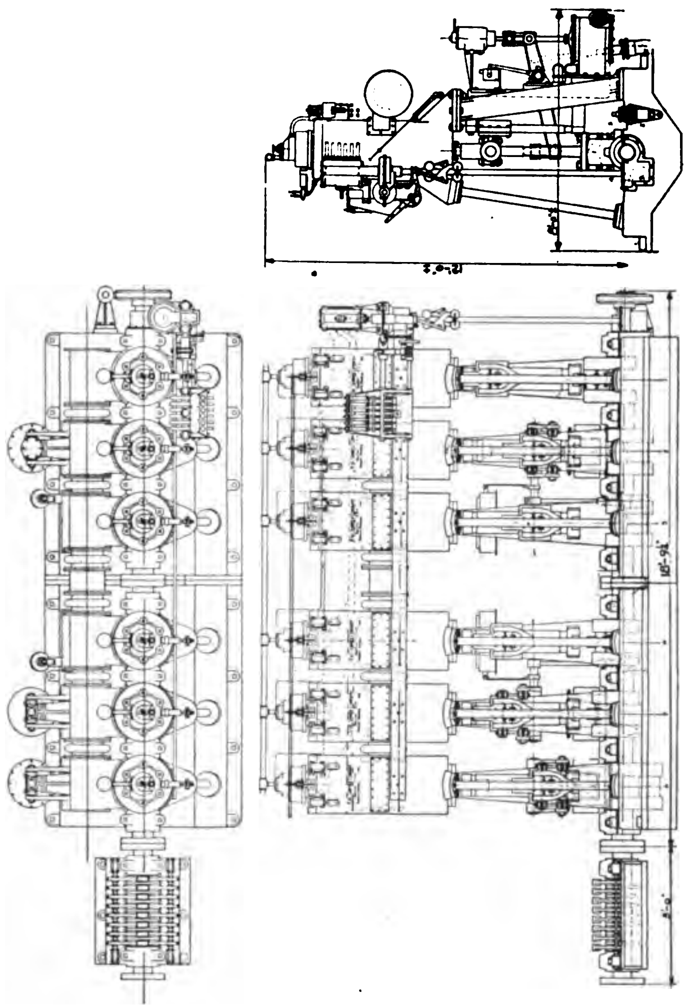


FIG. 66.—Sumner Engine, 350 B.H.P.

The hot combustion chamber is bolted to a water-cooled cylinder head, the water passing from the cylinder jacket to the head jacket through external connection pieces. The cylinders are supported on cast-iron box-section columns behind and turned steel columns in front, giving complete accessibility to crank pin bearings, crossheads, etc. The bedplate is of liberal design and strength, and the thrust bearing has separately adjustable sheaves.

The lubrication is by forced feed to main bearings, crank pin bearing, crosshead and gudgeon pins.

The Thermomotor.

The **Thermomotor** is a new four-stroke Danish engine, manufactured by the same firm as the **Hein** engine, described on p. 45.

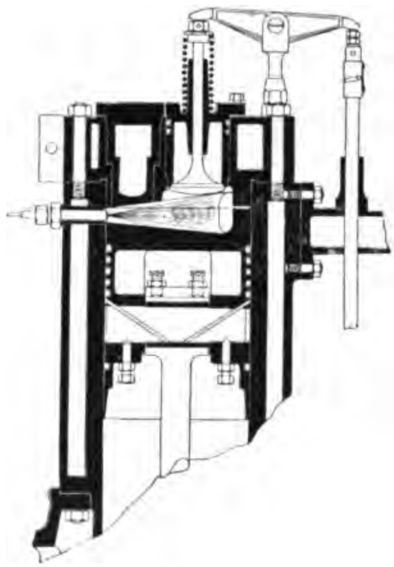


FIG. 67.—Sectional view, Thermomotor.

Strictly speaking, it is not a hot bulb engine, and its designers claim to be able to do away with the bulb without unduly increasing the pressures.

The fuel is injected direct into the cylinder, no compressed air being used, the injector or pulveriser being fitted horizontally. The cylinder head and piston are apparently of special formation to receive the injection without directly affecting the cylinder walls.

The experimental engine, the only one made up to the present time, is claimed to have the same power as a hot bulb engine on a much reduced consumption; in fact, it is stated that the consumption for even a small 6 B.H.P. engine is only 0·52 lb. per B.H.P. per hour when using solar oil, and is therefore equal to a Diesel engine of the same size.

The Tuxham.

The **Tuxham** is a two-stroke hot bulb engine, made in Denmark, up to 240 H.P. (see Figs. 68, 69 and 70).

The governor is of the centrifugal type, giving an injection

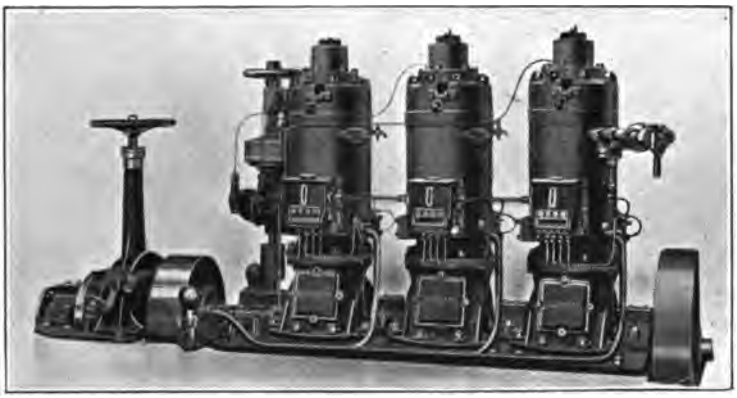


FIG. 68.—Tuxham Engine.

for every revolution. The speed is controlled by regulating the effective fuel pump stroke.

The governor is on a vertical shaft driven by skew gear from the crank shaft.

The engine is able to work up to about 80 per cent. of its maximum power without water injection. The water drips into the scavenge air passage and is controlled by a needle valve operated by hand.

The fuel pump is of bronze with hardened steel piston, the barrel and piston being accurately ground so that tightness is obtained without using any kind of packing.

A mechanical force feed lubricator is fitted for all parts

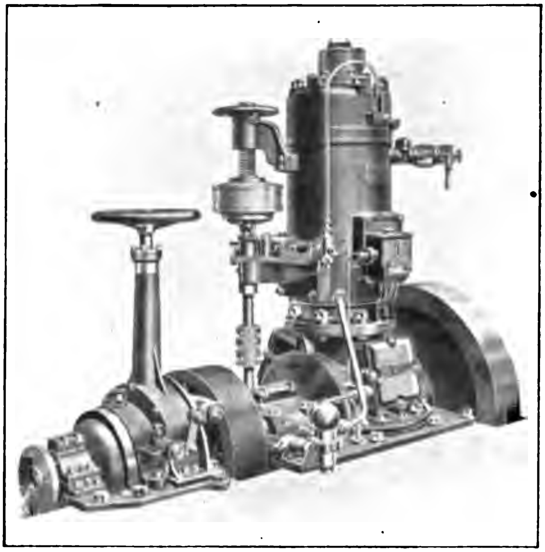


FIG. 69.—Tuxham 8 H.P. Motor.

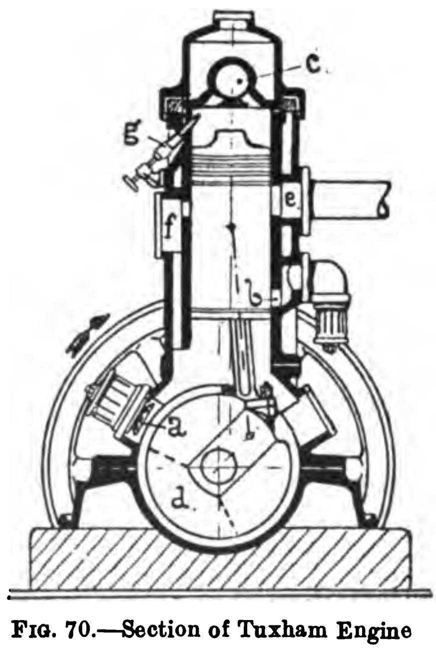


FIG. 70.—Section of Tuxham Engine

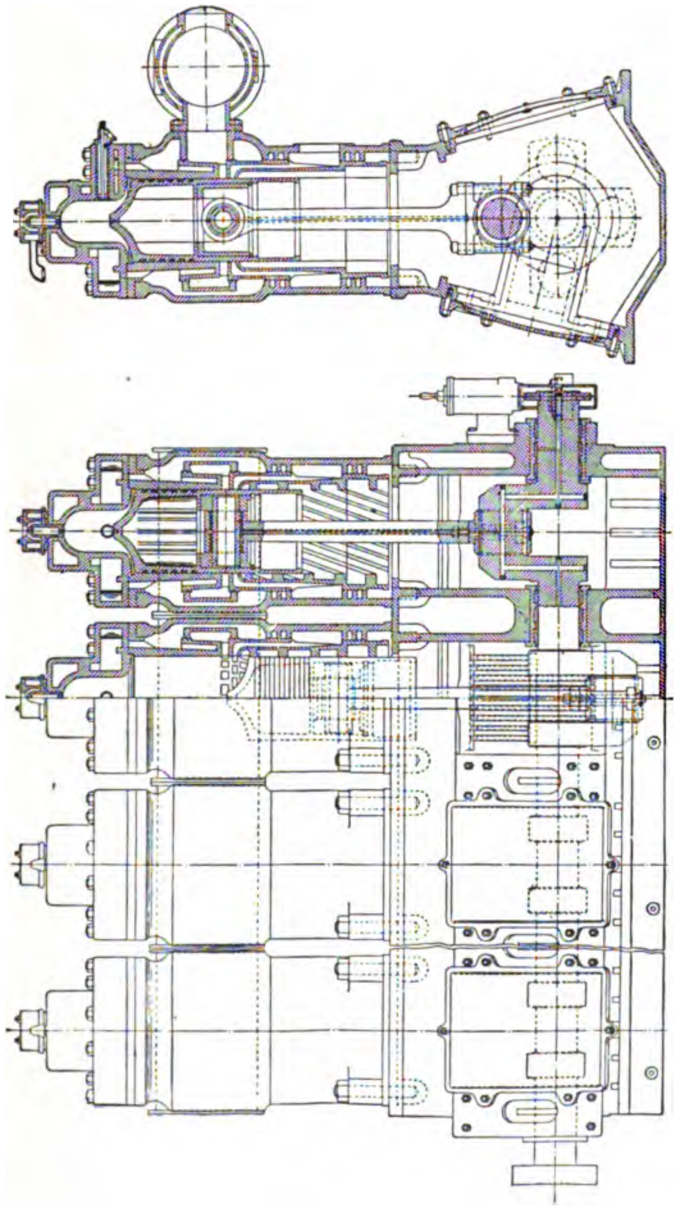


FIG. 71.—Weiss Engine.

except the main bearings, which are provided with ring lubrication.

Most sizes of the engine are not reversible and are fitted with clutch and reverse gear, but the firm also makes a four-cylinder engine direct reversible by means of compressed air.

The Weiss Engine.

The **Weiss** is a new two stroke engine made in the United States of America, the designer of which claims to have designed the first practical hot bulb engine in 1894. Many

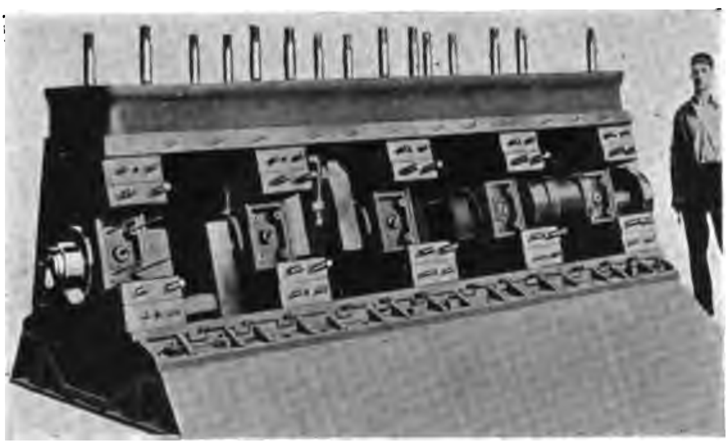


FIG. 72.—Weiss Accessible Crankshaft.

original features appear, separating it definitely from the generalised accepted Hot Bulb Engine practice.

The compression pressure is 200 lbs. per square inch, and maximum combustion pressure 500 lbs. per square inch, which alone constitutes a tendency towards Diesel conditions. The fuel is kept under constant pressure of 1000 lbs. per square inch, and the injection is controlled by distributor valve. The scavenging is quite novel, a preliminary scavenge charge being blown in by a fan blower through supplementary ports before the air compressed in the crank-chamber rushes through its ports. The piston has a conical top to deflect the first scavenge charge to the bulb. The main scavenge charge passes as an annular stream into the cylinder through the spiral passages indicated in Fig. 71.

The gudgeon pin is fixed in a yoke piece fitting inside the piston and held in position by a snap ring. This leaves a cleaner piston design giving equal heat expansion.

Another original departure of great interest is the arrangement of crankshaft and main bearings, whereby the crankshaft can be removed sideways from the one-piece crank case by simply removing the front covers and leaving the upper part of engine and all piping, etc., undisturbed.

The lubrication is forced throughout.

It will be seen from Fig. 71 that the cylinder has a separate liner which is not often the case in two-cycle design.

The White-Brons.

The **White-Brons** oil engine is of the semi-Diesel four-stroke type, made in England. The first engine of 20 H.P. was constructed and fitted by them in one of their own works launches in 1912.

Strictly speaking, this engine is not a Diesel and not a hot bulb engine, because it does not use the high compression of the former or the hot bulb of the latter. The engine starts from cold without requiring a lamp or vaporiser, ignition being obtained by the heat of compression of air in the cylinder.

The fuel consun·ption is said to be from 0·45 lb. in the larger to about 0·65 lb. per B.H.P. in the smaller sizes.

The 60 B.H.P. four-cylinder size, the largest at present made, runs at 500 revolutions per minute.

Compressed air is not used for injecting the fuel into the cylinders, but air at 200 lb. per square inch pressure is used for starting up.

Air is drawn into the cylinder through the air inlet valve and, at the same time, the fuel is drawn, *as a liquid,* into a pulveriser, fitted in the cylinder cover ; the heat of compression gradually evaporates a portion of the fuel within the pulveriser until a small quantity of oil vapour is ejected from the pulveriser into the cylinder, where it automatically

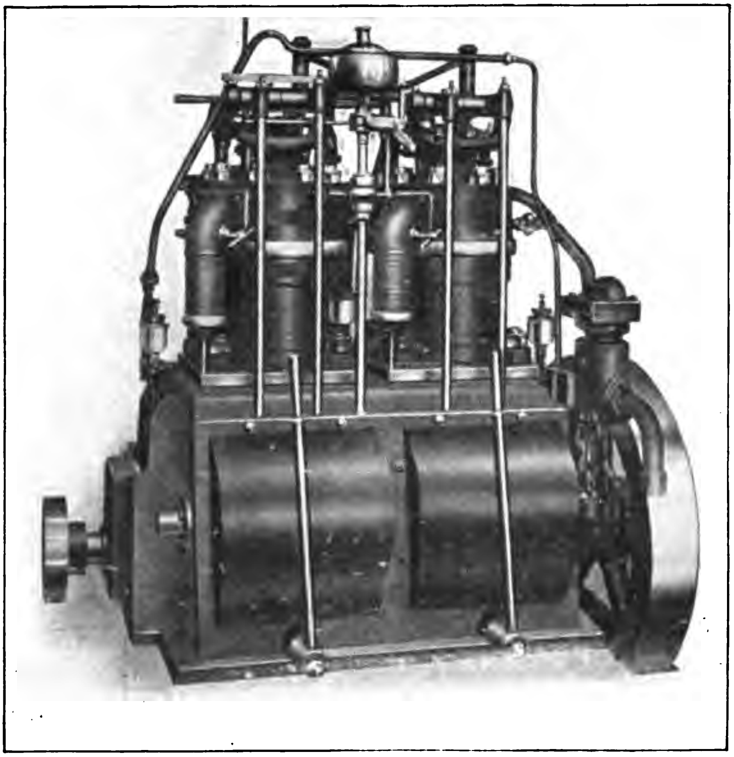
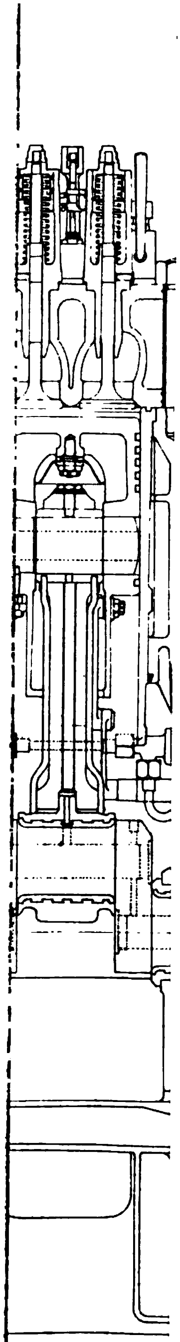


FIG. 73—White-Brons Engine.

ignites. The heat, generated by the initial combustion, rapidly vaporises and ejects into the cylinder the remainder of the fuel, which burns at practically constant pressure for an appreciable portion of the power stroke.

The lubrication is automatic and delivered to the bearings under pressure.

Any cylinder can be cut out of action and the fuel supply



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stopped without interfering with the operation of the other cylinders.

The air and exhaust valves are operated by levers and rods from a cam shaft in the crank case and driven by spur gearing.

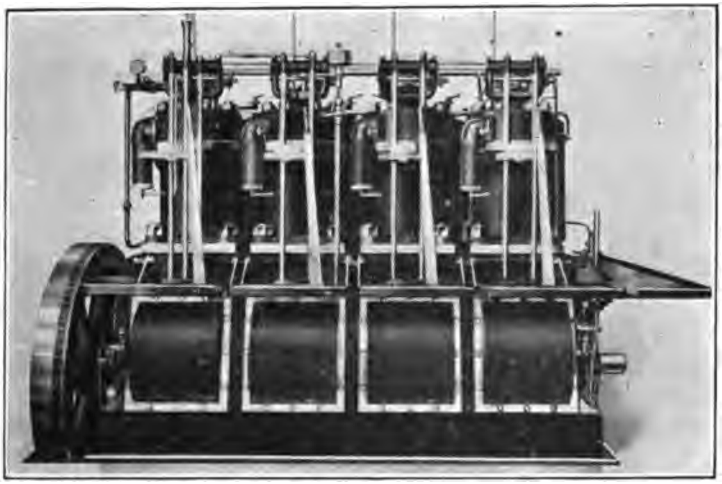


FIG. 74.—White-Brons Engine.

The principal advantages claimed by the makers are :—

(*a*) No hot bulb or vaporiser.

(*b*) Immediate starting from cold.

(*c*) Higher fuel economy.

(*d*) Each cylinder is fitted with a separate cast-iron liner.

Several other makers have submitted particulars of their engines since going to press and could not be included in this edition.

CHAPTER III

THIS chapter has been written to explain the hot bulb oil engine in its general broad aspects of design and construction so that owners and engineers may become familiar with the special features.

It usually requires a number of years of experience, not only in the design, but in the manufacture of oil engines to obtain anything like satisfactory results, and an enormous amount of research and experimental work lie behind the best engines on the market. Purchasers should remember that improvements are constantly being introduced, and when they are incorporated on the engines of successful makers of long standing they are backed by thoroughly sound practical trials.

The question of manufacture is equally important. Few existing engineering works are suitably equipped for the manufacture of hot bulb engines unless they have been established for that purpose, or for Diesel engines, or for manufactures requiring accurate work of a high order.

To obtain a successful engine it is necessary to have the very best design and the finest materials and workmanship obtainable, almost irrespective of cost. The manufacture, test, trials, and the improvements that the trials suggest require careful and progressive attention.

All this means an expensive engine, and owners should therefore be prepared to pay a fair price and ensure reliable and economic service.

Design of Engine.—The ideal engine would be one that would do away with the lamps for heating the bulb, tube or plate, and enable the engine to start from cold, but without the high pressure or complications of the Diesel. The evolution of the engine may take this form, although it will then lose many of the characteristics of the hot bulb engine and will become more genuinely semi-Diesel; several makers are busy experimenting in this direction.

A two-cycle hot bulb engine is usually designed to give efficient results at a low compression, and for marine work, at low revolutions enabling a large propeller to be used ensuring satisfactory propeller efficiency.

For marine work, the hot bulb engine is built as a vertical inverted engine of the single-acting type, usually with an enclosed crank case used for compressing the scavenge air by the action of the trunk piston, with separate cylinders, from one to four in number, a flywheel at the forward end, and a clutch and reverse gear or direct reversing mechanism, together with a thrust block, at the after end.

It should run satisfactorily on crude or residual oils.

Both the design and manufacture of heavy oil engines differ from those of steam machinery; from beginning to end they demand the perfection of thoroughness. As soon as the type of engine has been decided on, it is advisable to bring all the science and skill obtainable to bear in first working out the design and details, then in making an engine, testing it exhaustively, improving, altering and re-testing it again and again; then when it is almost perfect and quite reliable, it should be placed on the markets of the world—but not before. Unfortunately, many makers, not only of hot bulb engines, but of oil engines of all kinds, look round, obtain some orders, and then commence to manufacture with a delightful uncertainty as to the result, or the efficiency of the goods that they wish to deliver, which frequently leads to disappointment and sometimes disaster. It is true, however, that in the end sometimes the lost ground is recovered, and a leading place in manufacture is obtained, as in the case of some motor cars.

The extreme simplicity makes the design appear quite easy, especially as no high pressures are introduced. Apart from the question of material and workmanship, the chief difficulties lie in the design of a cylinder and head which will overcome the troubles due to temperature stresses and give efficient scavenging—so essential to economy—and at the same time enjoy a long life. A reliable forced lubrication to the cylinder and to both connecting rod bearings is quite essential, and a separate pump is advisable for each of these points. The question of reversing becomes of great importance above about 100 B.H.P., but the efficient direct reversing of some makes gives the desired reliability without any cumbersome and troublesome gear.

Materials.—Before dealing with the constructional details, a few points concerning the materials used and workmanship necessary may be considered.

The quality and suitability of the materials used are of the utmost importance for any good internal combustion engine. Ordinary castings and forgings as used in marine steam engineering practice will not do ; they will not stand the great and unequal variation in temperatures. In a steam engine, the interior of the cylinder is quite clean (even a little uncertainty in the quality of the lubricating oil does not matter), but in a low compression hot bulb oil engine the quality of the fuel oil is liable to considerable variations, and, in some measure, imperfect combustion will result and leave carbon and other deposits in the cylinder. These deposits and the relatively high temperature would soon destroy the cylinder walls if the metal were of only average quality, but the successful maker employs very special mixtures, and, after any amount of heavy work, the cylinder walls should present a fine glassy surface when cleaned.

The most difficult matter is the selection of the material for the hot bulbs. In the old type of engine with water drip in the passage way, a very special cast-steel alloy was necessary to withstand the white heat to which the temperature was sometimes carelessly allowed to rise ; this excessive heat sometimes caused the base of the bulb to drop or sag, which was occasionally followed by piston fracture. This special material was costly and sometimes unreliable. With the more modern type of engines, where the air supply to the bulbs can be varied and controlled, there is no necessity for anything but good cast-iron bulbs, which, with ordinary care, will probably be found to last several years.

The gudgeon pins and crank shafts should be made of the best material procurable, viz. : carbon steel, while the crank pin brasses should be lined with the highest grade white metal, especially where enclosed crank cases are used.

In the case of forgings, one well-known maker pays more for the material in the rough than others pay for the same part of the engine finished complete, ready for fitting in place. This is one of the points that justifies the higher price asked by the best makers and explains the narrow circle of firms whose reputation is unchallenged.

The use of corrosive fuel oils cannot always be avoided, and special metallurgical consideration and experiment is accordingly necessary to determine the iron mixtures for cylinders, pistons, piston rings and hot bulbs.

Workmanship.—Accuracy and first-rate workmanship should be the keynote of manufacture, though this, coupled with the necessity for the high quality of the materials, increases the cost of production considerably beyond that of steam engines of an equal weight.

Thoroughness in finish and accurate gauges are necessary, seeing that some parts, such as the fuel pumps are ground to within one-five-thousandth part of an inch—($\frac{1}{5000}$ in.) a degree of accuracy quite unknown in steam engineering practice : approximately, it is one-tenth of the thickness of a page of this book.

A tour through the most modern works in the world engaged in the manufacture of low compression oil engines, in which practically every important machined face is ground, raises and answers the question as to whether such accuracy is necessary and why. In such a works, no tool is too expensive, no work too much trouble. As soon as a real improvement is discovered and proved, it is adopted, no matter what the cost or what the inconvenience.

Beyond this, their engines are thoroughly tested over long and continuous runs on the bench previous to the trials on board ship, and not until they are proved sound in every way and fully up to their proper efficiency are they allowed to be despatched for fitting in the vessel.

The high price of the engine which is entailed is a secondary consideration, it being a well-known axiom that the finest and most perfect engines or machines always find a ready market, especially in these competitive times, when the majority of purchasers of machinery do not mind what they pay providing they get full value for their money, and usually the best is the cheapest in the long run.

It must in short be realised that a satisfactory low-priced engine cannot be produced: even if made in very large quantities, the price is necessarily high, judged from steam-engine or from paraffin-engine standards, taking power for power.

Jigs and Gauges.—Wherever a considerable number of engines, are made to the same specification, it is imperative that all the principal parts should be made to jigs and gauges, so that spare parts may be both cheap to produce and interchangeable for any other engine of the same type and model.

This applies, of course, to the manufacture of hot bulb engines, and the larger the works, and the larger the number of engines constructed annually, the more liberal will be the use of jigs and gauges for each engine, and, consequently, the smaller the number of parts fitted by hand, and the less the cost of labour per B.H.P.

Two-stroke Cycle *v.* Four-stroke Cycle.—For convenience and brevity, engines are referred to as "two-stroke" or "four-stroke," omitting the word "cycle," as would perhaps be more correct. The two-stroke, described on p. 12, is the cycle almost universally adopted for hot bulb crude oil marine engines, and probably results in the simplest oil engine in the world. Hot bulb or hot tube oil engines of the four-stroke type for land work are well known, although there are very few which have successfully been applied for marine work. The two-stroke engine can develop nearly double the power of the four-stroke for the same size of cylinder, which is a great advantage for marine engines, as the weight of the engine per brake horse-power is thus reduced by about 40 per cent., and it is therefore only necessary to provide displacement in the ship for the smaller weight.

The crank case compression adopted by most makers of the two-stroke engine is a considerable disadvantage, as it necessitates the boxing in of the bottom end bearings, and, again, it does not give quite such good scavenging results as the four-stroke engine.

The temperature and pressure of the exhaust of the ordinary two-stroke engine is rather greater than that of the four-stroke.

The efficiency of the four-stroke engine is about 5 per cent. greater than that of the two-stroke, because, in the latter, the exhaust gases are incompletely expelled, and secondly, work is lost at the end of the stroke when the ports are uncovered.

To sum up, the advantages of the four-stroke hot bulb engine over the two-stroke may be stated as follows :—

(*a*) Better scavenging.
(*b*) Open crank case.
(*c*) Reduced average temperature of engine.
(*d*) Greater flexibility.
(*e*) Reduction of heat in engine room.
(*f*) Cooler exhaust gases.
(*g*) Slightly decreased fuel consumption.

and for marine work the disadvantages are—

(1) Increased weight.
(2) Exhaust and air inlet valves, cam shafts and two to one gear necessary.
(3) Larger flywheel.
(4) Larger shafting necessary.
(5) Extra cost to manufacture.
(6) Longer time necessary to open up, inspect and clean.

In a Diesel engine there are advantages in the four-stroke engine for marine work that hardly apply to hot bulb oil engines, *e.g.*, the heat developed in a Diesel engine cylinder is very great and requires more efficient water cooling, which is increasingly difficult in the two-stroke design, which nearly doubles the power per cylinder volume.

The flexibility of the four-stroke engine is greater than that of the two-stroke, as it will turn the propeller smoothly at fewer revolutions per minute.

Vertical *v.* Horizontal Engines.—The question of vertical or horizontal engines for marine work is not of much moment, as nowadays the latter is practically never used, although a few can still be seen in barges in Holland, in some cases with belts for the go-astern drive. A horizontal engine for marine work is quite out of the question in these days; for one thing, the extra floor space required could not be spared, and the further additional space for taking out pistons and connecting rods would be prohibitive (especially when the engines are fitted right aft), the shaft line could not be kept low enough, and the engine bearers would be very complicated. One advantage is the lower centre of gravity, but this is greatly outweighed by the disadvantages, and, consequently, the horizontal hot bulb oil engine is not likely to be adopted for marine work, even for war ships, where it is an advantage to keep the machinery below the water level.

FIG. 76.—Water drip fitting as fitted to the "E" type Bolinder Engine.

Water Injection or Water Drip.—In the majority of engines it is found that above a certain load, the hot bulb gets bright red and would get still hotter if the load were maintained or increased without introducing water into the cylinder and spraying it into the bulb.

There are three methods in which this can be arranged :—

(1) Water is dripped from a hand regulated needle valve through a sight glass, into the scavenge passage in front of the cylinder, and the charge of air carries

the water up as a spray and flushes the inside of the bulb, see Fig. 76, where 7 shows the sight glass and 1 the water pipe to the air passage.

(2) A pump for water is employed as well as a pump for fuel, the two supplies mixing immediately previously to their injection, through a spraying nozzle into the combustion space.

(3) Separate pumps are supplied as in method (2), but the supply of water and fuel do not come into contact until they leave the injection nozzle.

The separate water pump used for (2) and (3) has a hand lever to enable the pump to be put in and out of gear or closely regulated as the load on the engine demands. The water consumption in this case is only half that required in method (1).

In any case, only fresh water must be used; so that on sea service or in muddy rivers and canals or waters known to contain acids or corrosive matter, it is essential to carry a supply of fresh water. In method (1) a three-way cock is usually fitted to enable the supply to be taken from the jacket when working in fresh water, and from tanks when at sea or in muddy water.

Sea water must on no account be injected into the cylinders, as it corrodes the cylinder walls and leaves a deposit on the bulbs which prevents the proper escape of heat. Very hard water is also to be avoided for the last-mentioned reason. After some months these deposits might so screen the heat that though the driver only saw quite a nice dull glow on the bulb, the inside might be seriously over-heated, and the distortion and destruction of the bulb might result. To use the jacket water for injection conserves the supply of fresh water carried, but whenever an engine is so fitted that the jacket water can be used when desired, the driver should be emphatically warned not to use it unless the boat is in fresh water.

Though water injection has enabled more power to be obtained from a certain size of cylinder, the aim of designers must be to do away with it. Many engines on the market already omit it, but not always without a sacrifice of power.

The employment of partially water-cooled cylinder covers and small uncooled bulbs proper has been adopted to this end.

In the most recent design of large hot bulb engines a medium pressure air compressor is employed to inject air with the fuel. This has done away with the water drip, while the power obtained from a given cylinder is the same as that previously obtained with water drip (see p. 27).

The chief objection to water drip is the necessity of providing fresh water tanks for sea work, thus hampering the engine room and diminishing to a slight extent, the cargo carrying capacity, but it is poor economy indeed to surmount this difficulty by fitting a larger and more expensive engine to get the same power. Hence it is necessary, before deciding on an engine without water drip, to see that it is an improvement and not an unwarranted sacrifice of power.

Double-acting Engine.—The tried and proved double-acting hot bulb engine has yet to be evolved, although the field for such a motor would be very large. The chief difficulties at present appear to be the following:—

(*a*) Imperfect scavenging owing to the shape and position of the lower of the two bulbs.

(*b*) Wear and tear on the piston rod, gland, and packing under the high temperature.

(*c*) The necessity of water cooling for the piston and piston rod introduces extra complication, thereby weakening one of the chief claims for the engine, viz.: essential simplicity.

(*d*) If the double-acting principle is used approximately to double the power per cylinder volume, the heat generated in the cylinder is of course approximately doubled. This entails the utmost viligance on the part of the designer to provide efficient cooling for the cylinder walls.

(*e*) Abnormal height.

The advantages are—

(1) Reduced weight for a given power.
(2) Reduced length and breadth of engine, which allows of a smaller engine room and, consequently, increased cargo space.
(3) Smoother running owing to its superior balance.
(4) Increased facility for lubrication of gudgeon pin owing to reversal of pressure.
(5) Cheaper first cost per horse-power when once a successful engine is placed on the market, and manufactured in large numbers.

It is probable that a successful double-acting hot bulb oil engine will do away entirely with crank case compression, which will in itself be an advantage.

A design for a double-acting engine will be found on p. 73.

Accessibility.—The accessibility of the working parts is a most important feature of the design of the two-stroke hot bulb engine. By taking off a few nuts on the cylinder head and lifting off the ignition bulb, the cylinder is open for cleaning (the four-stroke engine is not so accessible because of the valves, rods and levers on the cylinder head). The crank case, crank pin, main bearings, and connecting rod bearings should have equal facility for inspection, and in this respect the open crank case is very much better than the almost universal enclosed design and would enable the attendant to feel the bottom ends from time to time. The piston and connecting rod can be drawn upwards as soon as the crank pin brasses are let go, thus enabling the " top ends " to be removed, so that all the principal working parts of the engine can be opened out ready for examination in half an hour or so.

The crank case drain cocks should receive special attention and the attendant must not be tempted to presume they are in order and neglect them. If they are closed for any considerable time, or choked up from any cause, as they might be by rags inadvertently left in the crank chamber, lubricating oil is carried up to the bulb and heavy carbonisation results.

Another difficulty that should not be overlooked is the fact that the engines are frequently fitted in very confined spaces on board ship, sometimes right aft, sometimes between longitudinal bulkheads, so that the extra space needed for dismantling and inspecting must be a minimum.

There is no other type of engine in the world that can claim such simplicity and ease of overhaul and repairs as the two-stroke hot bulb crude oil engine, if the design receives ordinary consideration from practical men.

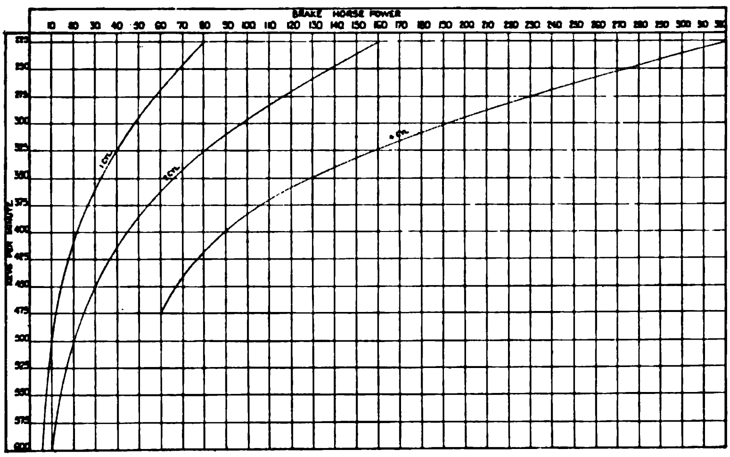


FIG. 77.—Revolutions for Two-stroke Engines.

Revolutions.—The employment for marine work of slow running engines with correspondingly low piston speed cannot be too strongly recommended. It is of the utmost importance to have a slow running marine engine in order to obtain anything like a good efficiency from the screw propeller. Petrol and paraffin engines are at a disadvantage in this respect, except for very fast vessels. Many failures of internal combustion engines in cargo boats, fishing vessels, canal barges, etc., etc., are due to the high speed at which the engine has been run. Some makers cannot resist the temptation to run any engine with a given sized cylinder, a tlitle faster. In this way they get more power, and their price and engine weight per horse-power appears lower than that of wiser competitors, but in the long run it does not pay. It is like trying to make a race-horse do the work of a cart-horse.

Fig. 77 gives a curve of the revolutions suggested for two-stroke engines by the author. It is better to design and build an engine to run in ordinary practice at less, rather than more, than the average revolutions.

Piston Speed.—This, like the revolutions of the engine, should be kept as low as possible to simplify the question of cylinder lubrication. The following table indicates sound practice :—

Power per Cylinder.	Piston Speed.
10	600 feet per minute.
20	675 ,, ,,
40	725 ,, ,,
60	725 ,, ,,
80	750 ,, ,,
100	750 ,, ,,

Reversing.—This is a very important feature for a marine oil engine builder to study, and it is an important point for intending purchasers to consider.

The purchaser will take into consideration the particular conditions of the vessel's service, the proximity, or otherwise, to repair bases, the size of the vessel, the likelihood of weeds if for river service, the likelihood of frequent manœuvring in difficult waters, and the desirability of minimising the space taken up for engine room and so forth.

The designer must fulfil these requirements with the most reliable mechanical means, with as little complication as possible, and with no unnecessary cost.

The systems in use are :—

(1) Direct reversing of the engine itself by pre-ignition.
(2) Reversing the engine by compressed air.
(3) Mechanical gearing.
(4) Reversible blade propellers.
(5) Electrical or hydraulic transmission of power to the propeller.

The last will not be considered here, as its cost and space occupied are prohibitive for any vessels suitable for hot bulb engines.

(4) *The reversible blade propeller* design is useful for small river or canal boats, and more especially for small fishing vessels, pilot boats, and boats which for considerable periods only require to keep steerage way, for the power can be reduced indefinitely without altering the revolutions of the engine. Its disadvantages are loss of efficiency, due to wear in the rack and pinions, and the inaccessibility of the rack and pinions. It is not a design to be recommended for engines above 60 B.H.P. or so.

(3) *Mechanical gears* are much used, but take up valuable space in the boat and are often cumbersome. The gears are apt to be noisy but only in reverse running, as nearly all designs have a straight through locked drive ahead, which is effected by having the drum carrying the pinions free when going ahead, and held fast by a brake strap for going astern. Their wide use is perhaps due to the strength of patents covering direct reverse designs.

(2) *Reversing by compressed air* is complicated and requires an air compressor of considerable capacity and very large receivers to ensure satisfactory working. It also introduces valves in the cylinder heads—almost making a different type of engine, and partly sacrificing the virtue of simplicity and ease of overhaul. It eliminates the clutch, however, and probably most engines above 300 B.H.P. will in future be reversed by compressed air.

(1) *Direct reverse by pre-ignition* is a very pretty and amazingly simple device. Although Messrs. Bolinders of Stockholm, have for many years used this on all their marine oil engines (excepting on certain small ones, where customers' requirements are better met by the reversible blade propeller), it is surprising, but true, that many people did think, and some still do think, that it puts excessive strain on the engine. This is a fallacy. Before reversal *can* take place, the declutched engine rapidly slows down to a speed which would only carry the free engine over one or,

perhaps, two more complete revolutions when the reverse fuel pump gives its injection, cushioning the piston and then reversing its motion. The extra strain conjured up by some people amounts only to reversing the free engine and fly-wheel when it is just going round. The torque, and therefore strain, on the crank shaft is no greater than in steam-engine practice, or in oil engines with a reverse gear. In the latter case the propeller and shafting are reversed, and at fairly high revolutions (in the hands of any average attendant), which is automatically impossible with the direct reverse type.

Bolinder engines have been reversed without declutching, which is a far more severe test than the proper way, but the engine was always unaffected except that, of course, it did not pick up speed as quickly with the propeller in action the whole time. The Bolinder engine is specifically mentioned simply because severe tests have been made on it for the benefit of unbelievers. No doubt the statement holds good for any good direct reversible engine.

For fishermen in all countries and for native drivers abroad, the best alternative to reversible blade propellers for small engines is perhaps the reverse gear, on account of small adjustments which may be required on a direct reversible engine after dismantling, for cleaning, or fitting spare parts.

Beardmore Direct Reverse.—This is an example of reversal by compressed air. The gear is so arranged that the engine may be started up in either direction by compressed air for any position of the crank shaft.

The following are the stages of reversal :—

(1) Engine stopped by cutting off fuel.

(2) Engine driven in the reverse direction by compressed air while a small amount of fuel is injected at each revolution.

(3) Firing commences in the cylinders and, momentarily or for short periods, the engine runs by combustion and compressed air.

(4) Compressed air is shut off while the amount of fuel injected is increased and the engine picks up speed.

The whole control is centred in one handwheel, of which the different positions bring about each of the above conditions.

The spindle of the control wheel has four cams, one regulating the stroke of the fuel pumps, and each of the other three operating a pilot valve in a box behind the wheel.

The larger pilot valve controls the supply of compressed air to a vertical cylinder, of which the function is to distribute

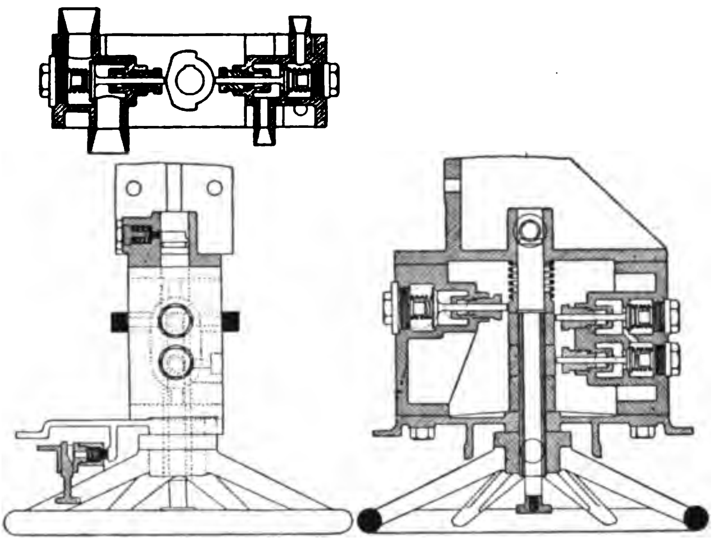


FIG. 78.—Details of Control, Beardmore Air Reverse.

compressed air to the engine cylinders to drive the engine ahead or astern. This cylinder has three air ports, the inlet in the middle, and outlets at the upper and lower ports leading to one or other engine cylinder respectively, the ports being controlled by a double piston (the lower piston slightly larger in diameter than the upper one held in neutral position by a spring). When compressed air enters, this double piston is forced down to make contact with one of two tappets, according to the direction of motion desired. The double piston then follows the motion of the particular tappet, distributing air to the engine accordingly.

Either tappet can be brought into operation, according to the position of an ingenious link system controlled by a

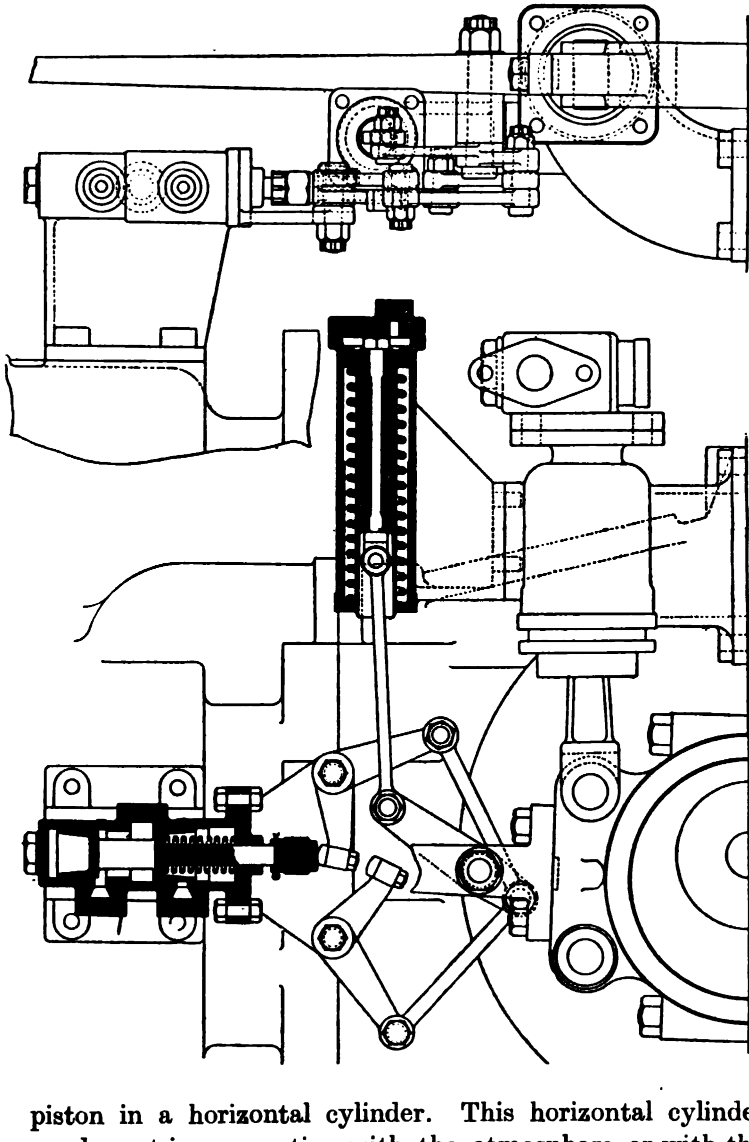


FIG. 79.—Details of Beardmore Reversing and Starting Gear.

piston in a horizontal cylinder. This horizontal cylinder can be put in connection with the atmosphere or with the air reservoir. In the former case the ahead tappet is in action, but when compressed air enters the cylinder, the piston is forced out, bringing the astern tappet into operation and leaving the ahead tappet working idly.

The two small pilot valves behind the control wheel serve to connect this horizontal cylinder with the atmosphere and the air reservoir respectively, and therefore control the direction in which the air drives the engine.

In order to keep the compressed air cut off from the main

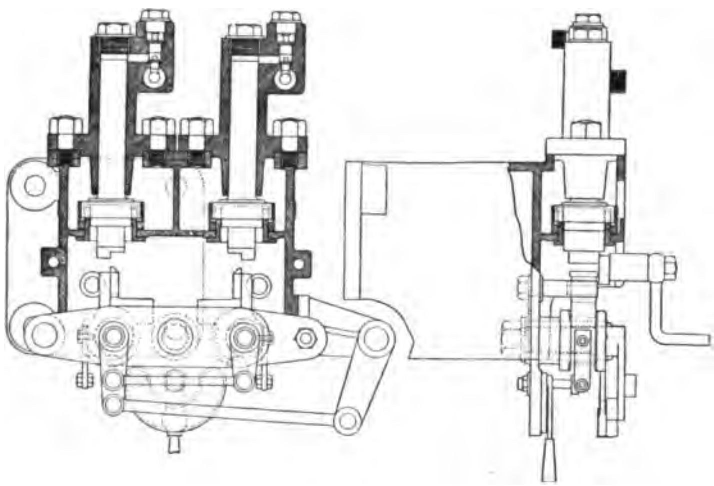


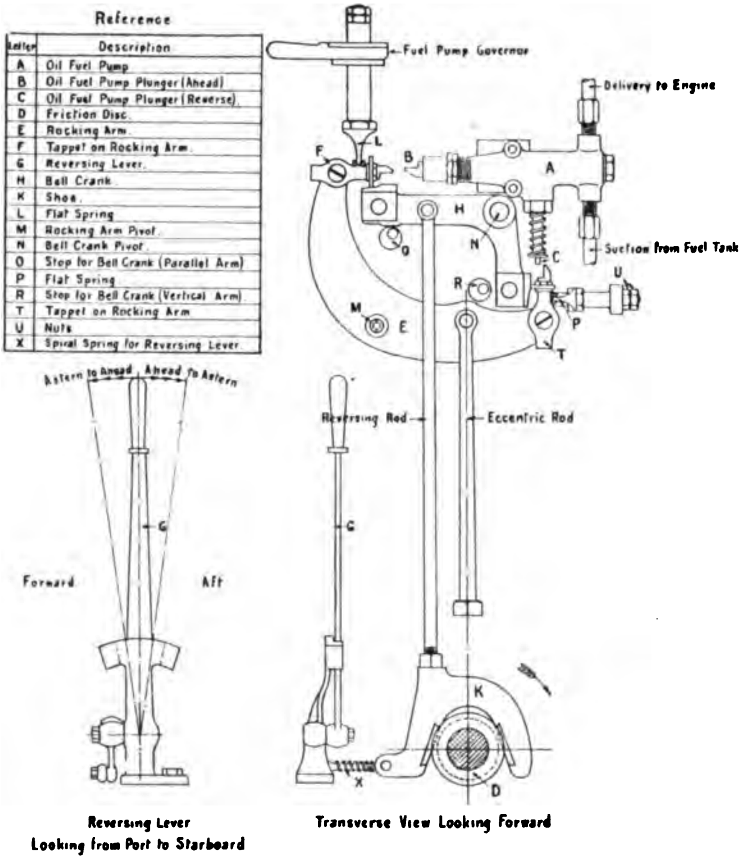
FIG. 80.—Beardmore Fuel Pump Gear for Air Reversible Engine.

engine until the wheel is turned back to "stop," the cam operating the big pilot valve is slid out of action and is arranged to return to its place automatically when the "stop" notch is reached.

The illustrations refer to a four-cylinder engine of 200 B.H.P., and all the reversing gear (except the control wheel and pilot valves and box) is duplicated, the forward group regulating two cylinders and the group aft regulating the other two, both groups being controlled by the one hand control wheel. The engine itself is illustrated on p. 20.

Bolinder Direct Reversing, illustrated in Fig. 81, may be made clear by the following description :—

General.—The oil fuel pump A has two plungers, B and C, of which the plunger B is adapted to work during normal



Letter	Description
A	Oil Fuel Pump
B	Oil Fuel Pump Plunger (Ahead)
C	Oil Fuel Pump Plunger (Reverse).
D	Friction Disc.
E	Rocking Arm.
F	Tappet on Rocking Arm.
G	Reversing Lever.
H	Bell Crank.
K	Shoe.
L	Flat Spring
M	Rocking Arm Pivot.
N	Bell Crank Pivot.
O	Stop for Bell Crank (Parallel Arm)
P	Flat Spring
R	Stop for Bell Crank (Vertical Arm).
T	Tappet on Rocking Arm
U	Nuts
X	Spiral Spring for Reversing Lever.

FIG. 81.—Diagrammatic Sketch, Bolinder Direct Reverse.

conditions when the engine is running in one direction or the other, while the plunger C effects reversal. An eccentric on the main shaft imparts a rocking motion to the arm E, which is pivoted on the bolt M. To this arm E two tappets, F and T, are attached, operating the plungers B and C, which slide on stepped tables on the bell crank H. This bell crank has a motion round the bolt N, the extent of which is determined by the stops O and R.

At L and P there is a flat spring to control the hit-and-miss action of the tappets F and T. The shoe K, overhanging the disc D, is connected by the reversing rod with the bell crank H, which latter can be lifted from the stop O and at the same time moved towards the stop R, by means of the reversing lever G, which engages one of the inside vertical edges of the shoe K with the friction disc D.

Running Position.—Suppose the engine to be running ahead in the direction of the arrow, the bell crank H is pressed against the stop O on account of its own weight and also by the weight of the shoe K.

The tappet T is prevented from striking the plunger C by the vertical arm of the bell crank, while on the other hand the tappet F, working during normal running for ahead or astern, is able to strike the plunger B.

Reversing.—The reversing lever G is thrown aft, so that the edge on the port side of the shoe K is brought into engagement with the friction disc D, which lifts the shoe and rod. The horizontal part of the bell crank H is thus lifted from the stop O, thereby raising the tappet F, so that it cannot strike the plunger B. The engine will slow down automatically to a speed suitable for reversing owing to the spring P not having sufficient tension to hold the tappet T against the table when the engine is running fast, but when the engine is running slow the tappet T strikes the plunger C upwards and consequently injects one charge of fuel into the cylinder. This can only take place when the engine has slowed down sufficiently for the spring P to overcome the jumping action of the tappet T. The charge will ignite before the cylinder piston has reached its top position, and the piston is thus stopped, driven backwards and the engine begins to rotate in the opposite direction.

Immediately the engine has commenced to rotate in the opposite direction, the shoe K is obviously moved downwards due to the friction created by the disc D being reversed. On account of this the horizontal part of the bell crank

H is automatically dropped towards the stop O, so that the tappet F is again in action and the weight T is thrown out of action.

If the engine is to be reversed from astern to ahead the lever G is thrown forward, and the reversal will take place as described above.

To test Adjustment after fitting on Board.—When the ahead fuel pump B is thrown out of action the engine should slow down to just the right speed, and at the critical moment a charge of oil be injected by the reverse pumps.

If when the plunger C has come into action the piston carries over the dead centre and continues the same direction of rotation as before, it will signify that the pressure on the spring P is too much and the nuts U should be slackened. If, on the other hand, the engine stops before reversal takes place, the pressure on the spring P is too little and the nuts should be tightened up.

When the tension is adjusted, care must be taken to see that the lock nut is screwed up tight again.

The **Gillespie** direct reverse is illustrated in Fig. 82, showing the end view and the side elevation. There are two cams G, H, mounted loosely on the crank shaft A. Between these cams is a collar, O, secured rigidly to the shaft. Through this collar extends a pin, P, projecting into annular groves in the faces of the cams. A metal block, or distance piece, is fastened in each cam groove, to prevent the pin P from passing round the entire circumference of the groove.

This pin, bearing against the block or distant piece, carries the cam round with the rotation of the collar. The cams operate vertical levers E, F, which in turn actuate the fuel pump plungers C, D, thus delivering a charge of fuel at each cam stroke.

Each vertical lever rests against a double eccentric disc J, K, secured to a spindle L, mounted on a pin M, and rotated by a hand lever N, working on a quadrant indicator.

The vertical lever E bears upon the disc K, and actuates the fuel pump plunger D, while the vertical lever F bears against the disc J and operates the fuel pump plunger C.

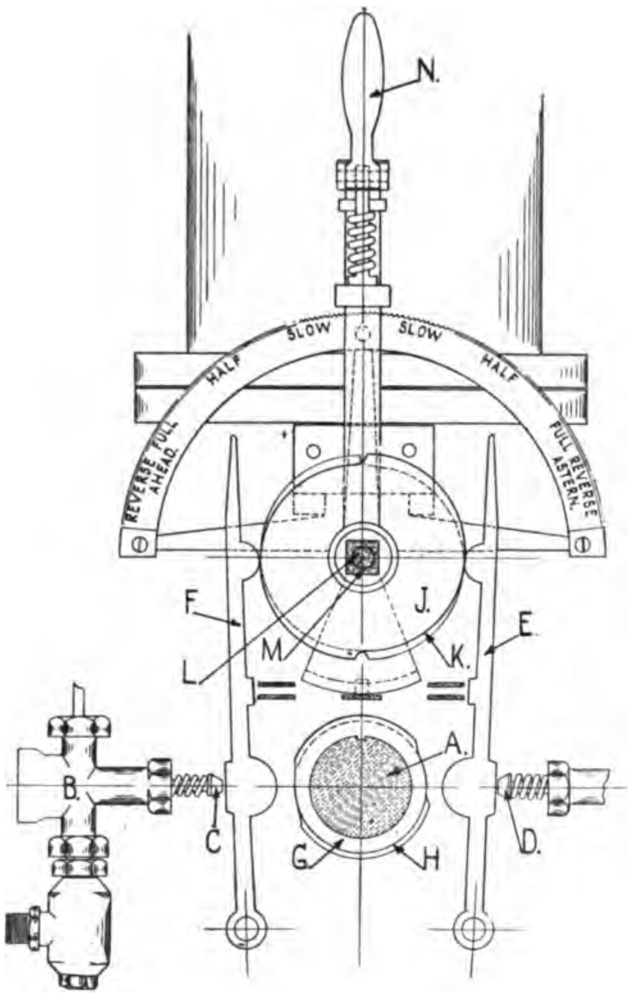


FIG. 82.—Gillespie Direct Reverse.

The action is as follows : so long as the hand lever N is in the vertical position, both vertical levers are held apart, out of reach of the cams G, H. When the hand lever N is moved to the left, the lever F moves inwards until the cam G strikes it and feeds fuel through the pump B, while the

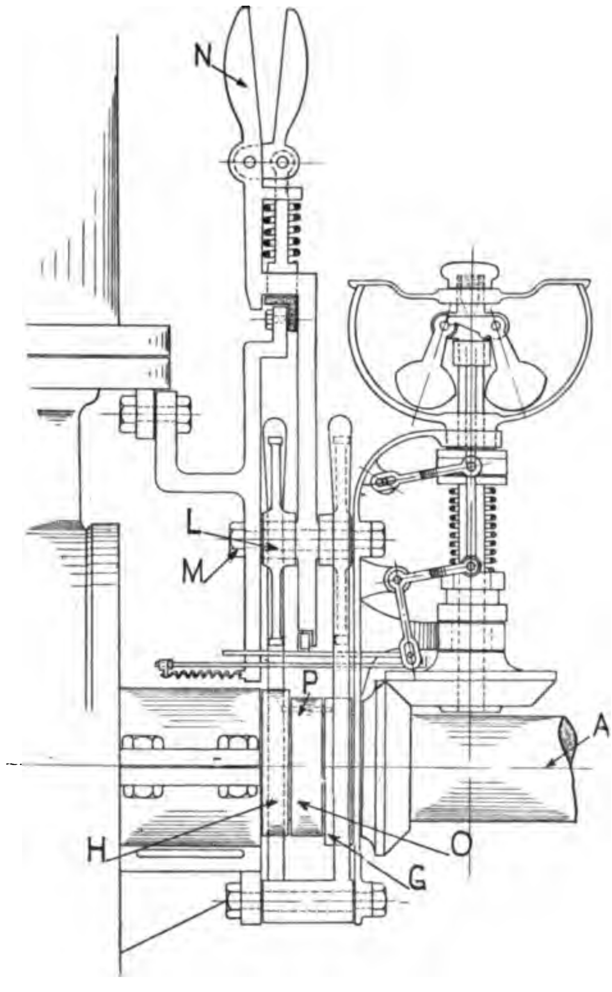


FIG. 82A.—Gillespie Direct Reverse.

lever E remains out of reach of the cam H, but when the hand lever N is moved over to the right, the levers E and F are respectively moved out of, and within reach of, their cams.

The engine, therefore, may be run in either direction, using a different cam, vertical lever and fuel pump for each direction.

Assume the shaft A (Fig. 82) to be rotating anti-clockwise with the lever N on the left, the cam G strikes the vertical handle F and drives the pump plunger C, the left-hand end of the rise on the cam G moving in a downward direction as it strikes the vertical lever. Now bring the hand lever N suddenly over to the right, thus putting the handle F out of range of the cam G, and bringing the handle E within range of the cam H. The shaft A is still turning anti-clockwise, so the right-hand end of the rise on the cam H strikes the handle E while moving in an upward direction, and thus reverses the engine.

Since the curved distance pieces in the cam grooves are of such length and so situated that when the end of a cam rise moving upward strikes a pump handle, the fuel charge is fed early on the up-stroke of the piston, which charge fires before the piston reaches the top centre, and starts it back the other way. That cam now slips, or rotates on the shaft, while the pin P travels in the cam groove until it strikes the opposite end of the distance piece in the groove, and thus carries the cam round in the new direction, feeding each fuel charge near the top of the compression stroke, and keeping the engine running in the new direction.

Avance Direct Reverse by Pre-ignition.—Figs. 83 and 84 show the gear itself and a diagrammatic sketch to illustrate the working.

The fuel pump gear is driven by eccentrics on a lay shaft, spur driven by the crank shaft.

The usual swivelled striker working on a stepped guide or regulating plane B provides the automatic cut-out governor. The spring holding the striker to the guide against the jumping action is in this case an adjustable spiral clock spring, the tension of which gives a permanent adjustment regulating the speed of cut-out. The speed of cut-out is further regulated by a hand lever C, which simply moves the regulator plane itself towards or away from the fuel pump plunger.

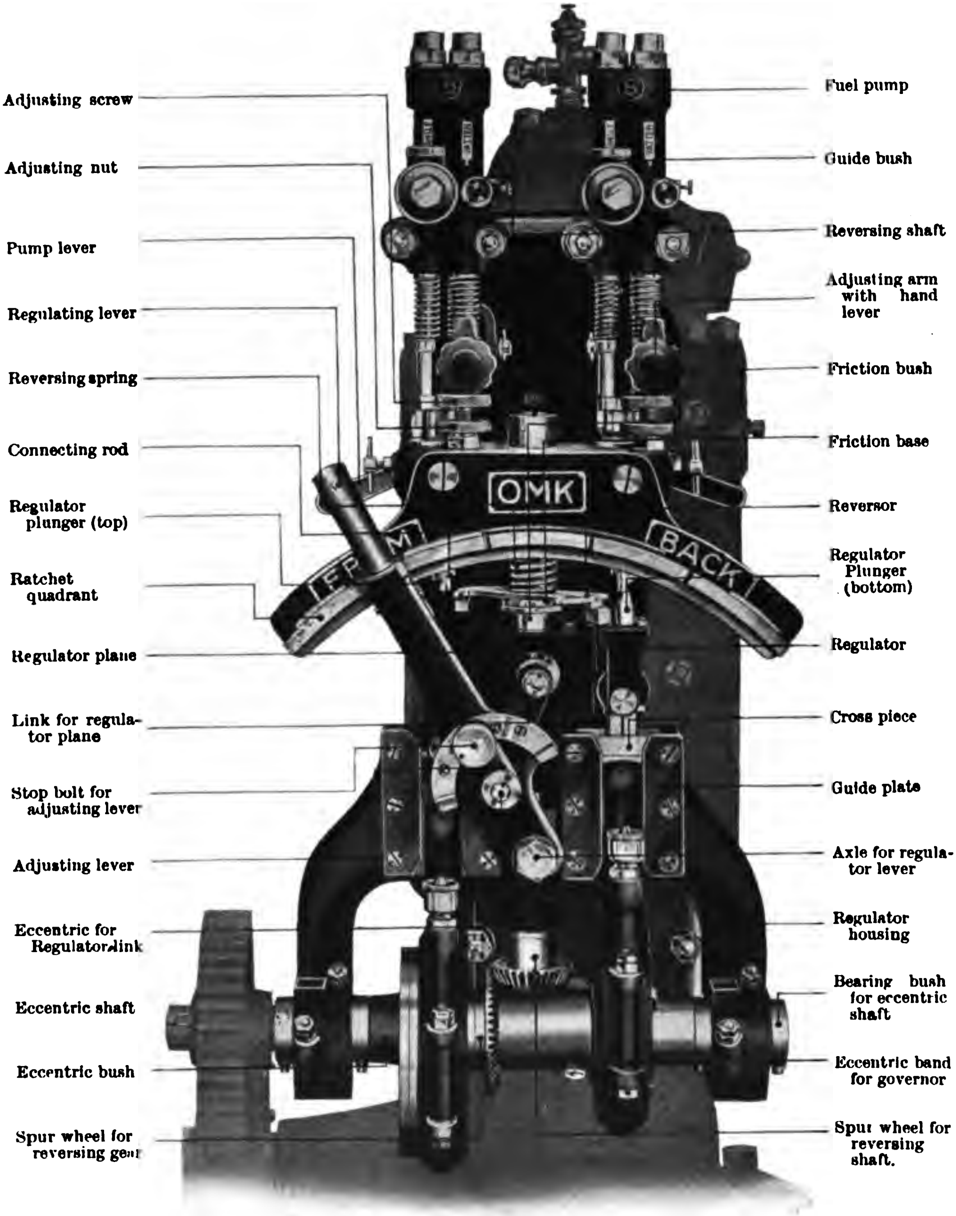


FIG. 83.—Avance Direct Reverse.

The reversal is accomplished by nterposing a distance piece between the striker and the plunger, thus increasing the stroke and making the injection begin much earlier in the cycle. This is done by a shaped distance piece D being moved into position by the speed regulating lever C, and arranged so that the distance piece cannot be interposed until the lever has already brought the regulator plane into a position corresponding to a "cut-out" of the fuel

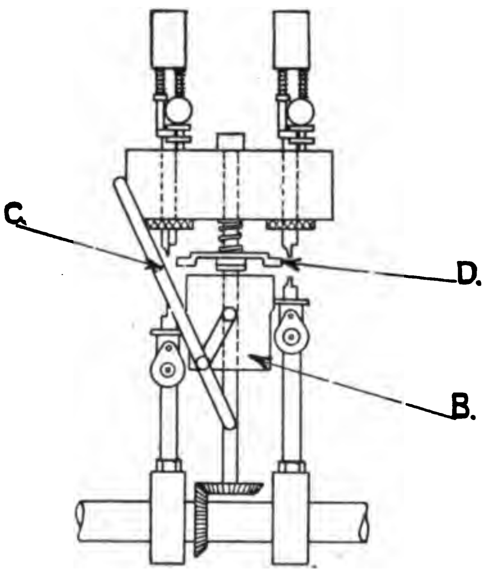


FIG. 84.—Avance Direct Reverse.

pump at a very low speed, so that the reversal is gentle and succeeds cushioning at very low revolutions as in the Bolinder.

The shaped distance piece D is pressed by a spring on to a friction disc, carried on a spindle revolved by bevel wheels from the lay shaft. This keeps the distance piece out of the way immediately reversal has taken place.

Supposing the engine to be going full speed ahead, the lever will then be in the extreme left position. As the lever is moved to the right the engine slows down, then when it gets to the first notch on the right, reverse takes place, the distance piece is then automatically swung out of place by the friction disc and the engine goes slow astern. As the lever is moved further to the right the engine goes faster astern. From astern to ahead is the same process, the lever being moved this time from right to left.

As this engine works with a fuel injection which finishes considerably before the top dead centre, the same time setting is unsuitable for ahead and astern so that a loose carrier driven by the lay shaft operates the fuel pump eccentrics, driving with one face for ahead and the other for astern, and so shaped as to give the appropriate timing to the fuel injection for ahead and astern.

It will be seen that the same striker which operates the fuel pump also operates a fresh water injecting pump, but by means of a little hand wheel which raises the plunger clear of the striker, the water pump can be put out of operation, previous to reversing, as is usual; the clutch must, of course, also be pulled out as in all internal combustion engines, unless reversed by external means such as compressed air.

Skandia Direct Reverse.—This direct reverse operates by the aid of compressed air, utilising a shifting lay shaft which has cams for running the engine on compressed air in either direction, from full ahead to full astern by two manipulations.

The governor and the fuel pump can be seen on the left side of Fig. 85. On each cylinder there is a manœuvring valve and a cock, and on the cam shaft are cams for operating each valve for either ahead or astern, according to the direction of the rotation of the motor. When the motor is to be started in the ahead or astern direction the cam shaft is moved backwards or forwards by means of the lever B. When this lever is in the forward position, the cams are arranged for ahead running, and when in the back position for astern running. The handle C controls the speed by altering the stroke of the fuel pump, and to cut these out entirely it has to be turned to the right.

On starting up, the hand lever C is turned to the left, and lever B is pushed forward. Compressed air then runs the

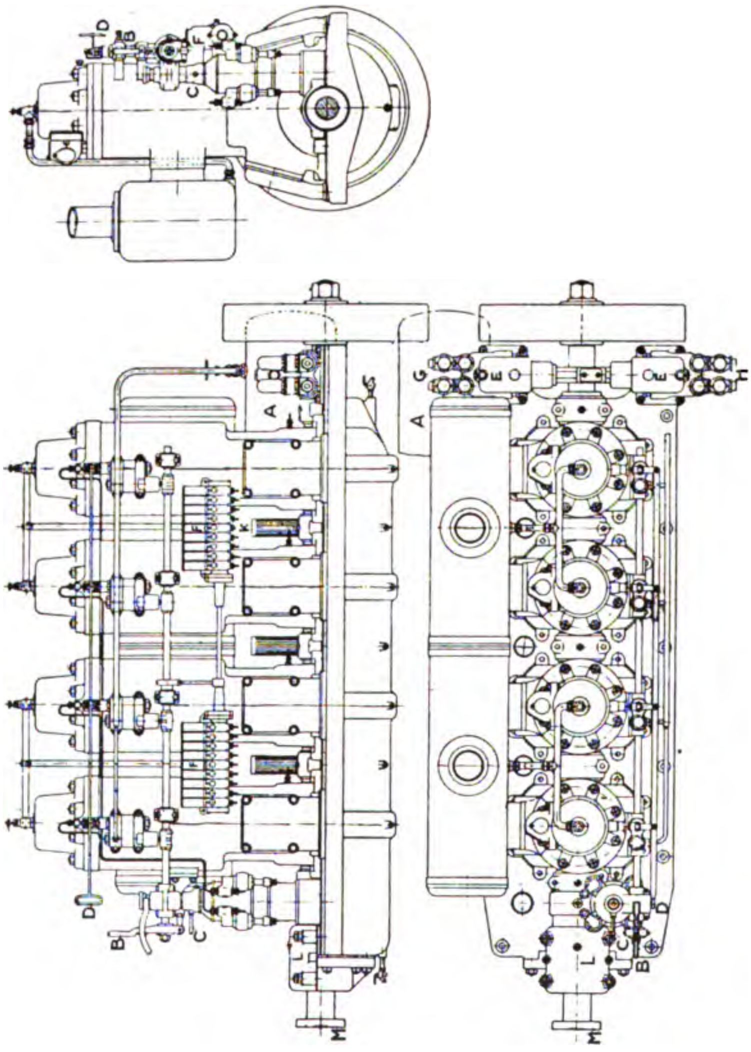


FIG. 85 —Skandia Engine, Direct Reversible by Compressed Air.

engine ahead and fuel is at the same time injected so that firing begins.

After a few revolutions the handle B is pushed back to the neutral position, which shuts off the compressed air after the engine has fired. When reversing, the handle C is brought to the stop position, and then turned to the left, the handle B being pulled back, and the engine then starts up in the astern direction. The handle B is once more returned to the neutral position when the engine fires. The lever D enables all the relief cocks to be opened simultaneously.

In direct reversible engines of this type no clutch is fitted.

Reverse Gears.—As many engines cannot have their direction of rotation changed, means have to be adopted to change at will the direction of rotation of the propeller shaft while maintaining that of the engine. This is achieved by gear wheels (sometimes with the addition of a chain) in a gear box, in which the clutch is usually incorporated as well.

Broadly speaking, there are two types :—

(1) Epicyclic gear with " sun and planet " motions.

(2) Gear wheels and a lay shaft, allowing power to be transmitted direct through the main shaft or through a train of gears to the lay shaft and back again to the propeller shaft.

Fig. 86.—Pinions of Ideal Reverse Gear.

In each case the " ahead " drive is direct, with gear wheels locked or running free so that only for "astern" running do the gear wheels transmit power. The large number of different gears on the market differ somewhat as to the grouping of the spur wheels and the detail design, but more as to the construction of the clutch. The lay shaft type is only a modification of the motor car reverse—a simpler, but much more massive design.

In the epicyclic design a spur wheel is keyed on the engine shaft and another on the propeller shaft (or more correctly, thrust shaft). A framework carries pinions meshing in pairs with each other and one of each pair meshing with the wheel on the engine shaft, and the other meshing with the wheel on the thrust shaft, see Fig. 86. The framework which carries the "planets" runs freely on each shaft and is keyed to neither, but can be held stationary by a brake band (or cone on fixed casing). The clutch is formed by this framework and a casting keyed to the thrust shaft.

When the clutch is engaged (the brake band being free)

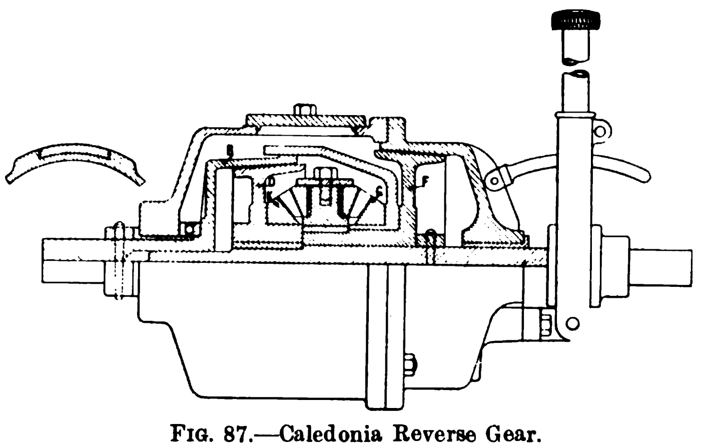


FIG. 87.—Caledonia Reverse Gear.

the drive is "ahead" and is solid, *i.e.*, the spur wheels and planets rotate locked together. When the clutch is disengaged and the brake band still free, the engine runs "free," and when the brake band is tightened (the clutch being disengaged), the drive passes through the train of wheels and transmits a reverse motion to the propeller shaft. These conditions are brought about by one lever or wheel having three positions, "ahead," "stop" and "astern." If bevel wheels are used in place of spur wheels, each pair of planet pinions becomes a single bevel wheel to effect the reverse, but bevel wheels are to be avoided on gears for heavy duties.

With these remarks, the various gears illustrated almost explain themselves, and only a few features need be cited.

Caledonia Gear.—This is a bevel wheel design (see Fig. 87). Cone B is driven with the engine and by an exten-

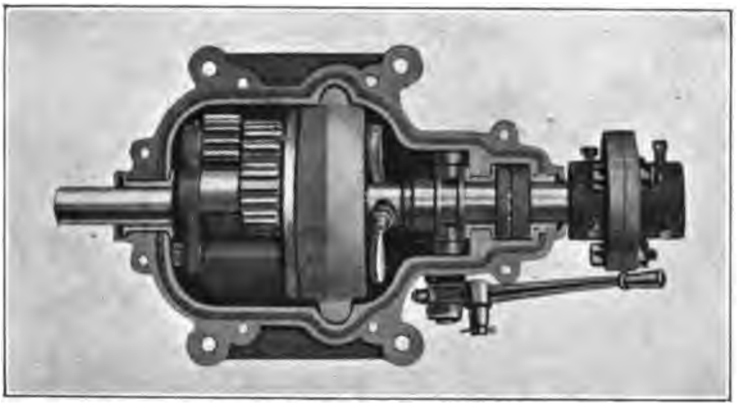


FIG. 88.—Gaines "B" Type Reverse Gear.

sion of it, with a sliding arm, the bevel wheel G is also carried round by the engine. The cone F carries the planet bevel wheels ; the cone D with the bevel K is keyed to the

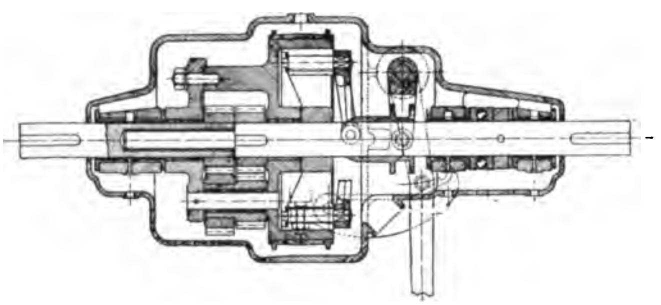


FIG. 89.—Gaines "B" Type Reverse Gear.

driven shaft. When B and D make friction contact the drive is ahead and locked. When F is held stationary by the cone face of the casing, the drive is astern through the bevels. The clutches are engaged by a lateral movement of the propeller shaft, the mid position corresponding to free engine.

Gaines "B" Type.—This is on similar lines to the **Skandia**, and is shown in Fig. 88 with the cover removed; the control lever and the sliding collar to actuate the expanding ring clutch are seen, but the links from the control lever to actuate the brake band are left out for the sake of clearness.

Ideal Reversing Gear.—Fig. 90 gives a good idea of the construction of this gear, which in its essential principle is similar to other epicyclic types. A portion of the "frame-

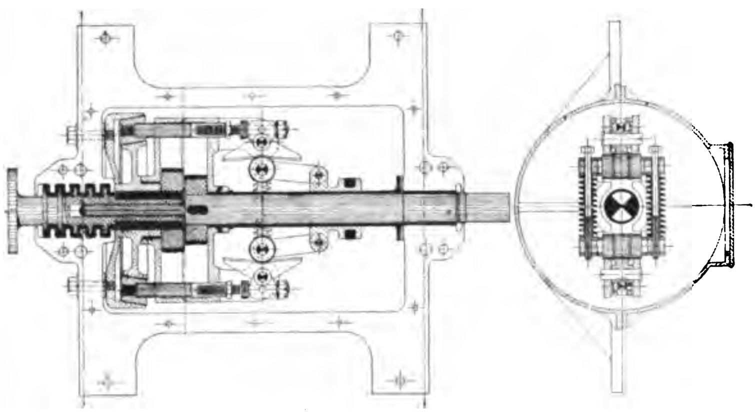


FIG. 90.—Ideal Reverse Gear.

work" carrying the "planets" is shown in Fig. 86, p. 111. A floating cone piece slides on spindles laterally through the "framework," the lateral movement being controlled by a lever operated by a hand wheel. There are three positions; in one position the "floating cone piece" clutches with an inner cone keyed to the driven shaft, producing a "solid" ahead drive with the pinions locked; in the other extreme position the floating cone piece engages with a coned surface fixed to the casing, when the drive is transmitted from the spur wheel on the driving shaft through the train of wheels and on to the spur wheel on the driven shaft, giving it "astern" motion. Free engine is obtained by an intermediate position when neither clutch is engaged, and in this position and in ahead running the framework pinions and the floating cone serve as an additional flywheel.

This gear is employed by Messrs. Beardmore on those of their hot bulb engines which are not direct reversible.

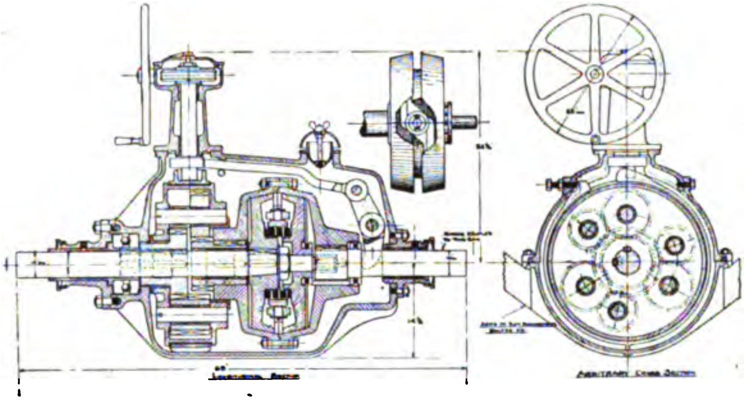


FIG. 91.—Langdon Reverse Gear.

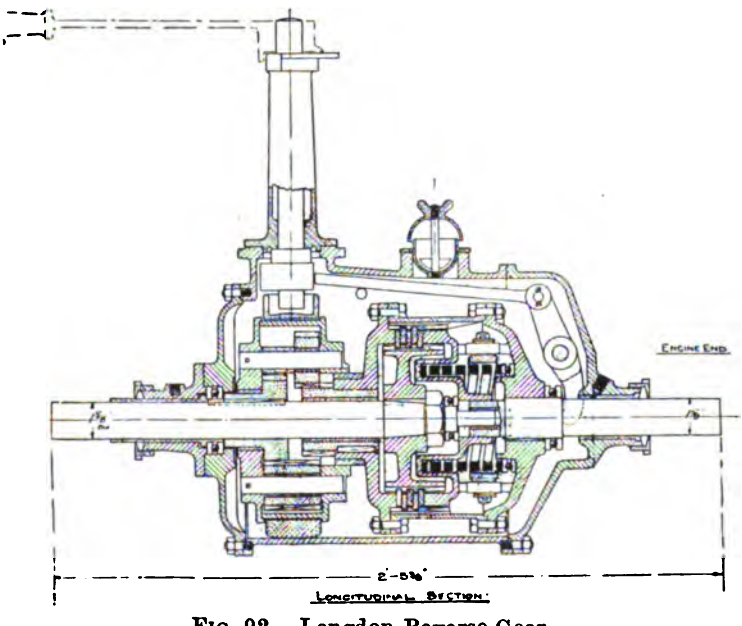


FIG. 92.—Langdon Reverse Gear.

Langdon Gear.—Fig. 91 is a sectional elevation of this firm's old type of gear. Locked ahead drive is produced when

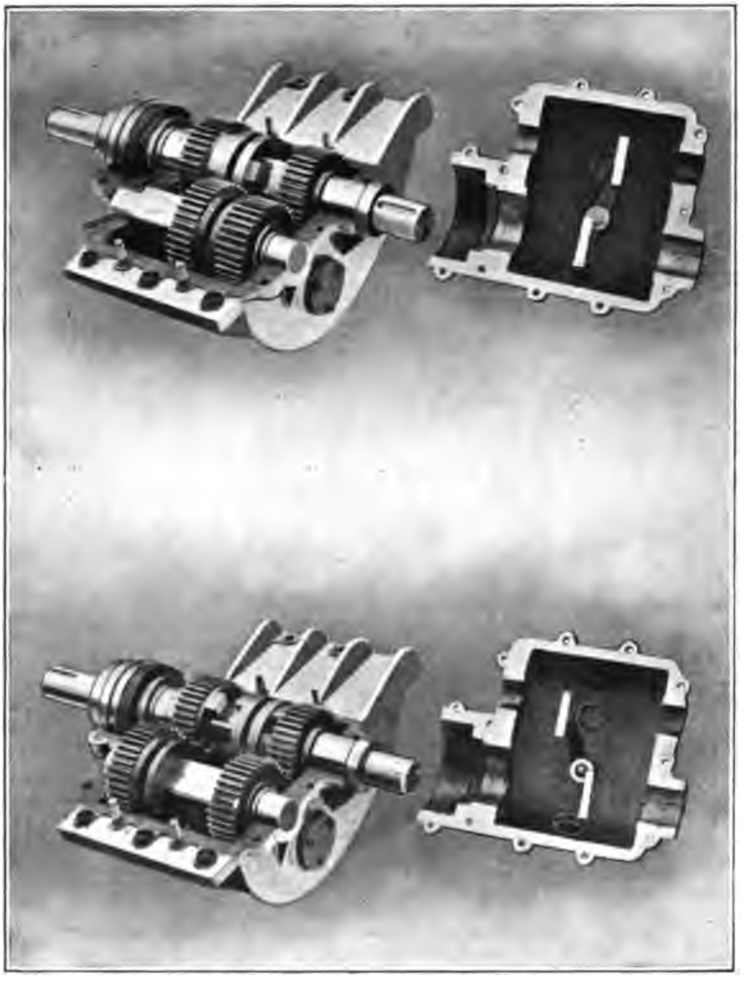


FIG. 93.—Parsons' Patent Reverse Gear.

the special cone clutch is in action. Reverse is obtained by a brake band on a drum carrying planets (the cone clutch being disengaged). The point in which this differs from other epicyclic gears is chiefly in the cone clutch, which is provided with inclined planes and rollers, whereby the torsional stress of driving is itself utilised to hold the clutch in gear. The clutch is not fierce, but takes up smoothly. One handle or hand wheel controls the clutch and the band brake, giving ahead, neutral and astern positions.

A newer design, Fig. 92, has been marketed by the same

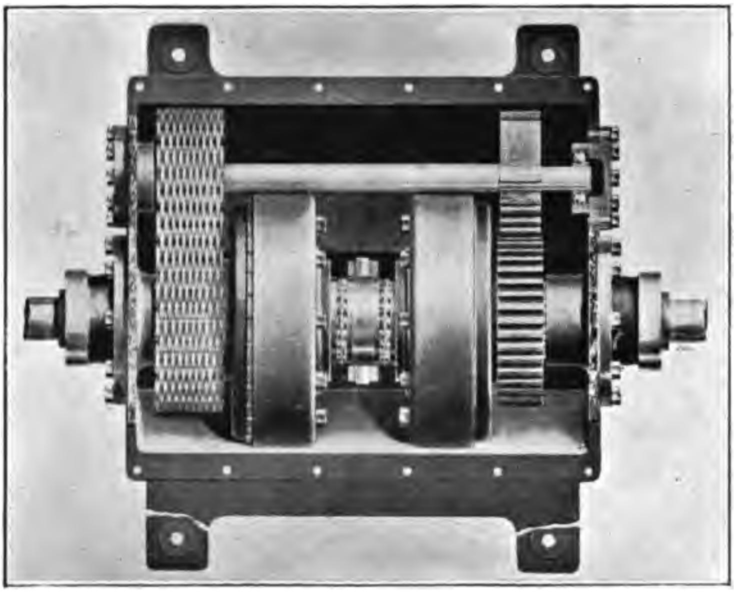


FIG. 94.—Shiners' Patent Reverse Gear.

firm, still incorporating the inclined plane and roller device, but using a disc clutch in place of the cone.

Parsons' Patent Gear.—As is seen by the illustration this gear employs a lay shaft and train of wheels (a chain only being used on small sizes).

The control lever operates the muff jaw coupling and one of the pinions of the lay shaft. In the ahead drive the lay shaft is stationary, the train of wheels transmitting reverse motion to the propeller in the astern drive. No clutch is incorporated and the gear must therefore only be fitted to engines already provided with a clutch.

Shiners' Patent Reverse Gear.—Figs. 94 and 95 show a sectional elevation and a plan with the cover removed. A lay shaft is provided with two pinions, one engaging with the pinion driven by the engine shaft when one cone clutch is engaged, the other driving by chain to a pinion which

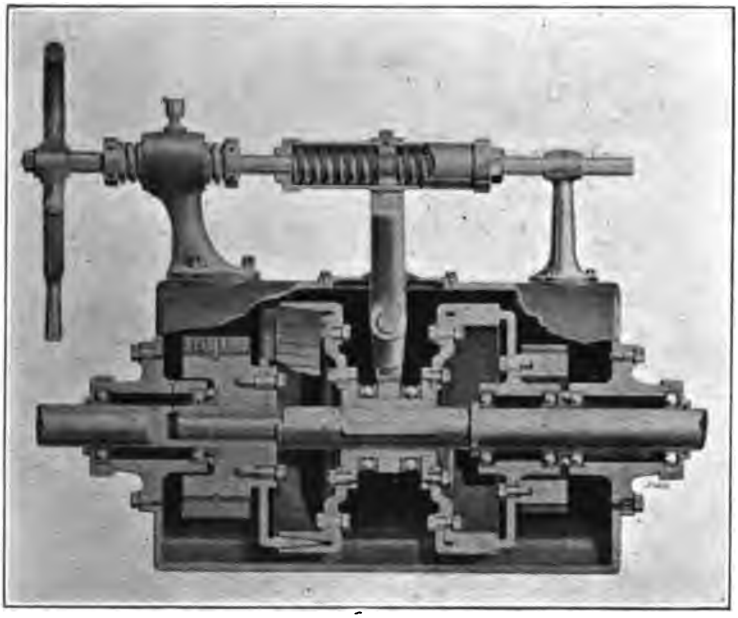


FIG. 95.—Shiners' Patent Reverse Gear.

drives the thrust shaft (hence the propeller) astern when a second cone clutch is engaged. A stout wheel control engages and disengages the clutches, the mid position being neutral with no clutch engaged.

Skandia Gear.—The general description above of an epicyclic reverse gear applies rigidly to this gear. In the illustration, A is the drum or "framework" carrying the pairs of planet pinions, J is the brake band holding the drum A when the lever G is in astern position. B is an expanding ring-type clutch which is engaged only when running "ahead" when G is forward. When G is in the intermediate position B is declutched.

Manœuvring Powers.—Vessels fitted with slow running oil engines are usually manœuvred more quickly than vessels fitted with steam machinery.

Many tests have been made as to the time taken from full speed ahead to full speed astern, including declutching and clutching again, of engines fitted with clutches, and even

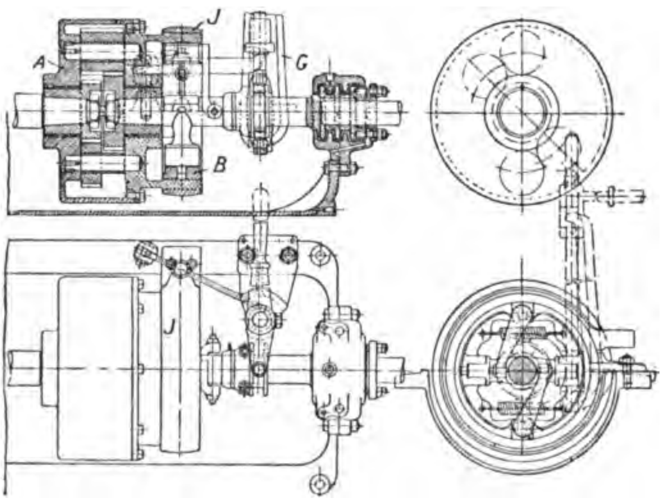


FIG. 96.—Skandia Reverse Gear.

with engines of 80 B.H.P. this has been accomplished in from three to four seconds, and with specially quick handling in a little less than three seconds—a manœuvre that could not be accomplished with a slow running steam engine of the same power.

The captain of the *May Baby*, ex *Bolinders*, fishing vessel, fitted with a 120 B.H.P. engine, reference to which is made on p. 280, certified that the manœuvring of this type of engine and of the vessel was as great as or greater than that of a steam vessel with similar power.

The manager of the same vessel also confirmed the manœuvring qualities, in a test which was made a few months previously (reference, p. 281).

Manœuvring with Reversible Blade or Feathering Propeller.—Many small vessels, especially fishing boats, are fitted with oil engines and reversible blade propellers.

With these engines, reversing from ahead to astern or

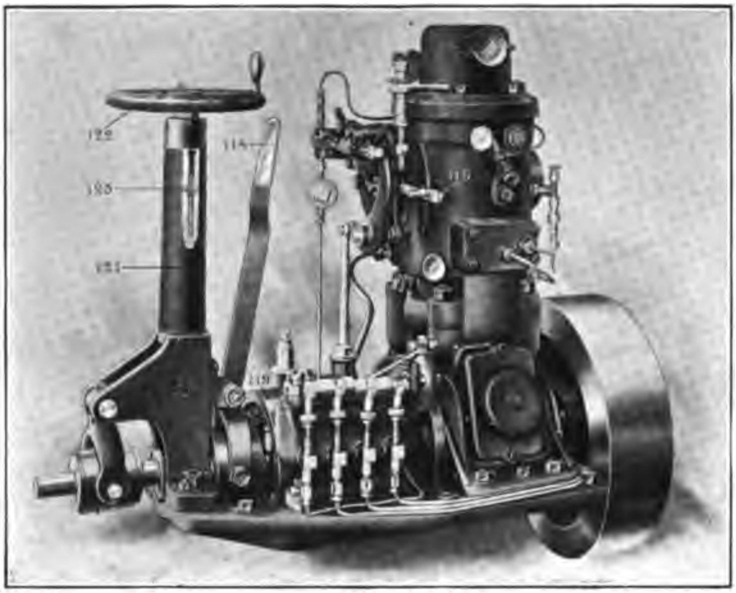


FIG. 97.—Bolinder Engine, with Reversible Blade Propeller.

vice versâ is accomplished by altering the pitch of the propeller blades, any reasonable pitch being obtainable.

The change is made through the hand wheel (122), the pointer (123) showing the pitch of the blades or the position to be taken to realise a certain speed ahead or astern.

The engine is also furnished with a friction clutch which disengages the propeller shaft from the engine, and which is operated by means of the hand lever (114). When sailing, the propeller blades can be turned so that they stand in a fore and aft plane, thereby reducing the resistance of the blades to a minimum.

The speed of the engine is regulated by the hand lever (38), and the stroke of the fuel pump by the hand lever (116).

This type of engine is greatly in favour with fishermen and pilots, with the former on the ground that the vessels can be driven at the nets at a slower speed than with any other type.

Other illustrations of engines with feathering propeller blades will be found on pp. 18, 41, 48.

Limit of Size of Engine.—Progress is so rapid that it is difficult to predict what will ultimately be the limit of size for hot bulb oil engines. They are at present manufactured in single units up to 600 B.H.P. in four cylinders, *i.e.*, 150 B.H.P. per cylinder.

There is a bright future for a reliable hot bulb marine oil engine of 750 to 1,000 B.H.P., irrespective of the number of cylinders, though preferably not exceeding four, as the market is almost unlimited. There does not seem to be any reason why this should not be accomplished in the almost immediate future.

Cylinders to develop 125 brake horse-power each are in the course of construction by several makers ; eight of these cylinders would give the desired result, and, later on, engines of 250 B.H.P. per cylinder and 2,000 B.H.P. per unit will no doubt be manufactured.

The greatest difficulty will probably be with the reversing. If a clutch is decided upon for these large powers, it should be operated by a pneumatic cylinder worked from the compressor, or by some other mechanical means, with a cushioning cylinder of oil and a variable bye-pass.

If it is thought desirable to dispense with the clutch, the reverse by pre-ignition must be dropped for these high powers, and compressed air employed, so arranged that the engine will start in any position. The necessity for large air receivers for this purpose would not be difficult to meet with installations of that size.

For large powered engines it is imperative that water injection should not be used. Probably an air compressor will be fitted so that the heat of the bulb can be controlled by air injection, and to avoid an undue length of bedplate a separate auxiliary engine and air compressor could be provided for, and for first-class installations a smaller engine and compressor set as a " stand-by."

Technical Notes.

It is not intended here to enter into theory or technical design, but rather to give a few notes which may be of general interest to many and, on occasion prove of value to owners and their engineers.

The notes are particularly intended to apply to the two-stroke valveless types of engine, the operation of which follow in general the description on p. 12.

Indicator Cards.—The taking of cards is not of great advantage, as it is in the case of steam engines and Diesel engines, for there is no need to alter the timing and there are no pulverisers to adjust. Also in the newer designs, where compressed air is injected into the cylinder (to improve the condition of the exhaust and control the heat of the bulb at varying loads), it is not necessary to regulate the pressure (as required in a Diesel engine), according to indicator cards.

The cards taken from a hot bulb engine have not the same degree of definiteness and regularity as is the case with the gas engine or the Diesel engine, that is to say, half a dozen successive cards, taken when the conditions are ostensibly unvarying, may show considerable variations. This is to be expected in an engine where a " solid " jet of fuel strikes the hot surface of a bulb and then ignites—a cruder operation than the ignition of a compressed gaseous mixture, or of a highly pulverised spray of fuel, igniting spontaneously on entering the cylinder.

Fig. 98 shows a number of somewhat typical cards, and they are only shown in order to give an idea to those unfamiliar with oil engine indicator diagrams.

Pressures.—It is the maximum pressure in the cylinder that is of greatest interest to owners and determines the scantlings and general strength of the engine design.

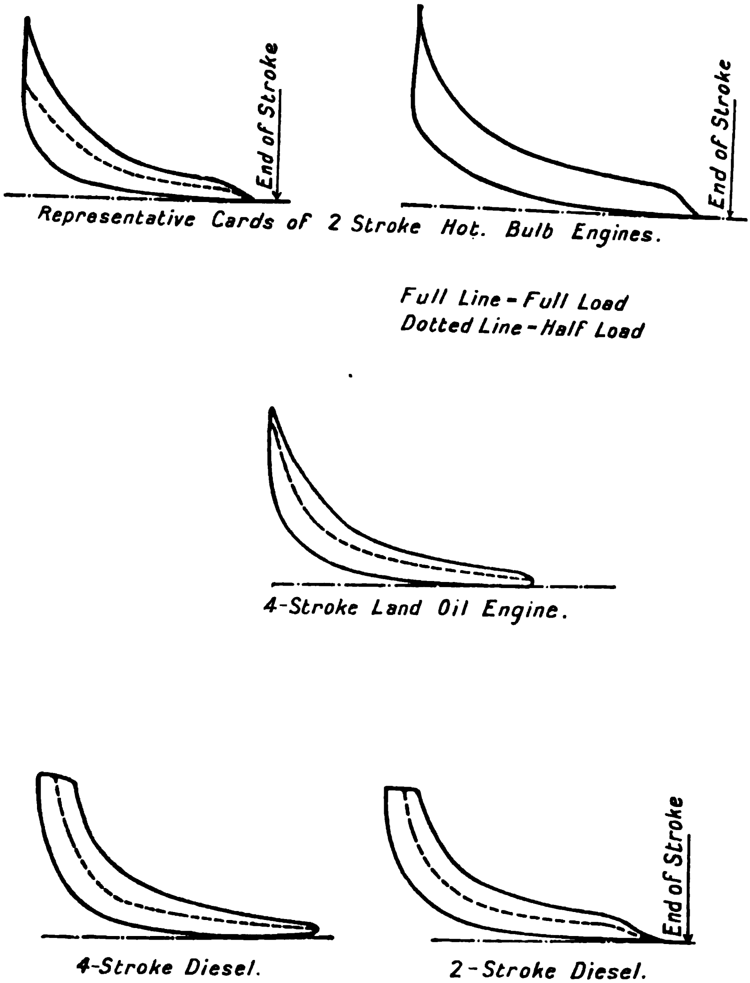


FIG. 98.—Indicator Cards.

The normal maximum pressure is usually about 250 lb. per square inch, and the greatest pressure attained when working at overload or under bad conditions is about

300 lb. per square inch. Under " bad conditions " would be included the case of an engine, designed for water injection at full load, being run for some time at full load without the use of the water drip.

There is no fear of enormous pressures arising to cause explosions, because it takes the greater part of the heat energy of the fuel to reach the normal maximum pressure at the top dead centre, leaving little air or unburnt fuel for further combustion.

This point is to be emphasised because very large pressures can occur, and have occurred, in Diesel engines through some defect, and result in accidents. By using a high compression and carefully timed pulverised injection the Diesel engine has a " constant pressure combustion," which means that most of the heat energy is still to be utilised *after* the maximum pressure is attained by compression. This results in high mean effective pressures and most desirable fuel economy, but involves the latent possibility of enormous pressures in the event of certain defects. The hot bulb engine avoids this possibility of the more refined and delicate engine, and is content to sacrifice some measure of fuel economy thereby and take its place as a simple reliable engine for a very wide range of commercial work.

The compression pressure may be anything from 120 to 150 lb. per square inch.

The pressure at release when the exhaust port is just beginning to be uncovered is normally about 15 to 20 lb. per square inch.

The pressure to which the scavenge air is compressed in the crank chamber before entering the cylinder ranges from about 4 to 7 lb. per square inch.

Fuel Consumption.—An average consumption for an engine above 100 B.H.P. is about 0·55 lb. per B.H.P. per hour, using a good cheap fuel of a specific gravity rather under 0·9, such as gasoleum and similar fuels mentioned in Chapter V. When running light the total consumption per hour is never likely to exceed, say, one-fifth of the full load figure.

When running light an engine will burn about 5 per cent. less fuel when governing by the fuel pump stroke than when the stroke remains full and the governing is solely by "hit-and-miss." Again, engines fitted with means of throttling the scavenge air effect a further saving of some 10 per cent. in the fuel consumption when running light.

Temperature of Exhaust.—When running fully loaded the exhaust gases enter the main silencer at a temperature of about 500° F., and at light load the temperature falls to about 300° F.

Temperature of Cooling Water.—This should never exceed, and should be considerably under, 150° F., and should be such that the hand can be held under the discharge overboard without discomfort from heat. It is not only the design of the engine and circulating water pump that affect the question, but also the size and careful installation of the pipes with a good free run and no careless joints partially blocking up the passages.

Timing.—No narrow range can be stated, as there is a surprising variation in the timing of different makes, chiefly determined by the construction of the cylinder head and bulb, and the arrangement of the injection of the jet of fuel; some engines finish the injection just about at the top dead centre, others considerably earlier.

CHAPTER IV.

Hot Bulbs.—It has been indicated elsewhere what is to be included in the term "hot bulb engine." The term "hot bulb" will be taken to mean that part of which the function is to provide the hot surface to effect the ignition in these engines (of which the compression rarely exceeds 150 lb. per square inch). The shape may be anything but a bulb, and in some engines is rather a plate.

In recent years it has become fairly usual to adopt a semi-water-cooled cylinder head, only part of which is a hot unjacketed portion, while formerly the typical design was a cylinder head in bulb form and wholly unjacketed.

The features to be aimed at are :—

(1) The engine to run without external heating of the bulbs when once the engine has been started, and to be able to do so even if run unloaded for an indefinite time.

(2) The time taken for the preliminary heating of the bulb to be a minimum.

(3) The scavenge charge to have a free, easy path, so that the bulb as well as the cylinder shall be efficiently scavenged.

(4) The material not to be subject to corrosion, undue "fatigue" or distortion, but to maintain its strength and efficiency as long as possible.

(5) To design to avoid overheating of the bulb at high loads and to enable water injection to be dispensed with.

The jacketing of part of the cylinder head aims at (4) and (5), but does so usually at some sacrifice of (1) and (2).

Longer life has recently been obtained by adopting a close-grained special mixture of cast iron in place of the more costly cast steel much employed previously. With this change, a bulb may be expected to last several years, whether totally unjacketed or partially water-cooled.

To avoid lighting the lamps when the engine has to run light for considerable periods (such as when a vessel is waiting for the opening of lock gates), a very simple means has been adopted by Messrs. Bolinders, quite apart from bulb design. It consists of a butterfly valve (hand operated), inserted in the scavenge passage, by means of which the air is considerably throttled when the engine is running unloaded. This diminishes the flushing of the bulb by cold air and the bulb remains sufficiently hot indefinitely without lighting the lamps.

The value of this was proved in 1913 on an engine installed on a vessel on the Thames. After the engine was started up, the lamps were turned out and the engine run for one hour in the ahead direction but declutched. Then the engine was reversed (Bolinders ordinary direct reversing gear), and run declutched in the astern direction for another hour, and then again reversed to ahead direction. Then the engine was shut down in the ordinary way, barred round to the starting position and re-started, still without lighting the lamps.

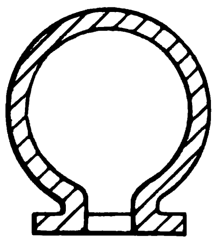


FIG. 99.—Early Type of Bulb.

There are many types of hot bulbs, the earliest type being of cast iron (Fig. 99).

The **Avance** engine has a combined water-cooled head and bulb as illustrated in Fig. 100. This consists of a small bulb on a larger water-cooled head. As will be seen, the fuel injection is at the top of the bulb, the nozzle being water-cooled. The fuel system does not impinge on any specific point, but the makers have a form of sprayer and nozzle from which the fuel (and water mixed when injection water is turned on) enters the bulb as a conical spray.

Fig. No. 101 illustrates the bulb of the **Dan** four-stroke cycle engine.

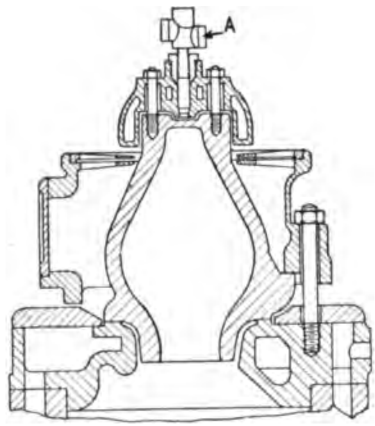


FIG. 100.—Avance Head and Bulb.

A bulb fitted to the **Koch** engine, built at Zurich, in Switzerland, is illustrated in Fig. 102, from which it will be seen that the hot bulb (*e*) is practically surrounded by water, and that there is a sort of sluice valve (*b*) which is operated by hand, so as to control the level of the water. In this way the temperature of the hot bulb is regulated according to circumstances. The fuel enters through the nozzle (*d*), water entering through a

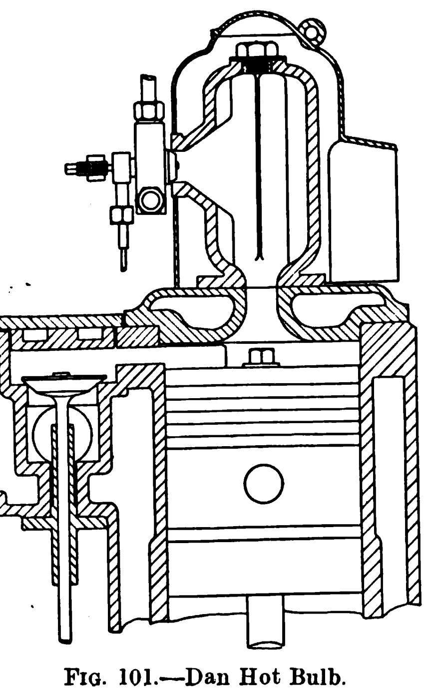


FIG. 101.—Dan Hot Bulb.

supply pipe (*a*), so that there is always a constant drip of water on the nozzle (*d*).

In another design of bulb illustrated in Fig. 103, there are

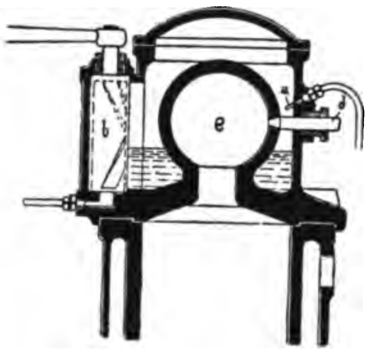


FIG. 102.—Hot Bulb of Koch Engine.

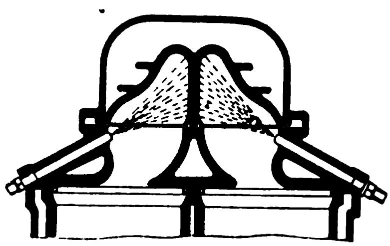


FIG. 103.—Hot Bulb of Koch Engine.

two fuel injection nozzles, one on each side of the cylinder, and these are arranged in the manner shown, to spray fuel up into the hot bulb against both sides of a wall which divides the hot bulb into two parts. This bulb is itself of special shape, and it is claimed that with this arrangement comparatively little heating by the lamp is required, as the temperature of the wall can be raised to the required extent in a very short time.

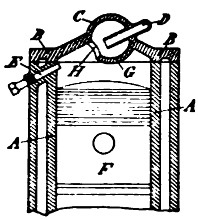


FIG. 104.—Neptun Hot Bulb.

The **Neptun** hot bulbs were patented in Denmark in 1910, and were finally accepted as patents in the United Kingdom in 1912.

The first patent, Fig. 104, is described in the specification as follows :—

"A is the cylinder, B the cover, F the piston. The wall C of the igniting head or the ignition chamber is arranged towards the exterior, and, as such, is subjected to conditions similar to those in the walls of igniting chambers as hitherto proposed, whereas the other part, the wall G, is arranged towards the piston or working chamber ; the wall G is thus exposed to a smaller loss of heat than the wall C.

" While the part of the igniting head which is exposed to the exterior is now made smaller as compared with other igniting heads it would be found more difficult to start the explosions through the heating by a lamp. To obviate this difficulty the igniting head is provided with a special, pro-

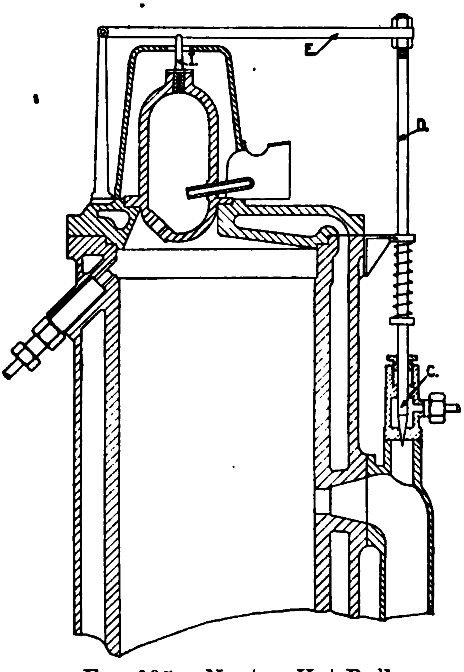


FIG. 105 —Neptun Hot Bulb.

portionately small ignition chamber, for instance, an igniting tube D which is easily accessible for such a heating.

" The tube D may, as shown on the drawing, project into the ignition chamber proper C, G, and its direction may correspond to that of the stream of combustible coming from the tube E, so that the stream of combustible passes directly from the opening H in the wall G into the tube D and is immediately ignited. The explosion will by such an arrangement be easily determined as it will take place at the same time as the combustible is injected.

"The shape of the parts C and G as well as that of the special igniting chamber D are optional."

The second patent, which is some six months later, June, 1912, is illustrated in Fig. 105. The object is to control the water injection automatically by the variation in the heat of the bulb as the load on the engine varies.

The device works as follows :—

"When the engine is running and the temperature of the ignition chamber rises the chamber expands and consequently the part I acts upon the lever E, which, being connected with the rod D, the valve C will open and water will flow in as long as the temperature remains constant or rises. If less power is developed then less heat will be generated. The valve will consequently close somewhat owing to the contraction of the ignition chamber, whereby less water will be supplied. At very small outputs the water supply will be completely interrupted."

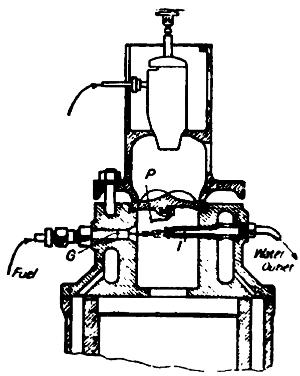


FIG. 106.—Hot Bulb or Plate of the "Original" Hein Motor.

The hot bulb of the "**Original**" **Hein Motor** is illustrated in Fig. 106.

The fuel enters through the nozzle G in the direction indicated by the dotted lines, and impinges on a water-cooled ignition tube. The point of injection is about five degrees before the crank reaches the top dead centre, and it is stated that the motor does not become over-heated even when running on overload, nor is there danger of pre-ignition.

In order that the engine shall be able to run continuously when on no load, there is no water injection, and there is at the top of the ignition chamber a nickel steel finger, indicated by P in the diagram, which retains sufficient heat.

The **Robey** engine originally had a bulb something like

Fig. 107, but the makers have now adopted a considerable improvement, as illustrated in Fig. 108, also Fig. 58, p. 67.

FIG. 107.—Early Bulb of Robey Engine.

The small bulb is heated by the pressure lamp, the heat then radiating over all the top portion of the bulb, the lower portion or cylinder head being kept cool by the water jacket. This head was introduced on the market in 1914, and is said to have given satisfactory results.

The **Rundlof** patent, shown in Fig. 109, having two passage ways, was a distinct improvement on the early type of bulb, Fig. 99, p. 127, the fuel oil being injected through the small orifice and the ignited gas passing through the larger orifice, after which the remnants of the ignition are swept out of the bulb by the scavenging air.

FIG. 108.—Robey Engine Hot Bulb.

The fact that the consumed gases of the previous charge are not opposed by the ensuing scavenge air greatly adds to the efficiency of this type of bulb.

The blow lamp or pressure lamp used for heating the bulb previously to starting up, plays on a hollow stud, which concentrates the greater part of the heat in its neighbourhood; the fuel is sprayed so as to impinge on the inside of the stud, and so time is saved in the preliminary heating.

FIG. 109.—Rundlöf Patent Bulb.

The **Skandia** ignition bulbs are illustrated in Figs. 110 and 111.

The best bulbs of the last few years have lasted for eighteen months, but perhaps an average life is from five to eight months of hard commercial service. An exceptional case was that of the bulbs on the motor barge *The Miller*—fitted with an 80 B.H.P. **Bolinder** engine—which lasted fully two years, during which time the engine was constantly at work.

In addition to the almost universal practice of heating the hot bulbs in the first instance by a pressure lamp, experiments have been made with an electric arrangement. If this could be perfected so as to start hot bulb oil engines from cold when using heavy oils, it would do away with

FIG. 110.—Skandia Bulb.

FIG. 111.—Skandia Bulb and Water-cooled Combustion Chamber.

one of the principal objections to this type of internal combustion engine.

In 1913 Mr. P. W. Harley, M.I.Mech.E., carried out a series of experiments with hot bulb two-stroke engines, fitted with a design of electric ignition under provisional protection.

The following extract from the specification will explain the method adopted :—

"The invention consists in a method of igniting the charge in an internal combustion engine by means of an electric ignition of the type comprising a resistance wire or body protected by a cover which, while allowing the necessary heat transmission, prevents the access of foreign substances to the resistance wire or body, by the use of which igniter the excessive heating of the material of the combustion chamber is avoided both in starting and running the engine.

"The invention also consists in the combination with a method of ignition of the foregoing type, of a heat retaining member which is capable of maintaining the heat necessary for ignition by remaining incandescent from one explosion to another.

"In carrying this invention into effect in one way, a dome shaped, water-cooled cylinder head or hot bulb of cast iron or other suitable metal is provided, into which is fixed, so as to project into the interior thereof, preferably upon the side opposing the inlet for fuel injection, an igniter formed of a platinum, or similar wire, resistance coil covered by a convex disc of silica or quartz glass made up upon a packing of steatite or other di-electric material; the ends of the coil are connected to a suitable electric current, making the coil incandescent and communicating its heat through the quartz glass cover to the injected fuel. The quartz glass cover may be of any other suitable form than convex, and the resistance may take the form of any suitable body of metal to give the necessary heat for the purpose as before described.

"In conjunction with this ignition device there may be provided a rose or twisted-up body of platinum or other suitable wire, or a disc of metal or other fire-resisting material, to be suspended or fixed within the dome or combustion chamber, and which will be capable of maintaining the heat necessary for ignition by remaining incandescent from one explosion to the next and thus relieving the electric current after the engine has been started and sufficient heat has been generated to heat the coil, rose or disc so used, and this coil, rose or disc may be made a portion of the electric igniter before described."

The trials were made on an engine with two cylinders of 4-in. bore, the element taking the form of a flat open coil of platinum, covered by a shield of quartz glass and backed up with a steatite cement. The diameter of the heated surface was 1·$\frac{3}{8}$ in., and current was supplied from an 8-volt accumulator. The fuel injection inlet was arranged to impinge upon the ignition disc, crude Texas petroleum being the fuel used.

A water-cooled head or bulb in which the ignition device was screwed was fitted to each cylinder.

There was no difficulty in starting up with a cold engine, and various trials were run, but in every case a stoppage occurred on account of the breaking of the protecting screen of quartz glass, but while the engine was running there was complete and regular ignition and combustion was quite satisfactory. The longest run made occupied 3 hours, 21 minutes, when the ignition broke down owing to the cracking of the disc and distortion of the resistance.

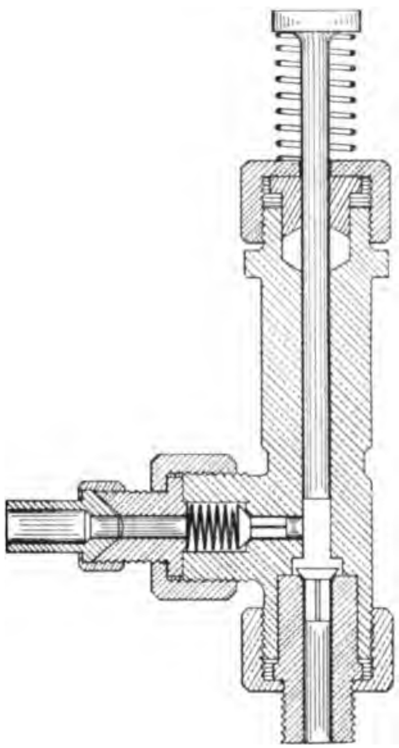


FIG. 112.—Ailsa Craig Fuel Pump.

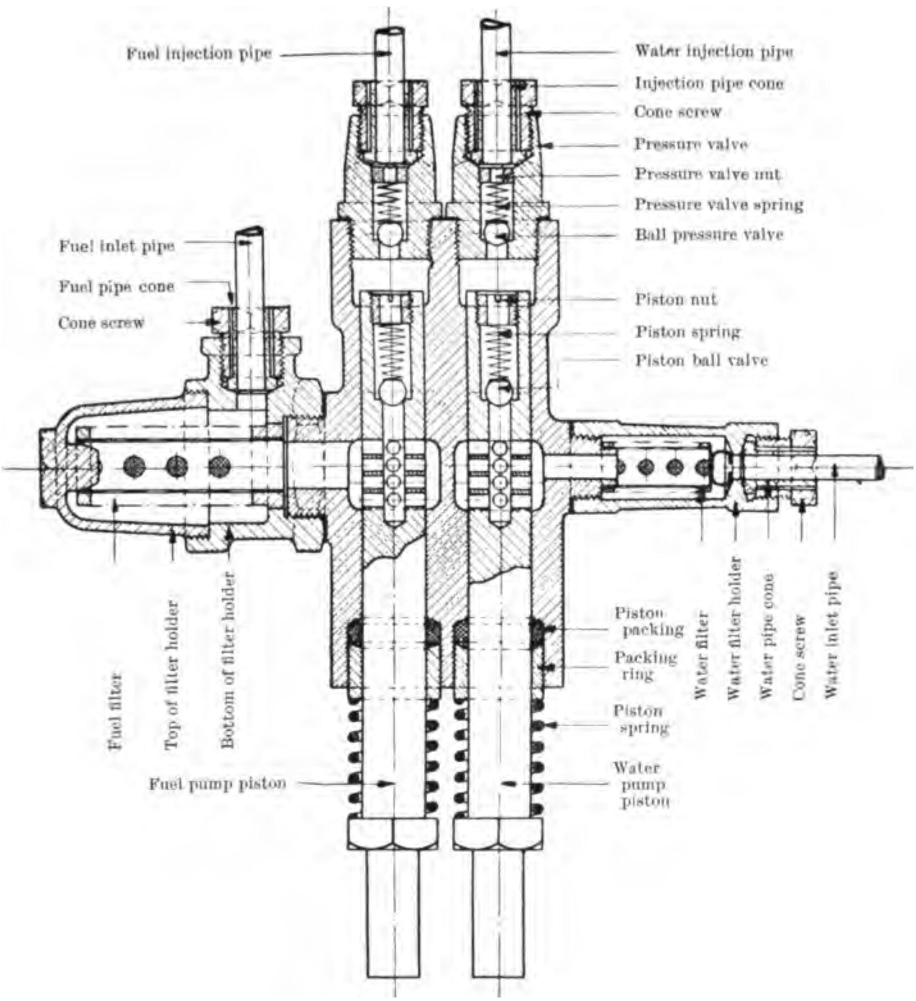
So far as the igniting device was concerned the various experiments occupied ten days — slight alterations being made from time to time in the design of the element.

Although the result of these experiments was negative, they go to show that a means of electric ignition is capable of use with this form of engine if the difficulty of the destruction of the igniting element can be overcome.

Fuel Pumps.—The fuel pump diameters and strokes differ considerably in engines of the same size and power per cylinder as built by different makers.

A fuel pump to feed a 50 B.H.P. cylinder varies in stroke as much as from 4½ mm. to 2 mm.—the diameters being proportioned to inject the requisite amount of fuel in each case.

VERTICAL SECTION OF "AVANCE" DOUBLE PUMP.



FUEL PUMP COMPLETE.

FIG. 113.—Fuel Pump, Avance Engine.

The fuel pump of the **Ailsa Craig** engine is illustrated in Fig. 112, and, as will be seen, this firm fits the pump with a gland.

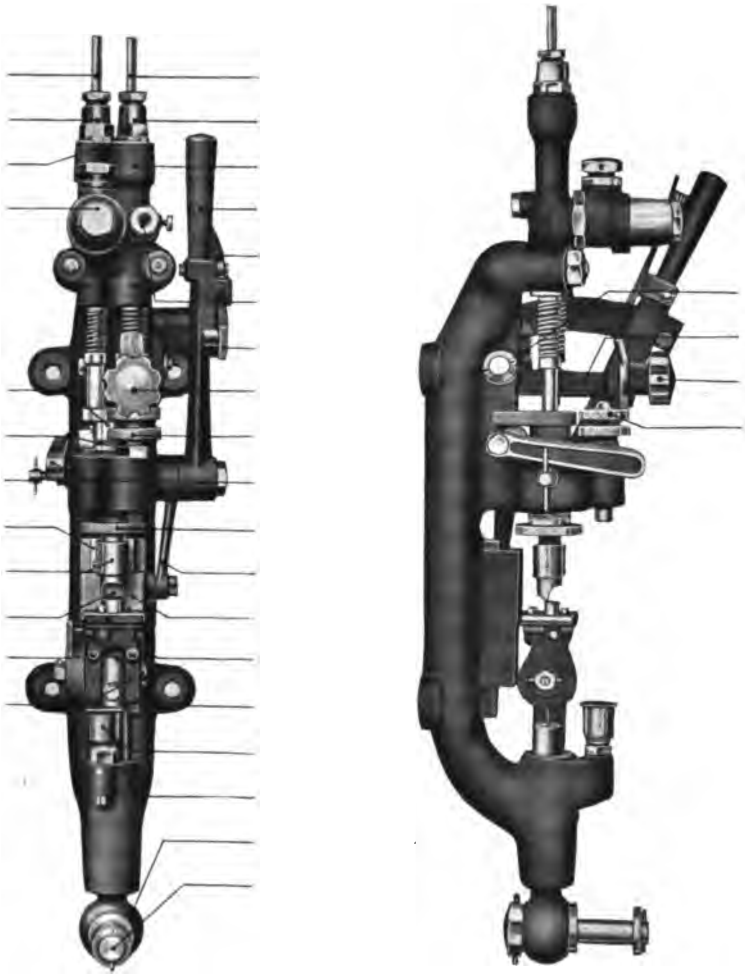


Fig. 114.—Fuel Pump, Avance Engine.

The gland is packed with asbestos cord and should not be screwed down harder than necessary, as this will bind the plunger and cause sluggish running and misfiring. All joints are ground. The lift of the valves should not exceed $\frac{1}{32}$ in.

The **Beardmore** firm employs vertical plungers, and mushroom valves for suction and delivery.

Adjustable stops are provided to control the bottom position of the plungers, and these serve as a permanent adjustment for any particular fuel. The strikers are mounted eccentrically on the rocking arm actuated by the fuel pump

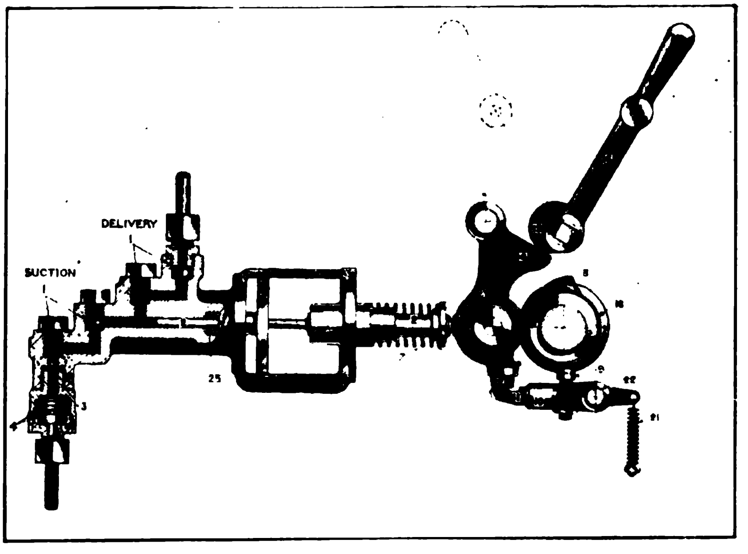


Fig. 115.—Fuel Pump of Cross Engine.

eccentric. These eccentrics are operated by the control wheel by linkage, thus regulating the fuel pump stroke. The strikers are given a tendency to " miss " the plungers by being unsymmetrically weighted (see Fig. 80, p. 100). As the speed increases this jumping tendency is increased, and so prevents racing when the propeller leaves the water. Hand adjusted springs control the jumping, thereby giving a hand regulation of the speed at which the pumps cut out. Both the stroke of the fuel pumps and the tension of the governor springs can be adjusted while the engine is running.

On a four-cylinder engine, two pumps are grouped forward and two aft, each pair serving cylinders of which the cranks are at 180° with each other, and thus one eccentric and rocker goes to each pair. Further photographs and plans are showing in the description of the engine, p. 20.

The fuel pump of the **Brooke** engine shown in Fig. 123 is an example of a pump without a gland, the body of the

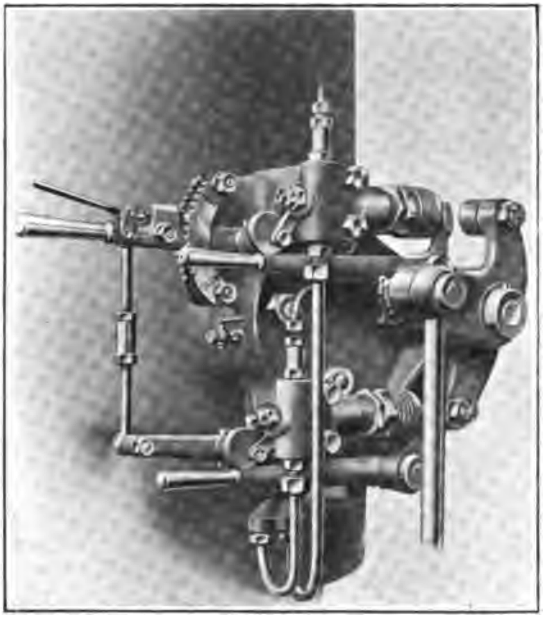


Fig. 116.—Petter Fuel Pump Gear.

pump and the piston being very accurately ground. The operation of the fuel pump can best be understood from an examination of Fig. 123. The governor is of the hit-and-miss type, and the general arrangement is such as has been proved satisfactory over a long period of work.

Fig. 115 is a view of the **Cross** fuel pump and governor. As is usual, two suction and two delivery valves are employed as a double check to leakage. The lift of the balls is $\frac{1}{32}$ in.

The strainer (3) has layers of fine gauze (4) to strain the fuel before it passes to the pump. The lever (16) is used to pump a few charges into the combustion chamber before starting. When placed in the position shown by the dotted

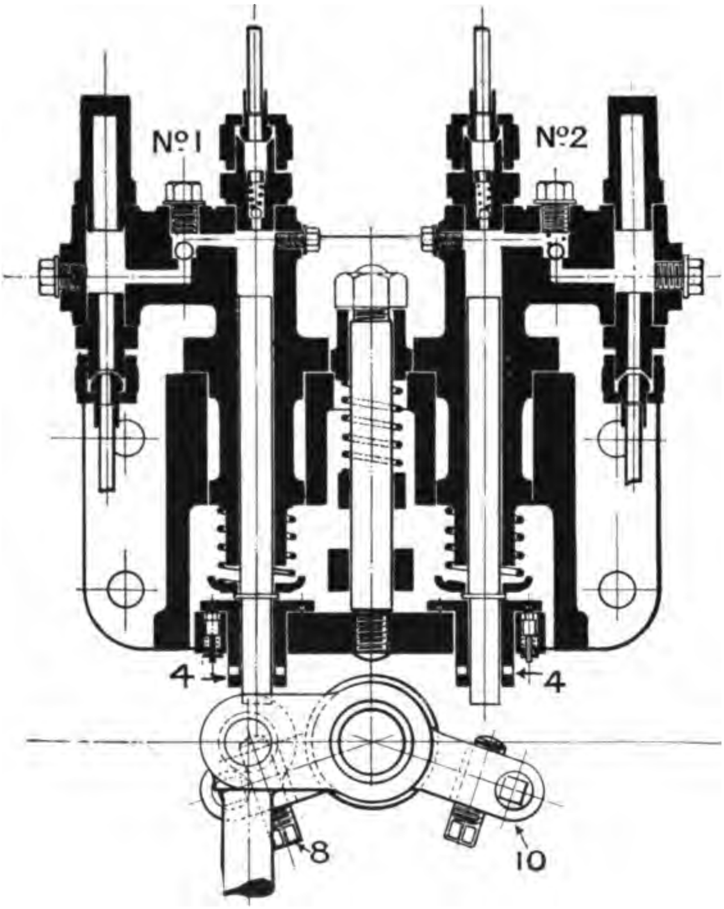


FIG. 117.—Robey Fuel Fump.

lines, the engine is stopped, as all movement of the plunger is prevented, and the fuel supply to the engine is cut off. The lever is also used as a hand adjustment to the stroke by fixing it in an intermediate position by means of the fly nut.

The fuel pump of the **Mietz** and **Weiss** engine is controlled by a centrifugal governor mounted on a bracket on the starboard side of the engine. It is operated by an eccentric on a shaft, chain driven from the crank shaft. The governor operates directly upon the fuel pump, shortening the stroke when the engine speed exceeds the normal revolutions. The speed is adjusted by a small hand lever fitted to the governor, which tightens or releases the governor springs.

The **Robey** fuel pump is illustrated in Fig. 117.

The **Skandia** pump, Fig. 118, has a stroke of 1 to 1½ mm. for the 20 and 25 B.H.P. cylinders, and 1½ to 2 mm. for the 30 and 40 B.H.P. cylinders.

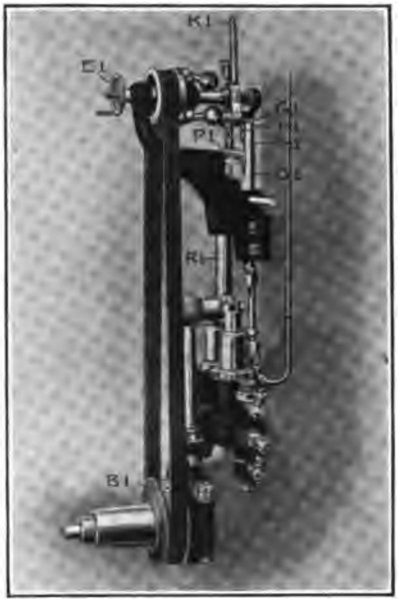


FIG. 118.—Fuel Pump and Governor, Skandia Engine.

The pumps are vertical for the skew driven governor engines, and have a packed gland, see p. 149.

Fuel Injection. — For many years the method generally adopted for injecting fuel into the bulbs has been to arrange a seating in the cylinder side, near the top, and to fit a nozzle either of brass or steel with a suitable holder, so that the oil is injected (usually inclined upwards) into the bulb through a very small nozzle orifice. An average design would be in the neighbourhood of 0·07 sq. mm. for every 10 B.H.P. per cylinder.

A more modern method when water injection is employed is to have a twin nozzle, one orifice being for the oil fuel and the other for the water, so that both are injected into the bulb. The holder is arranged with two connections, one for the oil and the other for the water, while in some designs the fuel and water are in contact in the nozzle.

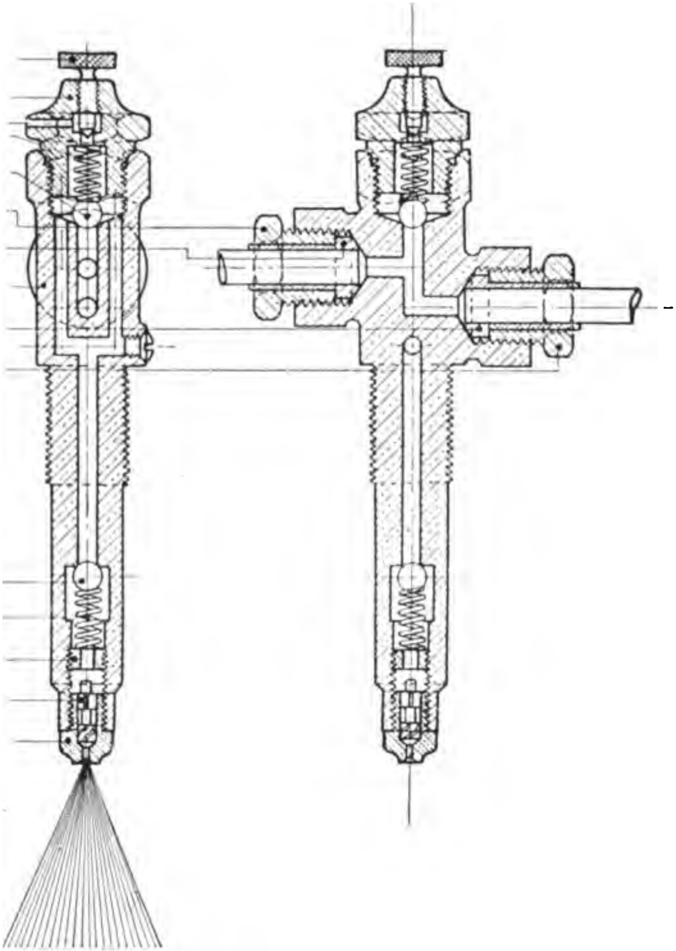


FIG. 119.—Injection Nozzle Avance Engine.

Other nozzles are fitted on the top of the cylinder head and arranged to inject the fuel downwards.

The nozzle and holder are usually held in position against the seat by a thumb screw, so that they can be easily and quickly removed for cleaning purposes in case the nozzle gets choked.

The fuel and water injection nozzle of the **Avance** engine is shown in Fig. 119.

The **Ailsa Craig** injection nozzle, Fig. 120, may be removed from the engine by slacking off one nut (6) and giving the bridge (4) a slight turn, when the injector, which seats on a ground joint in the combustion chamber head, may be pulled straight out.

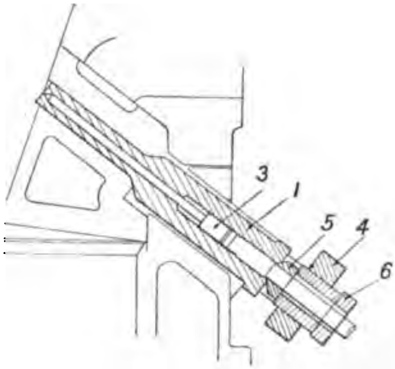


FIG. 120.—Ailsa Craig Injection Nozzle.

The injector consists of a body (1), and a spraying needle (2), with grooves cut in the point, through which the fuel is forced at high pressure by the pump. To take out the needle, the screw (3) inside the body should be removed, when the needle will fall out. Care should be taken in replacing to see that all joints in the pipe are tight, as a small leak here will produce bad running.

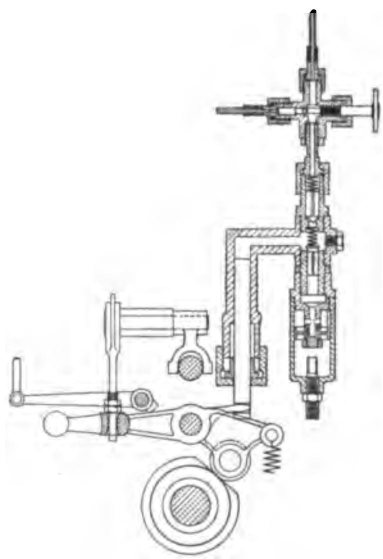


FIG. 121.—Hein Fuel Injection.

The **Hein** Fuel Injection is illustrated by Fig. 121.

The **Robey** injection nozzle or sprayer is illustrated in Fig. 122 ; it is fixed to the cylinder or vaporiser, see Fig. 58, so that it is water cooled.

A new and highly successful departure has been made by one well-known firm by injecting, in the case of their larger engines, a certain amount of air into the cylinder by means of a medium pressure air compressor. This gives better combustion and makes the engine more flexible as well as eliminating water injection entirely, without sacrificing any power.

Feed of Oil to Pumps.—In some engines a compensator is fitted, which relieves the suction valve of any abnormal load through the pressure of oil, and also allows the pump a good steady suction. This device consists of a box with one or perhaps two rubber diaphragms acting in the same way as a gas bag for ensuring a steady flow of gas to a gas engine.

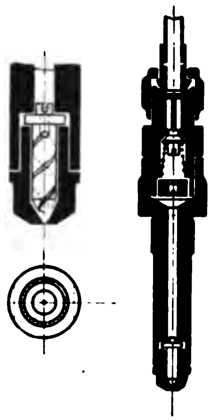


FIG. 122.—Robey Injection Nozzle.

Governors.—A marine oil engine has to be provided with a governing mechanism to prevent racing when the propeller leaves the water, just as in steam practice. But further, the large majority of hot bulb engines (practically all of less than, say, 200 B.H.P.) are fitted with clutches for manœuvring purposes and starting up, and these must all have efficient governors to enable them to run steadily at "free engine" for any desired time.

This then is the function of the automatic governor—to control the speed of the engine and prevent racing when the load is thrown off.

In addition to this a regulation is required corresponding to the link gear of a steam engine, to control by hand the speed of the engine, to give "slow speed," "half speed," etc., with the propeller immersed and running either ahead or astern.

For convenience, we will speak of the automatic, racing-preventing governor as the "cut-out," and the hand regulation for cruising and manœuvring speeds as the

" throttle," because the latter fulfils the precise function of the " throttle " of a motor car engine.

In the " hit and-miss " governor of a marine hot bulb engine, the " hit-and-miss " is usually achieved as follows : An eccentric rod works a rocking lever, to which a weighted striking piece (C), Fig. 123, is pin-jointed. The striking piece in its forward motion on a guide (D) encounters a

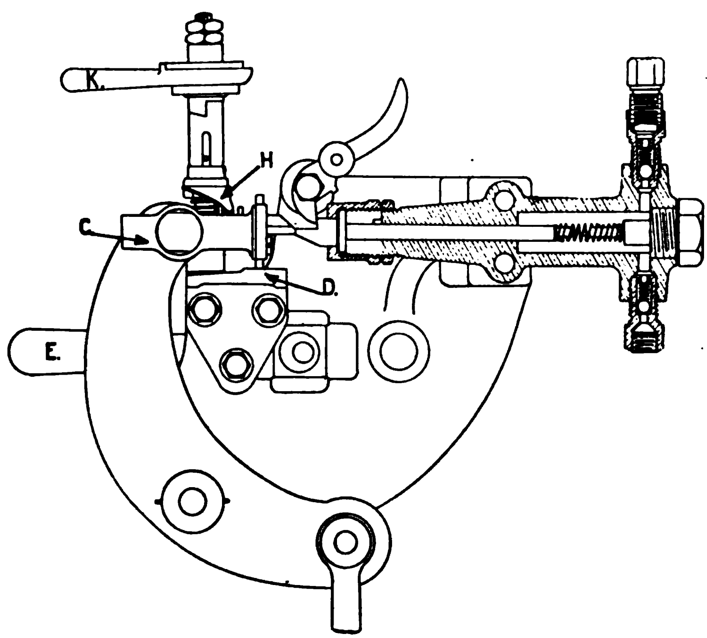


FIG. 123.—Brooke Engine Governor.

short curved incline which tends to jerk it off the guide. Spring tension (H), sometimes aided by gravity, opposes this jerking action, but when the speed is sufficient to overcome this opposition, the striker misses the fuel pump plunger. An alternative method is to make the striker very unsymmetrically weighted, and obtain the jumping action purely from the reciprocating motion acting kinetically on the striker (see Fig. 80, p. 100).

This then supplies the " cut-out."

The " throttle " is obtained by a simple hand adjustment (K) to the tension of the controlling spring. Tightening the spring "opens the throttle," until the engine either "cuts out" at an increased speed or until such a speed is

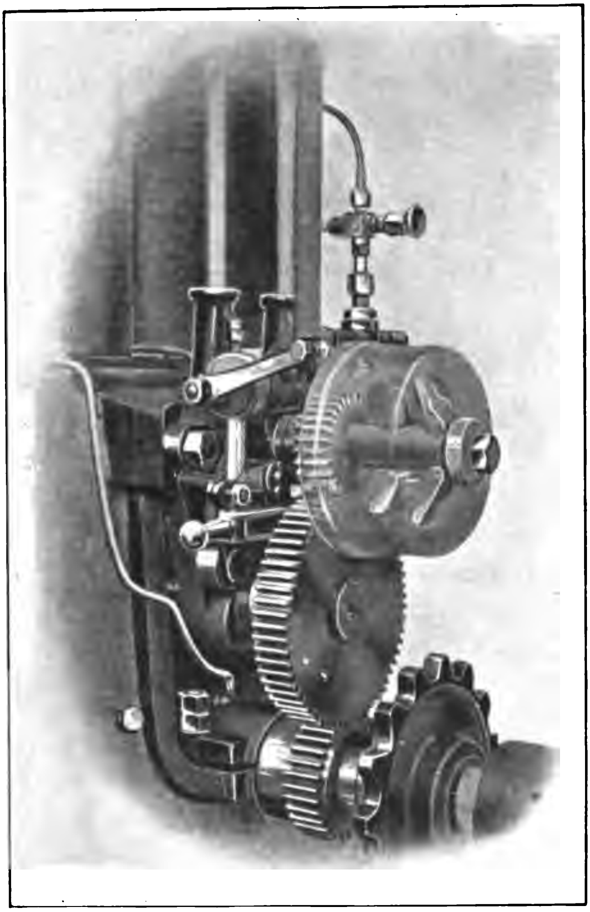


FIG. 124.—Hein Governor.

reached that the propeller absorbs the full power of the engine with an injection at each revolution. In the latter case, further tightening of the spring has no effect, for the throttle is full open and the engine is fully loaded. The hand adjustment is usually provided with a stop to prevent the spring being tightened further than the point at which " cut out " occurs at the highest designed revolutions.

Usually such governors have a second kind of " throttle " consisting of a handle by which the fuel pump stroke may be reduced when desired. This " stroke lever " (E) (see Fig. 123), is not used in manœuvring, but is useful when the engine is required to run at low revolutions for appreciable periods. By reducing the stroke, more even running is obtained, as a small quantity of oil is injected and fired at each revolution instead of a large quantity at one revolution followed by a miss or two, and so on.

This " cut out," " throttle " and " stroke lever " arrangement is flexible, and is very convenient to handle.

FIG. 125.—Hexa Governor.

For an illustration of the **Avance** governor, see p. 107.

An alternative method is a centrifugal governor operating in such a way as to give a smaller effective stroke of the fuel pump plungers when the speed rises. There are several ways in which the movement of the governor balls cause this variable stroke.

(1) The governor is so arranged that, as the balls fly out, they cause a floating wedge piece to be raised or lowered in between the fuel pump plunger and the striker, and as the finer edge of the wedge is brought into contact the stroke of the fuel pump is small (or zero—constituting a "miss"), and as the thicker part of the wedge is brought into contact the stroke is increased. When the balls are right in, the stroke is at a maximum (previously fixed by a permanent adjustment of the fuel pump).

(2) A tapered cam is laterally shifted by the action of the governing balls, thus varying the movement of a rocking arm and thereby varying the stroke given to the fuel pump

plunger. This is employed on the **Kromhout.** A neat and ingenious variation is adopted by the **Skandia** firm on their skew gear driven governor, Fig. 127, in which a combination of a fixed cam and a shifting tapered cam working on opposite arms of a rocking lever control the fuel pump stroke.

(3) The balls in flying out act upon the eccentric driving the fuel pump gear in such a way as to alter directly the throw of the eccentric, and thus controlling the fuel pump stroke (see Fig. 126).

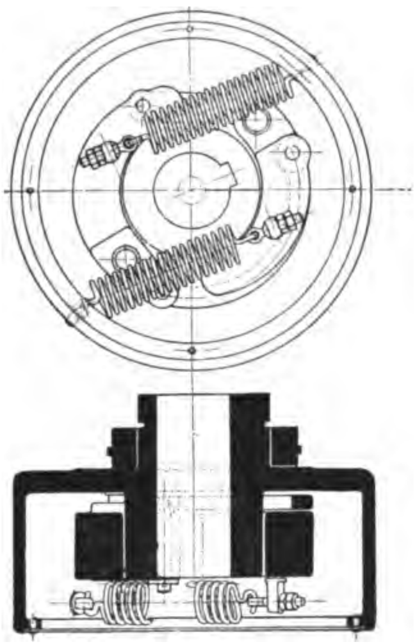


FIG. 126.—Robey Governor.

(4) The governor balls control the opening of the fuel suction valve or of a bye-pass between the suction and delivery, thereby rendering part or whole of the fuel pump stroke ineffective.

In each case the "throttle" is supplied by a hand adjustment to a spring acting against the governor balls, thereby regulating the speed at which the engine governs.

As regards drive, the governor is sometimes mounted direct on the main shaft (sometimes neatly packed in the flywheel), sometimes gear, chain or belt driven. The "hit-and-miss," described above, requires no drive other than the eccentric rod and rocker for working the fuel pumps. It is preferable to avoid gears, chains or belts, if possible, but if employed they might be selected in the order named.

To avoid the repetition involved in detailed descriptions of the many governors to be seen on hot bulb engines, the interested reader is referred to the makers' booklets.

Cylinders and Pistons.—Sectional views of cylinders are given in Chapter II., showing various makers' designs.

Above all things a manufacturer must get an excellent and special mixture of cast iron of proved worth for these parts, and both piston and cylinder should be ground to limit gauges. Otherwise, troubles will beset the customer, and do much mischief to the makers' reputation.

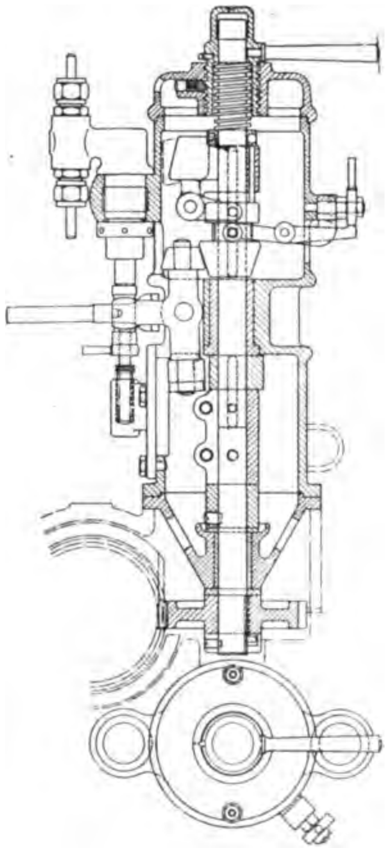


Fig. 127.—Skandia Centrifugal Governor, with Skew Gear.

The water jacket space must be liberally designed to ensure easy and uniform flow for the cooling water. At the topmost point a small bye-pass valve should be fitted and opened to allow steam to escape when the engine is shut down (this applies with greater force to a water-cooled head when fitted). When the engine is shut down the cylinder walls pass much heat into the water standing in the jacket, often sufficient to generate steam, which must have an outlet. Fractures occurred in Diesel engines in their early years, on account of the accumulation of heat on shutting down, and it is the opinion of many that engines above 500 B.H.P. or so, should have a small arrangement for keeping up a slow circulation for ten to fifteen minutes after shutting down.

This would also have the effect of making the engine freer and easier to start up.

Inspection doors at the top of the jacket should be fitted to allow the jackets to be cleaned and flushed through, when overhauling.

The piston should be uniform in thickness at the top. It is sometimes domed and sometimes ribbed in large sizes, but the ribs must be carefully designed to avoid large temperature stresses.

Four or five rings should be fitted above the gudgeon pin, and, on all but small sizes, an extra one below the pin. The gudgeon pins should be an easy push fit. The rings should be ground top and bottom and be interchangeable.

Fig. 128.—Piston of Robey Engine.

The compression or release cocks that are fitted to every cylinder should be of the angle type, and so arranged that when opened the gases are not thrown in the face of the man in charge. It is better for the cock outlet to face downwards.

Air and Exhaust Ports.—The exhaust port is larger than the air port, and each has ribs for the larger size of cylinders to compensate for the absence of material and maintain the strength of the cylinder, and prevent the ends of piston rings from getting into the ports.

The edges of these ports are usually slightly rounded off to prevent wearing and burning.

The bottom edge of both the exhaust and air ports is at a position coinciding with the edge of the piston at its outer dead centre. The exhaust port is the deeper, so that it is the first to be uncovered, so as to allow the pressure to be released before the scavenge takes place.

Very roughly, as an average for all sizes and makes, the depth of the exhaust port is about a quarter the stroke.

In the periodic cleaning of the cylinders, the exhaust ports should be cleared of carbon deposit to avoid back pressure.

Crank Shaft Air Rings.—An important requirement in the design of the crank case is to ensure air tightness in way of the shaft: this is obtained by running brass rings attached to the shaft with springs on the crank web to keep them close up to the machined face of the crank chamber, the rings being a nice sliding ground fit on the shaft. Some makers use " cup leathers," so that the compression pressure keeps them tight; the objection to this method is that when the leather gets dry it may become distorted and fail to do its work.

On each side of the shaft of the **Hexa** oil engine, two broad tightening washers of rings of gunmetal are fitted. These rings are provided with grooves and are made to fit the shaft accurately. They are kept tightly against the crank shaft on the one side and the crank chamber on the other side by the aid of springs. By means of this arrangement a so-called " labyrinth packing " between the shaft and the crank chamber is arrived at, eliminating all risk of leakage, even though the gunmetal washers may become worn after prolonged use.

Crank Chamber Air Valves.—These are light automatic suction valves, and are given a large area so that the suction pressure drop from the atmosphere to the crank chamber is insignificant, and the spring is very light, or *nil*, for the same purpose. The maximum pressure in the crank case is 6—8 lb., and the valve seals the crank chamber immediately the pressure exceeds that of the atmosphere.

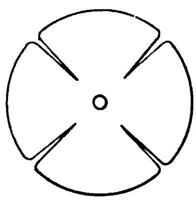


FIG. 129.—Leather Crank Chamber Air Valves.

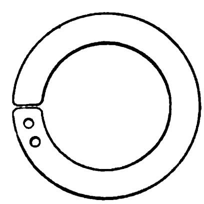


FIG. 130.—Brass or Steel Crank Chamber Air Valves.

Many makers at one time fitted leather flap valves (see Fig. 129). These worked satisfactorily whilst they remained soft and pliable, but if unused for any considerable time they became hard, and allowed leakage.

Some makers fitted brass valves, as shown in Fig. 130, but these were found to be liable to break at (A). Similar shaped valves of steel had much longer life.

The patented crank case air inlet valve of the **Hexa** oil engine consists of a steel plate which is formed as a spring and rests against the valve seat and door.

The **Robey** patent air valve, Fig. 131, is of solid metal, and the grooves between the surfaces cushion the contact so as to silence the action.

Fig. 131.—Robey Crank Case Air Valve.

Bedplate.—The bed or sole plate does not call for many special remarks. It is rather surprising, however, that very few of the makers have adopted a properly designed bedplate, for they are mostly too shallow, especially for the larger sized engines. This allows the bedplate to be "sprung" by the holding down bolts if the packing pieces are not fitted to perfection, and a relatively small spring in a bedplate for, say, a four-cylinder engine is sufficient to cause much trouble. Furthermore, a weak

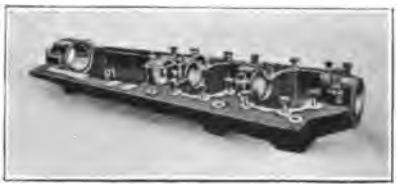


Fig. 132.—Bedplate, Skandia Engine.

bedplate adds risk to the slinging and handling of the engine in one piece.

It would be well to arrange for lifting bolts on the bedplate, from four to six, according to the size of the engine, as it is advisable to lift from the bedplate, unless the cylinders are well connected to each other at the top.

Bearings.—White metal is usually adopted for lining the crank shaft, the crank pin bearings, and the thrust block.

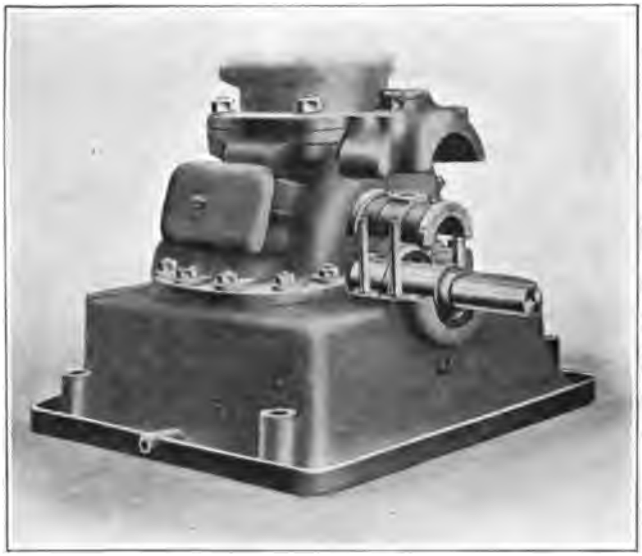


FIG. 133.—Bearing, Robey Engine.

The shells are usually of gunmetal, while the top end, or gudgeon pin bearing, is of a phosphor bronze able to withstand considerable heat.

It does not appear necessary that the shells should be of gunmetal, especially for the larger sizes, as cast steel or malleable iron, as used in steam machinery, would no doubt suit the purpose equally well, and be less expensive.

The main bearings (top and bottom half) should of course be made accessible without the removal of the cylinders. For small single cylinder engines, it is a frequent practice to make the crankshaft end bearings in one piece, although the advantages of a bearing in halves seem great and get over the difficulty of adjustment.

White metal will generally be found more satisfactory than bronze for the bearings or bushes of the stern tube and intermediate shaft bearing blocks. Some engineers and owners prefer to fit *lignum vitæ* strips in a bronze bush to run with a brass-lined shaft. The disadvantage of bronze if fitted to any portion of the tail shaft or stern tube of an

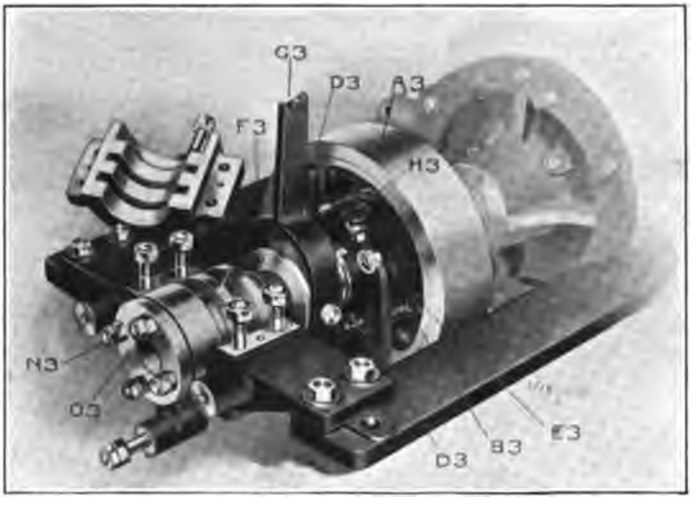


FIG. 134.—Skandia Solid Thrust Block and Clutch.

ordinary steel ship is the corrosion which is set up on the steel or iron.

Wooden vessels copper sheathed with bronze propellers are an exception to this rule, also reversible blade propellers; in the latter case it is almost imperative that bronze should be used to prevent the internal mechanism rusting up.

Thrust Blocks for small and medium-sized engines are usually arranged at the after end of the main bedplate, so as to make the engine a self-contained unit.

Thrust blocks may be arranged :—

(1) With solid covers.

(2) With adjustable shoes.

(3) With roller bearings.

The solid covers of cast iron lined with white metal or

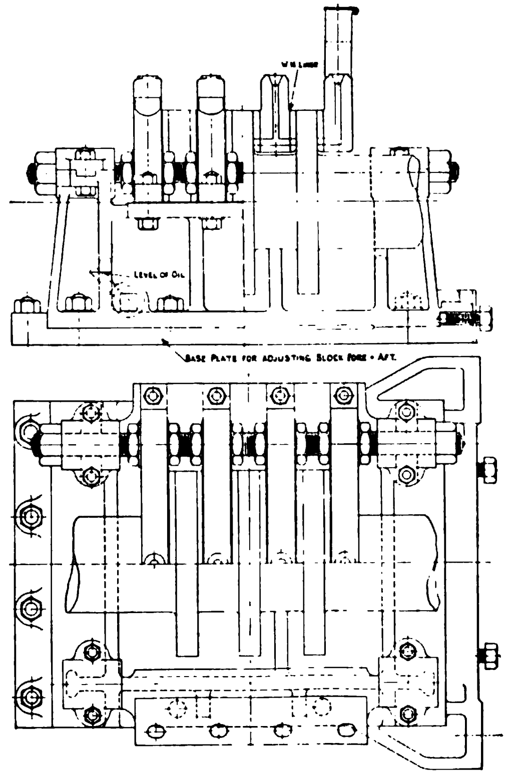


FIG. 135.—Adjustable Thrust Block.

bronze are almost universally fitted for engines up to 100 B.H.P. with two, three or four collars on the shaft. The **Skandia** thrust block with two collars, illustrated in Fig. 134, is a typical design adopted by most makers.

The adjustable thrust block, illustrated in Fig. 135, can be embodied in the after end of the bedplate, or, if the engine bearers are properly designed to suit, fitted clear of the bedplate to reduce the length of the latter.

This design has been arranged for three collars and four shoes, the shoes being lined with hard white metal, and having portable white metal plates dowel pinned on to form the friction faces giving easy adjustment by fitting tin liners. Each shoe is separately adjustable, which is a distinct advantage. The lower part of the block forms an oil bath, and has a drain hole Z drilled diagonally, which allows any water to overflow whilst the oil remains on the top, for lubricating purposes.

The total surface of the collars for the go-ahead side of solid or adjustable thrust blocks averages 0·75 sq. in. per brake horse-power, on the assumption that the whole of the collar is usefully employed by having a bearing on the bottom of the collar, as well as the bearing in the cap.

In some of the largest engines, such as the **Bolinder,** 320 B.H.P. direct reversible, a roller thrust block is fitted.

The Michell Thrust Bearing is worthy of special mention, in that friction is reduced to a minimum, allowing much smaller thrust surface to be employed without heating up, and at the same time therefore reducing the power wasted by the thrust block. This result has been achieved by putting into practice the scientific facts established as a result of Mr. Beauchamp Tower's experiments and investigations on the subject of lubrication. It was definitely shown that a journal bearing could carry a far greater load per unit area than a collar and thrust bearing, for the reason that the shaft takes up a slightly eccentric rotation in the journal, thereby maintaining a wedge of oil for continuous lubrication. In the case of the ordinary collar, the oil film is squeezed out and efficient lubrication prevented above a certain load per square inch of thrust surface.

This fact being definitely demonstrated, Mr. Michell many years later invented a self-lubricating thrust bearing, in which the collar was divided up into segments, each segment being pivoted either about a point or about a line in such a way that the segments were able to take up automatically a very slightly inclined position, thereby maintaining the required wedge of oil.

Such a thrust has a coefficient of friction of only one-fifth (or less) of that of an ordinary collar thrust as indicated by tests, and, indeed, its coefficient is only inappreciably greater than that of the ball bearing.

Fig. 136 shows the bearing dismantled. TD shows a complete thrust disc composed of an internal ring IR,

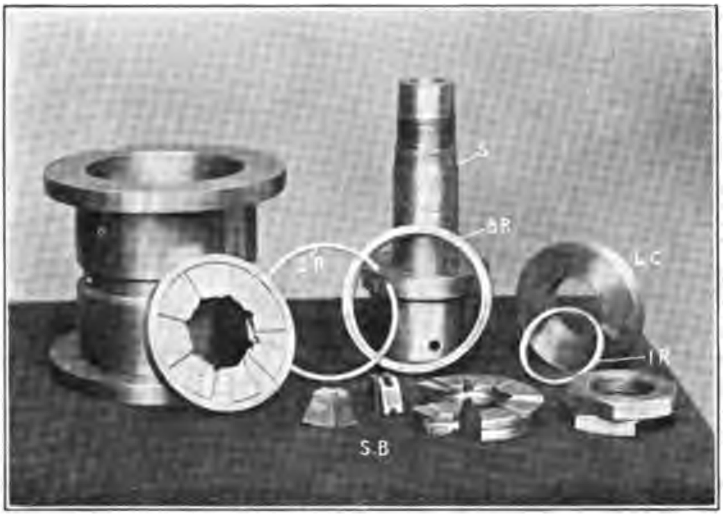


FIG. 136.—Michell Thrust Bearing.

a split ring SR, working in the outer groove of the segments as well as in the internal groove of BR, which acts as a binding ring.

Crank Shafts.—The crank shafts, thrust shafts, intermediate shafts and tail shafts for hot bulb oil engines require a higher factor of safety than do those for a steam engine of the same power, but not so high as for a Diesel engine. In the case of a Diesel engine it is possible to have in the cylinder a pressure of more than double the normal maximum pressure, whilst for a hot bulb oil engine it is not possible to have more than 50 per cent. in excess of the normal maximum. Some makers use nickel steel, in which case the diameter can be reduced. All crank shafts for these engines, even of the four-throw type, are solid, not built up.

FIG. 137.— Crank Shaft, Robey Engine.

Lloyd's scantlings will be found on p. 386.

For notes on the rings for keeping the crank case tight in way of the crank shaft, see p. 151.

FIG. 138.—Crank Shaft, Remington Engine.

Connecting Rods.—The best marine practice has fixed in the case of steam engines up to 500 B.H.P. a length of rod two and a quarter times the stroke, which gives little obliquity of rod and very little wear on the guides.

Hot bulb oil engines of the closed crank chamber and trunk piston design have shorter rods—about one and three-quarter times to twice the stroke. This cuts down the height of the engine, and makes it more compact—

almost squat, and keeps down the weight, but more important is the reduction in the volume of crank chamber space which must be kept small to give a correct pressure for the scavenge air, and this is still further aided by the larger balance weights on the crank web. An open cross-head design such as the **Bolnes** can use a longer rod.

FIG. 139.—Connecting Rod, Robey Engine.

The rods are sometimes round, sometimes of I section, and are massive, as the maximum load on them is large compared with the average load during the firing stroke, but unlike the double-acting steam engine, the metal is not subject to the fatigue of continual reversal of stress.

FIG. 140.—Connecting Rod, Remington Engine.

It may be repeated here that for all sizes of these marine engines the gudgeon pin bearing should certainly be made in halves, so that any adjustments are easily made if required at the periodical laying-up.

Clutches.—There are a number of different designs of clutches fitted to hot bulb engines; they may be classified as:—

(*a*) Cone clutches.

(*b*) Expanding ring clutches.

Practically all are operated by levers ; a wheel and screw is more powerful but is probably too slow for anything below, say, 350 B.H.P.

The cone clutch has the disadvantage of a fore and aft movement of the interior part of the clutch and the increased liability to sticking or locking, besides thrusting or pressing the crank shaft forward. These pressures, though subsequently released, take place every time the clutch is put in.

The expanding ring clutch, which only requires the movement of a wedge or toggle joint to "clutch" or "declutch," is becoming the favourite, as it is the most reliable, and does not thrust the shaft forward. The extra cost of construction is warranted by the results obtained.

Fig. 141.—Skandia Clutch.

It is desirable to use only metal to metal for the surfaces of clutches for this type of engine. The lubrication is important, especially on the sliding parts, to prevent sticking or rusting up. The friction faces should sometimes be given a little paraffin to clear away any grit and to avoid rusting. Lubricating oil on the friction faces is apt to cause slipping, and is to be discouraged.

All clutches require very careful adjustment, and ample room should therefore be given in the bedplate, so that the whole clutch or the various parts can be removed and replaced with ease, the engine floors and reverse frames being kept clear for the same purpose.

The **Avance** and **Skandia** clutches are shown in Figs. 141, 142, and 143, and further illustrations will be found under the heading of " Reverse Gears " in Chapter III.

Starting Valves in communication with an air container are usually fitted to all marine engines over 20 B.H.P., and sometimes even to engines of that power, because the

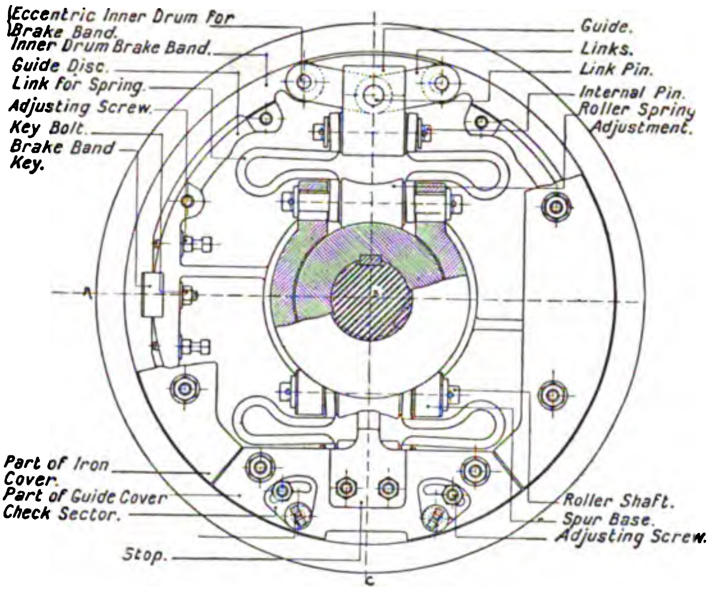


FIG. 142.—Avance Clutch.

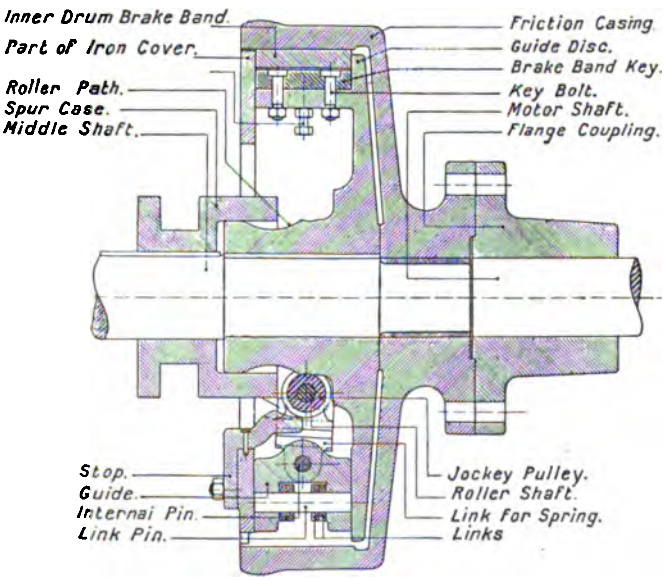


FIG. 143.—Avance Clutch.

alternative method of starting the engine by swinging the flywheel is not easy on board a small vessel, as it would be necessary to get down into the bilges. Sometimes the same

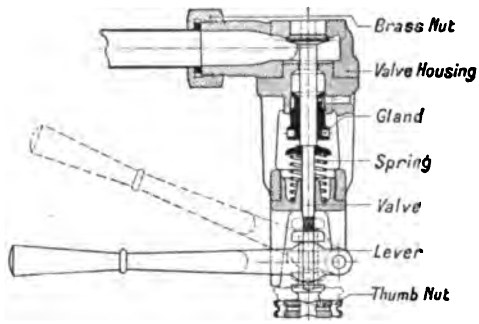


FIG. 144.—Starting Valve, Avance.

valve, and sometimes a separate valve is used for charging up the air containers from the gases in the cylinders.

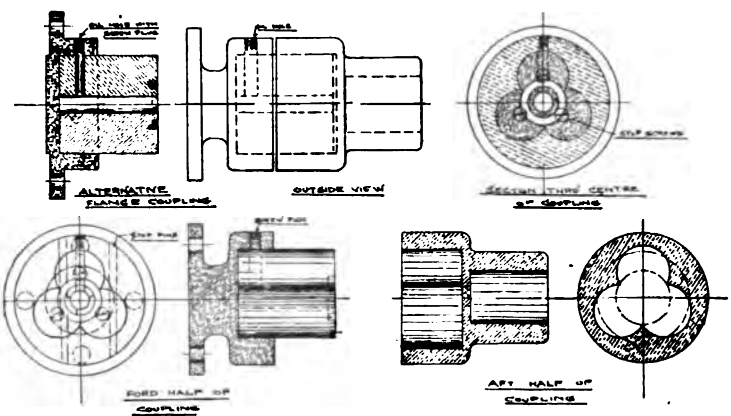


FIG. 145.—Langdon Patent Sleeve Coupling.

Except when the clutch is dispensed with and the engine completely manœuvred by compressed air, the valve is lifted off its seat by a hand lever and similarly closed by hand before half a revolution is completed. It is usual for the starting valve to serve one of each pair of cylinders of a two-cylinder or multi-cylinder engine not manœuvred by compressed air.

For engines without clutches and manœuvred by compressed air, an automatic distributing gear is used in conjunction with starting valves, and it is then arranged for each cylinder alike to have the same air connections.

FIG. 146.—Langdon Patent Sleeve Coupling.

Sleeve Couplings.—In many cases where engines are fitted as far aft in the vessel as possible it is necessary to fit a sleeve or portable coupling, to enable the tail shaft

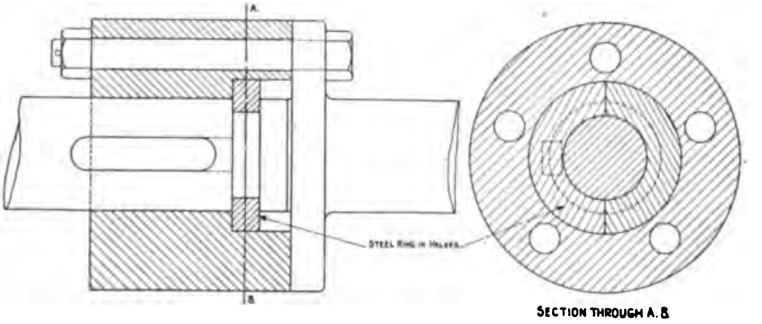


FIG. 147.—Loose Coupling.

to be drawn without disturbing the main engine, and of these there are a number of different designs.

Figs. 145 and 146 illustrate the **Langdon** patent sleeve coupling.

Fig. 147 represents a type adopted in many installations and actually fitted in steam vessels up to 500 H.P., and

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there is no reason why they should not be fitted to oil engines of even larger power.

Deck Control Gear.—Enough has been said in discussing governors to show that the speed control is very simple. For engine room control small hand levers or wheels are placed

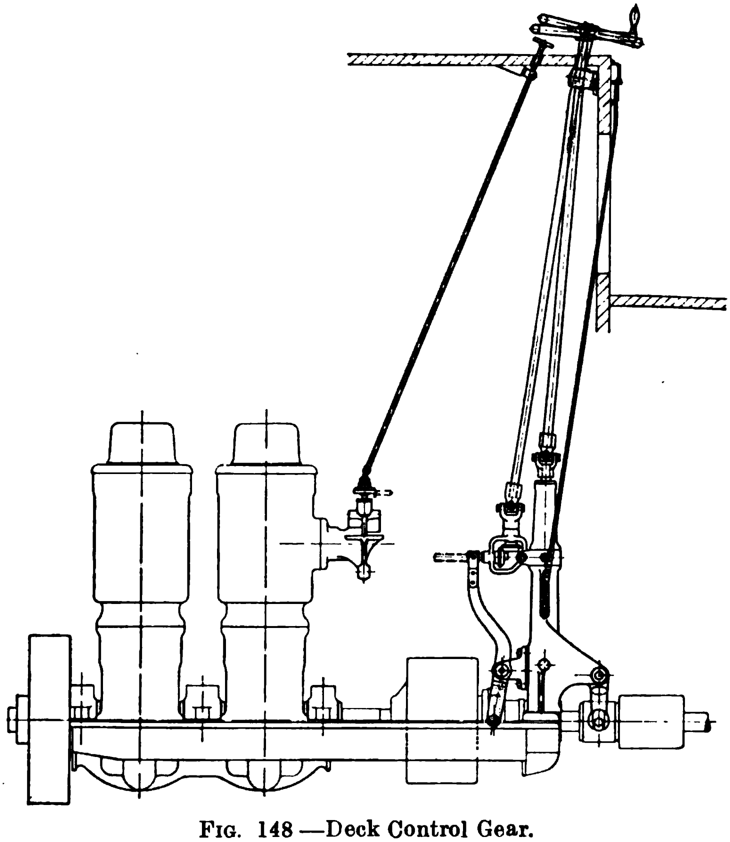


FIG. 148.—Deck Control Gear.

in a position which enables the driver to operate them (as well as reversing levers and sometimes the control for throttling the scavenge air) while standing in a position to throw the clutch in and out, so that all manœuvring is done without the driver moving about.

Deck control can be conveniently arranged for engines up to, say, 80 B.H.P., and even more if absolutely necessary by carrying up the levers to the side of the steering wheel. The only lever to transmit any considerable amount of force is the one for the clutch, and the transmission from the deck to the clutch must be proportioned liberally.

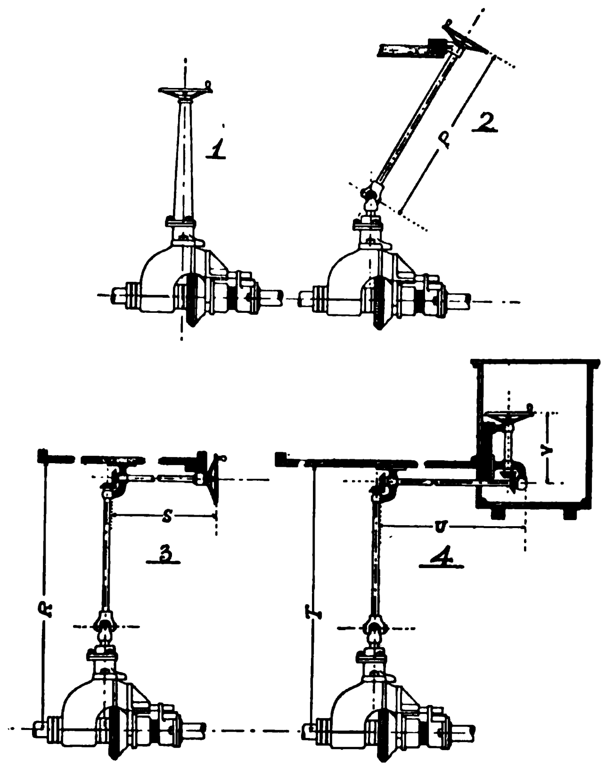


FIG. 149.—Deck Control Gear.

For small harbour vessels, ferry boats, etc., this is a great advantage, as it will sometimes allow one man to be dispensed with, as the skipper-driver can go below to start his engine, and then control it from the deck or from the navigating bridge, whilst, perhaps, a boy is letting go the ropes.

In some twin-screw jobs the arrangement is so efficient that for harbour and dock work the captain can steer and control the vessel by using the engine only and without touching the steering wheel.

In Holland motor barges can often be seen with a man working on deck, controlling the main engine drive for operating the cargo winch. The main engine is only used when comparatively small powered engines are installed.

Flywheel.—From a naval architect's point of view, big flywheels are a nuisance, as they usually get in the way of the keelsons, and nearly always in the way of the longitudinal strength of the engine bearers. Another disadvantage is that they make it awkward to fit auxiliary machinery, compressors or pumps at the forward end of the crank shaft.

The best design of flywheel is one of small diameter with a wide rim, so that the bearers for taking the longitudinal bolt holes can be made continuous and not have to be recessed for the flywheel.

Care should be taken in the design and fitting to ensure that the flywheel will not work loose. The nut should be a tight fit on the thread and require a spanner to screw it up all the way, when a cone seating and nut design are employed. When keys are employed they must be well fitted by a really good fitter.

Lubrication.—Mechanical or force feed lubrication is the only practical method and should include the main bearings for engines of 100 B.H.P. and over, and, if possible, even the smaller sizes.

There are many designs of mechanical lubricators, some being illustrated in these pages. It will be noted that the amount of oil distributed is automatically proportional to the speed for any one adjustment of the lubricator.

Fig. 150 shows the **Bolinder** lubricating box and pumps. The plunger 78 is pressed down by a distance piece 85, which receives its motion from the shaft 82, the up-stroke of the plunger being made by a spring 87. The amount of oil delivered by a pump is determined by the length of its distance piece 85, controlling the effective stroke, which can be changed at will by loosening the lock nut 84 and shortening or lengthening the distance piece 85 by the screw 83.

One advantage of this system is that if for any reason a bearing should start heating, the trouble can generally be easily remedied by working the pump by hand and flooding the bearing in question; to do this, remove the yoke or distance piece as shown in Fig. 151 when the spring and plunger can be worked by hand.

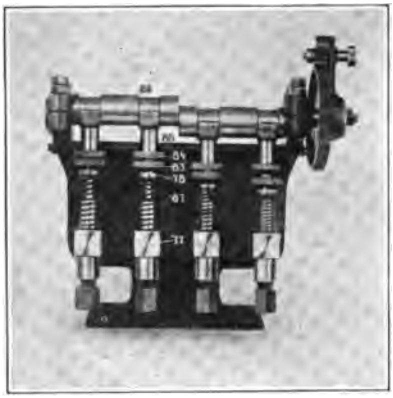


FIG. 150.—Lubricator Box and Pumps.

A small crank handle fitted at the end of the shaft of the mechanical lubricating device would be an advantage. It would make it easier, quicker, and more convenient to flood all bearings before starting and before stopping the engine, than is the case with the ratchet wheel only.

FIG. 151.—Illustration of Hand Flooding.

Any leakage from one of the oil valves can be detected by air bubbles rising in the oil box, in which case the valve should be attended to at once. As most engines are only tested for a few days at the factory it is impossible to adjust the lubrication so that the minimum amount of oil necessary is used. Only after the engine has run a considerable time should the amount of oil used be diminished, and great care should be taken to make the reduction very gradually.

The **Robey** lubricator, Fig. 152, is of the ratchet pump type, giving a positive delivery at every stroke. When the engine is in motion any feed can be flushed with oil by the plug or spindle P which passes through the feed regulating screw S, the actual feed being regulated with great nicety. To flush all the feeds by hand before starting, the lever D can be disconnected or the plugs P can be used.

In the **Rap** engine lubricator which is driven off the

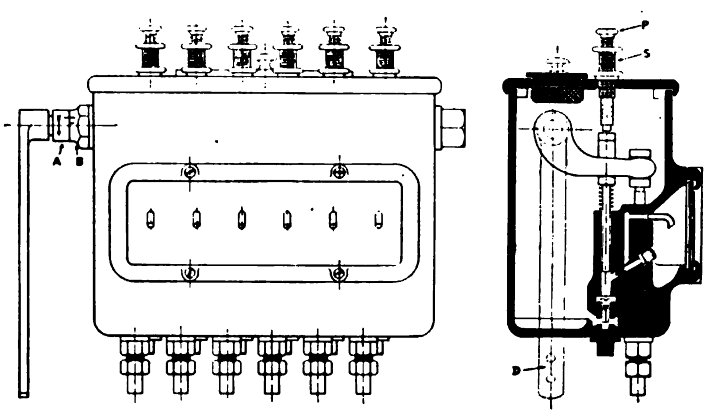


FIG. 152 —Robey Mechanical Lubricator.

flywheel end of the shaft and is illustrated in Fig. 153, the lubrication is automatic, and once the small valves are regulated to the required quantity for each bearing, it needs no further attention other than filling every morning.

The cylinder in most cases is fed by a force feed entrance into grooves in the cylinder wall. The top end of the gudgeon pin is arranged with a scraper which scoops up the oil and lubricates the connecting rod top end bearing.

The heat on the top end bearing where the piston is not water-cooled, as in the case of large Diesel engines, is considerable, and necessitates an efficient system of lubrication, carefully cut oil grooves and a good class of oil for high temperatures.

The one disadvantage of the closed crank chamber design lies in the question of bottom end or crank pin lubrication, and it is really a most difficult problem. In the majority of cases a hollow banjo ring running with the crank shaft is adopted, and oil is pumped into this ring, from which the centrifugal force sends it through a pipe which leads to a hole bored in the centre of the crank pin and thence to the bottom end bearing.

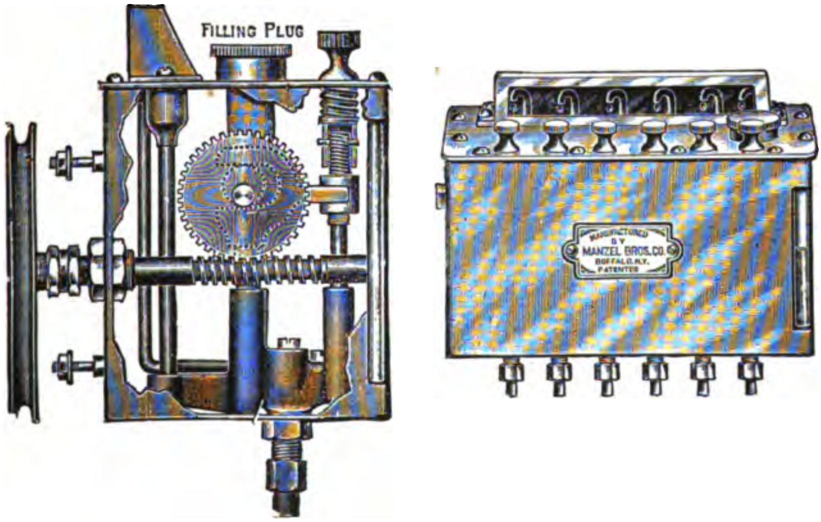


FIG. 153.—Rap Mechanical Lubricator.

Careless filling of the lubricator box without the proper precaution of straining or negligence in leaving waste (which should never be used in the crank chamber) inside where it can get in the banjo ring, may cause and has caused quite a lot of trouble to some owners. Certain refinements in design may mitigate this, but in return for the great simplicity of the closed design, these two points should be strongly impressed on the engine-room attendants, and the proper and quite simple and cheap equipment should be a permanent provision in the engine room ; therein lies the cure or rather the prevention.

Another system that is sometimes adopted consists in taking the oil from one of the main bearings into a ring on the crank shaft connected with the bottom end bearing, this main bearing, of course, having an extra large supply.

Water Cooling.—In addition to the cylinder itself, water cooling is often provided for part of the cylinder cover (see Hot Bulbs, p. 126). The silencer should always be water-cooled, and if for use in the tropics, and the engine room is rather confined, the exhaust pipes and secondary silencer (if fitted) may with advantage, also be water-cooled. Air compressors when fitted must be water-cooled, and in this case the water should enter the air compressor first, and then pass to the cylinder and the silencers.

Engines for tropical work require special attention with regard to water cooling. It is advisable to fit a separate pump for each cylinder of a two-cylinder engine and one large pump for each pair of cylinders of a four-, six- or eight-cylinder engine. This will, no doubt, in practice be found more satisfactory than increasing the size of the circulating water pumps.

The intending purchaser of an engine for tropical work should advise the maker of the maximum temperature expected in the water in which the vessel is to work, so that if necessary, a pump of somewhat increased capacity may be supplied, to avoid the possible necessity of running the engine rather under full power in the hottest seasons. This question also affects the size of sea-cocks and piping recommended.

Notes on the suction arrangement for obtaining water from shallow draft rivers are given on p. 373.

Circulating and Bilge Pumps.—In the majority of engines the pumps for circulating the cooling water round the cylinders, silencer, etc., are arranged on the main bedplate and driven direct off the crank shaft by an eccentric, which makes a compact arrangement. A bilge pump is usually fitted on the opposite side of the bedplate, often driven by the same eccentric. For arrangement of bilge pumps, see p. 377.

The **Avance** circulating and bilge pump, Fig. 154, is of a somewhat unusual type because it is driven by an eccentric through a bell crank, Fig. 155.

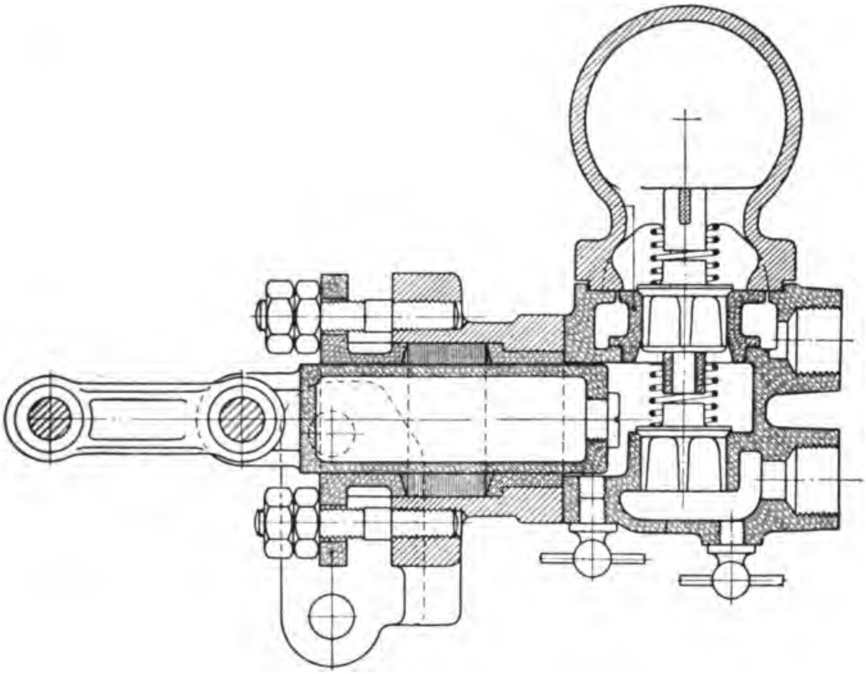


FIG. 154.—Avance Circulating Pump.

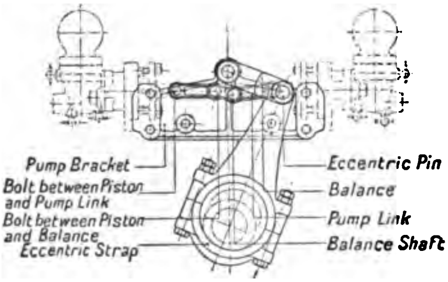
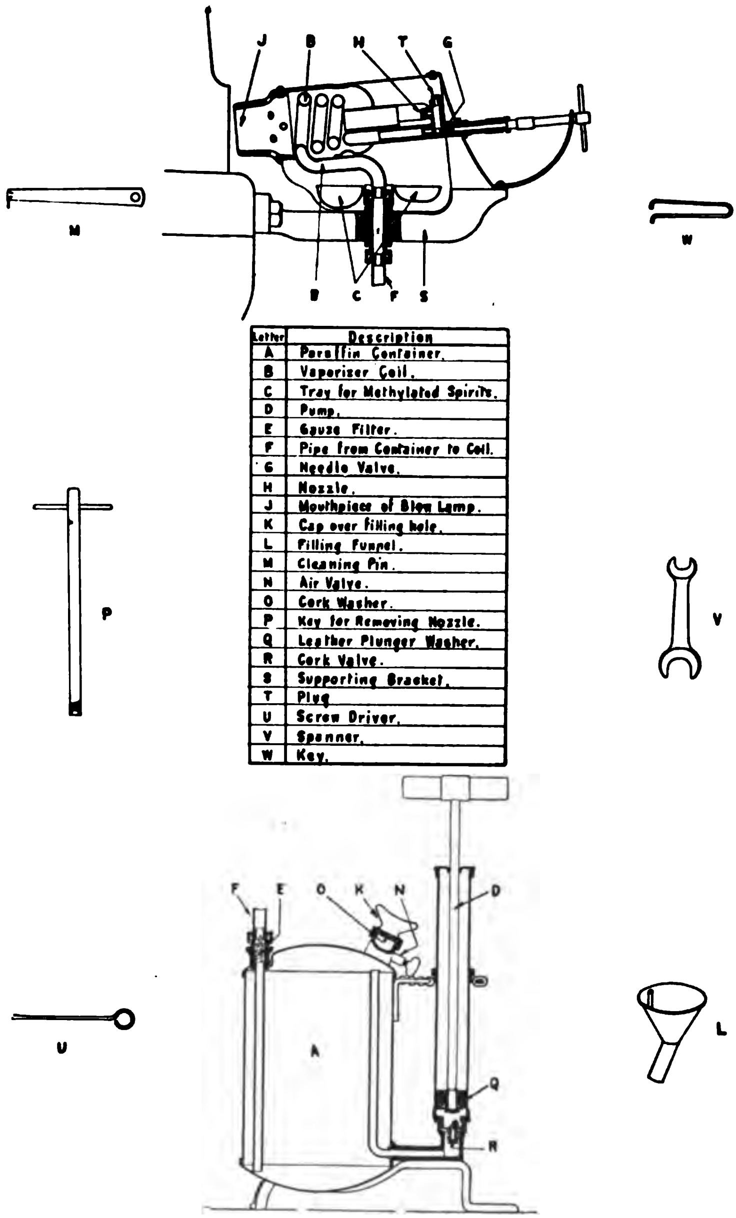


FIG. 155.—Avance Pump Drive.

If vertical scavenge pumps are fitted and driven by pump levers from the main crosshead pin as in the **Stallard**



Letter	Description
A	Paraffin Container.
B	Vaporizer Coil.
C	Tray for Methylated Spirits.
D	Pump.
E	Gauze Filter.
F	Pipe from Container to Coil.
G	Needle Valve.
H	Nozzle.
J	Mouthpiece of Blow Lamp.
K	Cap over Filling hole.
L	Filling Funnel.
M	Cleaning Pin.
N	Air Valve.
O	Cork Washer.
P	Key for Removing Nozzle.
Q	Leather Plunger Washer.
R	Cork Valve.
S	Supporting Bracket.
T	Plug.
U	Screw Driver.
V	Spanner.
W	Key.

FIG. 156.—Pressure Lamp and Container.

engine, there is no reason why the circulating and bilge pumps should not be fitted alongside. A longer stroke and a smaller diameter, which is to be preferred, could then be arranged for.

Lamps to Heat Bulbs.—Before a hot bulb engine can be started the bulb must be heated and up to the present the universal means employed is the paraffin pressure, or " blow " lamp. In some cases the lamps are made portable, when they are identical in every way with the painter's lamp, and should be lighted before being placed in position on the engine. More often the lamps themselves are bolted in position on the engine and the container for the paraffin is fixed conveniently on the floor, and a pipe led from the container to the lamp. Whatever arrangement is adopted the lamp itself, illustrated in Fig. 156, is the same and being a familiar everyday object, needs no description.

FIG. 157.—Hein Pressure Lamp Attachment.

Spare parts are always supplied with the lamps and engines are usually sent out with one or more complete spare burners.

It saves time to take care of the lamps and keep them clean and in working order, which the engine attendant can very easily do after reading the little booklet which is usually supplied with the spare parts in the first place.

For multi-cylinder engines, it is better to have one good large paraffin container, and this should have a separate screw-down valve for each lamp served, one large filling connection, a small pressure gauge, and the usual hand pump, which should be conveniently arranged on the container, and should have a good handle that can be properly gripped. A useful addition is a small connection at the top, whereby pressure can be maintained without hand pumping, by connecting up a pipe from the air starting receivers.

In the Hein engine the lamp is neatly attached to the engine and is very quickly removed for overhauling (see Fig. 157).

For engines fitted in open boats a wind screen round the lamp is necessary to get it to work well. This applies to the case of deck winches and any other auxiliary not in an enclosed or sheltered space. A simple small attachment of sheet iron is easily fitted.

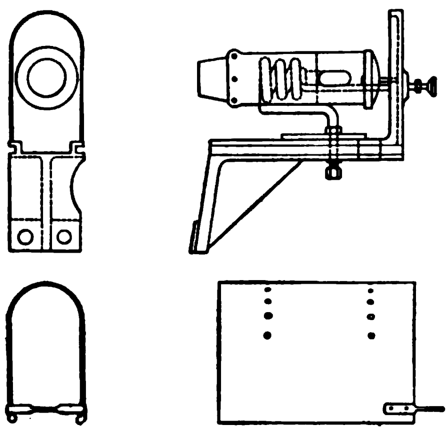


FIG. 153.—Blow Lamp Cover as fitted on Avance Engine.

Silencers. — The question of silencing the exhaust is rather more important for two-stroke than for four-stroke engines because the back pressure must be kept to a minimum to ensure good scavenging. Marine hot bulb engines are always sold with silencers directly attached to the cylinders, so that the exhaust gases as they leave the ports, expand immediately into a large box, of which the capacity is some four or five times the capacity of the cylinder exhausting into it.

Almost invariably this silencer is of cast iron and water-cooled, the water as it leaves the cylinders being led into the bottom of the silencer water jacket and led away from the top of the jacket to overboard. There should be no baffle of any kind in this silencer. In shape the box is cylindrical or rectangular; the latter is more compact and leaves a rather clearer engine room, whereas the former, besides being cheaper to manufacture, is less liable to damage when repairs are in progress and the silencer is perhaps roughly handled and badly slung. Silencers constructed of wrought steel would be far lighter but more costly than if

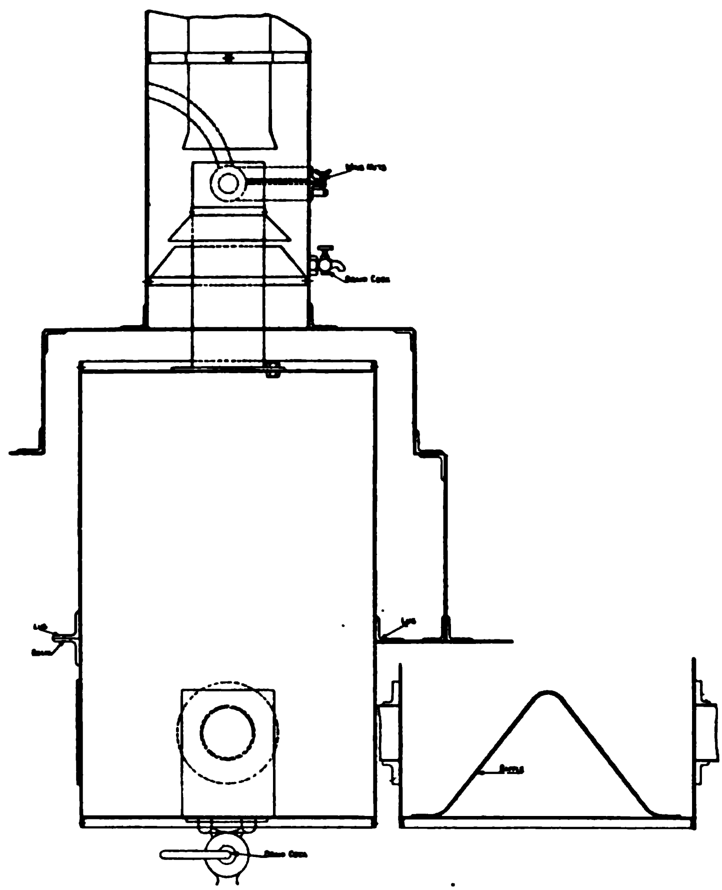


Fig. 159.—Secondary Silencer.

made of cast iron, while wrought steel is also inclined to produce a ringing noise in the engine room.

Water cooling cannot be dispensed with, as there is a very large surface radiating heat, which would make a very objectionable engine room. The practice of dripping water into the silencer itself must never be employed for sea work on account of the salt deposits which result.

In relatively small installations the exhaust pipe is led from this first silencer up through the casing or to the stern, all bends being made as easy as possible.

For larger installations the proper practice is to fit a secondary silencer.

Illustrations of silencers and connections are given in this book, such as Fig. 340, and suggestions for selecting the most suitable arrangement on p. 374.

There are many forms of secondary silencers in use, including :—

(*a*) A separate plate structure in a convenient position.

(*b*) A funnel arranged so as to form a silencer.

(*c*) Hollow steel mast.

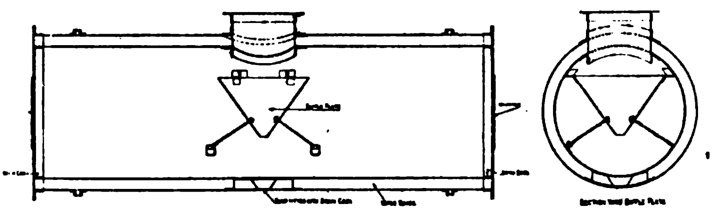


FIG. 160.—Secondary Silencer.

The first arrangement is formed by a cylindrical vessel of steel plates, riveted at one end and bolted at the other to facilitate cleaning. Such a silencer is often fitted in the engine-room casing, and the exhaust led into it from below and led out from the top up a funnel or to the stern of the vessel, as shown in Fig. 159.

In the second arrangement, that is sometimes adopted, the exhaust is led up to a funnel of fairly large diameter, an outer or double casing being fitted to keep the outside casing cool and retain the paint (see Fig. 161).

A steel mast makes an excellent secondary silencer, especially for auxiliary sailing vessels as in the *Earlshall*, and as a third silencer as in the case of the yacht *Belem*, Fig. 276, p. 306.

If this system is adopted, care should be taken that the steel mast is of ample diameter. The exit can be arranged by perforated holes so as not to unduly weaken the mast, and drilled, if possible, well clear of yards ; the area of the holes should be at least 50 per cent. greater than the area of the exhaust pipe because the small holes may become partly

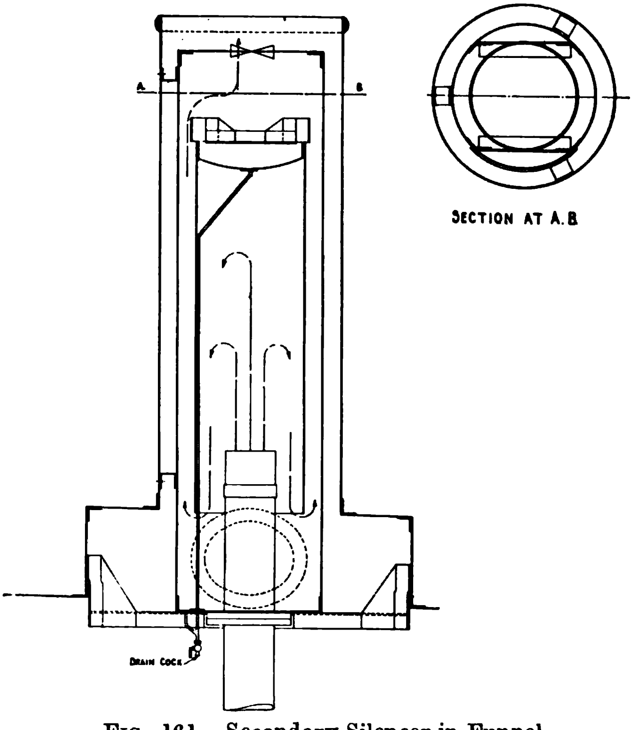


FIG. 161.—Secondary Silencer in Funnel.

filled up. If the exhaust is carried straight out at the top of the hollow steel mast a form of cap or bonnet should be fitted to prevent rain from getting down inside and rusting the mast. This cap should be from 2 in. to 4 in., clear all round, and overlap the top of the mast by 2 in. or 3 in.

It is advisable to make the exhaust pipes enter well above the bottom of the mast and to arrange for cleaning holes below the line of inlet to clean out any deposit, and to fit a $\frac{3}{4}$ in. to 1 in. drain cock to run off moisture and oil.

Air Containers.—There are a number of different types of air containers to hold the air for starting the engine, blowing the whistle and other purposes.

The welded steel container, illustrated in Fig. 162, is of a very usual type, but being closed at the top and bottom is open to the objection that it cannot be easily cleaned out.

The one that can be recommended has a bolted cover or

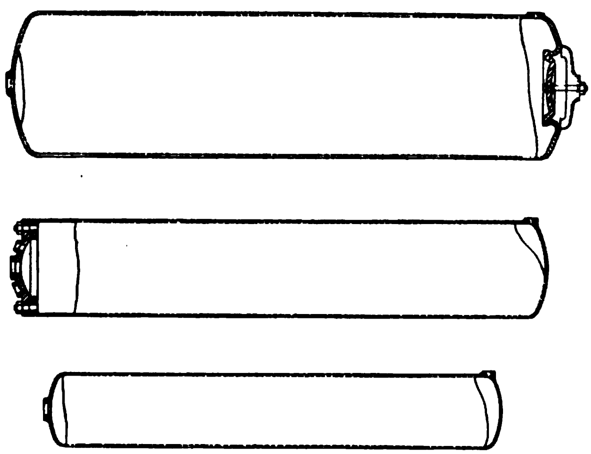


Fig. 162.—Air Containers.

top which can be removed to allow of cleaning. The containers should be lap welded or of seamless steel, and should be tested by hydraulic pressure to twice the desired working pressure, and in any case to not less than 350 lb. per sq. in. An engine cannot usually be started with less than 75 lb. per sq. in.

The size will depend upon the type of engine for which it is to be used, but in any case, it should be of sufficient capacity for five starts. The capacity recommended is twice the volume of one cylinder, based on the practice of using only one cylinder for starting, in which case the air container would be the same size for a 50 B.H.P. single-cylinder, 100 B.H.P. two-cylinder, or a 200 B.H.P. four-cylinder engine. If two cylinders are used for starting, the capacity would have to be doubled.

To avoid periodical cleaning out of the air containers it is better to have a small air compressor driven by the engine rather than to keep them charged with the compressed gases from the engine cylinder, as is more usually done. On any but the smallest installations it is absolutely necessary to fit such an air compressor when the whistle is blown by air from the containers.

Having decided upon the capacity, the makers would do well to adopt and stock only two or three sizes, and make up the capacity by a number of containers of stock size rather than one or two of large size. One advantage of having, say, three small containers instead of one large one is that with a proper arrangement of pipes and valves, one can be removed for repair if leaky, or for cleaning if dirty, whilst the others are still retained in use. A method adopted by the author is shown on Fig. 337.

They should all have the following connections: one to the air compressor, one to the air starting valve, one for the hand pump, and one for a pressure gauge.

Containers which are to be fitted on vessels classed by Lloyd's should be tested, passed and stamped in the presence of their surveyor.

For the fitting and connection of these containers, see installation plans, in Chapter VII.

Tail Shafts.—For ordinary vessels mild steel tail shafts are generally used. For small vessels, teak launches and pinnaces, and fishing vessels of small power, bronze shafts are sometimes used. Nickel steel shafts are sometimes used, but not often.

Reversible blade propellers are usually of bronze, and where this material is used it is advisable to have the stern tube and tail shaft of bronze.

In the case of steel shafts the practice is to line them with bronze or gunmetal and run them in stern tube bushes lined with *lignum vitæ*, the gland bushes and neck rings being lined with gunmetal. Unfortunately, this arrangement frequently sets up galvanic action and causes corrosion of the shafts and also in many cases of the steel work of the ship, especially where the bronze and steel come in contact with sea water. The author's practice is to dispense with the bronze or gunmetal entirely and fit naked steel shafts, made sufficiently large that they can be machined down, when worn, without coming below the size of classification, and run the shafts in bushes and glands lined with white metal. An increase in the diameter of the shaft of 10 per cent. for naked shafts and 5 per cent. when liners are used will, no doubt, be satisfactory.

The diameter at the top of the cone should be less than the diameter of the shaft in way of the stern bush, so as to allow for turning the shaft down when worn without disturbing the cone.

It is important to arrange for the tail shaft to be drawn easily for examination and repairs without disturbing the main engine. If there is room for a fair length of intermediate shaft, there is no difficulty, but, where the engines are right aft in the ship, as is often the case, it is advisable to fit a sleeve coupling and a portable rudder-post or, alternatively, to form a large hole in the rudder-post of a single screw vessel to enable the shaft to be drawn aft.

Propellers.—The only satisfactory way of arriving at a good propeller design for oil-engined vessels is to study the records of results of trials of previous vessels as nearly as possible of the same type as the one under consideration. Such records at times disagree entirely from accepted ideas on propeller design, and the subject is one on which opinions differ to an astounding extent.

Owing to the difference in revolutions of hot bulb engines and ordinary marine steam engines of equal power, past records of propellers in the latter case cannot be relied upon as a definite guide to practice with the oil engine.

Standardisation.—If we divide vessels up into their various classes, all vessels in one particular class (other than launches and fast pleasure craft) driven by a given power will have a speed falling within very narrow limits, unless the vessel is quite abnormal. As a result of this a standard propeller which will give the best all-round results can be used for an engine of any given size designed for a vessel of a given class, and no small variations in pitch are required.

This should prove a great advantage over the present idea that almost every vessel must have a different propeller, and will reduce the cost of propellers considerably,

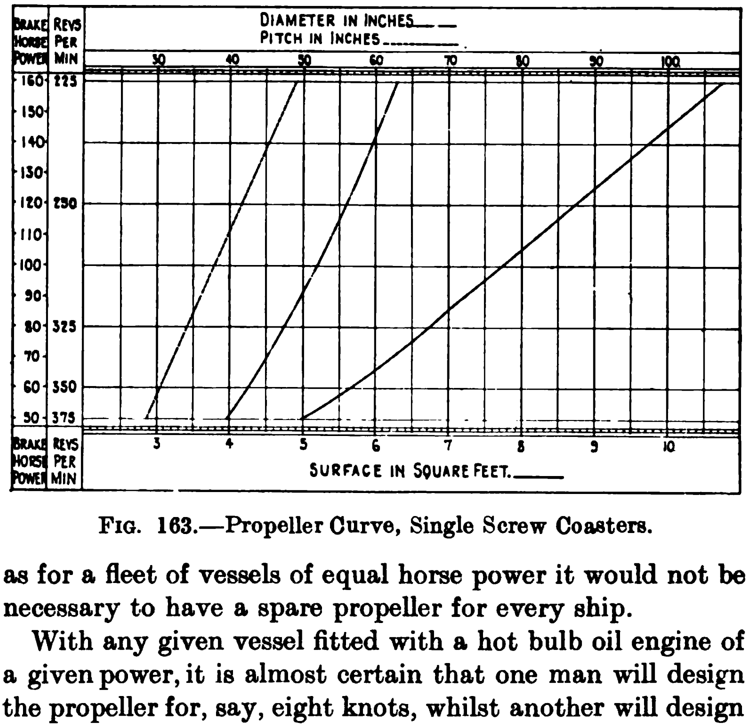


FIG. 163.—Propeller Curve, Single Screw Coasters.

as for a fleet of vessels of equal horse power it would not be necessary to have a spare propeller for every ship.

With any given vessel fitted with a hot bulb oil engine of a given power, it is almost certain that one man will design the propeller for, say, eight knots, whilst another will design for eight and one-quarter knots, while a third may arrange the design for seven and three-quarter knots. The explanation is that each designer firmly believes and hopes to obtain the speed given or perhaps a greater speed. In each case the pitch will be different by an amount smaller than the designer's probable error.

Take the case of coasters ; any normal vessel of this type with a coefficient of ·68 to ·73, commercially suitable for say, 150 B.H.P. engine, can quite well have a standard propeller because the vessel, which would be built on good commercial lines, would have a speed in either case of about eight knots, but this propeller would be unsuitable in the case of an abnormal coaster of ·6 coefficient, and better results would be obtained in such a case by taking the propeller designed for an auxiliary sailing vessel.

Fig. 163 gives curves of recommended diameter, pitch and surface plotted against size of engine (power and revolutions). This curve must not be regarded as too rigid, but gives the result of experience on many normal craft, and is based on the recommended shape of blades shown in Fig. 165, p. 185.

Similar curves for other types of vessels can be constructed from the results of experience.

Diameter.—Cases will arise when the diameter cannot be made as large as that shown on the diagram, as, for instance, when the draft is specially limited. Then to compensate for the reduced diameter, the pitch or surface, or both, must be increased, but the efficiency will not be as good as if the standard propeller could have been fitted.

For twin-screw boats a smaller diameter is not nearly such a handicap as for single screws, because the water has much freer access to the propeller.

A number of installations do not give good results because small diameter propellers are fitted close up to a heavy wooden rudder-post, especially in fishing vessels.

It is not uncommon to see a wooden vessel with 20 ft. beam and a 10-in. stern-post, perfectly square at the after end with a tail shaft projecting through the post, fitted with a propeller 2 ft. 6 in. diameter and, in some cases, as small as 2 ft. ; now, unless the propeller is 6 in. or 9 in. clear of the post, and the post above and below the shaft line is well chamferred and cut away it is impossible to get the water to the propeller and, consequently, the efficiency will be very poor and the results disappointing. This is an important point that designers of propellers and the person responsible for the installation of the engine should not overlook, as the oil engine is frequently blamed as the cause of the trouble.

In speedy, shallow draft vessels, it will probably be found more efficient to have a propeller or propellers of larger diameter than the actual draft, because at full speed the water will rise up under the stern of the vessel and give better immersion of the propeller.

As an example, take a shallow draft vessel 100 ft. in length, with a beam of 20 ft. and a draft of 3 ft., fitted with two sets of hot bulb engines each of 100 horse power, running at, say, 300 revolutions per minute. Greater efficiency and greater speed would be obtained by propellers of normal diameter, say, 3 ft. 6 in. (which would leave the tip of the blade in still water 2 in. off the bottom of the vessel and, say, 8 in. out of the water), than if propellers of 2 ft. 6 in. diameter were fitted and the tips consequently immersed 4 in., because at full speed the water will rise up about 1 ft. under the overhanging stern and immerse the larger propellers.

Pitch.—It has been mentioned that equally powered vessels of a given type vary very little in speed unless they are abnormal and that, therefore, the pitch can be standardised.

This means that there will be some variation in slip due to whatever speed variation there may be, but this is no detriment, judged by the study of a great many actual trial records and, in fact, these records discount much that has been held to be correct.

It is usual to fix on a percentage of slip and arrange the pitch to suit. For the type of vessels in which these oil engines are fitted it is very difficult to design the propeller and obtain a slip within 20 per cent. of that estimated, unless the results are at hand from a previous example of a very nearly similar vessel. A standard propeller would probably give a closer result and greater efficiency.

The difficulty in fixing the pitch is greatest in the case of tugs, whether required for towing pure and simple, or for combined towing and cargo carrying craft. Taking an extreme case, actual performances have shown that the best results have been obtained with canal tug propellers giving a large amount of slip, approaching 60 per cent., and that a modification of the pitch to give less slip and an adjustment of the diameter and surface to suit, has resulted in a considerable reduction in the towing speed of the craft. Towing performances require very reliably recorded and carefully investigated results to reach the best practical solution, which is often found to oppose many accepted notions. Canal towing requires special consideration and, unless all the conditions are carefully noted, false data and conclusions may easily follow.

Revolutions.—It is better to keep the propeller on the large rather than on the small side, so as to absorb the normal full engine power at revolutions slightly under normal but not reduced more than about 5 per cent.

It should then be borne in mind that the engine must ordinarily run at the slightly reduced revolutions, as normal revolutions would correspond to a small overload. In other words, with such a propeller the fuel pump setting (permanent or hand lever) must not be adjusted in order to reach the listed revolutions of the engine except when increased speed is specially desired for a time, when the overload may be used. A recent test showed that in such a case, for every 1 per cent. rise in revolutions the power developed by the engine increased by 2 per cent. and the speed of the vessel increased by two-thirds of 1 per cent.

Surface Area.—Fig. 163 shows the area recommended for normal vessels of the class named. In shallow draft vessels with smaller diameter propellers the surface must, of course, be increased to absorb the power, but the efficiency is then necessarily less.

Shape of Blade.—This subject is rather neglected and a stereotyped shape has come to be very widely adopted (see Fig. 164). Experience goes to show that with nearly all commercial small craft, better results are given by concentrating more area towards the tip as in Fig. 165. When this is adopted the surface area can be reduced slightly. Probably he explanation of this more efficient blade is that with small commercial craft the water does not flow evenly and easily to the inner portions of the propeller, which are therefore relatively of less value, while the water gets freely to the outer portions, which therefore account for a larger share of the thrust than if the water flowed easily to the propeller as a whole.

The recommended shape gives better "stern-way" and is an advantage for manœuvring.

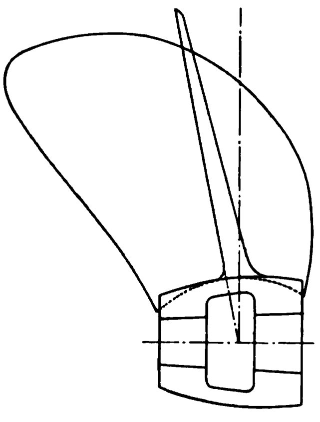


FIG. 164.—Usual Shape of Blade.

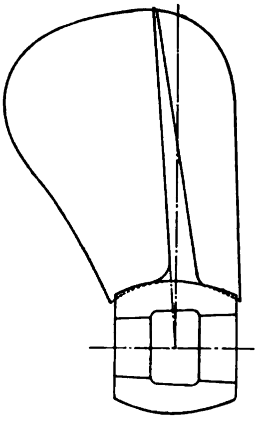


FIG. 165.—Recommended Shape.

Set-Back.—Propellers for ordinary commercial craft require no set-back at all. Set-back is a disadvantage for going astern and manœuvring, but is probably of value on fairly fast vessels, and any disadvantage in going astern is not important on such boats.

Immersion.—This has a very important bearing on the behaviour of the engine and the vessel. With the propeller partly out of the water, the speed of the boat is decreased, although the engine revolutions are increased, power being expended in churning water and air. In a recent series of trials, with a 4 ft. 8 in. diameter propeller, when the tip was immersed 8 in. the speed was 40 per cent. above that which, was obtained when the propeller tip was 4 in. out of water, which shows the importance of keeping the shaft line as low as possible on the vessel.

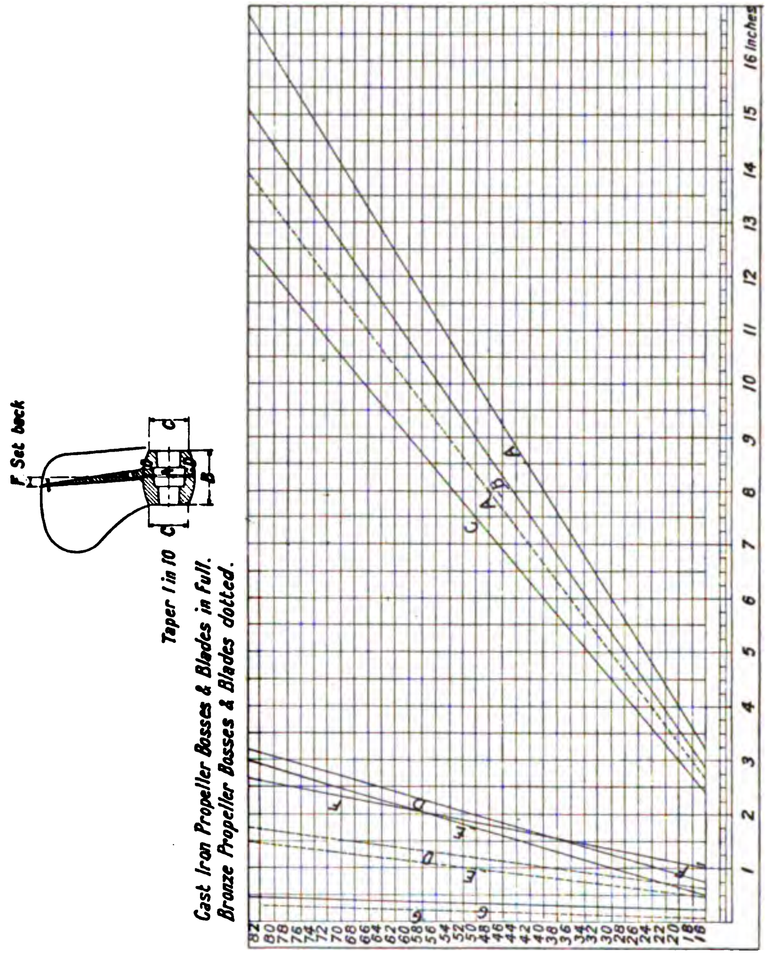


FIG. 166.—Propeller Scantlings.

In cargo boats and coasting vessels of full form, a sea voyage in rough weather without cargo may not be possible unless the lowest portion of the propeller is within 6 in. of the bottom of the keel line.

Scantlings.—In dealing with propeller designs, the diameter and length of the boss, the taper of the tail shaft, and particulars of the keyway should be standardised to reduce the cost of production and facilitate the trials of different propellers for testing purposes.

It will be seen that it is recommended that the diameter of the boss should be one-fifth the diameter of the propeller for solid cast-iron propellers and one-sixth for bronze or gun-metal propellers, the latter being reduced to economise the weight and cost, the length in both cases being nine-tenths of the diameter of boss. The taper in every case should be one in ten, and the keyway should be the full length of the boss.

Reversible Blade Propeller.—In cases where the vessel is required to make steerage way only for prolonged periods it is very convenient to have a propeller with adjustable blades. When only the low speed is required, the blades are adjusted by a hand wheel or lever in the engine room to give a smaller pitch. In this way the speed of the vessel and the engine power developed are decreased while the engine runs at its normal (and most economical) revolutions. After the neutral position is passed, the propeller is set for astern, while the engine continues running in the same direction of rotation as before. Hence, no reversing mechanism of any sort is required.

This form of propeller is well suited for fishing boats and auxiliary sailing vessels. In the latter case when the engine is shut off, the blades are brought fore and aft, thus causing the minimum of drag while sails alone are used.

It is not usual to adopt this device on engines above 60 B.H.P. In waters where many thick weeds are encountered, the weeds are apt to get caught and hinder the adjustment, and the engine has to be declutched or shut down while the propeller is being cleared.

The disadvantages of propellers when fitted to auxiliary vessels, and when vessels are under sail are dealt with on p. 262.

CHAPTER V

Oil *v.* **Coal.**—The question of oil *versus* coal does not, of course, only signify oil *versus* steam, because the oil fired, and partially oil-fired boiler has been adopted for marine work, more especially for warships. For any ordinary merchant vessel, however, the oil-fired boiler is a very half-hearted and uneconomical installation. It is using oil in a hopelessly spendthrift way, for all practical results show that oil engines burn a very much smaller amount of fuel than the equal powered oil-fired boiler and steam engine, as may be gathered from the following comparison of oil-fuel boilers and steam engines with Bolinder engines based on Straits Settlements Coastal Trade in normal times.

Dimensions of hull in each case.—200 ft. B.P. by 32 ft. moulded by 13 ft. mean draft, with 1,000 and 1,100 tons deadweight respectively for the steam and oil machinery.

Indicated horse power.—800 in each case.

Speed.—9½ knots.

Vessel working on an average of, say, sixteen hours per day for twelve months.

In exceptional cases an auxiliary oil-fired boiler may nevertheless be fitted with advantage, but otherwise it may be entirely dismissed from consideration, more especially as it has the further disadvantages of bulk and weight as compared with the oil engine.

The problem is thus reduced to one of the competitive claims, of some sort of oil engine or of the coal-fired boiler with a steam engine or turbine, say, 500 to 600 B.H.P. per engine for hot bulb engines or three or four times that in the case of Diesel engines. For battleships and very large merchant ships the steam turbine is likely to stand alone for some long time yet.

Bolinder Engines.	£	Oil-fired Steam Set.	£	Coal-fired Steam Set.	£
Fuel oil 0·56 lb. per B.H.P. hr., 930 tons at 40*s*. per ton	1,860	Oil fuel 1 lb. per I.H.P. hr. 2,080 tons, at 40*s*. per ton	4,160	Coal $1\frac{1}{2}$ lb. per I.H.P. hr., 3,120 tons, at 25*s*. per ton . .	3,900
Machinery staff: 3 engineers, 3 greasers, 1 electrician, say	1,150	Machinery staff: 3 engineers, 3 greasers, 3 stokers, 1 donkeyman, say . .	1,200	Machinery staff: 3 engineers, 3 greasers, 1 donkeyman, 6 stokers and trimmers, say .	1,380
No boiler, electric steering gear and winches.		Cleaning boiler . . .	120	Cleaning boiler	120
Lubricating oil, say 17 galls. per day of 16 hours. .	775	Lubricating oil, say 3 galls. per day of 16 hours .	140	Depreciation of stokehold floors and bunkers, say .	100
Saving per annum over coal-fired steam set	2,665	100 tons less cargo carried, loss per annum, say 10*s*. per ton per month . .	600	Lubricating oil, say 3 galls. per day of 16 hours . .	140
		Saving per annum over coal-fired steam set . .	230	135 tons less cargo carried, loss per annum, say 10*s*. per ton per month . . .	810
	£6,450		£6,450		£6,450
Saving per annum over oil-fired steam set . . .	£2,435				

The following is a summary of the factors which lead to the commercial superiority of the oil engine over steam plant using coal :—

(1) Reduced running fuel costs in most instances.
(2) Elimination of stand-by fuel losses.
(3) Quicker, cheaper and cleaner re-fuelling operations.
(4) Absence of the almost inhuman conditions of stoking, especially in hot zones.
(5) Reduction in crew and total wage bill.
(6) Reduction in total machinery space and weight.
(7) Largely increased radius of action for given weight or space occupied by fuel.
(8) Reduction in repair bill.
(9) Reduction in time for laying up.
(10) Greater ease of checking fuel purchased and logging the consumption during voyages.
(11) Reduced dependence of the economy of the machinery plant upon the human element.
(12) Supreme simplicity of installation as a whole.
(13) Absence of coal dust, ashes and smoke.

(1) Obviously the question of fuel economy depends on the relative market prices of coal and oil, and that again, at any particular time, varies greatly according to the part of the world in which the vessel is working.

It is true that in home waters during the time that oil began to be used for boiler firing, particularly in the Navy, the price rose a good deal above the earlier figures, mainly owing to the deficiency in oil tankers to bring to our shores the supplies required to meet the rapidly increasing demand. Previously to the war, however, the price was steadily declining, but on the outbreak of war the Navy's huge requirements caused a rise to inflated prices.

At the conclusion of the war the shipowner, in looking ahead to normal competitive conditions, will ask himself what will the future be regarding coal and oil prices, and his forecast will largely determine what machinery he will select for his vessels. Now it can hardly be doubted that coal prices will steadily increase above previous peace prices, as the years go on, because of the trend of labour conditions towards higher wages and shorter hours. On the other hand, the enormous demand for petrol is bound to keep up huge supplies of the heavier oils, and tankers will be available to bring them to our shores, from America, Russia, Persia, Burmah, the East Indies, Mexico, Galicia, and also Roumania, when the wells are again in operation.

This, as well as the discovery and operation of vast oil wells hitherto untouched, heralds a reduction in oil prices. For a rough calculation one ton of oil may be taken as equivalent to four tons of good coal and much more of such coal as is, for instance, often obtained in the East.

(2) The stand-by losses in a good many instances have a very considerable influence on the total fuel bill. The oil engine does not continue to burn fuel while standing by idle, whereas idle periods for steam vessels mean profitless waste. Hence a comparison of fuel costs calculated from consumptions under running conditions, whether favouring coal or oil, still does not give the oil engine its full credit in the relative fuel bills. In the case of tugs, salvage vessels, tenders, ferry boats, pilot boats and many other classes of vessel, the stand-by losses are enormous, a fact which many people are inclined to overlook, but it is really a big consideration.

(3) The process of fuelling an oil-engined vessel is so simple that quayside labour is practically dispensed with, and the ease, speed and cleanliness with which it is performed gives a great advantage over a coal-fired vessel. It is dirty and tedious work to bunker a steam vessel and requires a large number of men for the job. An interesting comparison is formed by the oil-fired torpedo-boat-destroyer or motor coaster coming alongside the oil quay, carrying the pipe aboard, returning it ashore and putting away to sea within an hour. In one case a man who was supposed to check the oil shipped on the various vessels, was heard complaining that a torpedo-boat had been alongside, loaded the oil and gone away again while he was at lunch.

At any quay where there is pumping plant for the purpose, one man is required to watch the tanks on board while another controls the valve ashore. It does not matter if the vessel is in the second or third berth because it only calls for an additional length of hose.

Vessels which require to load oil in places where this convenience is not yet to be had, require their own suction hose to lead from the shore tanks or barrels to a pump which has portable or permanent delivery pipes to the tanks on board. Either a little power pump is used for the purpose or, on smaller vessels, a semi-rotary hand pump.

(4) The human element will become more insistent every year. In all industries public opinion and labour opinion are bringing the betterment of working conditions to the fore, sometimes by slow evolutionary processes and sometimes in the form of labour crises and strikes. The stokehold of a ship in the tropics—and to a lesser degree in all localities—is one of the least enviable places to work in for white men, and the retention of large numbers of natives for labour on board ship is likely to cause much trouble from our own labour quarters as time goes on.

Quite apart from political forces and organised labour opposition, there can be little doubt but that in the very near future the men themselves will rather sign on for an oil-engined ship than for a steamer.

(5) The total elimination of stokers and trimmers and reduction in the engine-room staff gives a very different wages bill, as well as making the task of getting together a crew a good deal less difficult (see p. 189).

(6) A marine oil engine plant occupies a little more than half the space required by a steam plant with its boiler room and engine room, even leaving the question of bunkers out of account. This means that, say, 5 per cent. to 10 per cent. more cargo can be carried on the same size of vessel, the extra freight earned going almost entirely to increasing the profit, as the wages and fuel bills, are not increased by the carrying of this extra cargo. Alternatively, of course, a given cargo capacity can be obtained in a smaller vessel.

There are, it should in fairness be said, types of light high-speed engines with high-pressure water-tube boilers which compare favourably in weight, but they are not used in ordinary commercial vessels, coasters, etc.

Taking a hot bulb oil engine of average size, say, 120 brake horse-power, which is equal to, say, 150 indicated horse-power, the comparison would be :—

	120 B.H.P. Hot Bulb Oil Engine.	150 I.H.P. Steam Machinery with Boiler.
	Tons.	Tons.
Weight of engine and stern gear	$8\frac{1}{4}$	$19\frac{1}{2}$
Auxiliaries and fittings	$\frac{3}{4}$	$1\frac{1}{2}$
Weight tanks	$\frac{3}{4}$	—
,, of bunkers	—	1
Fuel, etc., for 100 hours	3	13
Total	$12\frac{3}{4}$	35

showing a nett saving in weight of $22\frac{1}{4}$ tons.

(7) Roughly speaking, the power obtained from one ton of fuel in an oil engine is four times that obtained from one ton of coal burnt by a steam plant, without counting stand-by losses, which still further increases the ratio. That gives a choice between two advantages :—

(*a*) The radius of action can be increased four times, saving time and expense in re-fuelling, dock dues, etc., and enabling more favourable fuel contracts to be made at ports where low prices prevail, or

(*b*) The same radius of action may be adopted as would have been the case with coal, and the reduction in fuel carried (three-quarters the weight of the bunker coal) can be utilised by increasing the cargo, thus further augmenting the increased freight receipts made possible by the lighter and less bulky machinery.

(8) The main reason for the reduction in the repair bill is the complete absence of boiler, bunkers, condenser, air

pump, etc. In the case of the oil engine there is the engine as a unit, the bilge pumps and, perhaps, a small air compressor, driven off the main engine for starting purposes, and to keep this plant in repair is relatively quite inexpensive. It is obvious, however, that an owner in fitting an untried engine or one which cannot point to records of good work and first-rate reliability, may or may not pay very dearly for its adoption. A good many firms, however, are now in a position to convince the most sceptical, as to reliability in long and arduous service.

(9) By doing away with all boiler scaling, replacement of firebars and zinc plates, boiler inspections for insurance, etc., the vessel is maintained in running condition for a considerably longer period each year, which means increased freight earnings.

(10) It is very convenient to be able to log the consumption of fuel from time to time so as to keep a good check on the vessel's performance, and with oil this is far easier than with coal. Also, it is quite easy to keep a check on the amount of fuel put on board by contract and so avoid intentional or unintentional discrepancies.

In this connection it may be noted that the greater uniformity as to the power obtainable from oil fuel again safeguards the owner, and variation in quality is more easily detected.

(11) The economic performance of a steam plant depends very appreciably on the experience of the engineer in charge and upon the experience and control of the stokers. This human factor is less important in the case of oil engines, and the engineer in charge can detect very quickly the cause of any drop in efficiency, and can soon put it right.

In general the above items apply to Diesel engines and hot bulb engines in varying degrees, though (8) and (9) would certainly apply much less to Diesel engines, and no doubt in many cases hitherto, the Diesel engine has failed in those respects.

(12) This very important advantage must be taken to apply to hot bulb engines in particular (though even the

Diesel plant may claim to be simpler than the *whole* steam plant).

The hot bulb engine might be said to be about the rock-bottom of simplicity for any complete power unit, which gives it a special scope in a wide field.

Ports in the cylinders take the place of valves and their operating gear; the fuel is taken straight from the tanks and injected into the cylinder direct in the form of a liquid jet; the engine is ready to start up within a quarter of an hour of notice being given that the vessel is required; there are no glands to require repacking; practically every part is mechanically lubricated; and above all, a conscientious man of little or no experience can soon learn to handle his engine with confidence and ease.

The disadvantages are few and not of great importance, but the following may be enumerated :—

(*a*) Paraffin blow lamps have to be lighted a quarter of an hour before the engine is ready to start.

(*b*) A flywheel has to be fitted and the floors must be arranged accordingly, though usually the flywheel diameter is kept very low (*e.g.*, about 3 ft. 3 in. for a four-cylinder engine of over 300 B.H.P.), and does not interfere with the bearers.

(*c*) The propeller revolutions are higher than in the case of steam engines of equal power and the same class which slightly decreases the propeller efficiency. For shallow draft, however, this constitutes an advantage, as a smaller propeller is used, which gives better immersion and, conse quently, better efficiency.

(*d*) The number of men who have learnt to drive hot bulb engines is not yet very great, but on the other hand it is quite remarkable how quickly even men unskilled in handling any engines at all, learn to look after hot bulb engines, to the owner's entire satisfaction. It is therefore of little moment if an experienced man is not available with this ideally simple engine, and this constitutes a very important advantage over the Diesel engine which certainly requires a specially qualified engineer on board.

Supply of Oil Fuels.—Since the time when the commercial economy of oil engines was approved and accepted fact, the question of the world's supply of oil has been a much discussed controversy. At the present time there is an enormous supply, and every year new fields are being opened up in both hemispheres. The opinion of most oil experts and geologists is that there are vast deposits untouched, and recent developments in Mexico and other parts of the world are beginning to indicate the truth of their assertions. The time may soon come when the earth's resources of oil will give rise to less apprehension than has been felt by some critics as to the industrial future of the coal supply.

Certainly it is not likely that any one now living will ever see the time when the world's oil supply begins to decrease. That being the case the present generation will witness a very large measure of transference from power derived from coal to that from oil, to the great benefit of all.

The remainder of this chapter is devoted to the oils now obtainable, but it cannot do more than touch the fringe of the subject and give intending purchasers an idea of the fuel they will require.

The fuels on the market which are suitable for hot bulb engines may be very roughly divided into three classes :—

Crude oils and residual oils.

Semi-crude oils.

Lighter and more refined petroleum products.

Crude Oils or oils as mined are practically only used for oil engines in oil-bearing districts, because it does not pay to sell crude oil as heavy fuel when it can first be made to yield the more expensive spirits such as petrol and then light oils such as common paraffin.

The crude oil as taken from the wells, to which alone should the word petroleum, strictly speaking, be applied, is subjected in the refineries to processes of distillation and when the lighter products have been taken there remains the residual oil sold for fuel for oil engines, for boilers, metallurgical furnaces, etc. Various firms sell this residual fuel under the general term "fuel oil," the specific gravity averaging 0·92.

It is no doubt quite right to say that all hot bulb engines can run on "fuel oil" on the test bench to a customer's satisfaction, but only a selected few will give satisfaction when using this fuel in service. Of these selected few, it is fairly safe to say that none but modern types, in which air is injected with the fuel, will work well without frequent cleaning out of the cylinders and silencers, without the loss of some 10 per cent. in power and without any objectionable exhaust. The latest and best types recently put on the market and having the low pressure of the hot bulb engine, but injecting air into the cylinder with the fuel do, however, run on these fuels without loss of power, with a good, practically smokeless exhaust, and the cylinders do not require the constant clearing of carbon and tarry deposit. In this way the fuel facilities of the Diesel engine are realised without the disadvantages of that engine which have rendered so many shipowners sceptical.

Semi-Crude Oils.—In this category are included the so-called "gas oils" and "solar oils" and similar qualities, the specific gravity varying from 0·84 to 0·88. This grade of oil is to be specially recommended for use in hot bulb engines, and is almost universally adopted, at any rate, for small and medium sizes in European waters.

It must not be imagined that this oil, being lighter, is dearer to any considerable degree. For some years now, there has been very little difference at all between the prices of these oils and of "fuel oils," owing to the large demand for the latter for boiler-firing, and indeed, there have been periods when "gas oils" and "solar oils" have been quoted at lower prices than the "fuel oils," even by the same company.

Lighter Petroleum Products.—For small engines such as those for yachts and other small craft which are in use for short periods during the year, and where the cost of fuel is of secondary importance, these oils are sometimes used. But they have no outstanding advantage and a distinct disadvantage in the lower flash-point, which renders them more liable to danger by fire. In out-of-the-way localities and in little-used waters it may be easy to get a drum or two of paraffin for a small boat at a moment's notice, where other oils could not be procured without delay. Then, by all means let it be used, and it is specially to be noticed that hot bulb oil engines with few exceptions require no adjustments of any sort whatever in changing from the usual oil to paraffin or other light oil of this class.

The selection of oils in the above classes, shown on p. 199, while not claiming to be anything like exhaustive may be of interest and assistance.

Ordinary commercial paraffin or the illuminating oils, such as those mentioned above, are quite suitable for hot bulb engines, usually without any adjustments being required, but being more expensive than the semi-crude oils should only be used when only very small quantities are wanted, or when the cheaper oils are not easily obtained in a particular locality.

Suitability of Oils.—The only satisfactory test of whether a particular brand of oil is suitable for use in hot bulb engines is to run the engine for some considerable time on that oil at various loads, including maximum and no load, measuring the consumption and then opening up and examining to find out whether abnormal deposits are left in the cylinder, hot bulb, ports, silencer and exhaust pipes. A couple of hours' test on the bench is not conclusive proof of satisfaction in service. Therefore, if there is any doubt, a quantity of the oil intended to be used should be sent to the engine makers to be used throughout their tests to enable them to give a sound report. A few notes may, however, be helpful.

Source of Oil.—It is safe to assert that practically any marketed oil fuel of a paraffin base, having a specific gravity between 0·8 and 0·88 will give satisfaction, but oils from an asphaltic base require thorough testing before any reliance can be placed on them. Asphaltic oils are usually very heavy, but specific gravity is not a safe guide, as any brand

Commercial Name.	Specific gravity.	Flash-point.	Remarks.
Crude Oils and Residue Oils.			
Anglo-American "Fuel Oil"	0·93	220° F.	The figures given can only be approximate, for there is no strict uniformity from one consignment to another. There is considerable variation in the impurities such as sulphur and tarry substances and pitch. Each and every hot bulb engine must not be assumed capable of using these successfully and in each case the builders should be consulted.
Pumpherston " "	0·86	224° F.	
Broxburn " "	0·84	200° F.	
Mexican crude . . .	0·95	180° F.	
California " . . .	0·91	160° F.	
Texas " . . .	0·94	—	
Borneo " . . .	0·96	—	
Tarakan " . . .	0·95	200° F.	
Trinidad " . . .	0·95	—	
Roumanian " . . .	0·90	—	
Galician " . . .	0·88	—	
Baku Residue crude . .	0·928	—	
Semi-Crude.			
Gasoleum	0·86	150° F.	This class of semi-crude oils are specially suitable for all hot bulb engines. They are almost as cheap as the residuals, and are far more uniform and more satisfactory for most of the engines.
Anglo-American "Gas Oil"	0·865	100° F.	
Pumpherston " "	0·856	220° F.	
Oakbank " "	0·84	120° F.	
Scotch shale oil .	0·83 to 0·87	—	
Russian paraffin . .	0·83	—	
Russian naphtha . .	0·88	—	
Lighter Petroleum Products.			
Russoline	0·82	84° F.	Standardised oil engine oils.
R.V.O.	0·825	86° F.	
Oil engine oil (shale) . .	0·8	99° F.	
White May . .	0·800 to 0·807	110° F. to 120° F.	Best lamp oils.
White Rose . .			
Snowflake . .			
Petrolin . . .	0·810	150° F.	Shale oils.
No. 1 paraffin . .			
Lighthouse . .			
Royal Daylight .	0·800	78° F. to 82° F.	American Standard White.
Royal Standard .			
Bear Creak . .			
Rocklight lamp . .	0·800 to 0·82	76° F. to 86° F.	Ordinary lamp oils.
Rocklight V.O. . .			
Homelight lamp .			
Homelight V.O.. .			
Crown diamond .			
Victoria . . .			
Empire . . .			
Gladiator . . .			
Bowrings V.O. . .			

containing a considerable percentage of pitch or tarry substance is likely to cause much trouble by deposits in the cylinder and gumming up the piston rings very quickly.

That certain asphaltic oils can be successfully used is indicated by the inclusion of Tarakan oil and California oil, though in such cases larger fuel pipes may be required (sometimes warmed by the exhaust gases) on the engine to allow these more viscous oils to flow freely to the fuel pump and thence to the injection nozzle. The hot bulb engined motor vessel *Aw Kwang* (see p. 292) has worked continuously in Eastern waters on a brand of Tarakan oil of specific gravity 0·95, but much trouble and annoyance will be saved if owners will consult the makers and send a few barrels of the proposed oil for practical tests where any doubt exists.

Chemical Composition.—There is very little variation in the ultimate composition of the oil fuels. They consist almost wholly of carbon and hydrogen, carbon averaging 84 per cent. and hydrogen 12 per cent. Sulphur is an impurity and should certainly not exceed 0·5 per cent., and should be considerably less in cases where water drip is used in the cylinders, as otherwise the life of the hot bulb and, possibly also the cylinder, will be reduced.

Water in the Oil.—If water is present in appreciable quantities, the engine will slow down and fail to fire properly. It is extremely unlikely that any ordinary fuel on the market would be found to have sufficient water mixed with it to do this unless gross carelessness has occurred, but in some installations a considerable amount of water has found its way to the fuel tanks, especially in heavy seas where properly guarded swan-neck vent pipes have not been fitted.

This can be confirmed as the cause of a slowing down by detaching the nozzle and spraying oil on the oily outside wall of, say, the cylinder, when the characteristic small water drops are detected. To avoid this (and also grit) the pipes from the fuel tank to the engine or filter should be taken from a position 2 ins. to 3 ins. above the bottom of the tank, as the water always settles to the bottom and can be drained off. Moreover, when a filter is fitted between the tanks and the engine there should be a drain at the bottom, and the pipes to the engine again taken from a couple of inches or so from the bottom.

Safety from Fire.—Lloyd's regulations require a flash-point not below 150° F. when determined by standard apparatus as "open flash-point." This means that a light placed over an open vessel of oil, when all the vapour conditions have settled, must not "flash" the oil, *i.e.*, ignite the vapour. Brands of semi-crude oi on the market fulfil these conditions, as, for instance, 'gasoleum,' obtained from the British Petroleum Co., while paraffin and the average illuminating oils do not nearly come up to this requirement which gives a measure of the safety of semi-crude oils since paraffin is usually regarded as a pretty reasonably safe oil, and, of course, safety is one of the points for which a paraffin engine is adopted in place of a petrol engine.

If a lighted match is thrown on the surface of a semi-crude oil such as instanced above, it does not have any effect; if the match is immersed the light will be put out, and f some is poured on a piece of wood and allowed to soak n and a match is applied, it will still not burn. These tests dispose of any fear as regards danger from fire or explosion, and it may here be remarked that the absence of a boiler eliminates one source of danger at sea.

Viscosity.—In some cases quite a suitable oil may be rather thick or viscous at the ordinary temperature in the engine room. In such cases the exhaust gases are utilised for heating the fuel pipes so as to cause an easy flow and sometimes, too, the pipes are made larger than standard for this purpose. In starting up an engine using such an oil the pipes may require heating with a lamp for a few minutes, or alternatively, the engine may be started up on a lighter oil and, when warmed up, switched on to the heavier fuel. Sometimes the oil may be made thin enough to flow satisfactorily by mixing one part of paraffin with twenty parts of the fuel.

Lubricating Oils.—The necessity of obtaining high grade lubricating oil cannot be too strongly emphasised. Generally speaking, this may be divided into two classes :—

(*a*) For lubricating the cylinder walls and gudgeon pins.

(*b*) For lubricating shaft bearings, thrust blocks, etc.

The best makes of oils for these purposes are those manufactured from selected Pennsylvania crudes, carefully fractionated, so as to get the maximum lubricating value, and refined by the most modern processes to remove bituminous and sulphurous matter.

The cylinder oil should also have an exceptionally high flash-point combined with heavy body, to ensure good lubrication in cylinders working at very high temperatures with practically no carbonisation. To attain this, the oil passes through further processes so that a good oil for cylinders (and gudgeons) costs more than the bearing oil used on other parts of the engine.

The engine oil also requires to be of good quality, due to the fact that in most engines the crank pins are enclosed, and to the fact that the engine is single acting.

It is usually wise to consult the engine makers before settling what brand should be used.

The density of lubricating oil is no indication of its lubricating properties, or its suitability for considerable temperatures.

For engines of a unit not exceeding 50 H.P. a double purpose oil to lubricate both the cylinders and the bearings can be used, the advantage being greater ease of handling. When purchasing an oil of this description care should be taken that the oil is in every way suitable for the work it has to do, especially for cylinder lubrication. It would, therefore, be necessary to have an oil superior to the ordinary bearing oil.

CHAPTER VI

Designs of Vessels.—In considering this important subject it is necessary to bear in mind that there are a number of new factors to be taken into account in connection with the adoption of the hot bulb type of machinery for the propulsion of vessels. Firstly, this type, in common with other oil engines, weighs very much less per horse-power than any of the usual forms of steam machinery, and consequently less displacement is required; in nearly all mechanically propelled vessels this affects the whole design.

Secondly, the revolutions of the engines are higher than those of steam machinery of the same power, which alters the design of the propeller and the lines aft, if the best results are to be obtained.

Thirdly, the engine room should be of different design, as although the dirty stokehold usually associated with steam machinery is dispensed with, it is very desirable to have a light and well-ventilated engine room and steel-decks and skylights above the engine. Usually safe fuels are used, but at the same time it is a wise precaution to fit as little woodwork as possible in the engine room, and to keep the oil tanks as far as possible away from the engines.

Fourthly, owing to the lighter machinery, the shaft line must be kept low so as to obtain the proper immersion of the propeller in light condition.

Motor vessels and, equally, steam vessels of all types should, therefore, in order to obtain the best results, be specially designed for the purpose for which they are required; standard designs (see p. 205, etc.), are preferable. With a view to assisting those who are considering the design of a motor-driven vessel, a number of tables of dimensions and powers of what will probably be successful vessels of various types, together with a series of plans and photographs of hot bulb engined craft which have done excellent work, and in many cases created world's records in their time, are given in the following pages. The tables are designed to give good all-round results, and are based on commercial requirements. Owners need not hesitate to build motor coasters or barges, providing they build them of normal dimensions, as indicated in the tables, and fit them with the best hot bulb marine engines, because in the event of loss of trade or of the need arising for a larger vessel, it would be possible to dispose of the old one at a reasonable figure and at a minimum depreciation.

In designing the hull of a motor vessel, the fact that the machinery space is less and the length of hold greater than the ordinary steam vessel of the same length, should not be overlooked, and provisions should accordingly be made for increasing the longtiudinal strength of the vessel in way of the hold.

For efficient and economical vessels fitted with hot bulb oil engines, the following coefficients of fineness are recommended, the draft being taken to the top of the keel :—

Ocean-going passenger vessels .	·60 to ·66
,, cargo ,, .	·73 ,, ·75
Motor coasters	·70 ,, ·72
,, barges and lighters . .	·68 ,, ·74
River passenger vessels . . .	·60 ,, ·65
Auxiliary sailing vessels . . .	·60 ,, ·64
Tugs	·50 ,, ·60
Fishing vessels	·40 ,, ·50
Yachts	·45 ,, ·50
Launches	·40 ,, ·45

It is rather surprising to find what a number of small vessels, particularly of the barge and fishing boat type, fitted with oil engines, are quite unsuitable for the purpose, generally because the models are much too full to obtain satisfactory results from the power and the propeller adopted, though the failure is usually attributed to the engines. Oil engines should not be fitted in existing hulls unless the hulls are really suitable for the purpose, otherwise more harm than good will be done to the cause of the internal combustion engine, which is now making considerable headway, and would have been in a still stronger position had it not been for failures due to causes entirely unconnected with the engines.

Standard Designs of Hulls.—It is somewhat astonishing to find that more progress in the standardisation of hulls has not been made. A few builders have confined themselves to vessels of a more or less standard type, makers of steel ship's boats have standard patterns for the hulls, and some owners have standardised their deck fittings and have the holes all drilled to one template for each pattern to facilitate fitting and renewals. Otherwise it must be admitted that shipbuilders throughout the world have made no attempt to introduce standardisation, and yet there is no reason why one owner of a barge to carry, say, 100 tons for river work should have one design and another owner of a barge of the same capacity for similar work should have an entirely different design ; it does not tend to economical construction or efficiency, it confuses working results and actual data, and hampers progress. In the near future, there will be more or less standardised hulls for almost every type of ship, ocean cargo vessels, coasting vessels, lighters, barges, fishing vessels and launches.

Taking as an example an intermediate type of ship, the sizes of motor coasters might be, say, 100, 150, 250, 400 and 600 tons deadweight, the co-efficient of fineness varying from ·70 for the small size to, say, ·72 for the large size, and having the engines aft, one large hold, and a speed of from seven to nine knots.

Again, taking a medium size single screw coaster of, say, 250 tons deadweight, the dimensions taken from the table on p. 229 would give length B.P., 110 ft., breadth moulded 21 ft., depth moulded 10 ft., draft 9 ft. 1 in. loaded, co-efficient of fineness ·71, speed $7\frac{7}{8}$ knots with a hot bulb oil engine of, say, 160 B.H.P. running at 220 revolutions per minute. The engine would be aft, there would be one large hold and hatchway, and one motor winch, all classed 100 A1 Lloyd's for coasting purposes. It seems difficult to find a reason why a handy little vessel like this should not be standardised in every respect, unless one owner desires a little more speed, another perhaps prefers a full forecastle deck or two winches, and so on, but they would probably be willing to surrender their little prejudices if they could only be brought to see the advantages of the standard ship. The sheer, frames, floors, bulkheads, hatchway and decks could all be standardised, say, to the general design given on p. 234, Fig. 194, or some other approved type, while the deck could be arranged if desired, so that two winches could be fitted, or additional accommodation provided for tropical work. The forgings, castings, and fittings would be to standard, all bollards, mooring pipes, pumps, deck and hatch cleats, etc., of the same size would be drilled to the same template ; each item of the same size should have the same number, so that when a fitting was broken it would only be necessary to quote the type of ship and the number of the fitting to obtain a new one ready to be bolted in place by the ship's crew. When additional vessels were required, the drawings, patterns and scrieves would all be ready, and probably a larger number of the fittings would be in stock.

If this standardisation were carried to its logical conclusion, all the straight plates would be to one template and, like the frames, floors, etc., might be kept in stock ready to go up in place. The ends of vessels would within reasonable limitations remain the same, but for the size immediately larger an additional length of plate could be fitted, a few more frames, floors, beams, etc., would be required and, probably, heavier keelsons and stringers to compensate for the increased length. If necessary, the additional plates and those adjoining them could be increased in thickness. See also notes and design on reinforced concrete vessels, p. 235.

The engine fittings, shafting, propellers, oil tanks, funnels, etc., could all be standardised in the same way, and the quantity and cost of spare parts considerably reduced.

The advantages of standardisation apply to the builder and the owner equally. To the builder they include reduced office and outdoor staff; smaller plant and workshops; smaller yard and fewer launching berths for a given output, because the vessels would be built more quickly, while materials bought in quantities would cost less, giving an all-round cheaper cost of construction, and in addition, a more exact knowledge of what the vessel would actually cost to build, what it would carry and what speed it could obtain after it was completed.

The advantages to the owner would be that he could see an exactly similar vessel, know exactly its speed, capacity, and cost of working; its reliability and suitability for his trade and, above all, he would obtain a useful commercial vessel at a considerable saving in cost combined with quick delivery.

It would also be in the interest of both parties to take greater pains over the design, and to give more attention to the details to ensure a thoroughly efficient job.

Arrangement of Engines and Propeller Shafts.—When it has been decided to fit hot bulb oil engines, the first question to be discussed is the number and arrangement of the propeller shafts and the number of cylinders most suitable for each engine.

For sea-going vessels of large horse-power twin or triple screws are necessary because the largest unit at present obtainable is 500 B.H.P., but for ordinary coasters, barges, lighters, yachts and launches, a single screw is preferable when an engine of the necessary power of the make decided upon can be obtained, because the total cost of installation is less than if twin screws are fitted, and a smaller engine-room staff is required.

There are exceptions; for instance, in fitting engines to existing ships, especially sailing vessels, a twin-screw installation avoids disturbing the deadwood, stern frame and rudder, and occasionally avoids disturbing the mizzen mast because the engines can be placed one on each side. For river boats, too, where sharp bends in the river have to be negotiated and for very light draft vessels where high power is required on the lightest possible draft, a twin-screw vessel has advantages.

Tunnel screw vessels are sometimes adopted for extremely light drafts, although it is impossible to go astern at any speed.

Paddle and stern wheel vessels can be conveniently driven by hot bulb oil engines, with either chain, worm or wheel gearing if this method of propulsion is preferred.

In tropical rivers both screw and paddles are liable to damage by trees and other obstacles floating in the river.

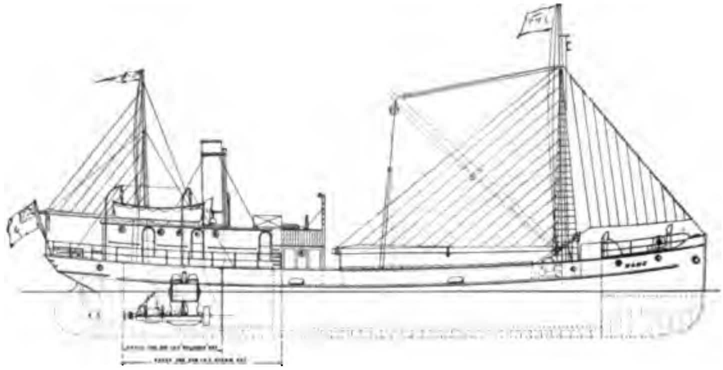


FIG. 167.—Comparison of Machinery Space for Steam and Motor Set.

In India, for instance, crocodiles often foul and damage immersed propellers. To overcome these troubles, aerial propellers have been tried, and as soon as an efficient transmission gear for driving them at high speed has been produced, more vessels of this type will be constructed.

Having settled the method of propulsion, the selection of the number of cylinders is a simple matter. For strong lighters, fishing boats, etc., single-cylinder engines can be adopted up to, say, 50 B.H.P., because the extra vibration will not be a serious matter.

For vessels with light scantlings requiring units of 30 to 150 B.H.P., two-cylinder engines will generally be satisfactory.

For vessels requiring more than 160 B.H.P. units three or four cylinders must be employed, because makers do not at present manufacture two-cylinder engines of such powers.

Saving in Machinery Space.—One of the great advantages of a hot bulb marine oil engine for small vessels is the saving in the space occupied by the oil engines compared

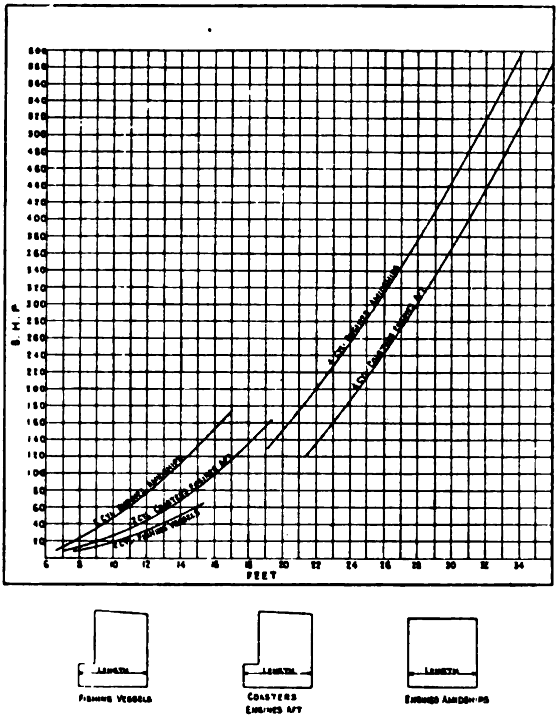


Fig. 168.—Length of Machinery Space.

with the corresponding space required for modern steam machinery of the same horse-power.

This advantage is clearly illustrated by Fig. 167, which is drawn to scale and is taken from an actual steam coaster, a hot bulb oil engine of exactly the same power being shown for the purpose of comparison. The saving of 9 ft. 9 in. in the length of the machinery space and 1,500 cubic feet in the capacity is a very considerable figure for a ship carrying

250 tons deadweight, and in this case the cubic capacity of the hold is increased by about 15 per cent. without increasing the cost. Alternatively, the same cubic capacity as that of the steam-ship could be obtained in the oil-engined vessel with a hull 12 per cent. smaller and 7 per cent. less in cost.

The diagram, Fig. 168, showing the length of machinery space required for hot bulb oil engines of different powers, will give naval architects, marine engineers and owners an idea, at a glance, of the space required to accommodate engines of various powers. In using this diagram it will be observed that the beam of the vessel has not been taken into consideration, as the sides are usually occupied by the fuel tanks, and the greater the beam the greater the capacity of the tanks that can be fitted.

Ample Power Necessary.—It is well for purchasers to remember that a motor vessel, or a steam vessel, should be overpowered rather than underpowered.

Fishermen have particularly suffered, especially a few years ago, by having engines of inadequate power fitted. The agent or traveller probably suggested as a suitable engine for a fishing vessel, say, 70 ft. long by 17 ft. 6 in. beam, one of 50 to 75 B.H.P., according to the type of engine offered, at a cost of £600 to £850, including tanks, etc., and fitted on board. The owner of the vessel, who valued his fishing boat at, perhaps, £250, usually considered the price exhorbitant and, finally, an engine of, perhaps, 25 to 30, B.H.P., costing £350 or £475 was contracted for, although the seller knew that it would probably be a disappointment if not an absolute failure. It is surely no satisfaction to say that the fisherman would not pay more, and therefore it was his fault.

In every type of vessel it is the same. Even during the boom of the Great War, September, 1915, there were a number of hot bulb oil-engined vessels for sale in spite of the fact that vessels with good engines of this type were at a premium, their unfortunate position being due to one of the causes mentioned.

There was, for instance, the case of a vessel fitted with an untried and unproved engine, which smashed up so badly that it nearly wrecked the ship and was immediately taken out, the makers stating that the trouble was due to an effort to obtain too much power out of the engine. In another case, a steel lighter 50 ft. long, constructed on economical lines, having a cargo capacity of 50 tons, was fitted with a hot bulb engine of only 15 B.H.P. and was a disappointment, whereas if the power had been 30, or even

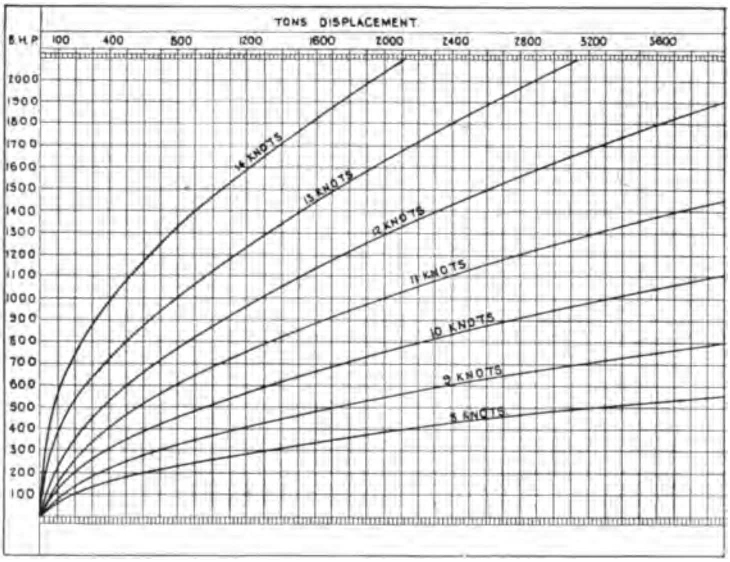


FIG. 169.—Speed and Power Curves for Passenger Vessels.

25 B.H.P., it would have been a great success, as it was quite a useful little craft.

Many such cases occurred some years ago, but they are not so likely to be repeated, and it is hoped that the dimensions and powers for good commercial vessels given in this book, will obviate such unfortunate experiences in the future. It is no use for an owner to buy a 30 B.H.P. engine, and, contrary to the maker's advice, alter the adjustment in the hope of getting 45 or 50 B.H.P. After the proper power has been selected, it is very important to get a good and reliable engine, which will really carry out the conditions required.

Economical Speed.—Motor craft like steam vessels have an economical speed at which they should be run. They should be so designed that the power required to drive them at their sea speed is developed when the engine is running at a little below its listed power.

The economical speeds recommended for various vessels are as follows :—

Vessels.	Knots.
Ocean-going vessels up to 5,000 tons .	10—12
Seagoing vessels, 700 to 2,000 tons .	9—10
Coasters up to 600 tons . . .	8— 9
River lighters and barges . . .	6— 7
Auxiliary sailing vessels above 1,000 tons .	6— 7
,, ,, ,, up to ,, ,, .	5— 6
Commercial launches	7— 9
Seagoing yachts up to 500 tons . .	10—12
Pleasure craft for enclosed waters . .	6— 8
Full powered trawlers, seagoing . .	10—12
Fishing vessels and drifters . . .	8—10
Small fishing vessels	5— 7

Power and Speed Data.—In designing vessels one of the most difficult problems to solve is that of the power actually required to obtain a given speed, and, inversely, the speed that will be obtained by fitting a given power.

To assist in the solution of this problem, power and speed curves have been prepared for vessels of various types with hot bulb oil engines (see Figs. 169 to 176). These curves are based upon vessels having the co-efficients of fineness recommended on p. 204.

For vessels having greater or lesser coefficients, the power should be slightly increased or decreased accordingly.

Shallow Draft Vessels.—The internal combustion engine may be employed to the best possible advantage in shallow draft vessels, though for fast boats of this type, hot bulb engines do not show to the same advantage as paraffin and petrol engines, except from the point of view of greater safety and fuel economy. For commercial craft, however, the hot bulb engine has manifest advantages. In the case of twin-screw tunnel boats, stern-wheelers and side paddle boats, for instance, light or loaded, the hot bulb oil engine will enable greater speeds to be obtained with the

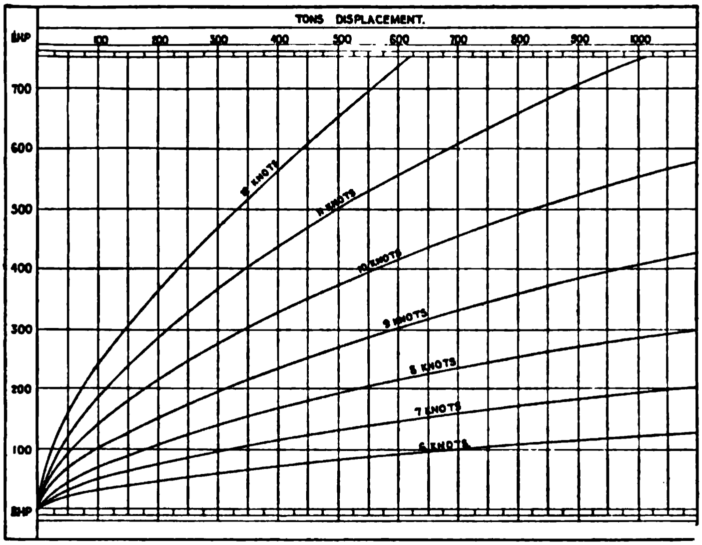


FIG. 170.—Speed and Power Curves for Motor Coasters.

same weight of machinery as compared with a steam set. In the case of tugs, the advantages are still greater because much more power can be obtained on the same draft.

For single-, twin- or even triple-screw vessels the problem of installation is simple, as the revolutions are suitable for direct coupling to the propeller. In the case of either stern or side wheel steamers, however, the revolutions are too high, so that a direct drive is impossible, and the question of transmission gearing must be satisfactorily solved before these engines will be generally adopted. Silent chains and helical gearing have most in their favour, but both of these methods have disadvantages over the direct drive of steam machinery, from a mechanical point of view, even when a large margin of safety is allowed in the gearing.

It may be asked what are the advantages of the hot bulb engine. They have been frequently quoted and are reiterated

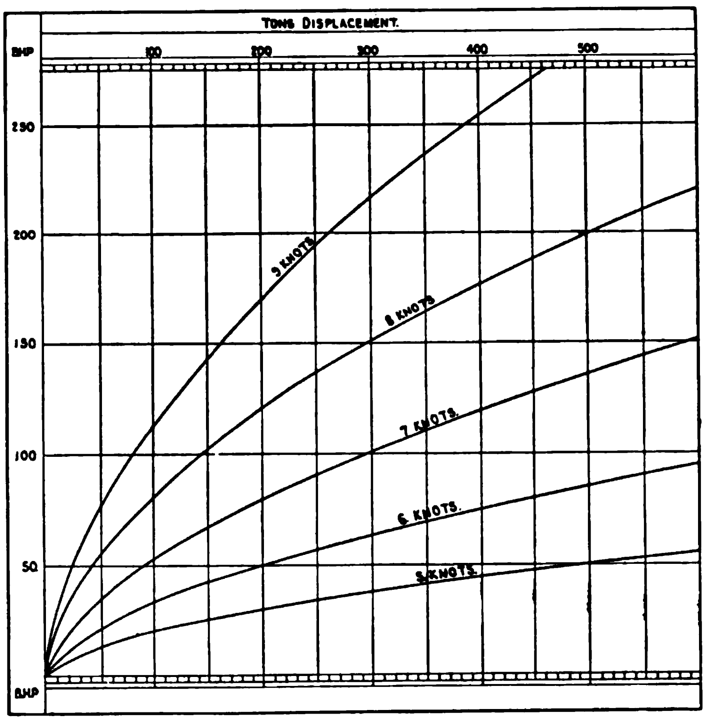


FIG. 171.—Speed and Power Curves for Motor Barges and Lighters.

in this book, viz.: lighter weight per horse-power, only one-third of the weight of fuel required to be carried per mile for the same speed, the fuel is more portable, no stoking is required, there are no sparks from the exhaust, there is no funnel, etc.

There are several important factors that are necessary to the successful future adoption of this method of propulsion for tropical use, viz.: a reliable and an efficient engine, an amply supply of crude or heavy oil, and reliable gearing where gearing is necessary; if all these can be guaranteed, it is not a very difficult matter to train natives to work the engines and obtain good results.

In spite of the fact that the screw boat has a higher degree

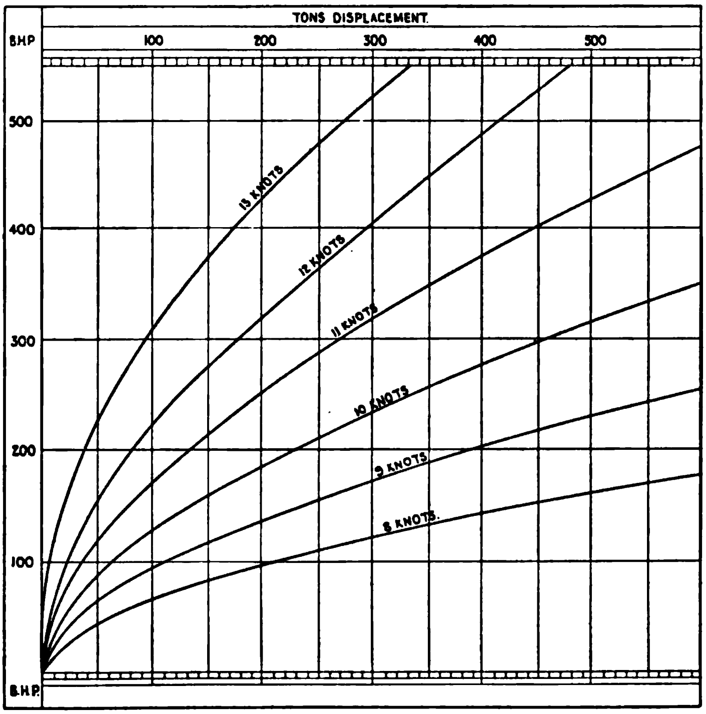


FIG. 172.—Speed and Power Curves for Yachts.

of efficiency, there are not many cases where shallow draft vessels are fitted with one or more screws in preference to the stern or side wheel, owing to the fact that the propellers either get choked with weeds, damaged on the shallows or by obstructions on the river bed, or fail to come astern quickly when the vessel is out of the proper channel and there is immediate danger ahead.

Shallow draft vessels for carrying cargo should be designed so that they can carry their maximum cargo at the greatest permissible draft in the winter, or when the river is deep, but at the same time be able to carry a smaller cargo efficiently on, say, 50 per cent. or 60 per cent. of the maximum draft, as on many tropical rivers such vessels could earn as much in the summer with, say, 50 per cent. of the

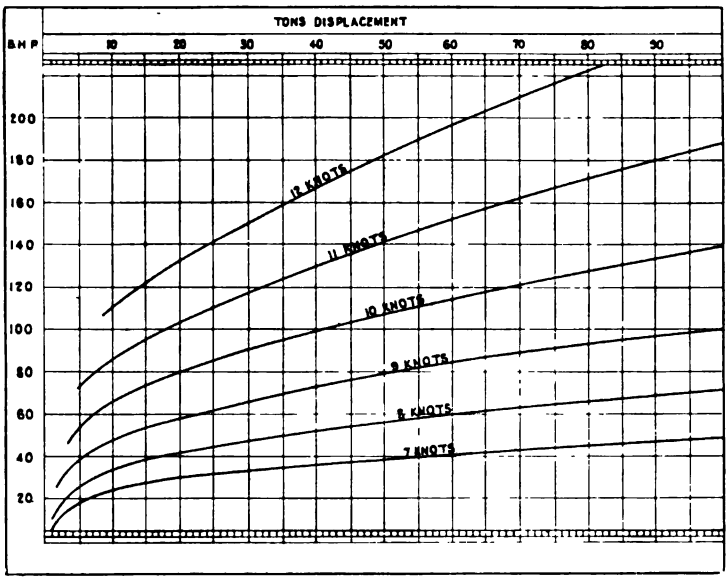


FIG. 173.—Speed and Power Curves for Launches.

maximum cargo, as in the winter, as the rate of freight in the summer is so much higher.

Although the actual propulsive efficiency of an aerial propeller cannot be so high, vessels so fitted have a distinct future for work on very shallow rivers as soon as a satisfactory transmission gear has been evolved for continuous hard work, as such a propeller, will not, as is the case with paddle or stern wheels, get damaged by the vessel getting ashore, by logs floating in the water, and, as in the Bramapootra River in India, by crocodiles.

The following table shows the advantages of the hot bulb engine over steam machinery in the case of a shallow draft vessel, length over all 100 ft., breadth moulded 20 ft., draft 2 ft., of light galvanised scantlings for tropical work.

	Steam Machinery.	Hot Bulb Oil Engine.
Speed loaded	8 miles	8 miles
H.P. of machinery	90 I.H.P.	75 B.H.P.
Weight of machinery . . .	14 tons	6 tons.
Fuel 100 miles (tons) . . .	1½ ,,	½ ton.
Cargo deadweight	25 ,,	34 tons.

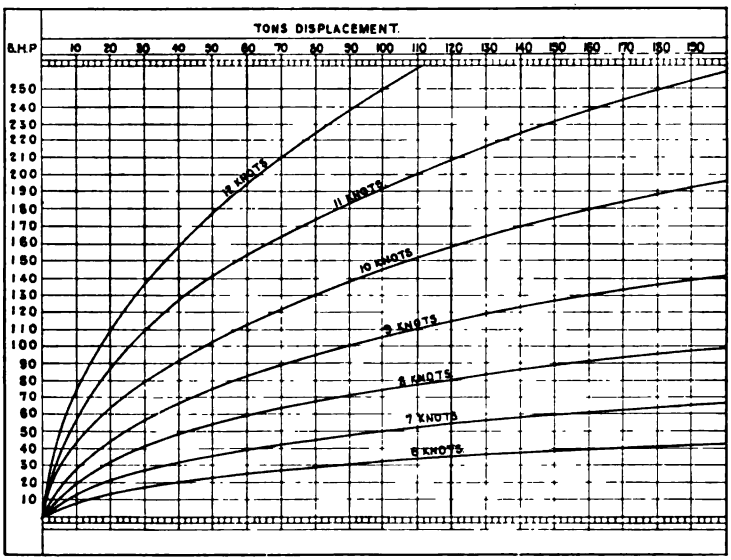


FIG. 174.—Speed and Power Curves for Fishing Vessels.

Alternatively, for the same cargo capacity on the same draft and with the same speed the hull cost and dimensions (cubed) could be reduced by 12½ per cent., and the power of the machinery by 10 per cent., or, roughly speaking, a vessel

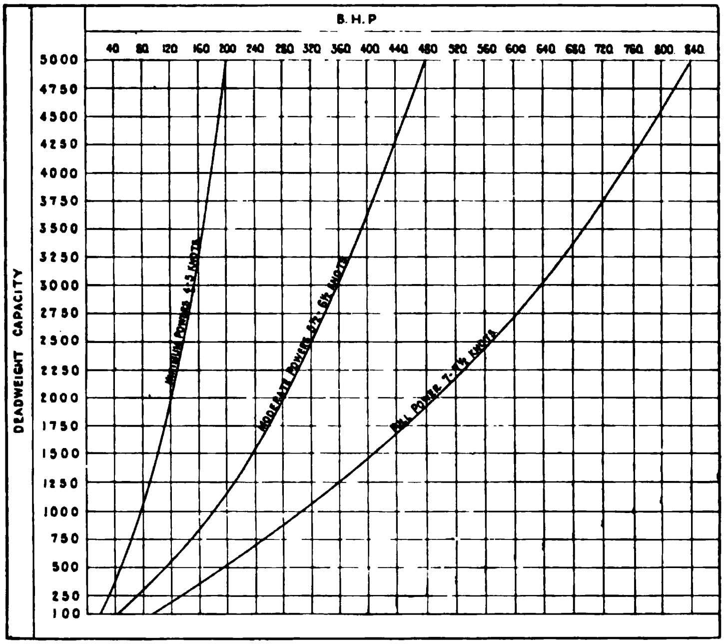


FIG. 175.—Speed and Power Curves for Auxiliary Sailing Vessels.

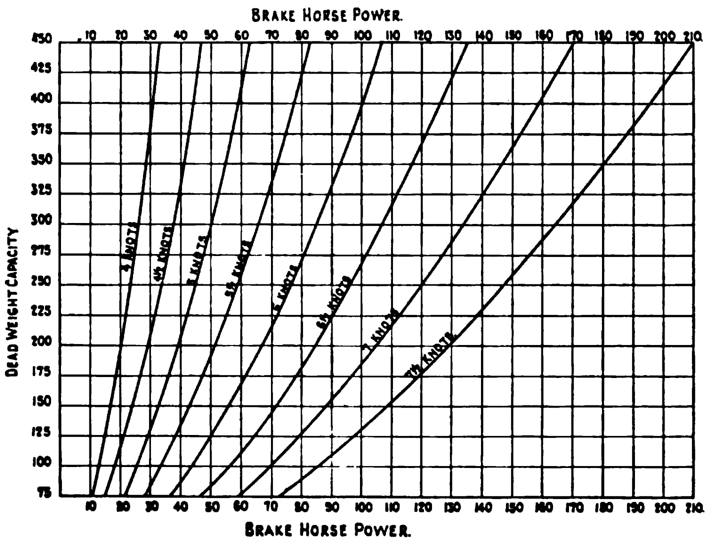


FIG. 176.—Speed and Power Curves for Auxiliary Sailing Vessels.

of, say, three-fourths the size and power would carry as much cargo and would do as much work and earn as much profit.

For illustrations of shallow draft vessels, see tropical vessels, p. 291.

Hot Bulb Engines and the Great War.—When the history of the present Great War is written, it will probably be found that the direct part played in it by the hot bulb engine is far greater than many people imagine. Details cannot be published for obvious reasons, but a few words may be said on the work accomplished by this prime mover in connection with the world's struggle.

The vital work of carrying food, provisions, etc., is at present being carried on with a large amount of help from hot bulb engines. On the canals, thousands of tons of all kinds of stores are being transported by these motor barges, while round the coast, wheat, flour, munitions of war, etc., are being carried by hot bulb-engined coasters. This work is the more important as coal is not being consumed, which means that more is available for naval and manufacturing purposes than otherwise would be the case.

Some hundreds of vessels fitted with these engines have been built for Admiralty work.

The small tank vessels have been especially useful.

Ocean Going Vessels are being fitted with hot bulb oil engines. The *Isleford*, **Fig. 177, built in 1911**, was at the time of her launch the most powerful hot bulb oil-engined vessel in the world. The following are her leading particulars :—

Length B.P.	149 ft. 0 in.
Breadth moulded	25 „ 6 „
Depth moulded	11 „ 0 „
Draft	10 „ 3 „
Deadweight	460 tons
B.H P.	320 „
Mean speed on trial	9 knots.
Consumption of fuel per 24 hours	1·707 tons.

One advantage obtained by fitting the oil engine in this vessel was that her hatchway was made 53 ft. long by 14 ft.

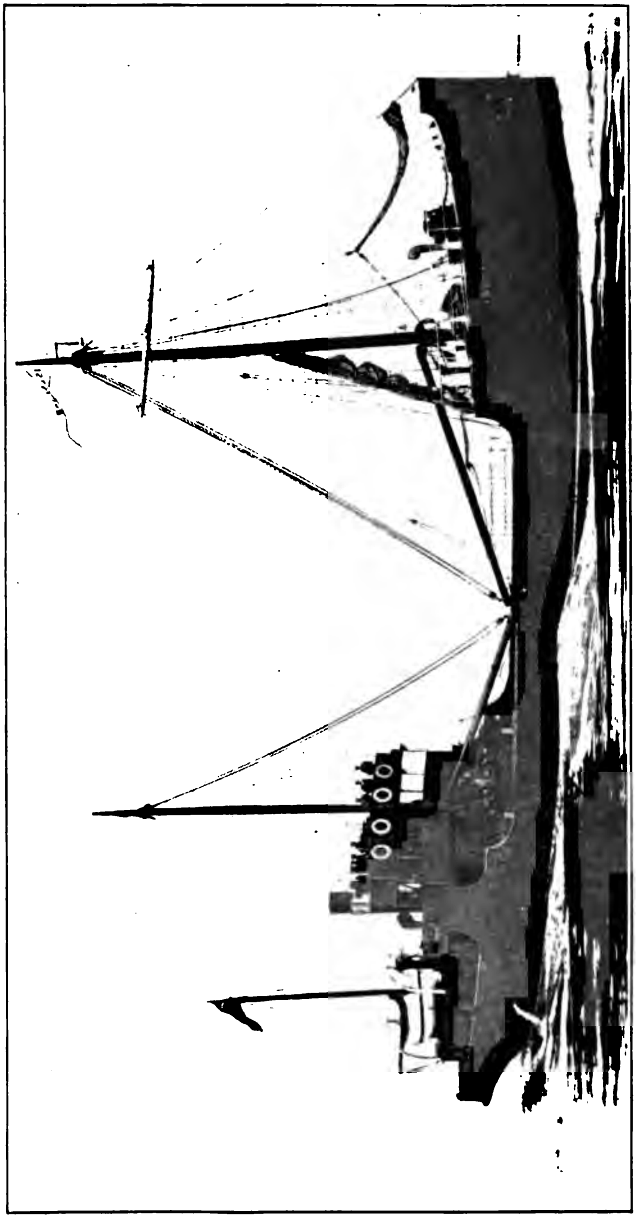


FIG. 177.—Motor Ship *Isleford*, 320 B.H.P. Bolinder.

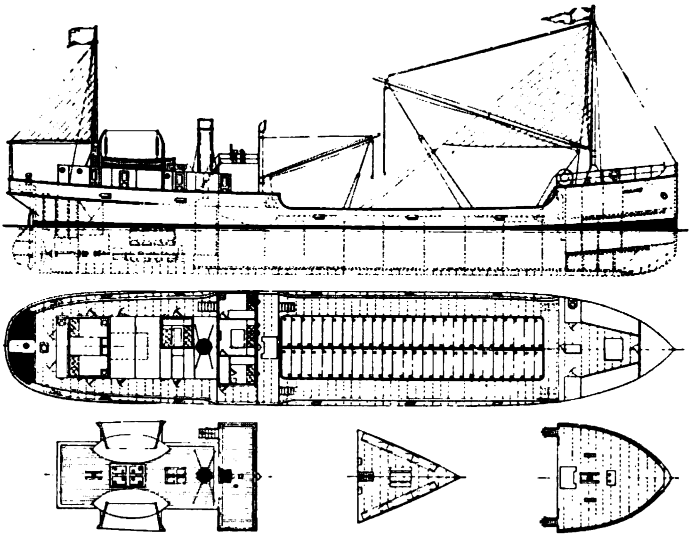


FIG. 178.—Motor Ship *Isleford*.

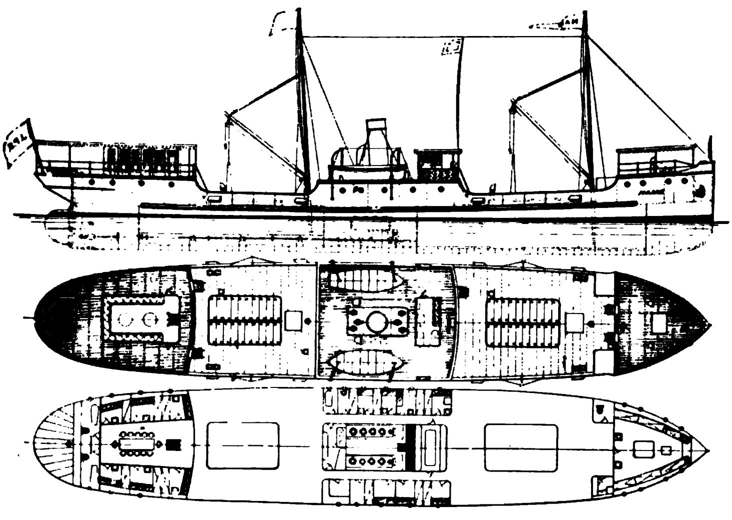


FIG. 179.—Design for Cargo and Passenger Service.

wide, and without any interruption in the way of permanent beams. A few weeks after completion she was purchased by the British Government.

One disadvantage in this vessel was that the oil-fired donkey boiler for driving the windlass, steering gear, etc., was fitted in the engine room, which was thus quite spoilt by the dirt. It is a pity that a separate boiler room was not provided, or electricity or independent oil engines used to drive the auxiliaries.

Much larger vessels have since been built, for instance, the 5,000 ton oil tanker *Bramwell Point*, etc., described on p. 244.

Other ocean-going vessels illustrated are the tanker *Gallia*, p. 245, and the yacht *Belem*, p. 306.

In the following table the particulars of a number of useful vessels are given :—

Ref.	Length B.P.		Breath.		Depth mld.		Draft.		Cargo d.w. tons.	Engines B.H.P.	Speed loaded knots.
	ft.	ins.	ft.	ins.	ft.	ins.	ft.	ins.			
173	150	0	25	6	11	0	10	3	460	320	9
174	160	0	27	0	11	3	10	6	600	320	8½
175	165	0	28	6	12	0	11	0	700	480	9¼
176	170	0	29	5	13	6	12	6	800	480	9
177	175	0	30	6	14	0	13	0	1,000	480	8¾
178	180	0	31	6	15	9	14	6	1,200	640	9½
179	185	0	32	6	16	6	15	3	1,400	640	9¼
180	190	0	33	6	17	6	16	3	1,700	640	9
181	215	0	3	0	20	0	18	3	2,200	1,150	9¾
182	235	0	36	0	22	0	20	0	2,500	1,150	9½
183	260	0	40	0	23	0	20	9	3,250	1,400	10¼
184	310	0	46	0	24	9	21	6	4,500	1,750	10½

Ocean-going Vessels.

Motor Coasters.—There are probably more motor coasters than any other type of commercial vessel, other than fishing boats, fitted with hot bulb oil engines, and the great demand for the future will lie in this direction.

It is somewhat difficult to define the difference between ocean-going vessels, motor coasters and motor barges, because some small vessels of 60 tons have performed ocean journeys, and some vessels of 1,000 tons displacement and more are used for river purposes only.

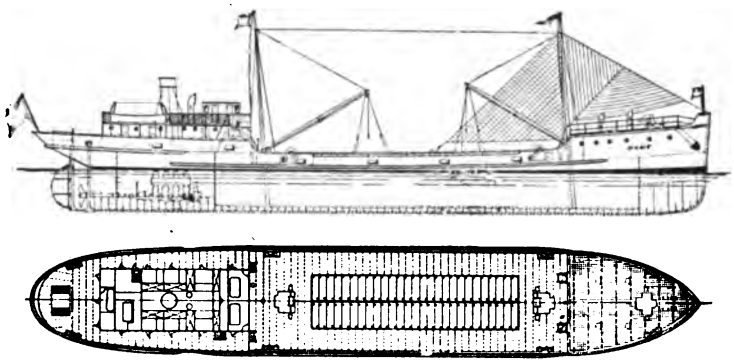


FIG. 180.—Design for Fast Cargo Vessel.

The *Innisshannon*, Fig. 181, length 115 ft. 7 in., breadth 21 ft. 6 in., depth 9 ft. 6 in., is a typical Clyde motor coaster; she carries 370 tons of cargo, and is fitted with a Beardmore oil engine of 250 B.H.P. of the direct reversible type.

FIG. 181.—*Innisshannon.*

The *Travers*, Fig. 182, built in 1910, length B.P. 70 ft., breadth 16 ft., depth 7 ft., draft 5 ft. with 63 tons of cargo on board was fitted with a 50 B.H.P. Bolinder engine to demonstrate the hot bulb principle. The total length of the machinery space, including cabin from the rudder post, was 19 ft. 6 in., the hold capacity including hatchway, being 3,800 cubic feet.

This little vessel was carried out to Havana on a ship's deck, was placed in the water, and with a crew of five men all told, proceeded under her own power to Trinidad, and created a record by making the voyage of 1,850 miles in 23 days, through gales of wind and high seas most of the time.

FIG. 182.—The *Travers.*

The Captain wiote:—

" During the voyage the engine has at all times kept running at a regular speed, not the same as a steam engine running at a gallop when the vessel is pitching and nearly stopping when the stern goes down into the water.

" I used to laugh at the idea of a motor in a seaway, but now I am convinced that a motor, if looked after, is quite as safe, and, if anything, better than a steam engine."

The *Salifus Sultan,* Fig. 183, is a handy type of cargo vessel 62 ft. 6 in. × 14 ft. 10 in., × 6 ft., fitted with two 20 B.H.P. Kromhout engines, deadweight capacity 30 tons, speed 7 knots.

The motor coaster *Ogarita,* Figs. 184 and 185, and fitted with a hot bulb oil engine of 120 B.H.P., was built of steel in 1911, and had the following dimensions :—

	ft.	in.
Length O.A.	92	6
„ B.P.	88	0
Breadth	19	0
Depth	7	8

FIG. 183.—*Salifus Sultan.*

FIG. 184.—*Ogarita.*

After eighteen months' working the engine was found in excellent condition, and she was purchased by a Liverpool firm. The vessel proved so satisfactory that the owners have purchased a number of hot bulb engines, and at the

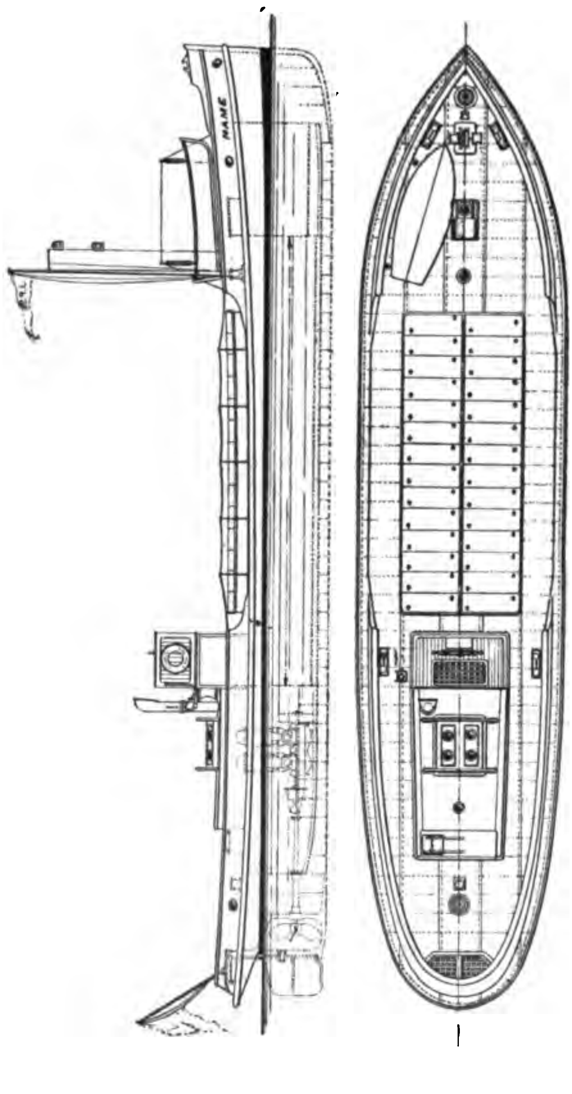


Fig. 185.—*Ogarita.*

present time have a fleet of seven vessels. An illustration of this vessel towing is given on p. 253.

The *Lingueta*, Figs. 186 and 187, length B.P. 61 ft., breadth 15 ft. 6 in., draft 5 ft. 7 in., built of wood and fitted with a Bolinder engine of only 30 B.H.P., was navigated from England to Pernambuco, Brazil, a distance of over 4,500 miles in the depth of winter, 1912, the trip taking thirty-five days.

It is surely an astonishing feat for a vessel of the length of a railway carriage and the power of a motor car, to make

FIG. 186.—*Lingueta*.

such a trip in the depth of winter without a convoy or any assistance.

The *Sir William*, Fig. 188, was designed for Liverpool work, and carries a deadweight of nearly 275 tons general cargo, and 240 tons of wheat, and is able to do this without trimming, owing to the fact that the total hold and hatch capacity is 11,000 cubic feet, which in a power vessel having a length of only 98 ft. would not have been possible unless oil engines were adopted. A steam vessel, to have the same special features, would require to be at least 10 ft. longer.

The Miller, Figs. 189 and 190, is another useful type of vessel which has been working in the Thames district since 1913.

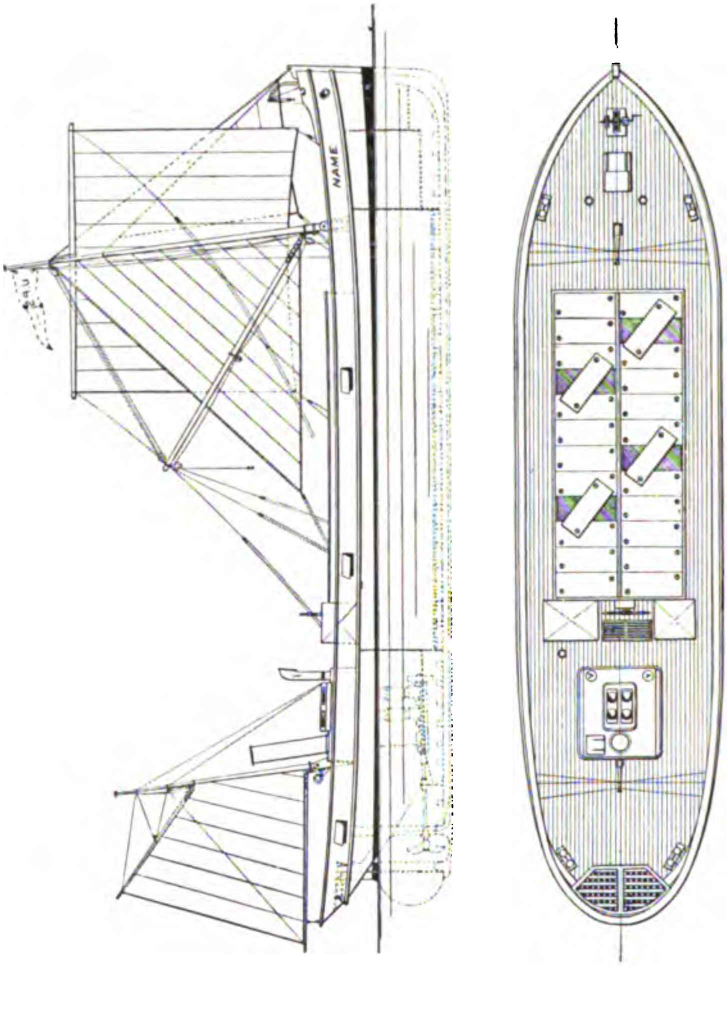


FIG. 187.—*Lingueta.*

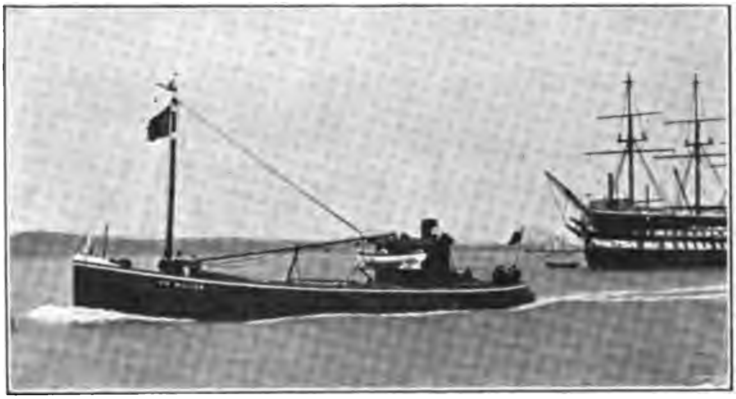


FIG. 188.—*Sir William.*

The following suggested dimensions for hot bulb oil-engined motor coasters may be found useful :—

Ref. No.	Length B.P.		Breadth mld.		Depth mld.		Draft loaded.		Cargo Tons on Draft Given.	Cargo Tons per inch.	Speed, knots		Oil Engine B.H.P.
	ft.	ins.	ft.	ins.	ft.	ins.	ft.	ins.			Light.	Loaded.	
195	85	0	18	6	9	9	8	10	160	3·0	$9\frac{1}{4}$	8	120
196	90	0	19	0	10	0	9	1	180	3·3	9	$7\frac{3}{4}$	120
197	95	0	19	6	10	0	9	1	195	3·6	$8\frac{3}{4}$	$7\frac{1}{2}$	120
198	100	0	20	0	10	0	9	1	210	3·9	$8\frac{1}{4}$	$7\frac{1}{4}$	120
199	105	0	20	6	10	0	9	1	230	4·1	$9\frac{1}{4}$	8	160
200	110	0	21	0	10	0	9	1	250	4·5	$9\frac{1}{8}$	$7\frac{7}{8}$	160
201	115	0	21	6	10	0	9	1	270	4·9	9	$7\frac{3}{4}$	160
202	120	0	22	0	10	3	9	4	295	5·2	10	$8\frac{3}{4}$	240
203	125	0	22	6	10	3	9	4	335	5·6	10	$8\frac{1}{2}$	240
204	130	0	23	0	10	6	9	6	390	6·0	10	9	320
205	149	0	25	6	11	0	10	3	460	7·5	$10\frac{1}{2}$	9	320

Motor Coasters.

For the smaller size vessels less power can be fitted if the craft are for river and harbour work.

The *Lindores*, Fig. 191, is a steel coaster, 82 ft. × 17 ft. 6 in. × 8 ft., built in 1913, and fitted with an 80 B.H.P. Bolinder

FIG. 189.—*The Miller.*

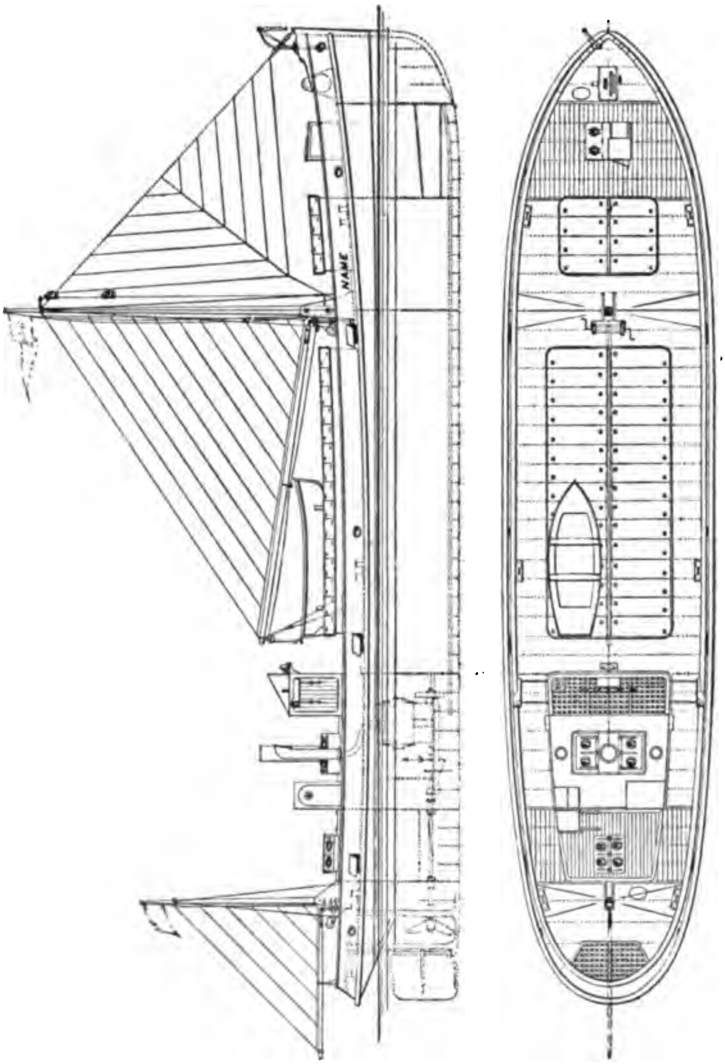


FIG. 190.—*The Miller.*

engine; immediately after the official trial she started on an Atlantic voyage and completed a non-stop run to Pernambuco, a distance of 4,500 miles in thirty-seven days.

FIG. 191.—*Lindores.*

FIG. 192.—*Innisagra.*

Whilst in the Bay of Biscay the mainmast was broken off near the deck, but the passage was continued without the assistance of any of the sails and without stopping for repairs.

The *Innisagra*, Figs. 192 and 193, is another type of motor coaster used especially in Scotland, and is really the shortest possible vessel for the deadweight carried, namely, 140 tons with a gross register of only 95 tons; a steam vessel of the same cargo capacity would register 120 tons.

The *Leelee*, Fig. 194, is a type of coaster of which a number have recently been constructed, and is specially suitable for

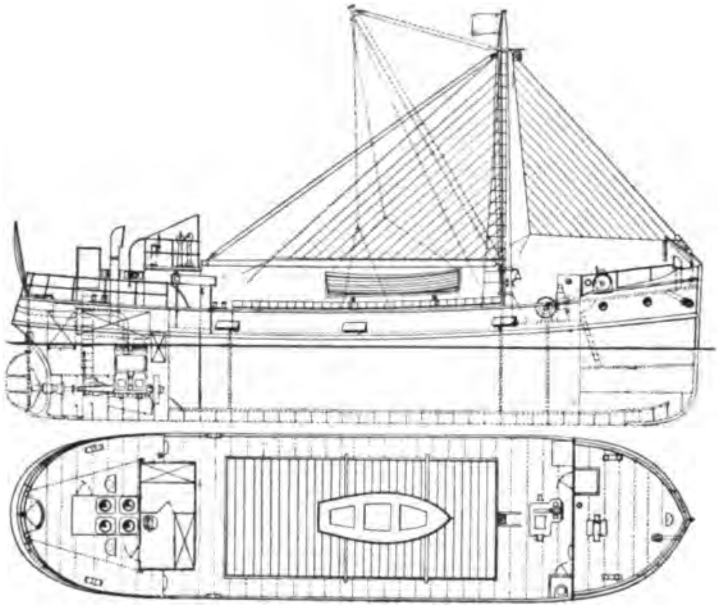


FIG. 193.—*Innisagra.*

coastwise work, while being at the same time adaptable for river and still water conditions.

A still larger and more sea-going type of vessel is the *Lutona*, Figs. 195 and 196, a type that is suitable for almost any part of the world and which will no doubt prove to be more economical than any other type of vessel of the same size and power.

The *Mary Birch*, Fig. 197, is another interesting type of modern coaster, fitted with a Kromhout engine of 180 B.H.P., her speed loaded with 250 tons being $7\frac{3}{4}$ knots.

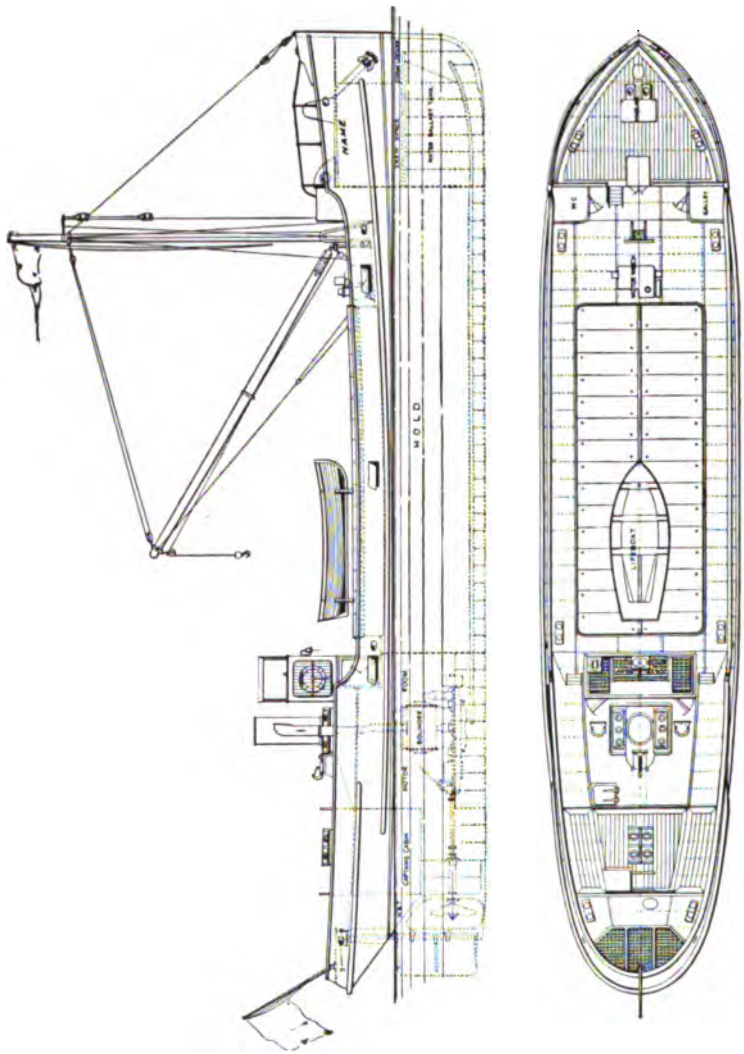


FIG. 194.—Design of Motor Coaster.

The motor ship *Ada*, Fig. 198, 261 ft. × 40 ft. 6 in. × 23 ft., with a deadweight capacity of 3,000 tons, is fitted with two sets of 320 B.H.P. Bolinder engines.

The *Santa Elena*, Fig. 199, is one of five wooden vessels, 225 ft. × 42 ft. 6 in. × 15 ft., and is fitted with two sets of 320 B.H.P. engines, the speed being said to be 8 knots.

Reinforced Concrete Vessels.—Hot bulb engines are specially suitable for reinforced concrete vessels owing to the

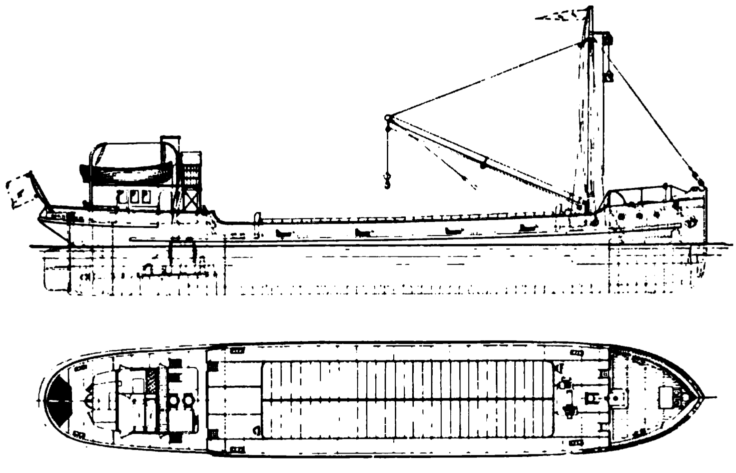


FIG. 195.—Design for Motor Coaster.

great reduction in the weight of machinery, which partially compensates for the increased weight of a concrete hull.

This subject, which is interesting enough in normal times, is of special interest in war time. Beyond one notable instance, a reinforced concrete lighter completed for use on the Manchester Ship Canal in 1911, very little was done in this country to further this type of construction prior to the war, though it had received more consideration in France, Germany, Norway, Sweden, Denmark and America. In 1918 and subsequent years it is probable that numbers of these vessels will be built in England and in all parts of the world.

The time is not ripe for a definite pronouncement as to the relative advantages and disadvantages of this type of construction, but the following are the results of study and experience :—

Advantages.

(1) Quicker construction.

(2) Cheaper construction owing largely to the reduction

FIG. 196.—*Lutona.*

in the time and the number of skilled men required, since platers, anglesmiths, and riveters are unnecessary. This applies even to a first vessel, but much more strongly when a number of vessels are built to a standard model, so that the same shuttering can be used each time.

(3) The practical elimination of maintenance charges, since concrete improves with age, and chipping and painting are unnecessary.

(4) The fire-resisting capacity and absence of corrosion or decay as in steel or wooden vessels.

Fig. 197.—*Mary Birch.*

(5) The great facility of repair work. Concrete has been used for some time for the repairs of steel hulls.

Fig. 198.—Motor Ship *Ada.*

(6) The great reduction in the amount of steel required. In many cases the steel used in a concrete vessel of 300 tons deadweight would be about 31 tons, or a reduction of 70 per cent. of that required for a vessel of the same capacity built of steel. This

point is most insistent for war time when economy in steel is imperative.

Disadvantages.—The one great fundamental disadvantage is the increased weight compared with that of a steel hull of

FIG. 199.—Motor Ship *Santa Elena.*

equal size, which amounts to practically 100 per cent. in the case of a vessel of 500 tons carrying capacity. This, however, adds, roughly, only 25 per cent. to the total displacement or 8 per cent. to each linear overall dimension. In other

FIG. 200.—The *Namsenfjord.*

words, a coaster of normal dimensions built of steel to carry 400 tons deadweight cargo would, if built of reinforced concrete to the same dimensions, carry 300 tons deadweight, but would give almost the same cubic capacity. It is to be noted in this connection that it is only the weight of cargo carried which is diminished for a ship of a given size, and that the cubic capacity is not decreased, so that for light goods (even north country coal), the cargo is not decreased at all. As an illustration, a 300-ton deadweight coaster of steel and ordinary design will only carry 260 tons of north country coal, but a 300-ton deadweight reinforced concrete vessel will carry 300 tons of similar coal.

FIG. 201.—The *Namsenfjord.*

The *Namsenfjord* (Figs. 200 and 201), length 84 ft., breadth 20 ft., depth 11 ft. 6 in., with a cargo carrying capacity of 200 tons, built in 1917 by Mr. Fougner at Moss, Norway, is probably the first full-powered seagoing reinforced concrete vessel. She was fitted with an 80 B.H.P. Bolinder engine, a speed of about 7 knots being obtained.

A straight-lined vessel of a new design was introduced by the author in July, 1917 (see Fig. 203); it is a reinforced concrete auxiliary coaster, dimensions 125 ft. × 25 ft. × 11 ft. 9 in., and a coefficient of 0·72, which will carry 300 tons of cargo on 10 ft. draft. Curved work is dispensed with in connection with the reinforced concrete, the vertical sections consisting of a series of straight lines; this reduces

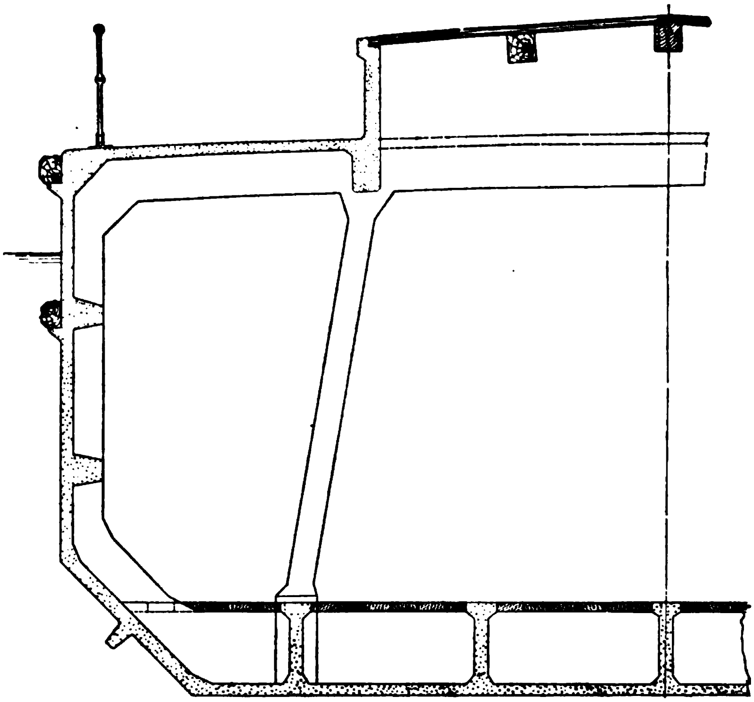


FIG. 202.—Section of Pollock's Reinforced Concrete Coaster.

the cost of construction, and makes it easier to keep the steel rods for reinforcement in their correct position. Horizontally the straight lines have the corners rounded off.

Reinforced concrete construction is also specially suitable for tugs and lighters.

Motor Lighters and Barges.—It is sometimes difficult to distinguish between a coaster, lighter and a barge, so that some vessels that might have appeared under this heading will be found in other sections of this chapter.

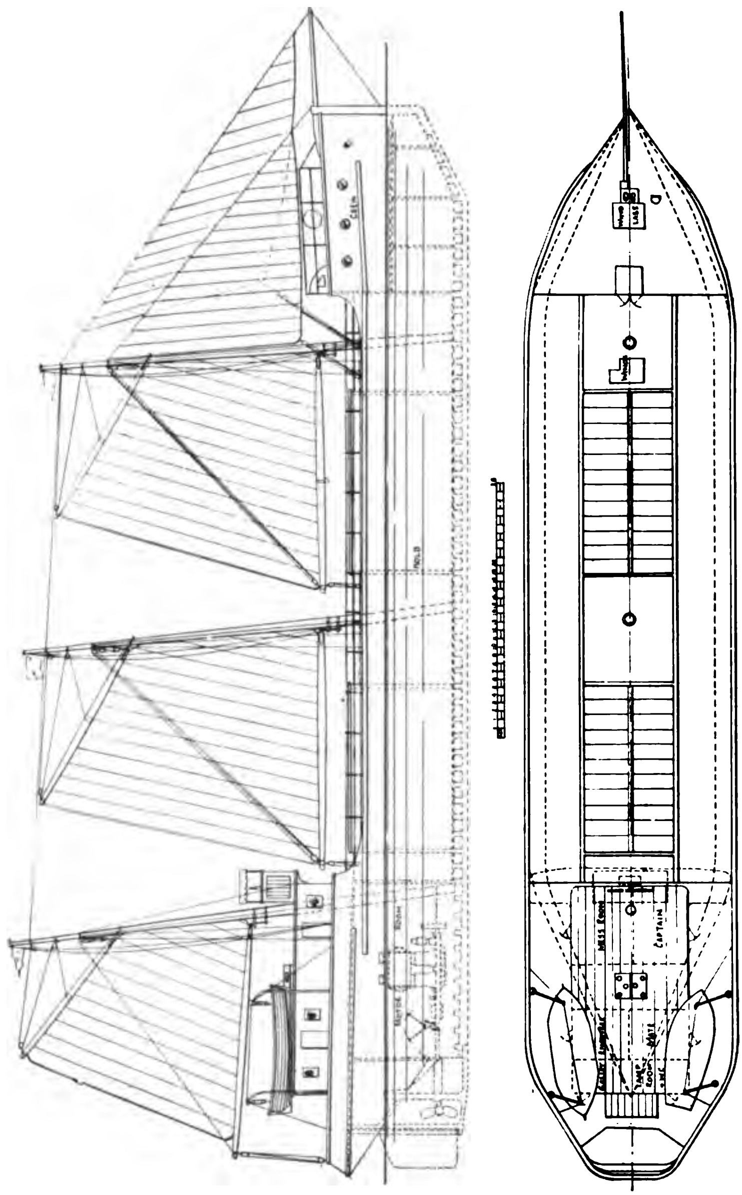


FIG. 203.—Pollock's Improved Design of Reinforced Concrete Auxiliary Coaster.

The *Baltic*, a Swedish vessel, length 227 ft., breadth 40 ft., depth 15 ft., originally had steam engines, but these were removed and two Bolinder engines fitted, each of 240 B.H.P. A boiler is, however, still fitted for supplying steam to their original steam winches, which have been retained. The cargo capacity is 2,000 tons.

The river lighter illustrated in Fig. 204 is part of a fleet built to work on the Danube. Steam power would not have been practical in this instance, owing to the restricted draft.

The *Tommy Atkins*, length 61 ft., breadth 15 ft. 6 in., is a somewhat new type of lighter for Thames work, and is

FIG. 204.—*Uebigau*, fitted with two 120 B.H.P. Motors.

designed to carry fifty tons of cable on large drums and at the same time to tow, when necessary, one or two swim barges. An 80 B.H.P. Bolinder engine is fitted for the dual purpose.

The *Eliza Holt*, 75 ft. × 17 ft. 6 in. × 7 ft. 9 in., carrying 120 tons and fitted with a 65 H.P. oil engine, working on the Thames, made on an average three round trips per week between London Bridge and the Albert Dock, with 100 to 110 tons of cargo on board, and sometimes towing one or two swim barges as well. The fuel oil used only cost 9*s*. per week (during 1915), a result that is very remarkable, and a convincing proof of the economy of hot bulb oil engines. Many vessels of this type are working with a captain, a mate and a boy, the mate driving the oil engine, so that an engineer is dispensed with.

The *Rose Macrone*, illustrated in Fig. 205, is of the dimensions given under reference No. 224, below. A number of

FIG. 205.—*Rose Macrone.*

lighters of this type with hot bulb oil engines have been working successfully for several years in England, Ireland, and elsewhere.

Ref. No.	Length B.P.		Breadth mld.		Depth mld.		Draft loaded.		Cargo Tons on Draft Given.	Cargo Tons per inch.	Oil Engine. B.H.P.	Speed, Knots. Light.	Speed, Knots. Loaded.
	ft.	ins.	ft.	ins.	ft.	ins.	ft.	ins.					
221	45	0	10	6	5	0	4	3	20	·8	40	9	$7\frac{1}{2}$
222	50	0	11	6	5	3	4	6	28	1·0	50	$8\frac{3}{4}$	$7\frac{1}{4}$
223	55	0	12	6	5	6	4	9	36	1·2	50	9	$7\frac{1}{2}$
224	60	0	12	6	5	6	4	6	45	1·3	25	7	6
225	60	0	13	6	6	0	5	3	52	1·4	50	$8\frac{1}{2}$	7
226	65	0	14	9	6	6	5	9	68	1·7	60	$8\frac{1}{2}$	$7\frac{1}{4}$
227	70	0	16	0	7	0	6	2	90	2·0	60	$8\frac{1}{4}$	7
228	75	0	17	0	7	6	6	8	110	2·3	80	$8\frac{1}{2}$	$7\frac{1}{4}$
229	80	0	18	0	8	0	7	2	135	2·6	80	$8\frac{1}{4}$	7
230	85	0	18	9	8	6	7	6	160	2·9	80	8	$6\frac{3}{4}$
231	90	0	19	6	9	0	8	0	185	3·1	120	9	$7\frac{1}{2}$
232	95	0	20	3	9	9	8	9	230	3·4	120	$8\frac{3}{4}$	$7\frac{1}{4}$
233	100	0	21	0	10	6	9	6	270	3·7	120	$8\frac{1}{2}$	7
234	105	0	21	6	11	0	9	9	310	4·0	120	$8\frac{1}{4}$	$6\frac{3}{4}$
235	110	0	22	0	11	3	10	0	340	4·3	160	9	$7\frac{3}{4}$

DIMENSIONS OF USEFUL MOTOR BARGES AND LIGHTERS.

Oil Tankers.—Oil tankers are ideal vessels for fitting with hot bulb oil engines, and those that have been built up to the present time have been very successful. The largest of these,

FIG. 206.—*Bramell Point.*

the *Bramell Point,* and three sister ships, Figs. 206 and 207, were built in America, dimensions 306 ft. × 47 ft. × 28 ft., carrying 5,000 tons of cargo and bunker fuel on 22 ft. 8 in. draft. Each boat is fitted with three sets of four-cylinder

FIG. 207.—Propellers of *Bramell Point.*

Bolinder engines of 500 B.H.P., giving a total on the three screws of 1,500 B.H.P. or corresponding to over 2,000 I.H.P. of steam machinery. There are thirteen separate tanks for the 4,500 tons of cargo. The speed is said to be 10½ knots

FIG. 208.—Oil Tanker *Gallia.*

loaded. An oil-fired steam boiler is fitted for winches and auxiliaries.

The *Gallia*, Figs. 208 and 209, 190 ft. × 33 ft. 6 in., carrying 1,185 tons deadweight on 15 ft. draft, is another interesting

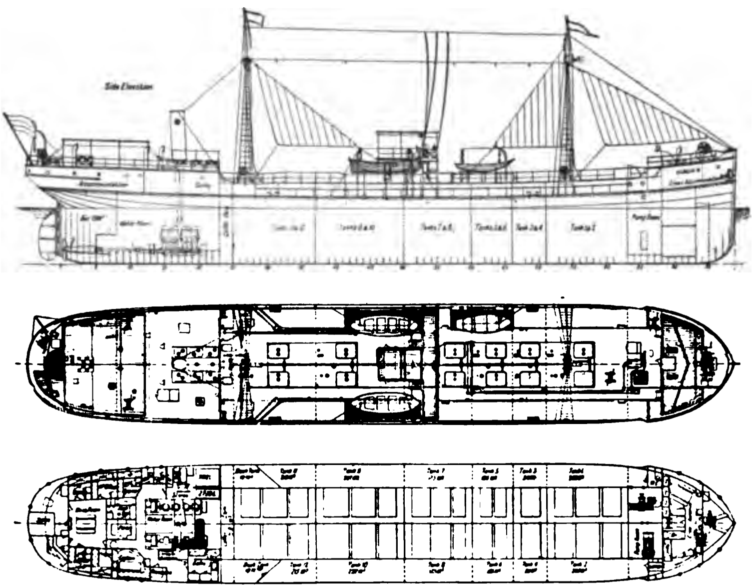


FIG. 209.—Oil Tanker *Gallia.*

tanker which was built in 1914. This boat was the first tanker to have hot bulb oil engines of 640 B.H.P., and these gave her a loaded speed of 9 knots.

The *Drente*, Fig. 210, was an ocean-going towing lighter, 214 ft. × 40 ft. × 14 ft. 3 in., and after some years' service was fitted with two sets 320 B.H.P. Bolinder engines, giving a speed of about 8 knots with 1,500 tons of cargo.

The *Hera*, Fig. 211, is an oil tanker carrying 450 tons of oil or spirit, length 163 ft., breadth 28·5 ft., depth 12 ft. 4 in., with a draft of 11 ft. The machinery consists of two sets of 275 B.H.P. Kromhout engines, illustrated on p. 53.

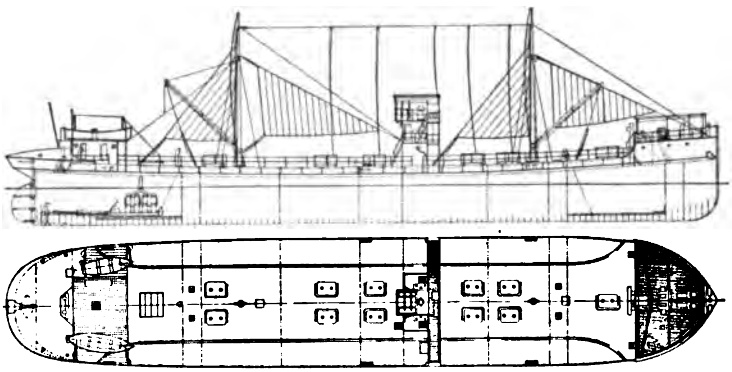


FIG. 210.—*Drente.*

A 12 H.P. Kromhout auxiliary set, Fig. 358, p. 402, supplies electric light and compressed air for the main engines. An oil-fired donkey boiler is fitted to supply steam to the deck winches, to the pump to discharge the fuel cargo, and for the radiators in the cabins.

The *Ialine*, Fig. 212, 105 ft. × 22 ft. × 9 ft. 3 in., carrying 210 tons on 8 ft. 2 in. draft, is a twin-screw vessel fitted with two sets of 120 B.H.P. Bolinder engines. She was specially built with three tanks, so arranged that two tanks filled with tar or other heavy liquid loaded the vessel down, while the three tanks could be filled when a light oil was used.

The *Nitrogen*, 79 ft. × 17 ft. × 7 ft. 2 in., built in 1911,

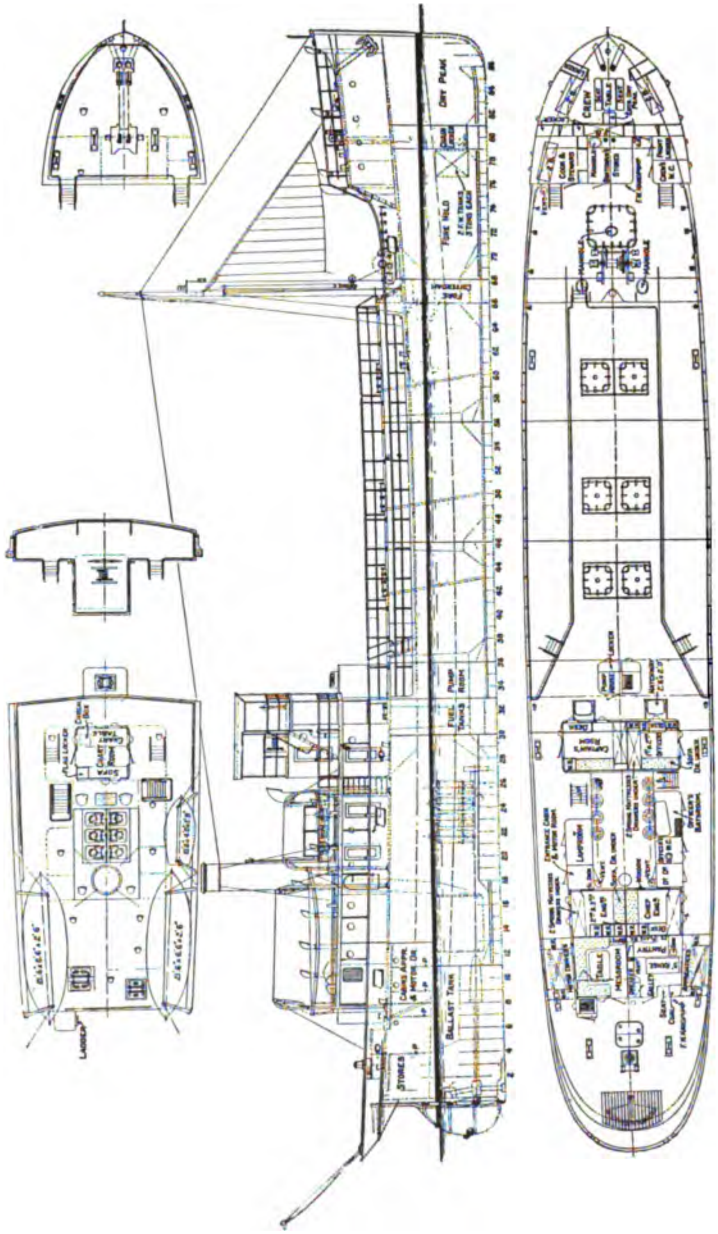


FIG. 211.—Oil Tanker *Hera*.

has always been worked entirely in charge of the captain, with a small crew, and without an engineer, and although only fitted with an 80 B.H.P. engine, the towing of a vessel larger than herself is part of her regular work.

Tugs.—It was a fairly general opinion some thirty years ago that the only way to propel a tug really satisfactorily was by means of paddle engines. This opinion has been completely upset by the progress made in the practical development of screw propellers, and in the design of sterns

FIG. 212.—Oil Tanker *Ialine.*

most suitable to their use, and indeed very few paddle tugs have been constructed during the last twenty years. Until quite recently slow-speed steam engines had the monopoly, but tugs fitted with hot bulb oil engines have, in a small way, proved their towing power, and the remarkable fuel economy has made them already a serious competitor. If, in addition to this reduction in running costs, the steam-tug owner can be shown that he can get the same power and manœuvring ability with a smaller oil engined vessel (or conversely, more power and reduced running costs with the same size of vessel) he cannot fail to become interested.

The keen competition in tug work demands strict attention to running costs, and the heavy oil engine not only scores in fuel cost while running, but obviates the stand-by losses of the steam tug which consumes fuel during the many unavoidable idle periods of waiting for a tow. The reduction in crew (by the elimination of the stokers), the diminished upkeep costs, and the much

FIG. 213.—*Miri.*

shorter laying-up periods for overhauls, due to the absence of a boiler, are also points not to be overlooked in making estimates.

As regards deck evidence, the captain of an oil-engined tug working in crowded waterways has the great advantage of the absence, or great reduction in size, of the funnel, which allows him a more unrestricted view from any position, and so helps to avoid damage to other craft.

For such crowded waterways as the Pool and the Albert Dock on the Thames, the docks on the Humber, etc., the advantage of concentrating high power in as small a hull as possible is very great. The higher revolutions of the oil engine constitute a disadvantage as compared with the steam engine, but the crucial test is the towing power which can be obtained with a tug of a given size. The oil-engined tug gives a bigger dynamometer pull at rest or when towing than the same sized steam tug, and that is a measure of its earning power.

A few examples of motor tugs and a short description of the work that they have performed may be of interest.

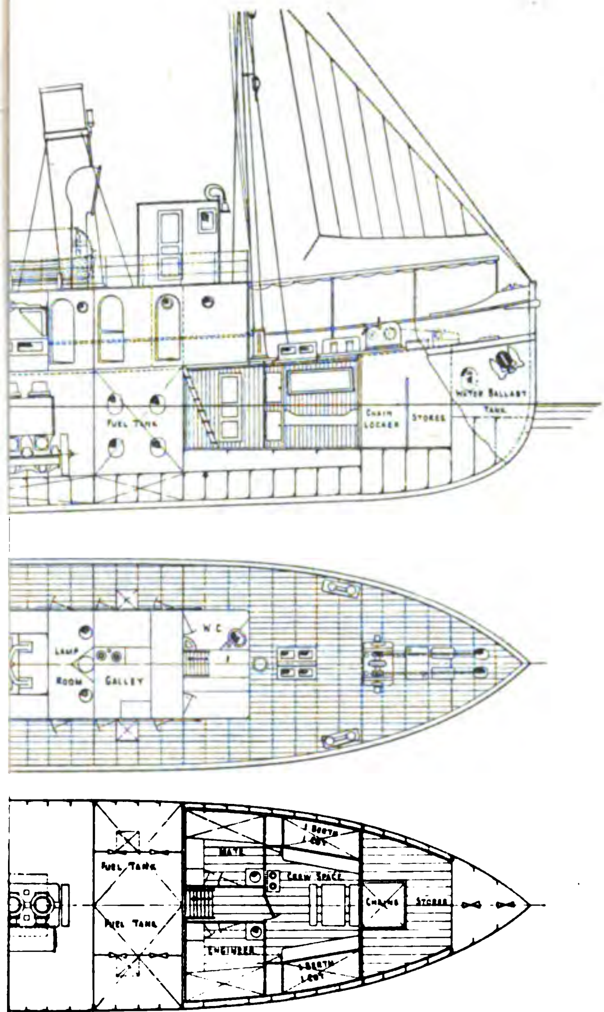
In September, 1914, the barge tug *Cepcrone*, with only 65 B.H.P., went up to Antwerp and towed the 150-ton motor coaster *Transport I.* all the way to London, encountering heavy weather in the North Sea.

FIG. 215.—*Kromhout VII.*

Fig. 213 illustrates the twin-screw tug *Miri*, length 85 ft., breadth 17 ft. 6 in., draft 5 ft. 6 in., fitted with two Bolinder engines, each of 80 B.H.P. This vessel was navigated from the United Kingdom to Singapore, a distance of 8,000 miles entirely under her own power. The total cost of spares used was 1*s.* 4*d.*

Fig. 214 is an illustration of the tug *Pioneer* fitted with a 240 B.H.P. Bolinder engine. This vessel is now performing very useful work in the Mediterranean.

The twin-screw tug *Nikolai*, 100 ft. × 20 ft. × 8 ft. draft, is fitted with two 80 B.H.P. Bolinder engines, which give the vessel a speed of 10 knots.


FUEL TANK
CHAIN LOCKER
STORES
WATER BALLAST TANK
W.C.
LAMP ROOM
GALLEY
FUEL TANK
FUEL TANK
CREW SPACE
STORES
Tug *Pioneer*.

The *Kromhout VII.*, Fig. 215, length overall 69 ft., breadth 15 ft. 9 in., depth 9 ft. 2 in., draft 6 ft. 7 in., is a very hand-

FIG. 216.—The *Marie L. Hanlon.*

FIG. 217.—*Marie L. Hanlon* towing *Manga Reva.*

some tug and is fitted with a 130 B.H.P. Kromhout oil engine.

The *Marie L. Hanlon*, Fig. 216, 71 ft. 5 in. overall, 17 ft. 5 in. beam moulded, is a wooden vessel built in 1914. The draft aft is 8 ft. 2 in. She is fitted with a two-cylinder Bolinder direct reversible engine of 160 horse-power running at 224 revolutions per minute, which gives her a speed of 11·28 miles an hour.

The owner of the *Marie L. Hanlon* had a steam tug of the same dimensions, fitted with compound engines 10 in. and

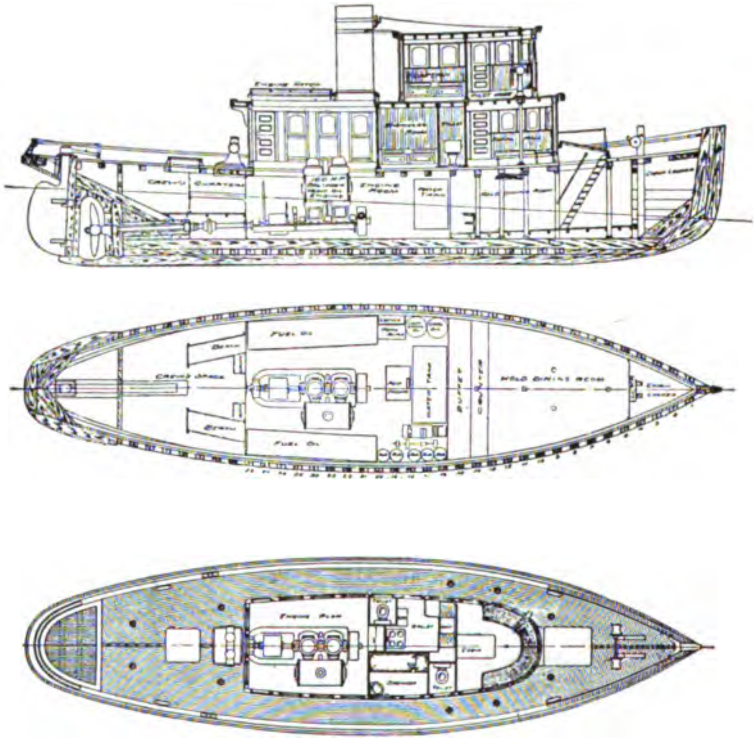


FIG. 218.—*Marie L. Hanlon.*

20 in. by 18 stroke, driving a propeller 6 ft. 4 in. diameter, and supplied with steam by an oil-fired Scotch marine boiler 7 ft. 6 in. diameter by 9 ft. long, with one 36 in. furnace and 116 2 in. tubes, each 6 ft. long, working pressure 140 lb.

The comparison of the working costs of these two vessels from actual results is as follows :—

	Steam.	Oil Engine.
Horse-power	160	160
	£ s. d.	£ s. d.
Cost of machinery installed	2,700 0 0	2,300 0 0
FUEL.		
Consumption per day of 10 hours, gallons	420	137
	£ s. d.	£ s. d.
Cost of 1 day's fuel (10 hours)	1 12 0	0 13 9
Cost of 30 days' fuel	48 0 0	16 12 5
Cost of engine repairs per month	6 0 0	3 0 0
Cost of boiler repairs per month	4 0 0	—
ENGINE ROOM CREW PER MONTH.		
Engineer	25 0 0	25 0 0
Fireman	13 0 0	—
Total engine room wages per month	38 0 0	25 0 0
Total fuel and wages in engine room per month	86 0 0	41 12 5
Total fuel and labour per year	1,022 0 0	499 8 10

These figures are based on American prices for oil, wages, etc.

FIG. 219.—*Ogarita* towing.

In a vessel of the cargo type, the hot bulb engine method of propulsion would show a saving of 40 to 50 per cent. in the space required for the power plant, and would therefore increase the cargo space and at the same time give the boat a larger radius of action at a much less operating cost.

The owner, Mr. D. J. Hanlon, states that—" with regard to handling, the engine reverses much quicker than steam."

The illustration, Fig. 219, is a view of the *Ogarita*, described on p. 224, towing sailing craft.

Regarding this vessel, the owner wrote: " Motor barge *Ogarita* when loaded with 150 tons towed with perfect

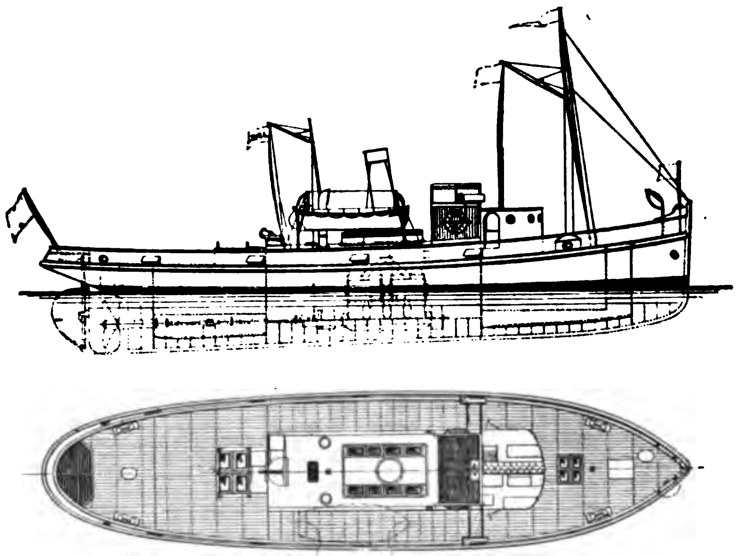


FIG. 220.—Design of Sea-going Motor Tug.

ease three barges carrying respectively 150, 137 and 100 tons, making a total of 537 tons of cargo all told, at a speed of about five knots."

The probable weight of the four vessels without cargo was 364 tons, so that the *Ogarita's* 120 B.H.P. engine was propelling through the water a total of 900 tons displacement.

Examples of up-to-date oil-engined tugs are shown in the plans, Figs. 220 and 221. These vessels, if fitted with a reliable hot bulb engine, would show great economy in their reduced working costs, upkeep, etc.

The launch tugs, as illustrated in Figs. 222 and 223, were designed and built for towing work in very shallow waters, and require only a 20 B.H.P. engine.

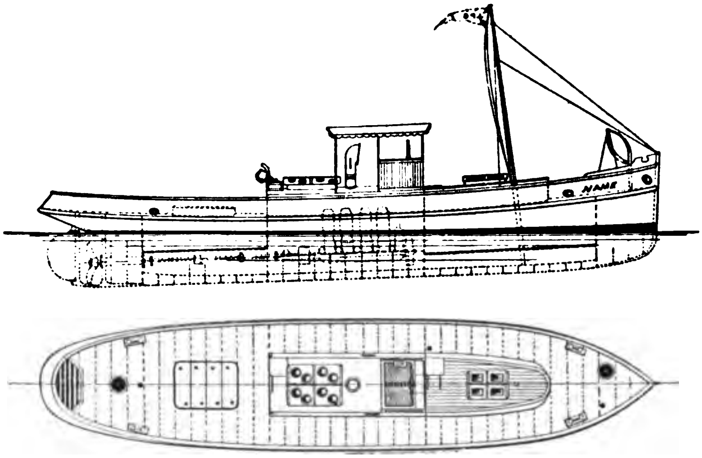


Fig. 221.—Design of River Motor Tug.

Fig. 222.—Photograph of Launch towing.

The canal tug *Panama* is a somewhat unusual type of vessel, and although she is only fitted with a 40 B.H.P. hot bulb oil engine she often has as much as 1,000 tons behind her.

The *George*, Figs. 224 and 225, 40 ft. × 6 ft. 3 in. × 4 ft., is a canal motor tug fitted with a 20 B.H.P. motor, and can

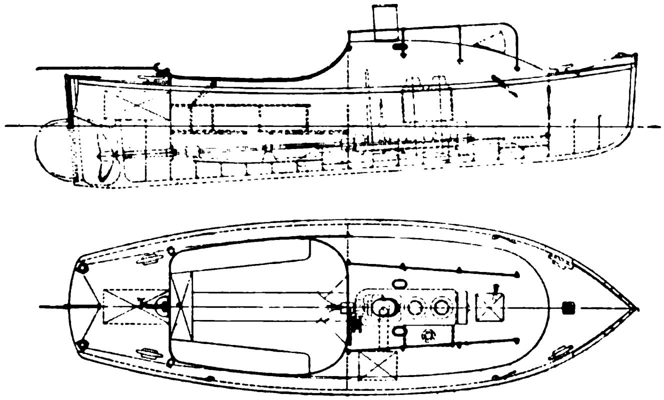


FIG. 223.—Plan of Launch for towing work.

FIG. 224.—Canal Tug *George* towing.

tow four loaded "monkey" barges at a speed of three miles per hour.

Auxiliary Sailing Vessels.—The first auxiliary iron sailing vessel was undoubtedly the *Q.E.D.*, which was built

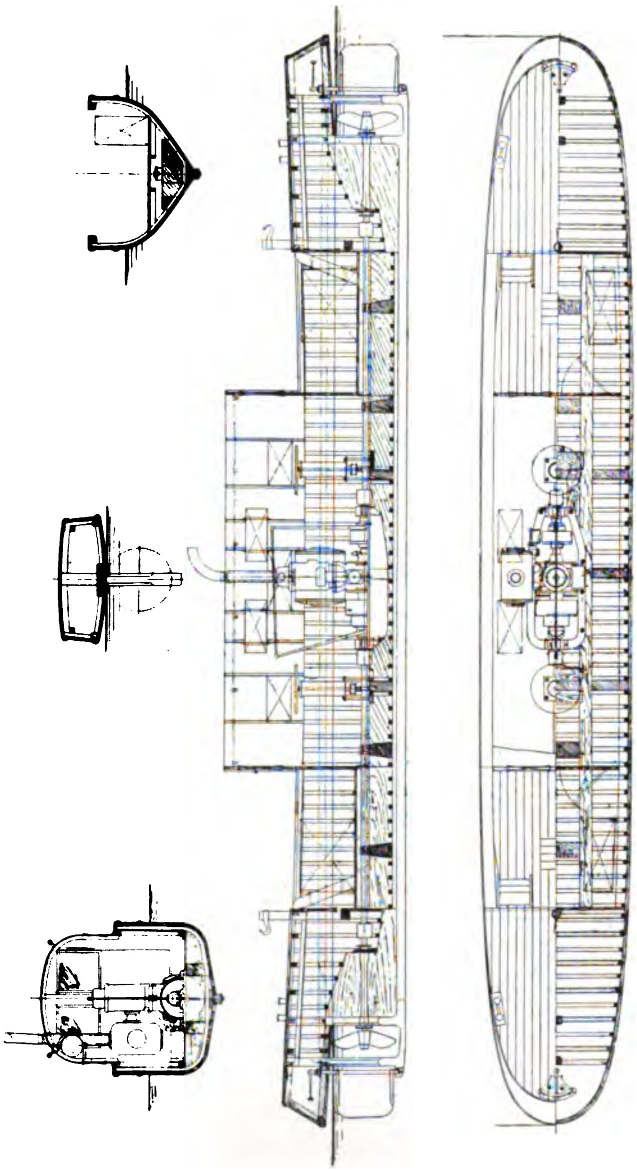


FIG. 225.—Canal Tug *George*.

on the Tyne in 1884. She was a barque-rigged vessel fitted with steam auxiliary machinery, the mizzen mast being used as a funnel; she was also the first ship to be fitted with a double bottom for water ballast.

The auxiliary sailer did not become fashionable until the introduction of internal combustion marine engines in recent years. The results have so far given sailing vessels a new lease of life, and in some cases have been remarkable.

To see an ordinary sailing vessel arrive in the Thames, Mersey or Clyde, in these progressive days causes almost as much astonishment as the early steamers caused seventy years ago.

It is interesting to note that the first steamer for the great Siberian river, the *Armoor* or *Armur*, was taken out in pieces on the sailing ship *Orus* in March, 1859, the trip to Vladivostock taking three months; the author's father went out in the *Orus*, re-erected the steamer and ran it for a year or more.

The greatest handicap of the sailers is their inability to make even slow progress in calms and against light head winds and their helplessness in rivers and docks without tugs, as well as their having to wait until all the steamers have finished their "turn" and are discharged or loaded before she can obtain a "berth."

The new lease of life not only affects the medium-sized sailing vessel, but also those of the largest size.

Paraffin engines were installed in some of the earlier and smaller vessels, but owing to the heavy cost of running and the high revolutions of the propeller, they were not largely adopted. Some vessels of larger sizes were fitted with Diesel engines, but they have not so far obtained the success that the enterprise deserved.

The slow running hot bulb oil engine has been successful and is now being largely adopted, although not so quickly as its suitability and success warrants.

The advantages of fitting hot bulb oil engines to sailing vessels are:—

(*a*) Increased earning power.

(*b*) Freight rates equal to those for steamships.
(*c*) The reduction of freeboard if a fair speed is obtained.
(*d*) The same deadweight by reduction of freeboard.
(*e*) The reduction of net tonnage.
(*f*) The ability to work in and out of port without tugs.
(*g*) More rapid voyages.
(*h*) Equality with steamers in obtaining their " turn " in dock.
(*i*) Ability to get into port when dismasted, and so avoid salvage claims.
(*j*) No increase in number of crew.
(*k*) Economical handling of water ballast.

The increased earning power is obtained by the ability of the motors to drive the vessels through a calm, and thereby decrease the number of days and often weeks on a trip, and by securing the same freight rates and demurrage as for a similar-sized steamship, on the assumption that the auxiliary will average with sail and power about the same speed.

A reduction of freeboard is allowed (see p. 261), if a fair speed is obtained. This reduction of freeboard naturally gives increased deadweight, which in practice, will be found to equal approximately the weight of the auxiliary machinery, tanks and fuel. It will therefore be seen that although auxiliary machinery is fitted to existing sailing vessels, the original deadweight is not necessarily reduced.

The reduction of net tonnage is a distinct gain and this is obtained by the increased percentage that is allowed off the gross tonnage for the space passed for the main machinery, so that although the cubic capacity is reduced by, say, 4 per cent. or 5 per cent., the net tonnage will be reduced from 8 per cent. to 10 per cent.

The advantage of getting in and out of port without the use of tugs and not having to wait for tugs to move the ships about, can be appreciated by all owners as well as the advantages of obtaining the steamer's " turn " in dock, and not having to wait until all the steamers have been discharged and loaded before the vessel can obtain a berth.

Auxiliary vessels have the same privileges as steamers when entering harbours or docks, and will get preference over ordinary sailing ships, providing they have fair power and are well fitted up with motor winches for working cargo.

The case of the *Earlshall* can be quoted as an instance of rapidity of voyages; the time of the round trip from St. Johns, Newfoundland, to Pernambuco and back to St. Johns was reduced from 101 days to 71 days, a saving of 30 per cent., which means a considerable increase in the earning power. In the case of a vessel making a round Atlantic trip, which with an ordinary sailing vessel would occupy thirteen or fourteen months, the installation of motors would reduce the time to nine or ten months, and the freight or earning capacity of the vessel would be increased by at least 30 per cent. It would only be necessary to deduct from this increased freight or earning capacity, the cost of running the engines, since for the reasons given on p. 261, the same deadweight would be carried.

Probably one of the advantages that would appeal most to owners and underwriters is the fact that the vessel can get in and out of port even when dismasted and thus avoid the probable loss of the vessel, or at least, heavy salvage claims. Illustrations of the *Earlshall*, Figs. 226 and 227, pp. 263 and 265, give clear proof of this point. It is probable that the claims arising from sailing vessels being dismasted and the consequent damages are greater than all the other insurance claims put together when sailing vessels alone are taken into consideration.

Although main and auxiliary machinery is fitted, it is found in actual practice that the number of the crew need not be increased, as although one man is required below all the time the oil engine is running, one less is required on deck.

The water ballast can be easily and economically handled by pumps driven off the main engine, and in small vessels a deck cargo winch can be fitted also, driven from the main engine, for discharging or loading sand or other movable ballast.

The exhaust pipe can be led into a steel mast with an outlet, say, 15 ft. to 50 ft. above deck, or if wooden masts are retained it can be carried up the side of the mast to a suitable height. In some vessels there is no objection to a small squat funnel being fitted.

By fitting motors to sailing vessels the freeboard may be reduced, provided the power fitted is sufficient to drive the vessel when loaded without the use of sails at the following speeds :—

For a ship 60 ft. long	5 knots.
„ „ 120 „ „	6 „
„ „ 180 „ „	7 „
„ „ 240 „ „	8 „
„ „ 300 „ „	9 „
„ „ 360 „ „	10 „

For every fraction of a knot by which the speed of the vessel is less than that shown above, a proportionally smaller reduction in freeboard is allowed, till the speed is 20 per cent. less than that shown when no further reduction in freeboard is allowed.

A sufficient supply of fuel must also be carried, and in no case may the reduction of the freeboard be greater than is given by the following formula :—

$$d = \frac{12\,c}{L \times B}$$

When d = reduction of freeboard in inches.
c = capacity of tanks in cubic feet.
L = length of vessel on load water line in feet.
B = registered breadth of vessel in feet.

The reduction allowed, when the motor can be promptly put into action, is one half the difference between the freeboard of a steam vessel and that of a sailing vessel.

The maximum reduction of freeboard in a vessel, say, 180 ft. × 28 ft. × 17 ft., fitted with a motor sufficiently powerful to give a speed loaded of, at least, 7 knots, without the help of sails, would be approximately 4 in.

Two sets 120 B.H.P. engines giving a total of 240 B.H.P. with the necessary fuel for propelling the vessel under power alone a distance of, say, 2,000 miles, would weigh about

40 tons, while the reduced freeboard would give an increased displacement of 40 tons, so that the vessel would carry the same deadweight as before. For a vessel, say, 300 ft. × 42 ft. × 25 ft., the maximum reduction would be, approximately, 6 in.

A point raised against the fitting of auxiliary machinery, especially with solid propellers, is that the propellers would cause a drag on the vessel. A test made on the *Bolinder VII.*, showed that whilst sailing at about 6½ knots, with the engine declutched, the propeller revolved at 120 revolutions per minute, which indicates that there was little or no drag. In this respect an engine with a clutch or a reverse gear that has a neutral position is an advantage.

The reason given by some owners for not adopting oil engines as auxiliaries on their sailing craft is that insurance companies charge such heavy premiums. This is to a certain extent true, but they will soon become aware of the reliability of the best makes of hot bulb oil engines, and of the advantage to the owners and underwriters of having sailing vessels fitted with this type of engine, which adds greatly to the safety of the vessel and ensures the return of the vessel to port, as instanced by the *Earlshall*, p. 264.

In normal times Norwegian underwriters insure vessels sailing under the Norwegian flag, if fitted with reliable oil engines, at a rate of £7 7*s*. per cent. on an "all risk" policy, and there is really no reason why British underwriters should not quote equally favourable rates, and, in fact, owners can look forward to rates nearly as favourable as soon as the splendid performances of these vessels become better known.

The performances of the *Lingueta*, *Fort Churchill*, *Fort York* across the Atlantic, and many others, will no doubt create a good impression with the insurance companies, and this difficulty of insurance will gradually disappear.

Fig. 175, p. 218, has been prepared to assist owners and naval architects in deciding on the power to be fitted to existing sailing vessels to convert them to auxiliary powered ships.

It is necessary to be very cautious in quoting a speed for vessels of this type, as the only reliable speed is that obtainable in absolutely calm weather, a condition that is very unusual. The difficulty of obtaining a reliable speed to quote is due to the very great resistance of the masts and rigging when going against a head wind, though, on the other hand, an artificially increased speed is obtained under power when going with the wind, even if there are no sails set.

To estimate the cost of installing hot bulb machinery in new vessels of any type is a comparatively simple matter, but it is more difficult to give an average cost for fitting

FIG. 226.—*Earlshall* leaving Liverpool.

such machinery into an existing vessel, as the necessary alterations will vary considerably. In some cases bulkheads will have to be moved, deck alterations made, trunkways and skylights fitted, whereas other vessels will not require any of these alterations.

Generally speaking, it will be found more economical to fit twin-screw machinery because :—

(*a*) The stern frame, deadwood and rudder will not require to be touched.

(*b*) The mizzen mast need not be disturbed.

(*c*) The propellers will obtain greater immersion.

(*d*) The height of engines will be less.

The cutting and scarphing of a few frames and the fitting of new boss plates for the stern tubes will be a comparatively simple matter.

The following approximate figures based on normal prices, and estimated on a total of 250 B.H.P. in each case for new and old vessels may be useful.

	Single Screw.		Twin Screw.	
	New.	Old.	New.	Old.
	£	£	£	£
Main engines of modern type, including stern gear . .	2,100	2,100	2,200	2,200
Auxiliary pumps . . .	50	50	50	50
Tanks for 100 hours . .	100	100	110	110
Installing and fittings . .	240	240	240	240
Hull alterations . . .	—	1,050	—	900
For 250 B.H.P. total .	£2,490	£3,540	£2,600	£3,500

The corresponding figures for the following horse-powers will be :—

	£	£	£	£
For 125 B.H.P. Total.	1,280	2,230	1,550	2,300
„ 320 „ „	2,980	4,100	3,450	4,400
„ 500 „ „	5.000	6,300	4,900	6,000

The running costs depend largely upon the cost of the fuel, the cost of insurance will vary from 7 to 10 per cent., while the cost of upkeep, repairs and renewals will be 3 per cent. One or two engineers will be necessary for the larger vessels, and an allowance for interest on outlay should be provided for before the net profit can be taken.

The *Earlshall* is an interesting example of a successful installation. It is recorded that in 1912, after she had been fitted with a 120 B.H.P. Bolinder oil engine (although the vessel was thirty years old), she sailed from the Clyde, and after a month's buffeting she put back into Swansea; on December 16th the voyage was resumed and nothing further was heard of the vessel until January 21st, 1913, when she came into Queenstown under her own power, crippled and battered about almost beyond recognition, with boats, foremast and main topmast gone, and 10 ft. of water in the hold. The oil engine was in splendid order, and its

FIG. 227.—*Earlshall* after return under own power.

continuous working under such trying conditions saved the ship. The owners, Messrs. Job, Brothers, wrote :—

"We have pleasure in informing you that throughout the late unfortunate voyage of our barquantine *Earlshall*—the Bolinder auxiliary oil engine worked to our entire satisfaction.

"Since the installation was completed on November 7th last—the engine has proved its simple reliability under the most severe conditions.

"As a result the captain was able to refuse assistance when the vessel was dismasted and thus avoid a heavy claim for salvage.

"The *Earlshall* (dismasted) returned to Queenstown unassisted and under her own power."

So much confidence had the captain in his motor that he refused the assistance of a tug off the West Coast of Ireland.

although the weather was boisterous and he had 10 ft. of water in the hold.

No more convincing object lesson of the benefits of fitting a reliable oil engine to sailing vessels could be wished for. Without the engine the *Earlshall* would undoubtedly have been lost. This vessel was probably the first ocean-going vessel to be converted into an auxiliary with a hot bulb engine.

Scandinavia owns the largest fleet of sailing vessels, and also owns a larger percentage of motor fishing boats than any other nation, and it is therefore to be presumed that we

FIG. 228.—*Fingal.*

shall see the countries that comprise Scandinavia lead in motor auxiliary vessels.

The *Fingal*, Fig. 228 of 2,435 tons register and 3,900 tons deadweight, built in Belfast in 1883, was equipped in 1915 with two direct reversible engines, each of 160 B.H.P., making a total of 320 B.H.P. When stiffened with 1,500 tons of ballast the vessel is said to have obtained a speed of 7·5 knots. Reversing from full ahead to full astern can be effected in seven seconds, and as the engines are placed right aft, the forward bulkhead being on frame 20, very little of the original hold space was lost. The fuel tanks have a capacity sufficient for a continuous forty-day voyage.

The *Caracas* is 218 ft. × 33 ft. 6 in. × 18 ft. 3 in., carries

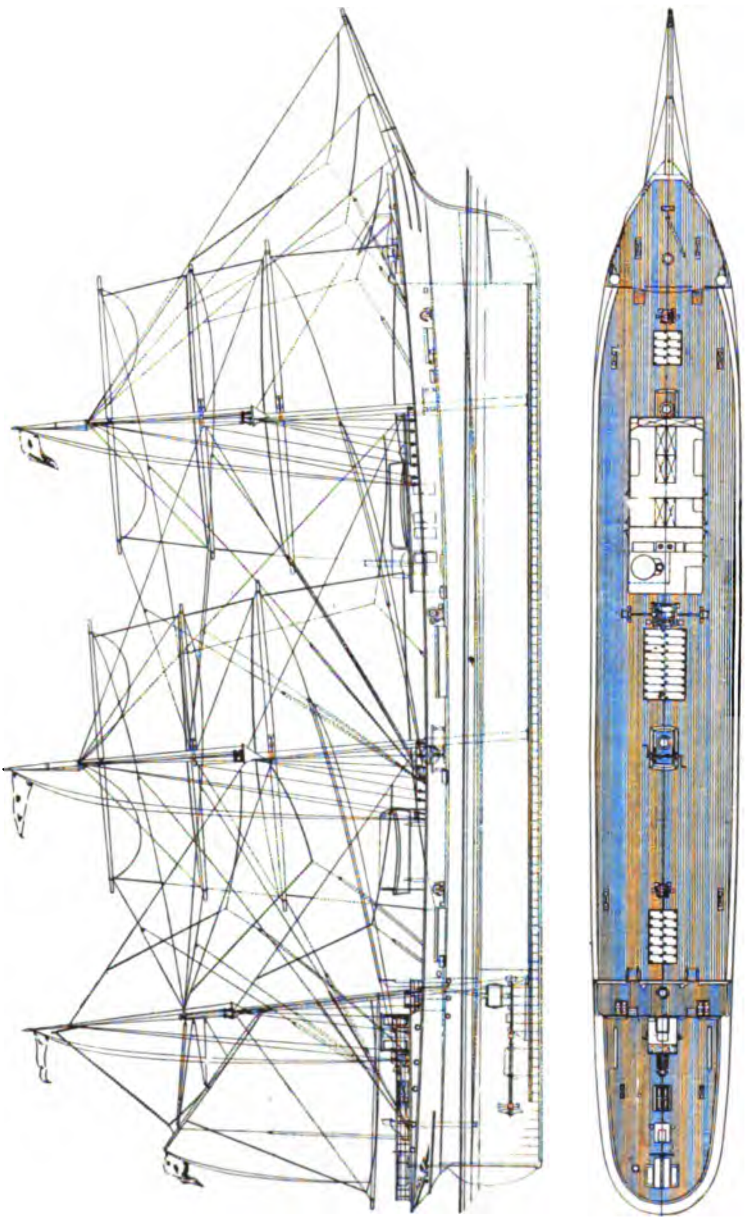


Fig. 229.—*Caracas.*

about 1,500 tons of coal, and is fitted with two 160 B.H.P. engines, running at 225 R.P.M.

Her consumption for the two engines averaged in 1915: fuel oil 110 lb., cylinder oil, 1·28 lb., and bearing oil 2·8 lb. per hour, whilst both engines were at work.

On a voyage home from Miramichi two other ships left at the same time as the *Caracas*, but these had not arrived in the Bristol Channel fourteen days after the arrival there of the *Caracas*.

The *Strathcona*, illustrated in Fig. 230, was built for the Pacific Cable Board for inspection and other seagoing

FIG. 230.—*Strathcona.*

work. Her dimensions are length overall 110 ft., beam 24 ft., and draft 12 ft., and she is fitted with an 80 B.H.P. two-cylinder Bolinder engine. Besides her main engine, this little boat has an 8 B.H.P. motor driving refrigerating machinery.

A few years ago nobody would have considered for a moment the building of steel sailing ships, but the success of the hot bulb oil engine has entirely changed this view and, not only makes the auxiliary sailing ship possible, but frequently advisable, and from a ship-owning point of view, profitable also, according to the figures given in these pages.

One of the early vessels to demonstrate the practicability of building new steel sailing vessels with auxiliary power was the *Morten Jensen*, length 135 ft., breadth 30 ft., depth 11 ft. 10 in., displacement 690 tons, deadweight 500 tons, which was specially built for the purpose in Denmark in

Fig. 231.—*Goodwin.*

1914. The propelling machinery consists of a 160 B.H.P. oil engine fitted well aft, which is said to give her a speed of 7½ to 8 knots in light condition; with sail power in addi-

Fig. 232.—*Hjalmar Sorensen*, under power only.

tion and in a fair wind this was increased to 12 knots. The oil tanks have a capacity of 30 tons. A trip was made in June, 1915, which lasted 100 days, the motor was working 700 hours, during which time 15 tons of oil were used, the speed of the vessel being kept at 8 knots, and the ship being run under sails alone when the wind was favourable. The

FIG. 233.—*Mabel Brown.*

advantage of reliable power as an auxiliary to sailing vessels was well demonstrated during 1915 when the *Morten*

FIG. 234.—*Mabel Brown.*

Jensen on two separate occasions managed with her power to escape from a German submarine.

The *Goodwin*, length 134·0 ft., breadth 24·8 ft., depth 8·7 ft., with a deadweight of 380 tons, Fig. 231, was built of steel in 1912 as an auxiliary vessel and had two hatchways with a motor winch to each. The main engine is a two-cylinder 160 B.H.P. The fuel tank capacity is 17 tons, of which 12 tons is carried on deck and 5 tons in tanks in the engine room.

At a demonstration test in August, 1915, after about fourteen months' work, the engine was started from cold in the remarkably short time of eight minutes. A few weeks previously the vessel made several trips from London to Rotterdam, and the average cost of fuel for the main engine was only £2 for each round trip. This vessel works with a crew of nine all told, including an engineer and assistant.

The *Hjalmar Sorensen*, length 165 ft., breadth 33 ft. depth 12 ft. 9 in., deadweight cargo 750 tons, was built in 1915 of steel by a Danish builder, and rigged as a four-masted schooner. She was the first vessel to be fitted with Bolinders "M" type engine of 240 B.H.P., as illustrated on p. 25. The first trip to South America was made in May, 1915.

In America twelve new wooden five-masted schooners, similar to the *Mabel Brown*, Fig. 233, were completed in 1917 for the lumber trade. These vessels had a length of 225 ft., a breadth of 44 ft., a depth of 19 ft. and 3,500 tons deadweight capacity. Two sets of Bolinder "M" type engines are fitted, each of 160 B.H.P., giving a total of 320 B.H.P. The operating expenses of such a vessel in America, under sails alone, in normal times would be £14 per day, and the engine-room expense, including engineers, fuel and lubricating oils £6 per day when working the engines at full load.

Fig. 235 is an illustration of a three-masted vessel designed by the author for the English trade. The dimensions are :—

Length	148 ft. 0 in.
Breadth	31 ,, 0 ,,
Depth	16 ,, 0 ,,
Draft	13 ,, 6 ,,
Deadweight, approx. tons . .	750
Power of hot bulb motor B.H.P. .	160
Speed loaded, knots . . .	6½

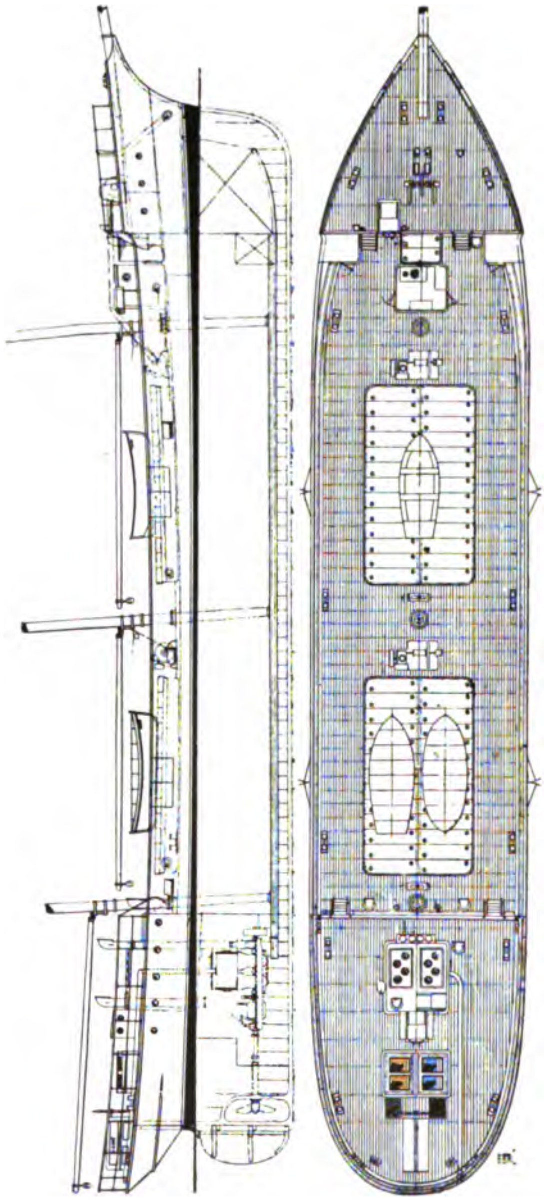


FIG. 235.—A Three-masted Schooner.

A four-masted vessel, more suitable for longer voyages, is illustrated in Fig. 237, the dimensions being :—

Length	160 ft. 0 in.
Breadth	35 ,, 0 ,,
Depth	13 ,, 6 ,,
Draft aft	12 ,, 6 ,,
Deadweight, approx. tons . .	750
Horse-power of motor, B.H.P. .	240
Speed loaded, knots . . .	7½–8

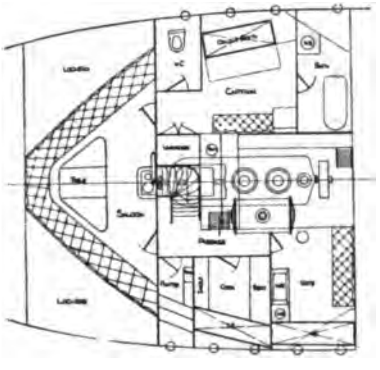


FIG. 236.—Aft Accommodation of Three-masted Schooner.

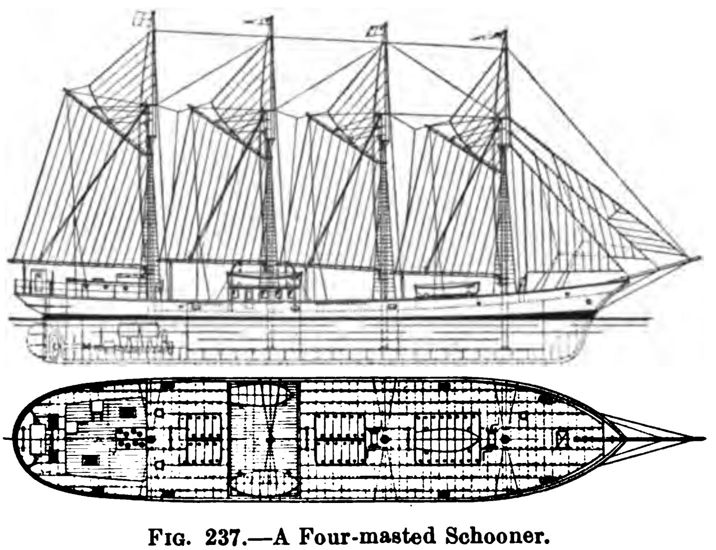


FIG. 237.—A Four-masted Schooner.

The *Elfleda*, a fully rigged steel barque of 1,023 tons net register and 1,900 tons deadweight, was built in 1888, and is fitted with two Bolinder engines, each of 120 B.H.P. By this installation, and the adoption of a motor room the net tonnage was reduced by 110 tons (about 10 per cent.), while the deadweight capacity was reduced by only 4 per cent.

The *Elfleda* was probably the first vessel to make a serious attempt to carry on a regular trans-Atlantic service by means of auxiliary sailing vessels, the idea being to reduce working expenses to a minimum while taking advantage of the reserve power represented by the oil engine in the absence

FIG. 238.—*Result.*

of wind. The total fuel consumption of this vessel on her passage from Sandefjord to New York in June, 1915, her first voyage, was said to be 12 tons of oil, the trip across having been made at an average speed of 9 knots. The oil at New York cost 3 cents a gallon, and as the two engines combined used 17 gallons per hour, the cost for fuel was only 2*s*. per hour.

There are so many sailing vessels fitted with motors that only a selected few more can be illustrated in this book.

Several vessels of 250 ft. × 43 ft. × 21 ft. have been built in America of wood since 1916 for the lumber trade, and fitted with two 240 B.H.P. four-cylinder Skandia engines, each driving a 67-in. three-bladed propeller. A

75 B.H.P. electric light set provides the power necessary for the electric cargo winches and for lighting the ship. The frames of these wooden hulls are sided 12 in. and moulded 26 in. at the keel, 15 in. at the bilge, 10½ in. at the deck, 9 in. at the rail and spaced 32 in. centres. The keel is 20 in. sided and 24 in. moulded, the stem 20 in. sided and 24 in. moulded, the keelsons 20 in. sided and 22 in. moulded, and the beams 15 in. sided and 15 in. moulded, with a 10 in. pillar under each.

The *Result*, Fig. 238, length 102 ft. × 21 ft. 7 in. × 9 ft. 1 in. has a deadweight capacity of 190 tons, and is fitted with one 40 B.H.P. Kromhout engine.

FIG. 239.—*Fort York*, the Old and the New.

The *Fort York* and *Fort Churchill*, Figs. 239 and 240 and 241 have both made voyages across the Atlantic, their dimensions are :—

Length	80 ft. 9 in.
Breadth	21 „ 9 „
Depth	9 „ 1 „
Deadweight tons	85
Horse-power of Bolinder motor .	80

From the plans the arrangement generally adopted for the engine room can be seen. It will be noticed that this does not extend right across the vessel, but is bulkheaded off from the accommodation, which greatly reduces the space required for the motor. A trunkway for ventilation is also arranged through the accommodation.

These vessels were built in Cornwall to the design of Mr. Harley Mead. The *Fort Churchill* left Penzance for her destination in the Arctic regions on August 27th, 1913. The voyage had to be made direct, as there was no intermediate port of call possible. When about two days out, a rope got foul of the propeller and bent the tail shaft. Notwithstanding this, the engine was run for a period of about

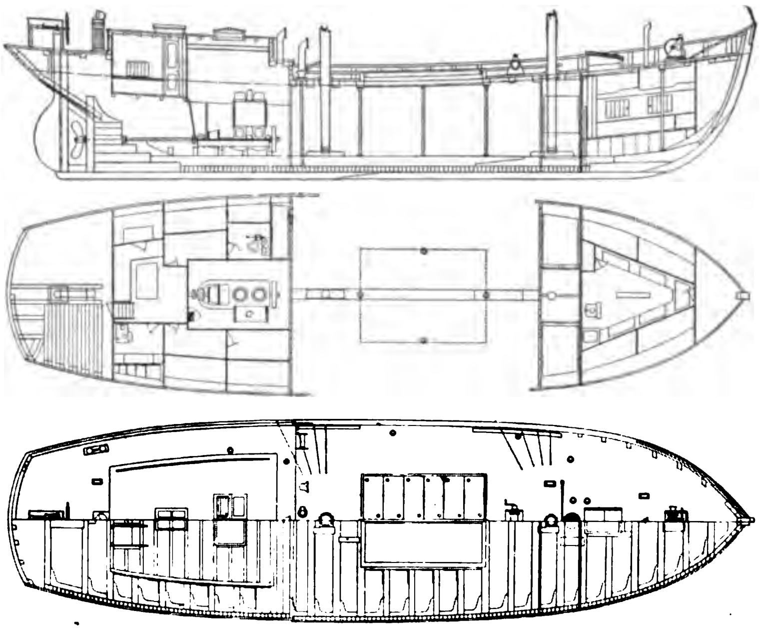


FIG. 240.—General Arrangement of *Fort York*.

ten days, which enabled the ship to reach Greenland, where she was beached, the tail shaft withdrawn, and a new one fitted. After this, a non-stop run was made to her destination.

It is interesting to note that for the first time in history His Majesty's Mails were conveyed across the Atlantic by a motor vessel, as the *Fort Churchill* had the last mails of the year 1913 aboard, for the port after which she was named.

Sailing *versus* Motor Barges.—A number of sailing barges have been fitted with hot bulb oil engines, including the *Grit* with a Kromhout engine. It is somewhat surprising

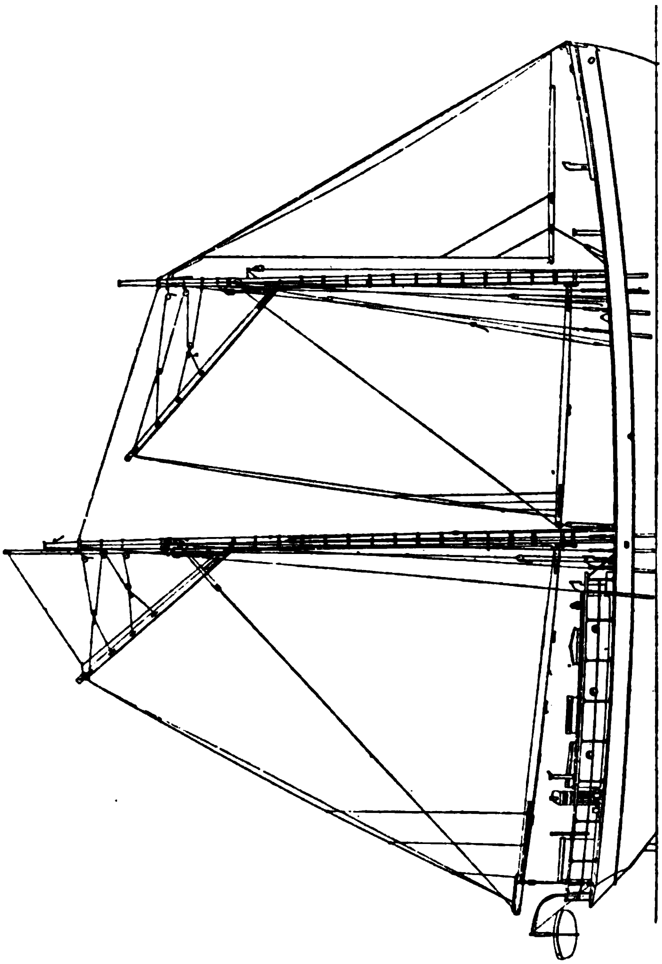


Fig. 241.—Rigging Plan of *Fort York.*

that more barges have not been so fitted. The following actual figures clearly point out the enormous advantage to be gained by a motor barge over sailing craft.

The motor tanker *Nitrogen*, of 110 tons deadweight, was built of steel in 1912 and fitted with a hot bulb motor of 80 B.H.P., to assist a trade where two sailing barges, each of the same capacity, had previously been employed. After three months' trial, it was found that the *Nitrogen* could do all the work and then have time to spare.

Some idea of the superiority of the *Nitrogen* can be gained by the fact that while the sailing barges between them did 120 miles, consisting of three voyages from Southampton to Newport, Isle of Wight, the motor boat did 2,000 miles, consisting of eleven trips to Poole in the same period. This, of course, was an exceptional case, as the sailing craft had had bad weather, adverse tides, etc.,

FIG. 242.—*Arctic*, 50 B.H.P.

to contend with, but, nevertheless, under normal conditions this motor-vessel far out-classed her sailing competitors.

The *Arctic* is a typical Thames sailing barge, 85·5 ft. × 19·1 ft. × 6·7 ft., built of steel with a square chine or bilge. After being used as a sailing barge with the usual spritsail rig for eighteen years, a 76 B.H.P. Petter engine was fitted, and the sails were altered to cutter rig.

Another Thames sailing barge was fitted with two 23 B.H.P. Rap motors in 1916, each driving a 32-in. diameter reversible blade propeller. Many of the Thames sailing barges are suitable for fitting with twin-screw sets of hot bulb oil engines.

Fishing Vessels.—There are more fishing vessels fitted with oil engines than all the other types of vessel put together, the reason being that the motor vessels are much more economical than steam vessels and much more efficient than

FIG. 243.—*Bolinder VII.*

sailing vessels. Every make of hot bulb oil engine has been fitted in this type of vessel.

FIG. 244.—*May Baby.*

The hot bulb oil engine will cost more than a light paraffin or petrol high-speed engine of the same power, but the extra outlay is easily repaid by increased efficiency, reduced repair bills, smaller fuel consumption, lower price of fuel per gallon, reduced depreciation, slower running and increased reliability.

As an illustration of reliability, the *Bolinder VII.*, Fig. 243 can be quoted. This vessel was built and engined in 1908, and has since been navigated about 60,000 miles, and was probably the first hot bulb oil-engined vessel to visit the

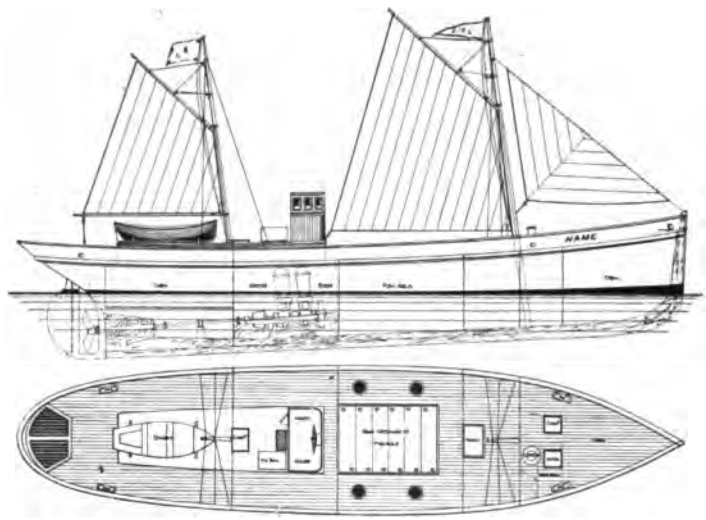


FIG. 245.—*May Baby.*

British Isles, an all-round demonstration tour being made in 1909.

The *May Baby,* Figs. 244 and 245, is a full-powered fishing vessel, which proved herself to be, under actual test, the fastest oil engine propelled fishing vessel at that time, viz., 1911, and also faster than any steam drifter; her dimensions were length 74 ft. 9 in., breadth 18 ft. 8 in., depth 9 ft. 9 in., and she was fitted with one 120 B.H.P. Bolinder two-cylinder direct reversible oil engine.

The vessel worked throughout the English, Scottish, and Irish fishing seasons, on many occasions in direct competition with the finest steam drifters on the East Coast, and in some cases organised races were arranged, the result on each occasion being entirely in favour of the oil-engined vessel.

The manager wrote from Aberdeen in 1912 :—

"I personally tested this vessel in the vicinity of the fish market as well as the open sea, and I must say that I would have every confidence in manœuvring the ship as speedily as with steam."

In the case of the *May Baby* an account of her expenses were kept, and during the winter of 1912, the following comparison was made :—

MOTOR DRIFTER "MAY BABY."				STEAM DRIFTER "NEW DAWN."			
Dimensions.				*Dimensions.*			
82 ft. 9 in. × 18 ft. 8 in. × 9 ft. 9 in.				96 ft. × 8 ft. 8 in. × 8 ft. 8 in.			
Speed—11 miles.				*Speed*—10 miles.			
Expenses.	£	*s.*	*d.*	*Expenses.*	£	*s.*	*d.*
Fuel . . .	35	13	8	Fuel . . .	79	11	2
Engineer's wages.	15	0	0	Wages . .	15	0	0
Dues . . .	11	2	3	Dues . . .	11	1	2
Stores . .	10	14	1	Stores . .	3	5	6
	£72	10	0		£108	17	10

It is interesting to note that in Denmark fifteen years ago, the owners of fishing smacks were content with 10 H.P., but they have seen the advantage of having larger horse-power and every year or so the size of engine has increased. At the present time the same sized boats are fitted with 40 H.P. engines. In the early stages they were used for auxiliary purposes only, while now they are full-powered boats.

Every fisherman knows of the inshore limits and prohibition of trawling under power by motor boats within the restricted area, but there is really no reason why fishing vessels should not use their oil engines to get to and from the fishing grounds, and only trawl or fish under sail power for inshore work if proper arrangements could be made with the authorities ; no doubt in due time the great advantages of this arrangement will be appreciated by all fishermen and all restrictions removed.

Comparison of working costs :—

Basis-Steel Steam Fishing Drifter 86 ft. × 18 ft. 6 in. × 9 ft. 6 in. . . . . Basis-Steel Motor Fishing Drifter 82 ft. 9 in. × 18 ft. 6 in. × 9 ft. 6 in.. .	Value of either vessel—£2,900.					
	Steam. 160 I.H.P.			*Motor.* 120 B.H.P.		
Costs per annum :						
Depreciation.	£	*s.*	*d.*	£	*s.*	*d.*
Steam Vessel, Hull at 5 per cent. . . Mch. „ 8 „ . .	172	0	0			
Motor Vessel, Hull „ 5 „ . . Mch. „ 5 „ . .	—			145	0	0
Interest, 5 per cent. on total value . .	145	0	0	145	0	0
Bunkers, 8 hours per day for 300 days per year—						
Steam, 2·5 lb. per I.H.P. per hour at 20*s.* per ton	428	0	0			
Motor, 8 gallons crude oil per hour for 2,400 hours at 4*d.* per gallon . .	—			320	0	0
Stand-by losses at 3*s.* per day . .	45	0	0	*Nil.*		
Insurance, steam or motor . . .	Club rate.			Club rate.		
Boiler—Scaling and repairs . Fire bars . . . Zinc plates . . Bunker sides, ashguards, plates . . . } at 12*s.* 6*d.* per week	26	17	6	*Nil.*		
Engines—Steam, Renewals and repairs at 5*s.* per week	10	15	0			
Packing at 1*s.* 6*d.* per week	3	4	6			
Motor, Renewals at 2*s.* 6*d.* per week	—			5	7	6
Lubricating—Steam at 3*s.* per 24 hours .	15	0	0			
Motor at 8*s.* 9*d.* per 24 hours	—			43	15	0
Paraffin for lamps on engines . . .	*Nil.*			15	0	0
Lamp Oils at 2*s.* per week	4	6	0	4	6	0
	£850	3	0	£678	8	6

The above approximate figures compiled from two craft actually in commission show a saving for the motor-driven craft on one year's fishing of 27,400 miles of £171 14*s.* 6*d.*, which should appeal to fishermen both in large or small ways of business.

Another comparison of working is :—

Basis-Wooden Steam Fishing Drifter 70 ft. × 18 ft. × 7 ft. . . . . . Basis-Wooden Motor Fishing Drifter 60 ft. × 18 ft. × 7 ft.		Value of either vessel—£1,050.						
		Steam. 70 I.H.P.			*Motor.* 50 B.H.P.		
Costs per annum :							
Depreciation.		£	*s.*	*d.*	£	*s.*	*d.*
Steam Vessel, Hull at 5 per cent. Mch. at 8 „ . .		69	0	0			
Motor Vessel, Hull at 5 „ . . Mch. at 5 „ . .			—		52	10	0
Interest, 5 per cent. on total value . .		52	10	0	52	10	0
Bunkers, 8 hours per day for 300 days per year —							
Steam, 3 lbs. per I.H.P. per hour at 20*s.* per ton		225	0	0			
Motor, 3·5 gallons crude oil per hour for 2,400 hours at 4*d.* per gallon . .			—		140	0	0
Stand-by losses at 1*s.* 6*d.* per day . .		22	10	0		*Nil.*	
Insurance, steam or motor . . .		Club rate.			Club rate		
Boiler—Scaling and repairs . Fire bars . . . Zinc plates . . . Bunker sides, ashguards, plates . . .	at 8*s.* per week	17	4	0		*Nil.*	
Engines, Steam, Renewals at 3*s.* per week.		6	9	0			
Packing at 1*s.* „ .		2	3	0			
Motor, Renewals at 1*s.* 6*d.* „ .			—		3	4	6
Lubrication, Steam at 1*s.* 6*d.* per 24 hours.		7	10	0			
Motor at 3*s.* 6*d.* „ „ „ .			—		17	10	0
Paraffin for lamps on engine . . .			*Nil.*		10	0	0
Lamp Oils at 1*s.* 6*d.* per week . . .		3	4	6	3	4	6
		£405	10	6	£278	19	0

The larger the vessel the greater is the saving, but even with the above, the benefit to be gained by fitting the oil engine amounts to £126 11*s.* 6*d.*, which means more often than not the difference between a season which is successful or otherwise.

N.B.—In connection with pp. 282 and 283, the following should be noted :—

Wages.—Not allowed for, as crew usually share the earnings.

Crew.—Number of hands generally reduced with the motor vessel.

Deadweight.—Greatly increased when an oil engine is fitted as against a steam set.

Power.—The power transmitted to the propeller per B.H.P. of an oil engine is 25 per cent. of that transmitted per I.H.P. of a steam engine.

When a progressive fisherman is deciding on the motive power for his sail boat, one of the greatest considerations

FIG. 246.—*Yarmouth*, 30 B.H:P. Dan.

has to be simplicity, as in nine cases out of ten he has to drive the engine himself, and it would never be a success if it was complicated, and always requiring adjustments. All such complicated devices, such as electrical fittings, magnetos, cams, valves, etc., are eliminated in hot bulb oil engines, and all working parts are of the simplest possible design.

Motors can easily be run by any intelligent man with the aid of the exhaustive notes on how to work their engines that are issued by nearly all makers, and it is not necessary to be an engineer or have an engineer on board. Thousands of hot bulb oil-engined fishing vessels are being run by fishermen who have no knowledge of engineering.

To obtain success in fishing vessels and to obviate the troubles that fishermen may have with an engine, better training should be given to suitable fishing hands; it is quite unnecessary that they should have previous motor experience.

Firms selling hot bulb oil engines to fishermen or to owners of sailing barges and small coasters should rest their arguments on the fact that any intelligent fisher-lad can learn to drive the engine, and that a supposed engineer is often a source of danger, because he usually wishes to run the engine his own way instead of as instructed by the maker.

A really good motor engineer can earn far more in other directions than a fisherman could afford to pay him for driving his engine and, inversely, a fisherman could not afford to purchase a motor that required an expert and, consequently, an expensive man to work it.

Again, fishermen should be encouraged to admit their want of knowledge of the engine and to ask for explanations of the working, of what they should do and what they should not do, and how they should get over the small difficulties that they experience from time to time.

Every piece of machinery requires attention and care to keep it running in a proper way, even the apparently simple mechanism of an ordinary bicycle; it should therefore be apparent that any form of internal combustion engine, even that of the most simple design such as is described in this book, requires care. The "Notes on Working," on p. 340, and subsequently, are typical of what should be observed, and variation will be made by any maker to suit his particular engine.

If the fishing vessel is working at a convenient port, the owner should try and arrange for the makers' expert representative to inspect the engine periodically, say, once every three or six months. In some cases this will be superfluous, especially where the man in charge has become experienced, but until he has confidence in his engine a little advice and assistance should be helpful and tend to economical running and to add to the life of the engine.

However, when a fishing vessel is working in an out-of-the-way place, where it is not practicable to have a man from the makers to inspect the engine occasionally, the installation should be run quite successfully, providing the man in charge of the engine is of ordinary intelligence.

As an instance of this, the *Shamrock*, 55 ft. × 15 ft.

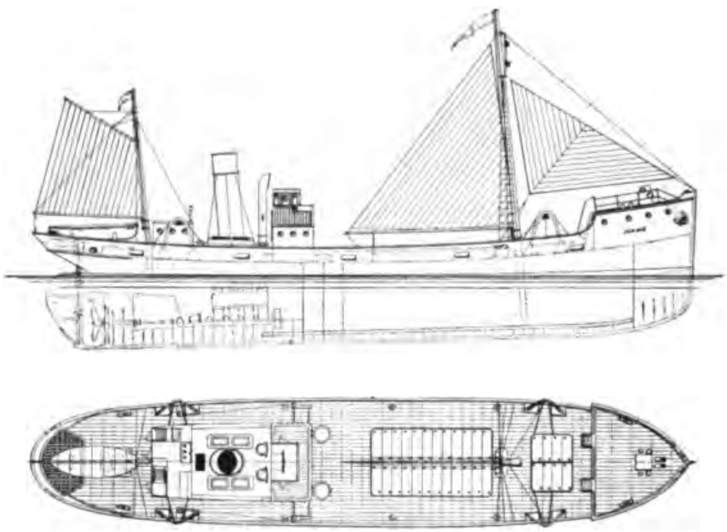


FIG. 247.—High-powered Trawler fitted with a Hot Bulb Oil Engine.

× 8 ft., can be quoted. This vessel has now been running for four years between Ireland and France, without any one from the makers of the engine being with the vessel, even for the trial trip, which was run by those entirely without experience of the engine. Notwithstanding this, the author does not know of this boat ever having had a breakdown or missing a tide through an engine trouble.

Fishermen who have oil engines in their fishing boats should be supplied with a simple treatise on safe and dangerous oils, and they should understand that oils having a specific gravity of 0·8 and above, such as fuel oils, Solar oils, crude Scotch shale, etc., are safe under any conditions. Paraffin oils having a specific gravity of from 0·73 to 0·80 with a flash-point of from 85° F. to 100° F. are dangerous unless exceptional care is taken, leakage entirely prevented, and a naked light kept well away even from an opening in the top of a tank.

This can be brought home clearly by giving the men a list of the oils that can be obtained locally and placed under the three heads referred to on pp. 196 and 199.

The more recent installations of motors in fishing boats in the British Isles show a larger average horse-power than the earlier practice. As the size and power of the fishing boats increase, the opportunities for the hot bulb engine will increase, and it will obtain almost a monopoly for powers of 50 B.H.P. and upwards.

Those makers who wish to obtain orders for their engines for installation in fishing vessels should not overlook the advisability, in fact the necessity, of having demonstration vessels as nearly as possible like the particular type for which they wish to cater.

The difficulties at the present moment in getting owners to adopt hot bulb oil engines for full-powered trawlers are the question of the trawl winch drive, and the fact that the hot bulb oil engine will not give the same elasticity and flexibility as the steam engine.

The former is not by any means so simple as it would appear, because when the trawler is hauling in her gear in a heavy sea, the pitching and rolling of the vessel causes great variations in the strain on the trawl warps, amounting to probably 90 per cent., according to whether the winch is racing away, or slowed down almost to a stop. This problem should receive more attention, but there are two solutions :—

(1) A separate motor winch on deck or below.

(2) A drive from the main engines to the winch shaft.

The second solution, Figs. 248 and 249 may probably prove the best, as the main engine is really never required to develop full power when the " otter boards " are down, but only sufficient to keep " way on the vessel."

If the engine is fitted below deck it would not affect the

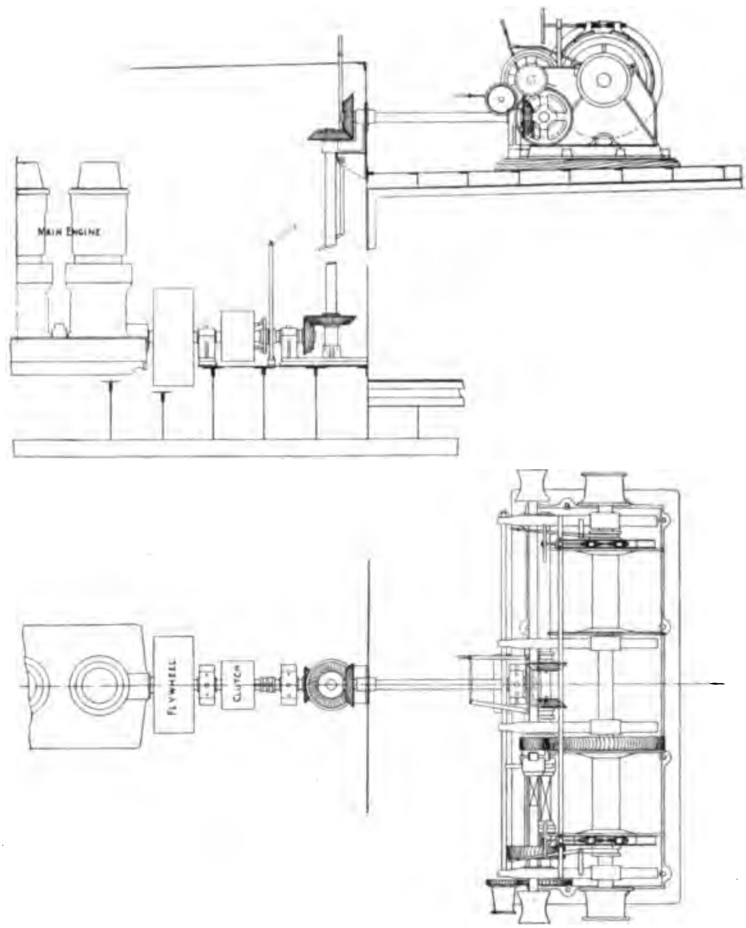


FIG. 248.—Trawl Winch Drive from Main Engine.

fish holds, as the space taken up by the main motor and the motor winch would still be considerably less than that needed for a steam engine and boiler, and this arrangement would have the advantage of leaving much more deck space for sorting out the fish, while the winch would be out of the weather (a considerable advantage in the case of an oil

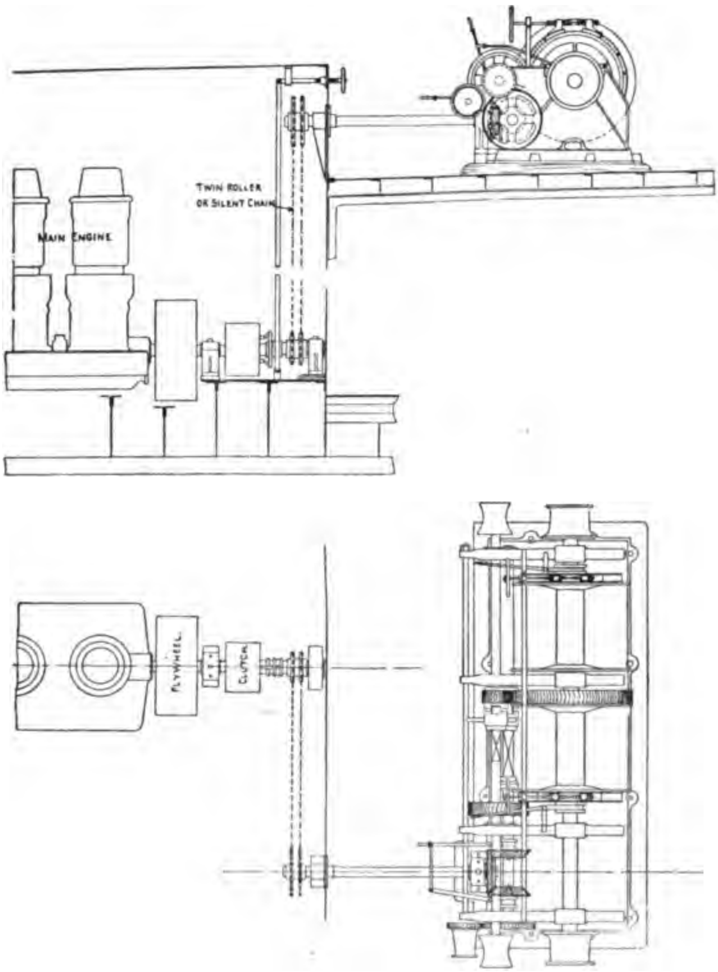


FIG. 249.—Trawl Winch, Chain Drive.

engine), and the controls would all be brought up to the deck. The objection of taking water below with the wire when hauling in would present no difficulty.

A powerful clutch would be required, adjusted so that it would slip after a predetermined strain on the wire was reached and thus save it from breaking.

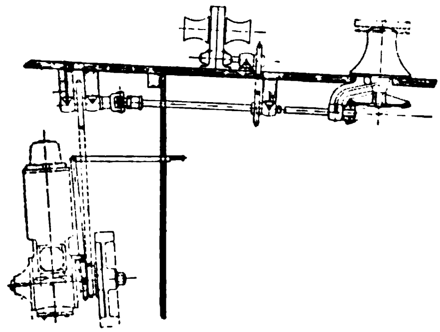


FIG. 250.—Skandia Winch and Capstan Drive.

Capstan and warping winches can be fitted, as shown in Figs. 249 and 250, though instead of a chain, a belt and

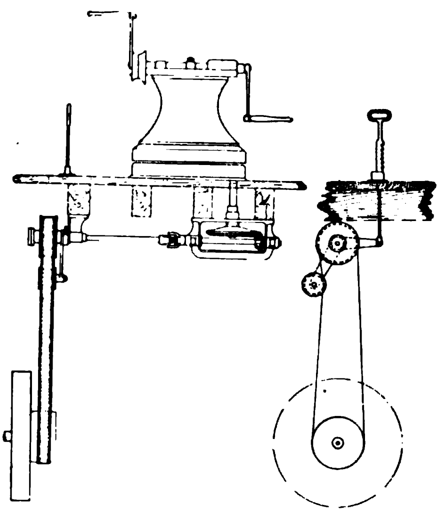


FIG. 251.—Dan Capstan Drive.

jockey pulley can be fitted as in Fig. 251, the belt hanging loosely under the flywheel when the capstan is not in use. When power is required on the capstan the jockey pulley tightens up the belt and transmits power from the main engine.

Tropical Vessels.—It is difficult in some instances to define clearly the different types of vessels and separate them under the sections of this chapter. Some of the ocean-going vessels, coasters, shallow draft boats, etc., might be placed under "Tropical Vessels," or *vice versâ*.

There is ample scope for hot bulb oil engines and vessels for tropical work. Purchasers and users abroad are not usually obsessed with the deep-rooted prejudice of the average Briton.

The transport of fuel is greatly facilitated by being carried in tanks or barrels, and as the freight is a considerable

FIG. 252.—*St. George.*

item, it is obvious that as one ton of oil will equal nearly four tons of coal on a propulsive or ton-mile basis, oil fuel is transported more economically. In one particular case, the cost of transit of fuel was so great that the saving in this item alone paid for an oil engine in nine months. An objection is sometimes raised that the tropical temperatures will evaporate the oil and the loss will be greater than the depreciation of coal by the loss of the gases that the latter contains, but this is not necessarily so because tanks can be sunk in the ground or partly sunk in the river bed to keep the oil cool, and by a simple pump the oil can be drawn out when required.

Owners know and designers should remember that for 95 per cent. of tropical vessels the maximum cargo-carrying capacity and speed are required on the minimum draft.

The cargo being mostly "measurement," large hold capacity should be provided for, with facilities for rapidly getting the cargo on board and ashore. If permanent awnings are fitted over holds, as is usual, the difficulties are increased, but large hatchways, low freeboard, hinged bulwarks and motor winches will facilitate the work of loading and discharging.

To obtain the maximum power for any given deadweight of machinery the hot bulb engine is ideal, as the same propulsive efficiency will be obtained with five-eighths the weight in the machinery alone, as compared with steam, and the same sea or river mileage with one-quarter of the

FIG. 253.—*Aw Kwang*, Twin Screw, 240 B.H.P. Engines.

weight of fuel. The heat from the hot bulbs, even when the lamps are alight, will not be found to be greater than that from the furnaces, and very much less when the lamps are not in use. Most hot bulb engines are designed to run light, or are fitted with air regulators so that the engines can run light, *i.e.*, without load for any period, without the use of the lamps.

A vessel fitted with any form of power should be specially designed to accommodate the power and get the best results therefrom. For tropical work it is necessary to have shallow draft, which usually adds to the difficulty of steering, while rapid handling qualities are specially necessary for winding and narrow rivers, in order to avoid trees and other obstacles met with from time to time. An owner in India stated that his great difficulty was to avoid crocodiles and even if the bow of the launch missed them, the propeller was not always so fortunate and was frequently damaged, so an aerial propeller was fitted as a remedy (see Fig. 302). The fitting of aerial propellers is discussed later.

Large rudder area, strong rudders and heavy steering chains and rods are necessary. The steel hull should have a flat plate keel, and an outside strake of extra thickness, and a spoon bow to deal with rough waters occasionally met with and to reach well into the shore. For some rivers it is advisable in the design of cargo carriers to allow for trimming tanks in the peaks, so that if the bow runs on a

FIG. 254.—*Kasai*, fitted with 240 B.H.P.

sand or mud bank the vessel can be trimmed by the stern to help get her off.

A few years ago many well-known makes of paraffin and petrol marine engines were tried for tropical work, but the majority were unsuccessful, not because the engines were wrong, or because they were not at the time suitable for the work they were called upon to perform, but because native drivers could not be found to manage the four-cycle engines with their magnetos, sparking plugs, cam-shafts valves, etc. The natives had learnt to manage simple steam jobs and became fairly proficient in their use, but the internal combustion engine of the type referred to was too much for them and they could not master it. However, the introduction of the hot bulb engine really revolutionised this tropical trade and the number of native drivers capable of handling the engines is increasing everywhere, especially in West Africa.

Fig. 255.—*Itu*, two 25 B.H.P. Motors.

In Demerara it was interesting to note how readily the natives took to this type of engine, and although they had

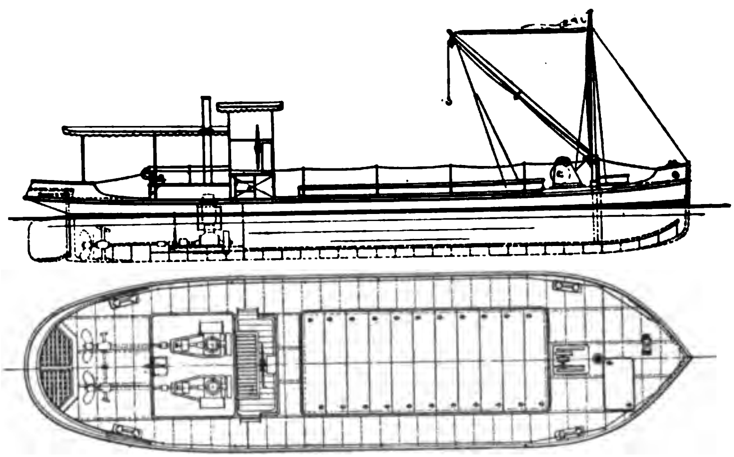


Fig. 256.—Plan of Motor Lighter *Itu*.

little or no experience with any form of machinery, other than having seen sugar machinery at work, they were able to start and work the hot bulb engine after a few hours' instruction.

The supplying and fitting of spare parts of an oil engine is a very simple matter, because they are made interchangeable and hardly require a fitter, whereas for steam engines and boilers it is rare to find two sets alike and very rare to find the parts strictly interchangeable. For working under similar conditions it is easy to guarantee that the cost of upkeep will be less than that of steam machinery and that a substantial saving will be made by the owner of the oil engine.

It is very difficult to find a type of tropical or semi-

FIG. 257.—*Ila* and *Ifr*.

tropical vessel up to 2,000 tons displacement that is not specially suitable for the modern hot bulb engine.

The stokehold of some steam vessels when working in tropical climates is often a veritable inferno, and in some cases so much so that a white man cannot possibly work there. This, however, is not the case with a well-designed hot bulb-engined vessel, and they are, therefore, very popular with tropical owners. Quite a lot of high-powered craft are working in tropical climates, and large numbers are to be seen working in China, Borneo, West Africa, the Congo, Straits Settlements, etc.

A few examples of typical tropical motor vessels are given in these pages.

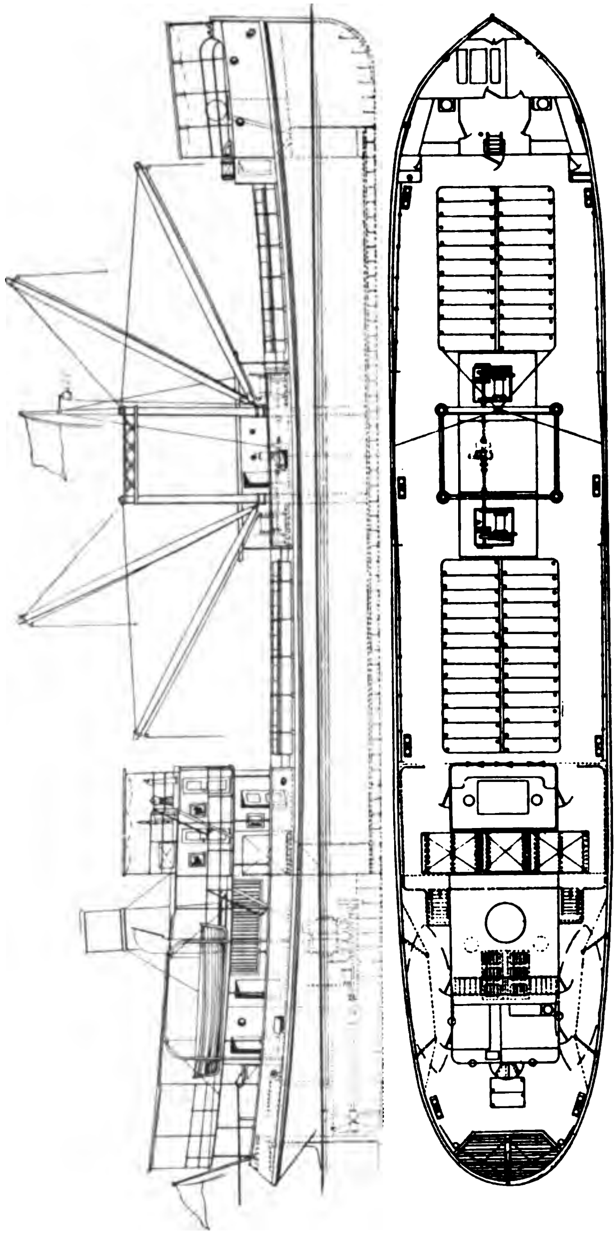


FIG. 258.—*Ila* and *Ife*.

The *Ila* and *Ife,* 135 ft. in length, with a beam of 25 ft. and a depth of 10 ft., were each fitted with two 120 B.H.P. direct reversible Bolinder engines. They have been working at Lagos for some years with native drivers.

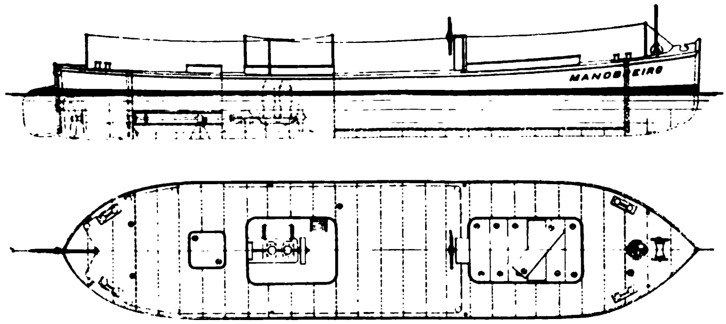


FIG. 259.--Plan of Single Screw Light Draft Motor Barge.

Fig. 259 illustrates a light draft, single-screw motor barge, while Fig. 258 represents a twin-screw vessel of still smaller draft. In this vessel accommodation is arranged for a small crew for extended voyages up rivers, etc.

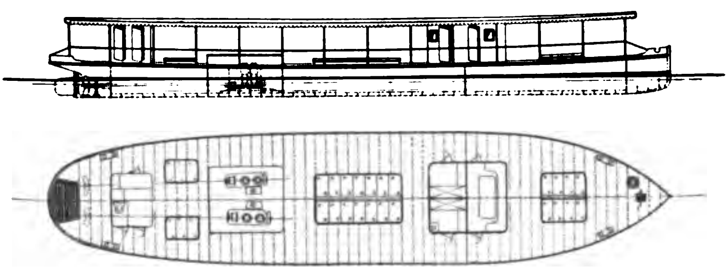


FIG. 260.—Plan of Twin Screw Light Draft Motor Barge.

An example of a motor house lighter is shown in Fig. 261. This type of vessel is very popular in the tropics, especially on the Amazon and other Brazilian rivers.

Figs. 262 and 263 represent two useful designs of passenger and cargo river and coastal vessels. These vessels have good accommodation with a thorough system of ventilation, besides having hold capacity for a reasonable amount of cargo. Fig. 264 also shows a tropical cargo vessel with only small passenger accommodation.

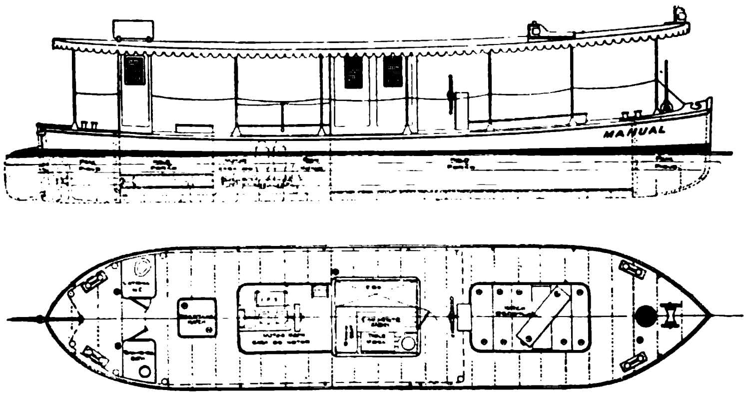


FIG. 261.—Steel Motor House Lighter.

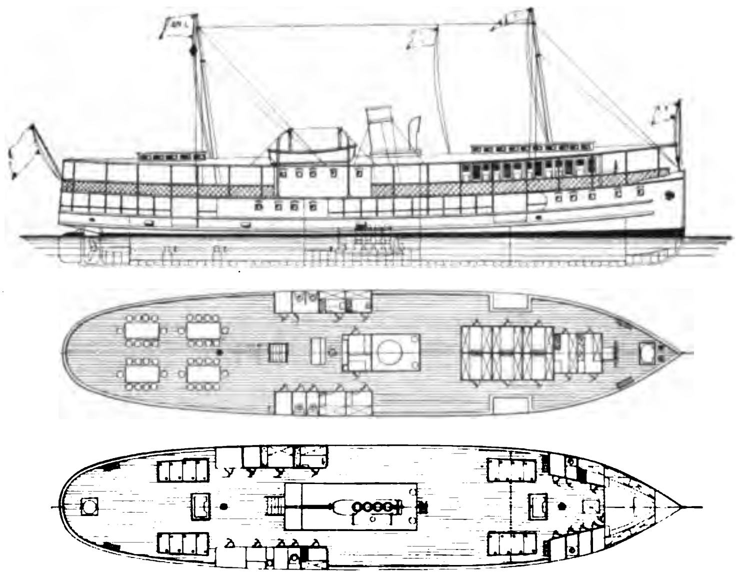


FIG. 262.—Motor Passenger and Cargo Vessel.

On shallow rivers where it is impracticable to use propellers, paddle-wheel craft are often used. Hot bulb engines are quite applicable to these vessels (see design, Figs. 266

and 267), where the engine is placed transversely or drives the paddle shaft through bevel gearing.

FIG. 263.—Tropical Passenger and Cargo-boat *Sinu.*

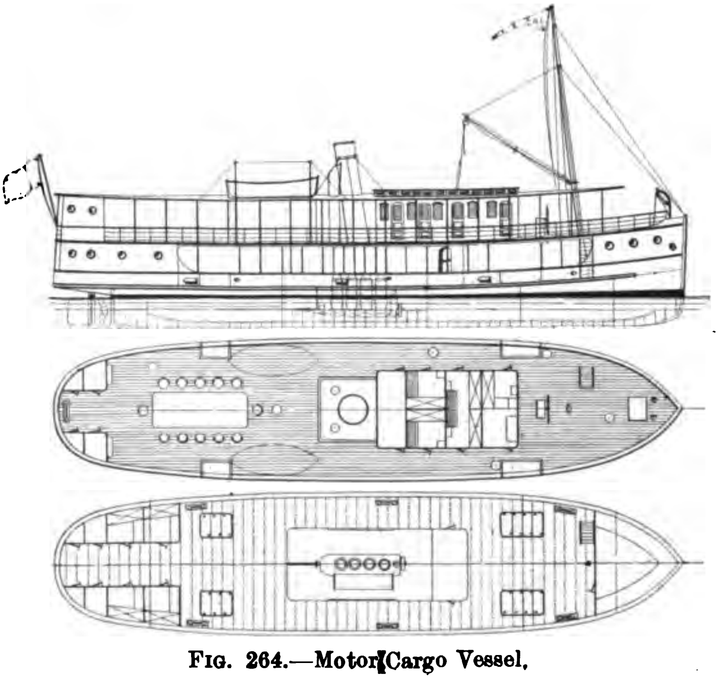


FIG. 264.—Motor Cargo Vessel.

Another class of vessel that has been recently developed is the motor stern wheeler, and there are several successful

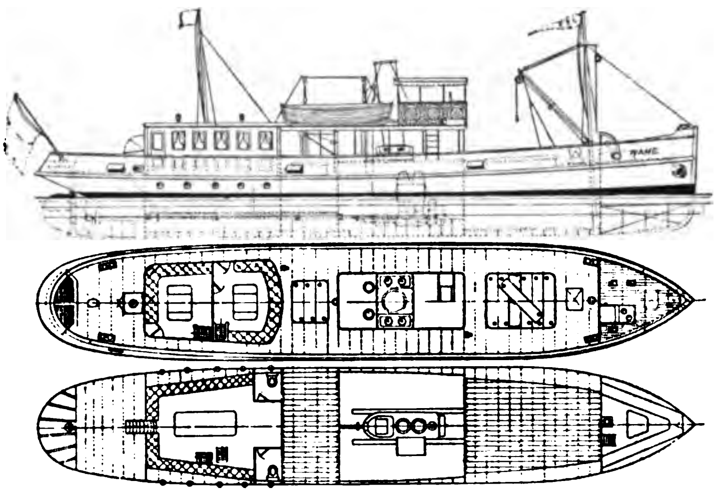


FIG. 265.—River Launch and Cargo Vessel.

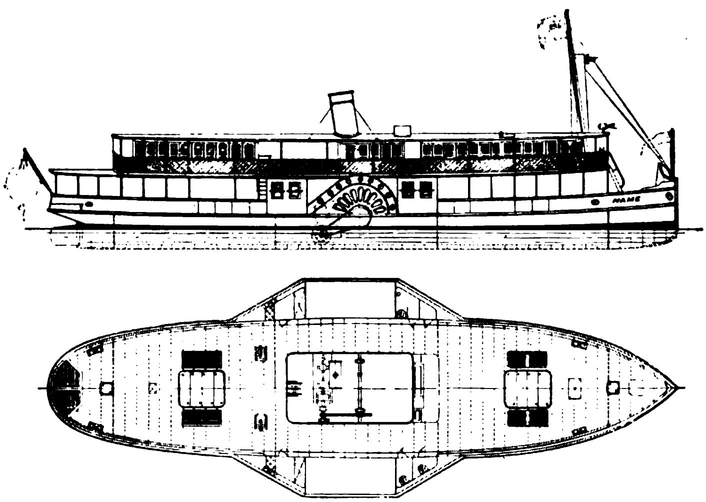


FIG. 266.—Motor-driven Paddle Passenger Vessel.

installations in commission. Two designs are illustrated in Figs. 268 and 269; the engines in these cases being placed amidships on the deck and drive the stern wheel through a shaft and gearing. Engines aft and locomotive boilers forward mean a loss of 10 per cent. in steam power alone, due to condensation in the long steam pipes.

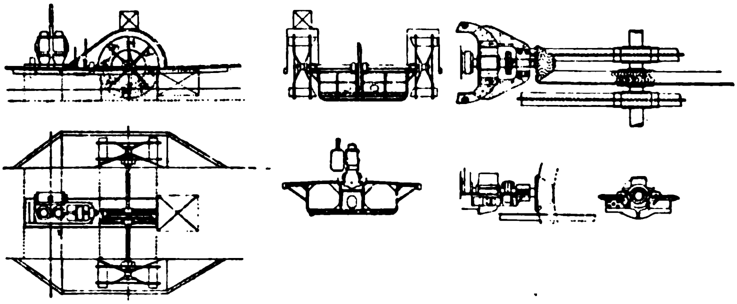


FIG. 267.—Suggested Paddle-boat Drive.

Ice Breakers and Arctic Vessels.—For the purpose of ice breakers, hot bulb crude oil engines of a simple type and construction have many advantages over their steam rivals. For instance, ice breakers should have a very strong and

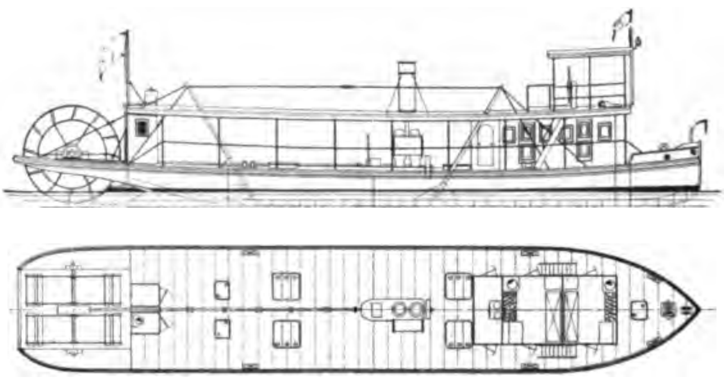


FIG. 268.—Motor-driven Stern Wheeler.

heavy hull, without necessarily having heavy machinery, a condition best fulfilled by an oil engine. The oil engine, too, has not so many pipes to get frozen, and can develop greater horse-power and ice-breaking ability for the same total displacement than a corresponding steam-engined vessel.

The *Albert*, illustrated in Fig. 270, recently made a trip into the Arctic regions, and on several occasions had to act

FIG. 269.—Stern Wheeler, with two Decks driven by Remington Engine.

as an ice breaker in order to extricate herself from the surrounding ice. If the *Albert* had not been fitted with a

FIG. 270.—*Albert*, 120 B.H.P. Engine.

motor, she would in all probability have been caught and lost.

The *Maud*, length 118 ft., breadth extreme 40 ft., depth 16 ft. 9 in., Figs. 271, 272, and 273 is Captain Amundsen's exploration ship, specially built for work in icebound regions. She is of great strength, the frames or ribs touching each other for the full length of the ship. The engine is a four-cylinder Bolinder of 240 B.H.P., a speed of 7·6 knots being obtained when the vessel was light.

Yachts.—For yachts of small tonnage, the motor has already eliminated its steam competitor, but for large vessels it must be admitted that steam has preference, although developments have taken place with large motor yachts.

The advantages that the motor yacht possess over the steam yacht are considerable. The reduced machinery

FIG. 271.—The *Maud,* Amundsen's Exploration Ship.

space leaves room for accommodation, the working costs are greatly reduced, and also, with the motor yacht fuelling is a clean operation, and simply a matter of running a pipe from the shore into the oil tanks, whereas when a steam yacht has to replenish her bunkers, the dust and dirt, etc., causes a great deal of annoyance to the visitors on board. This is a point that carries great weight with yacht owners.

In the case of a 100-ft. yacht like the *Atair*, with a speed of, say, $11\frac{1}{2}$ knots, a machinery space of 23 ft. is ample for the 240 B.H.P. hot bulb machinery and fuel for six days, whereas for steam machinery and six days' coal fuel, a length of at least 37 ft. would be required. The additional length of the centre of the ship in the case of the oil-engined

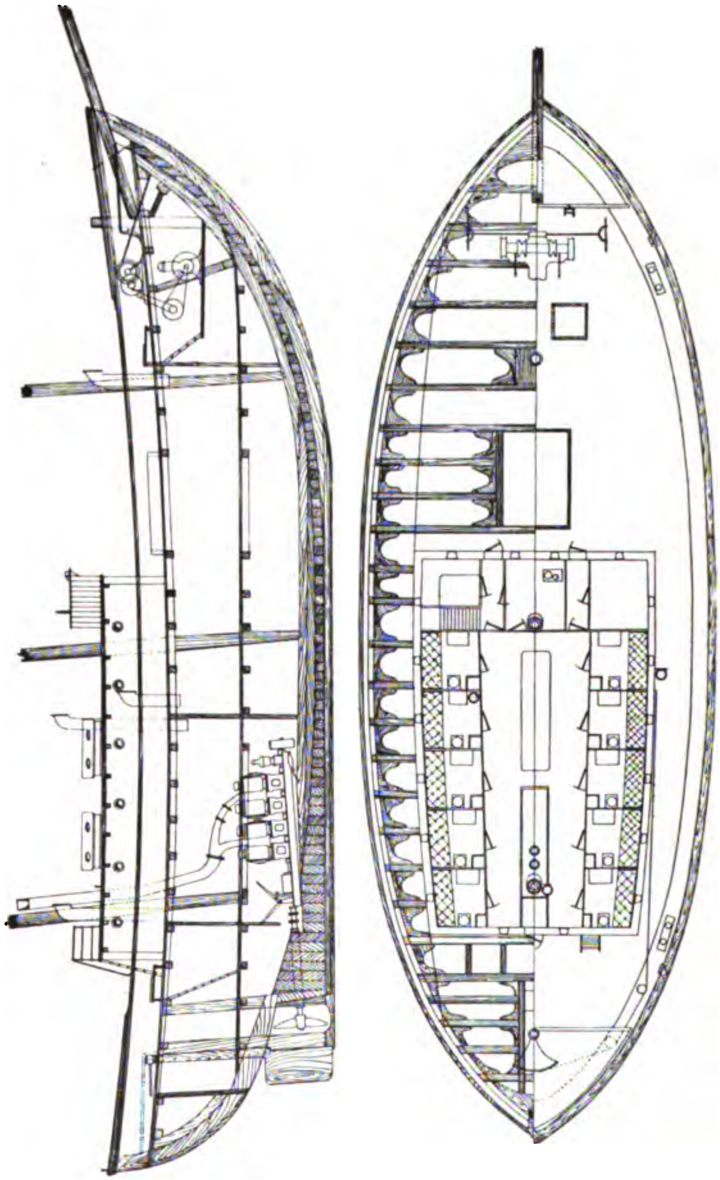


FIG. 272.—General Arrangement, *Maud.*

vessel is therefore 14 ft. Again, the hot bulb oil engine and six days' fuel would only weigh 30 tons as against 80 tons

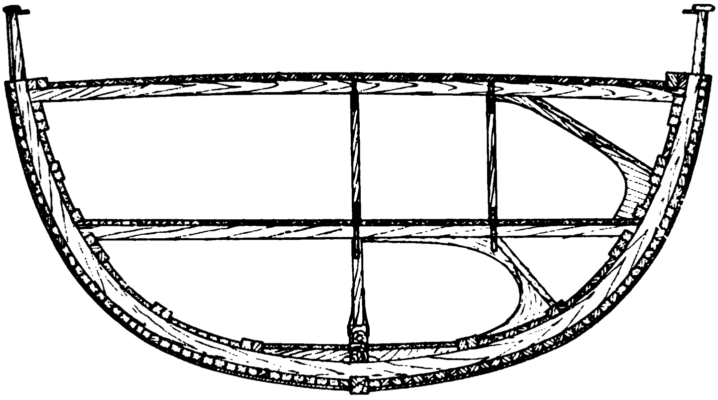


FIG. 273.—Midship Section, *Maud.*

for steam machinery, showing the considerable saving of 50 tons.

In designing, particular attention should be paid to the

FIG. 274.—*Atair,* 240 B.H.P.

position and fitting of the fuel oil tanks, and they should be arranged so that no smell gets to the accommodation ; drip trays should be fitted underneath all tanks with suitable draining arrangements to prevent the oil getting into the bilges, and so being conveyed to all parts of the vessel.

The *Atair*, length 100 ft. × 16 ft. 5 in. × 8 ft., Figs. 274 and 275, was designed and built in this country in 1914 by

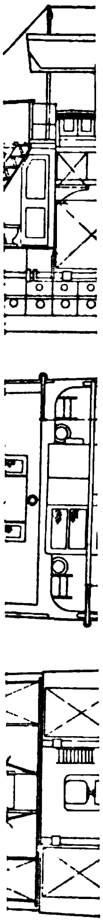
FIG. 276.—*Belem*, 480 B.H.P.

Messrs. Camper and Nicholson, and fitted with two 120 B.H.P. Bolinder motors. As will be seen she was quite a handsome vessel, and is a contradiction of the idea that motor craft cannot be built to such graceful lines as steam vessels.

FIG. 277.—*Manatee*.

The *Atair* proceeded from this country to Buenos Aires, her destination, under her own power.

The *Belem*, another large motor yacht, length 168 ft., breadth 29 ft., depth 15 ft., was originally a cargo boat, but was purchased by His Grace the Duke of Westminster, converted into a motor yacht, and fitted with two Bolinder



engines of 240 B.H.P. each. The *Belem* will be used for making long ocean voyages, and the 70 tons of fuel that her tanks

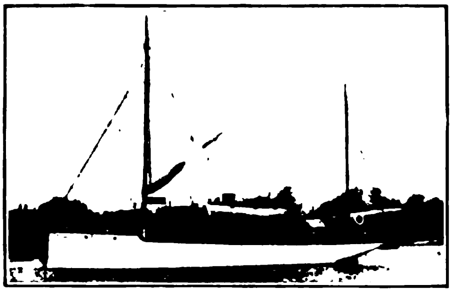


Fig. 278.—*Puffin*, 40 B.H.P.

hold should be sufficient for a voyage of 10,000 to 15,000 miles, depending, of course, on the amount of actual sailing.

Fig. 279.—*Thelma*, 30 B.H.P.

The *Manatee*, Fig. 277, is 110 ft. × 16 ft. × 7 ft. 6 in., with a draft of 4 ft. 6 in., and is fitted with two 76 B.H.P. Kromhout engines.

The *Puffin*, Fig. 278, was for some while employed in the service of the Royal Naval Volunteer Reserve as a patrol boat.

FIG. 280.—*Komuri.*

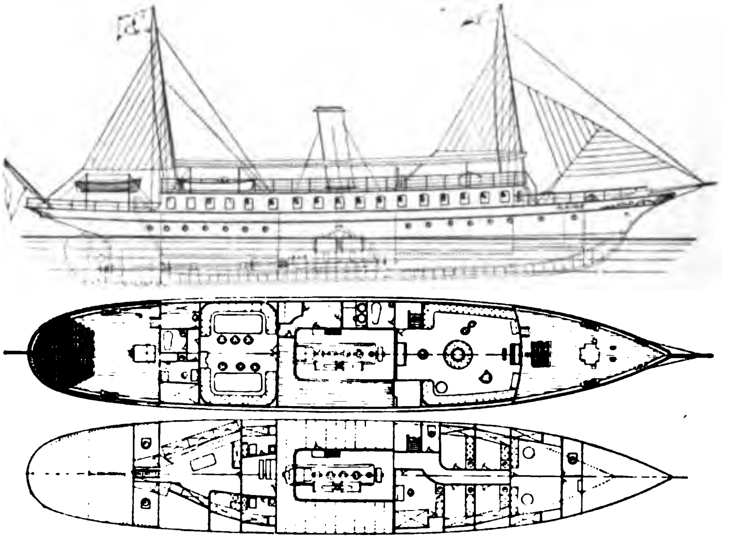


FIG. 281.—Sea-going Yacht with Oil Engines.

It is essential for the comfort of those on board yachts that the vibration caused by the motor should be reduced to a minimum. To this end substantial bearers should be designed, running as far forward and aft as practicable.

In yachts it is generally quite easy to do this, as the bearers can be carried for any length.

Another point that requires consideration is the silencing of the engines. In small yachts the most popular arrange-

FIG. 282.—Yacht *Amazon*, fitted with Remington Engine.

ment is to carry the exhaust into a funnel which forms a secondary silencer, but where this is not possible, it may be carried out through the stern, providing there is no likelihood of its becoming choked by heavy seas.

In other cases, such as the *Belem*, Fig. 276, etc., the exhaust gases have been carried up a hollow mast into the atmosphere. This necessitates a rather large mast, and where this is not an objection, the arrangement is really ideal.

The *Komuri*, Fig. 280, had an exciting experience over the famous "Catlins" Bar, near Dunedin, New Zealand, in January, 1915. A huge sea fell on board and immersed the vessel, and the crew thought that they were overwhelmed and would not survive the ordeal, as the ballast had shifted. However, the 24 B.H.P. Bolinder motor pulled her through.

Fig. 281 is a design by the author of a motor yacht arranged with the maximum accommodation and also with good sea-going qualities. A careful study of the plan will make the numerous advantages apparent.

Ships' Launches.—Considering the proved advantages of the internal combustion engine, it is somewhat surprising that so many steam launches are still built and carried by ocean liners and by the vessels of the Royal Navy. The motor launch weighs less, is faster, and much more powerful for towing, and in every respect superior to the steam launch if the motor launch is fitted with a good hot bulb engine. To prove this, a motor launch was designed and constructed in 1912 to compete with a steam launch, the particulars of the two boats being as follows :—

	Steam Launch.	Motor Launch.
Reference	S.A.	M.B.
	ft. ins.	ft. ins.
Length O.A.	32 0	32 0
Breadth	8 9	8 9
Depth	4 0	4 3
Draft	3 0	3 0
Weight, complete	$10\frac{1}{2}$ tons	7 tons.
Speed, miles	7	$7\frac{1}{2}$
Engines	5 in. × 10 in. × 6 in.	20 B.H.P. Bolinder.
Boiler	3 ft. 9 in. × 5 ft. 1 in. 120 lb.	—

After the trial the owners reported that :—

"The motor launch worked very well during the time we were in the rivers. She is superior to the steam launch for towing and also for speed. Several tests with these launches were carried out which included placing the boats stern to stern with a long tow-rope between and letting them go full speed ahead, when the motor launch pulled the steam launch up and down the river. The motor launch was also tried by towing a raft of logs and she towed them very well. Then the two launches were tried for speed, when the motor launch was again successful in beating the steam launch."

FIG. 283.—Motor Launch for carrying on Steamers' Decks.

Ships' launches should for preference be constructed of steel if they are to have oil engines fitted, as the steel boats are much stronger, and with an ordinary bar keel keep the shafting in alignment better than any wooden launch. Again, the steel boat can resist the almost continuous vibration that is experienced on the boat decks of large vessels, expecially of the ocean liner type.

For tropical work steel boats have many advantages over wooden ones, as they are not affected by hot weather and, consequently, do not have to be partly filled with water to keep the seams tight. With care and ordinary attention they do not rust and do not leak. If they are damaged by swinging alongside the ship's side they will probably not be broken but only indented, which will not prevent their use until such time as repairs can be made. If a wooden launch is damaged it will probably be useless until properly repaired.

Launches.—There are, of course, many different types of launches, and for some classes the hot bulb oil engine is really not as suitable as the petrol or paraffin engine, for instance, craft in which very high speed is desired. For commercial launches, however, there has been a great demand for hot bulb engines, especially where it is desired to do some towing or heavy duty. In this direction installations

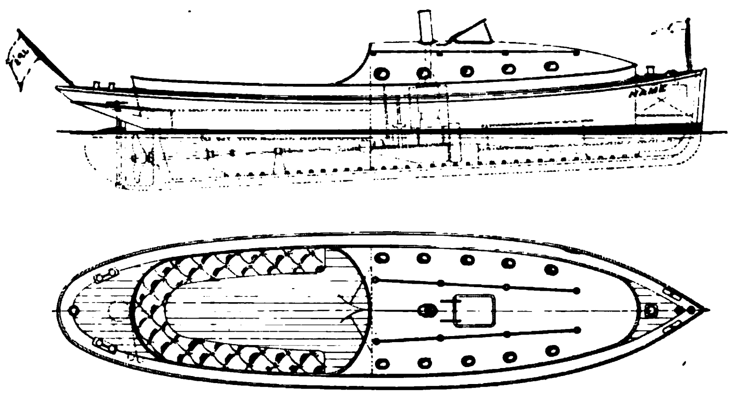


FIG. 284.—Plan of Motor Launch for carrying on Steamers' Decks.

have been made in launches for carrying on steamers' decks, harbour and dock craft, missionary and passenger boats, tenders, etc.

A plan of a hot bulb-engined launch is given in Fig. 284. Boats of a similar design have been supplied to some of the best known shipping companies for carrying on their steamers' decks, and to put in the water in tropical countries for towing merchandise and cargo out from the shore, over bars, etc., where it is not possible for the steamers themselves to load alongside the quay.

The engine is, of course, situated amidships, with a large cockpit aft and turtle back forward. As these little craft often have to work in rough water, the exhaust is led to a funnel, which eliminates the possibility of the engine being stopped in a sea-way by flooding.

FIG. 285.—Launch towing.

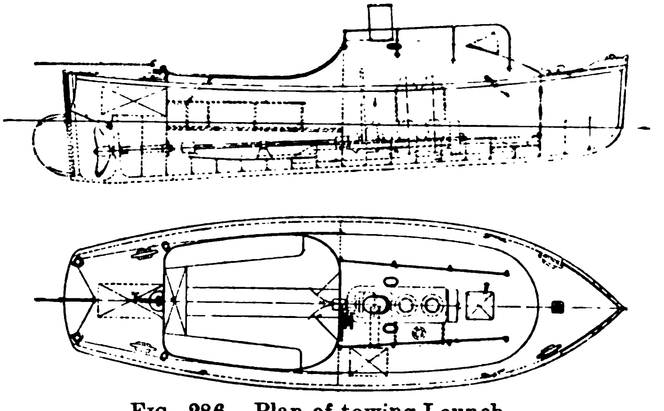


FIG. 286.—Plan of towing Launch.

Figs. 285 and 288 are photographs of some of these vessels in commission. Owing to the economy of the type of engine that is being dealt with in this book it has been favoured for passenger work, that is, where the owner is running his craft as a commercial proposition and to make a profit. Another great point in favour of this type of engine is its safety, as there have been several fire accidents with petrol and paraffin passenger launches, in which, unfortu-

FIG. 287.—Three Launches, side view.

nately, loss of life has occurred. There is not, however, on record, a similar case with hot bulb oil-engined launches.

FIG. 288.—Launch.

Naturally, this point is of importance to purchasers, and the hot bulb oil engine is coming more and more into favour

FIG. 289.—*Singapore.*

for passenger craft. In Sweden, Russia, Denmark, etc., it has practically supplanted the paraffin engine.

An interesting installation was that of the *Tamate*, Fig. 292, fitted with a 50 B.H.P. Bolinder motor. Before the order for this engine was placed, the owners had to satisfy themselves that they would get machinery that was absolutely reliable, and would give no trouble in the hands of

FIG. 290.—*Haycrone.*

inexperienced drivers, as the launch was to be used for missionary work in practically unexplored rivers in New Guinea. The performance of this boat when in commission fully justified the owners' choice. She was shipped to the East Coast of Australia and made the voyage of several

FIG. 291.—Passenger Launch for Swedish Navy, 50 B.H.P.

thousand miles up the coast to New Guinea, in the hands of the missionary himself, who had not only had no experience of hot bulb motors, but was a layman with any type of machinery. Notwithstanding this, the *Tamate* reached her destination in good time, with boat and engine in first-class order.

Fig. 294 shows a handsome, fast motor launch suitable for a yacht's tender, fitted with a hot bulb motor.

FIG. 292.—*Tamate.*

The following particulars of the machinery of two 50-ft. launches illustrate the advantage of oil engines over steam.

FIG. 293.—*Pinmill,* 20 B.H.P. Dan.

The steam machinery is taken as a set of 7 in. and 14 in. × 9 in. stroke compound surface condensing engines, with a

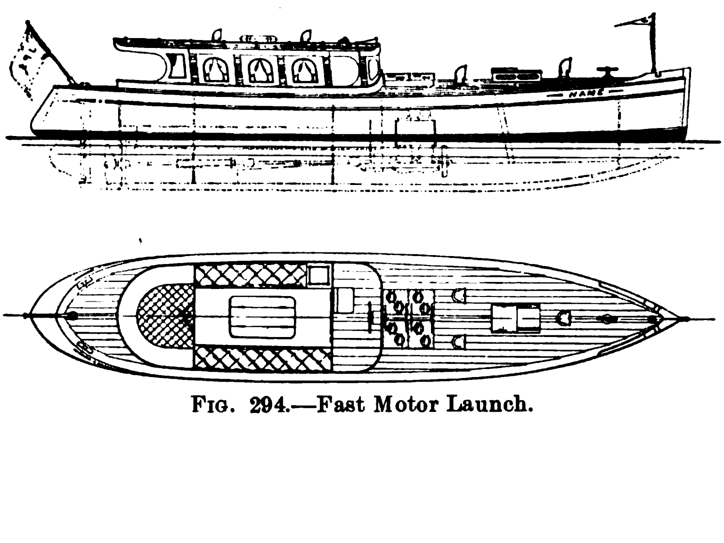


FIG. 294.—Fast Motor Launch.

boiler 6 ft. × 6 ft., working at 120 lb. pressure, with usual auxiliaries. The oil engine is an ordinary hot bulb engine by well-known makers.

	Steam 60 I.H.P. 2 cyl.	Oil Engine 80 B.H.P. 2 cyl.
	Tons.	Tons.
Machinery	9	6·5
Water	1	0·5
,, tanks	0·25	0·25
Fuel	1·5	1·25
Tanks or bunkers	0·25	0·5
Total	12	9

Approx. vertical C.G. above bottom of keel	4 ft. 9 in.	3 ft. 11 in.
Speed, knots	9	10
Consumption per hour, lb.	180	47·6
Radius of action, hours	18·5	58·8
Radius of action, sea miles	166	588
Length of machinery space fore and aft	17 ft.	12 ft.

(*a*) Reduction in weight—3 tons.
(*b*) Speed increased by 1 knot.
(*c*) Reduction in the vertical C.G.—10 in.
(*d*) Radius of action increased by 350 per cent.
(*e*) Machinery space reduced by 5 ft.
(*f*) A safe fuel oil can be used.

Canal Barges.—In considering the question of propulsion for canal barges in Great Britain and Ireland, the natural difficulties should not be overlooked. With few exceptions the barges are quite small, on account of the narrowness and shallowness of the canals and the small size of the locks. The most important canals go through hilly country, involving many locks which necessitate the frequent stopping and starting of the engines, or running light for a considerable period. On the Worcester Canal the average fall is 15·8 ft. per mile, and on the Birmingham to London canal, 8·5 ft. per mile.

On these canals the almost universal means of propulsion was by horse haulage, and sometimes by men and women haulage. For the last twenty years, steam tugs and steam barges have made a bid for favour, but owing to the heavy weight of efficient machinery, the limited breadth and depth of the canals, they have not entirely supplanted the ancient horse towage.

About 1895, oil engines were introduced and various types of engines were tried, but they did not find favour. The petrol and paraffin engines failed because of their high revolutions and small propellers. In 1910 the two-cycle

FIG. 295.—*Speedwell*, 20 B.H.P. Motor.

hot bulb oil engine was introduced and has since made considerable progress. The objection to the hot bulb engine used to be that it was necessary to have a pressure lamp burning to keep the bulb hot enough to keep the engine running when going through locks. On the other hand, the stand-by losses with a horse are considerable, because if a barge is stopped for a week or so, the horse has to be fed all the time, and housed at night time.

The use of hot bulb oil engines for the propulsion of canal barges has proved a boon to the traders and coal companies, and has undoubtedly drawn attention to the possibilities of our inland waterways. A few years ago there was not a successful motor canal barge in the British Isles, now there are over 100, and the increase is steady and continuous.

The advantages of motor canal barges are numerous.

In the case of one company, the cost of transporting goods by motor barges in Ireland was 4*d.* per 40-ton mile, or 0·10*d.* per ton mile as against 10½*d.* per 40-ton mile for horse-drawn craft or 0·262 per ton mile. Such a remarkable result was bound to revolutionise the business. On the English canals the economy is just as pronounced, and the number of firms who are being converted is steadily increasing.

Any canal bargee in charge of a motor barge, if asked why he was converted, will say that he is fond of his motor vessel because he has not to be always trudging along

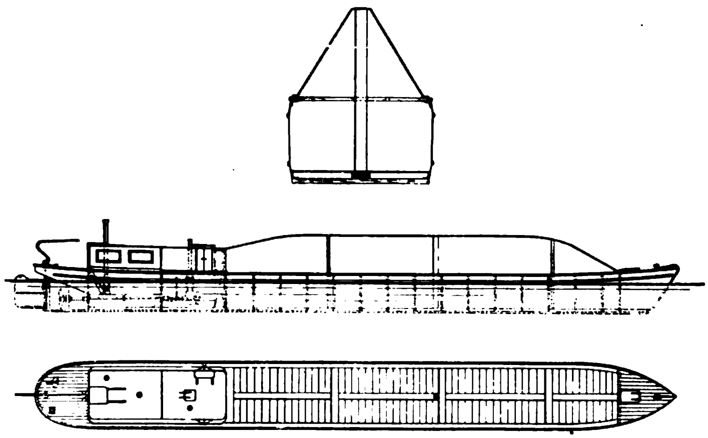


FIG. 296.—Canal Barge of the "Monkey" Type.

towing paths, which have not been kept in a fit state for human or horse traffic, he does not have to work so hard, and even with the smaller amount of labour he can earn more money.

The canal horse is often an object of pity, and there is a society that keeps inspectors on the towing path to protect these animals. With the motor barge, however, all this will disappear in time.

The British canals are all of very limited dimensions, and compared with the Continental canals, very small.

The majority of the canal boats in England are known as "narrow" or "monkey" boats, and are 70 ft. long × 7 ft.

beam × 3 ft. 6 in. deep. A comparison between a steam and a motor boat of this type, which is the only comparison that can be made outside of the horse-drawn barge, shows that with 15 H.P. in each case the motor-driven boat will carry 26 tons at $3\frac{1}{2}$ miles per hour against the 19 tons of the steam-driven boat at the same speed, and with same crew in each case. If long journeys are made without taking in fuel, the comparison is still more in favour of the motor barge.

Even to this day a number of barges can be seen working between Gloucester and the Birmingham district, where the motive power along the canals is obtained by two donkeys and along the river by steam tugs, the procedure being somewhat as follows :—

The barge leaves Gloucester in charge of a steam tug, the pair of donkeys being lifted on board the barge ; on arrival at Worcester or Stourport, the steam tug is discarded, the donkeys lifted ashore, and the canal portion undertaken by the animals to the outskirts of Birmingham. The donkeys bring the barge back again usually with coal cargo to, say, Worcester or Stourport, and are placed on board and go with the barge and cargo to Gloucester by steam tug. Here is an opportunity for hot bulb oil engines for the cost of towage, and handling and feeding the donkeys must be enormous compared with the running cost of a good oil engine.

The reason why the hot bulb oil engine is not adopted for this and many other trades is no doubt due to the capital cost, the wooden horse-drawn "narrow" boat costing in normal times from £120 to £155, and the motor vessel of the same size costing £370 to £450.

The boat owners frequently overlook the fact that the motor-driven boat can get more quickly to its destination and, consequently, can carry more freights per month, with the corresponding larger takings and profits. As an example, the *Bournville I.*, a canal barge with only a 15-B.H.P. motor, was navigated under her own power, with full load, from Gloucester to Kinver, a distance of fifty-two miles, going through fifteen locks on the journey, and completed the trip in 11½ hours, truly a remarkable performance. A similar narrow boat, horse drawn, would only do about twenty miles a day and would, therefore, take two and a half days for the journey. The motor barge would earn the same freight in less than half the time.

A common error, and one that has caused much expense and disappointment to canal barge owners and others, is that all oil engines of the same horse-power should give the same results and drive the barge at the same speed. This is not so, as the lighter petrol or paraffin engines run at a greater number of revolutions with very poor driving power at the propeller, and are more costly to run than hot bulb oil engines. A 20 B.H.P. engine running at 400 revolutions per minute will give much greater propulsive power for a heavy barge, than a 20 B.H.P. paraffin engine running at 750 revolutions per minute.

As an example of the great economy of canal transit, the following actual figures are given.

Two barges, one a motor and the other a "butty," or towing boat, made a trip from Brentford to Leicester, a distance of 140 miles by canal. The motor boat carried 24 tons and the butty 28 tons, that is to say, a total cargo of 52 tons was conveyed. The captain received 1*s.* 10*d.* per ton for the trip, and from this he provided ropes, crew, driver (usually captain's son), food, etc.

	£	*s.*	*d.*
The captain, crew, and driver received	2	3	4
The fuel consumed was 1 gallon per hour and the trip lasted for five 15-hour days, and with fuel at 4*d.* per gallon the cost was	1	5	0
Add 5 gallons paraffin, 1 pint methylated spirits and stores, say	0	5	8
	3	14	0
Interest at 5 per cent. per annum on £400	0	5	6
Depreciation at 4 per cent. on £400	0	4	5
Total cost of transit	£4	3	11

This makes the cost per mile for 52 tons 6¾*d.*, which is about [illegible] of a [illegible]. No consideration has been given to [illegible] as these are standard for all types of vessels. Any owner of canal boats knowing the freights that can be carried can work out the economy.

Canal Failures.—In the pioneer days of motor canal barges a lot of harm was done to the cause of the motor propulsion by the failures of some of the efforts of manufacturers of light and high speed motors. The fault really lies with the owner, as he would not be brought to appreciate that to put an engine with high revolutions in a slow speed

Fig. 297.—Pollock Twin Rudder on *Bournville I.*

barge, and then expect a bargee to run it, was like giving a navvy a table of logarithms, and expecting him to use it.

For a long while these ideas were retained, and in one case four different engines of the high-speed class were tried in one barge, and not one of them was satisfactory.

Even now when the superiority of the hot bulb engine has been proved without a doubt, some owners are still experimenting with twin-screw engines, each of 10 B.H.P. to drive a canal boat three miles per hour, when a single-cylinder engine and single screw would be superior in every way.

Fig. 297 illustrates a twin rudder designed by the author; the advantages claimed are :—

(*a*) The banks of the canals are not washed away, as the two rudders keep the stream of water in the centre of the canal, especially when going round bends or passing other barges.

(b) The total length of the barge overall is less, as the rudders do not require to be so long as a single rudder.

(c) Both rudders can be folded more conveniently across the stern of the barge when going through a lock.

Canal tugs are referred to on p. 255.

Aerial Propelled Vessels.—With the present rapid progress in aeronautical engineering, it is possible that the efficiency

FIG. 298.—*Aerotug.*

and usefulness of aerial propellers may be increased for boats in which the ordinary propeller has insistent disadvantages.

To obtain good efficiency from an aerial propeller is much more difficult for water-borne vessels than for aircraft, owing to the much slower speed of the former. The aerial propeller is therefore only suitable for vessels in which the ordinary propeller is prohibited for specific reasons, such as the necessity for abnormally shallow draft for navigating in the presence of tree stumps, thick weeds, and so forth. In such cases, however, it has been used with success, both for passenger and cargo carrying in tropical waters. High propeller revolutions are necessary, involving chain or gear drive, which is the chief difficulty in making a really reliable installation.

The hot bulb engine is selected for the work mainly for its simplicity and reliability, and the ability of natives to drive it satisfactorily. It has one great disadvantage—that of heavy weight for light draft boats.

FIG. 299.—*Aerotug*, running light at Five Miles per Hour.

The first experimental vessels had light high-speed petrol type engines and turned out failures, not on account of the principle of propulsion, but owing to unsatisfactory results from the engines with their numerous small parts.

FIG. 300.—*Aerotug*, towing 30 Tons Displacement.

Having observed the results obtained from the light petrol engines, experiments were made with a hot bulb engine. One of the first results was the *Aerotug*, Figs. 298, 299 and 300. The hull was built of steel, and had a length of 30 ft., a breadth of 8 ft., and a draft of only $8\frac{1}{2}$ in., although the bottom plating was nearly $\frac{1}{4}$ in. thick, and a heavy oil engine of 15 B.H.P. was fitted, a mean speed of five miles per hour was obtained.

FIG. 301.—Aerial Propelled Vessels.

As will be seen by the illustrations, the framework to carry the propeller was built of steel angles and heavy cross bracing, and when the propeller was designed as a " tractor " this bracing was found to seriously detract from the effi-

FIG. 302.—*Aerial.*

ciency. In later experiments tubular framework without bracing near the periphery of the propeller greatly increased the efficiency.

Propellers were designed and made of varying surfaces and pitches, but all of two blades, the revolutions varying from 850 to 1,150 per minute with diameters up to 9 ft., so that the peripheral speed of the propeller was as much as 370 miles per hour. The propellers designed as "pushers"

FIG. 303.—*Elspeth.*

were found more satisfactory, as the air passing the framework and entering the propeller only had a speed of from five to eight miles per hour, the air leaving the propeller at,

FIG. 304.—*Elspeth.*

say, eighty miles per hour, having a clean run, without any obstacle to resist its passage.

The results of the towing trials of the *Aerotug*, Fig. 298, and of other shallow-draft vessels with aerial propellers pleased and surprised the technical people present.

A passenger vessel called the *Aerial* was fitted in India with a four-bladed aerial propeller driven by a 50 B.H.P. Bolinder oil engine, see Fig. 302. In 1915 and 1916 this vessel was used as a Red Cross launch in Mesopotamia.

The *Elspeth*, Figs. 303 and 304, is a shallow-draft steel launch and tug, length 35 ft., breadth 8 ft. 6 in., draft $8\frac{1}{2}$ in., fitted with a 30 B.H.P. Bolinder hot bulb oil engine, and obtained a speed of nearly seven miles per hour.

Fig. 305.—Tin Dredger, three 45 H.P. Kromhout Engines.

Besides the elaborate tests of propellers, various types of chain drives were also tested with the result that silent chain was preferred, where the heavier weight was not of great importance and a jockey pulley was not of great consequence. On others, a bushed roller chain and jockey pulley was considered preferable, and although the life was not so long, the compensating advantages were attractive. So far, these drives have not proved absolutely reliable.

It is necessary for the table to carry the propeller shaft bearing and thrust block to be of rigid construction and to have a planed surface to facilitate the lining up of the bearings. It is also important to run the high-speed "driven" shaft in ball bearings and use roller bearings for the thrust block with convenient means for oiling, overhauling, and adjusting.

A guard should be fitted round the lower part of the propeller to prevent accidents to the crew whilst going fore and aft.

The engine should be made reversible, as, although it is difficult to get "sternway" on the vessels, it is of importance to be able to stop the vessel from going forward in case of danger ahead.

FIG. 306.—China Dredger.

Weed boxes for the circulating water and other special features should be fitted to all vessels of this type when of shallow draft (see Fig. 336, p. 373).

Motor Dredgers.—There are quite a number of successful motor dredgers both of the suction and bucket type in operation. Their advantages over the steam dredgers lie in their reduced cost of operation, reduced draft, longer working range, the absence of stand-by losses, and the fact that unskilled labour only is required, etc.

In Alaska, a dredger designed to dig at 35 ft. below the water level is working well and the hot bulb engine is run on Californian oil. The engine is connected to a $3\frac{1}{2}$ cubic ft. bucket elevator dredge, with close connected bucket line, revolving screen, and belt stacker.

The tin dredger (Fig. 305) is 82 ft. × 33 ft. × 4 ft. 5 in., with a draft of 2 ft. 9 in., and fitted with three 45 B.H.P. Kromhout engines, driving dredging gear, etc., and an 8-H.P. Kromhout for electric light.

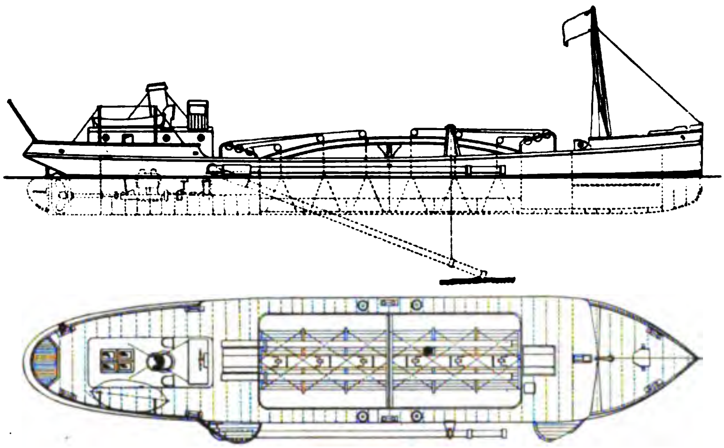


FIG. 307.—Motor Suction Dredger.

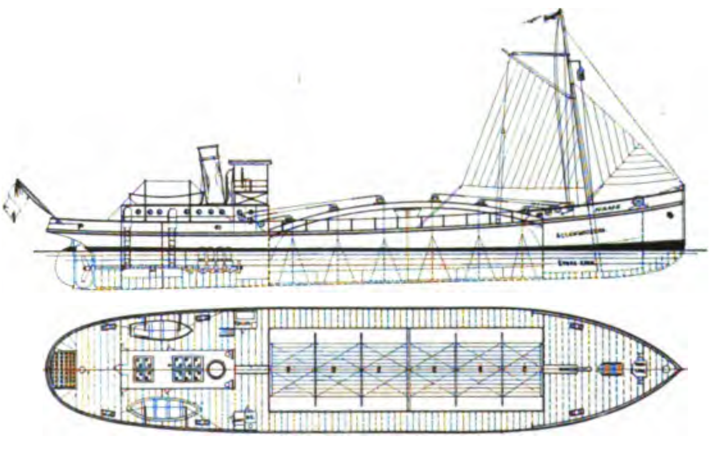


FIG. 308.—Hopper Barge.

Fig. 306 shows a motor bucket dredger working in Hong Kong. In this case the engine was of the horizontal type and drove the elevator through a belt.

Fig. 307 illustrates a motor propelled suction dredger, of which the dredger was also worked by the main 50 B.H.P. hot bulb motor; she has been in successful commission for several years.

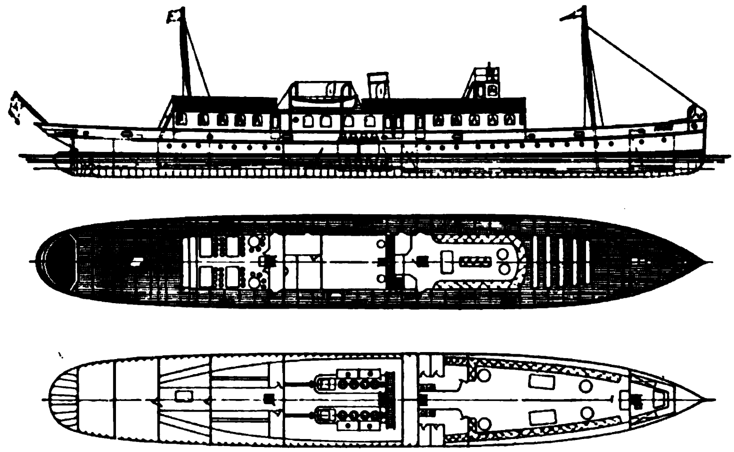


FIG. 309.—Twin Screw Motor Passenger.

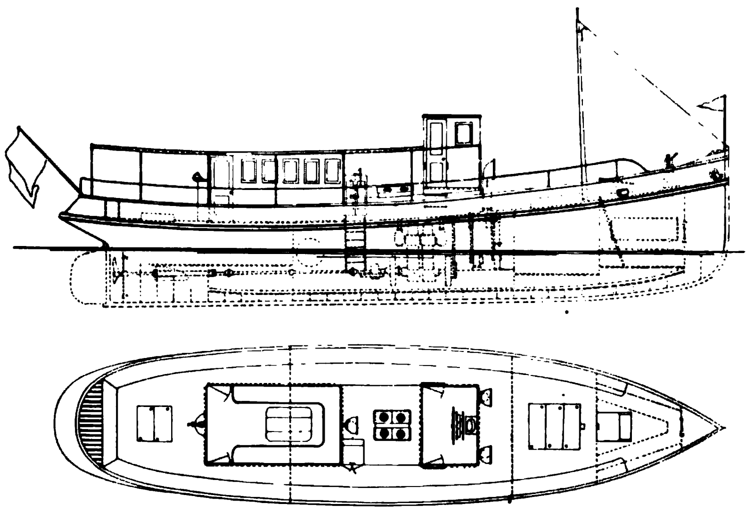


FIG. 310.—Passenger Boat, Dan Engine.

Dredgers frequently are only able to work during certain periods of the tide, and during the remaining period the steam-engined vessels have to remain under banked fires, with consequent heavy stand-by losses, which a dredger fitted with a hot bulb oil engine would obviate.

FIG. 311.—Water Boat *Aquadon.*

Hopper Barges.—Hoppers are also suitable vessels in which to install these engines for main and auxiliary power. Besides the ordinary types of vessels already dealt with

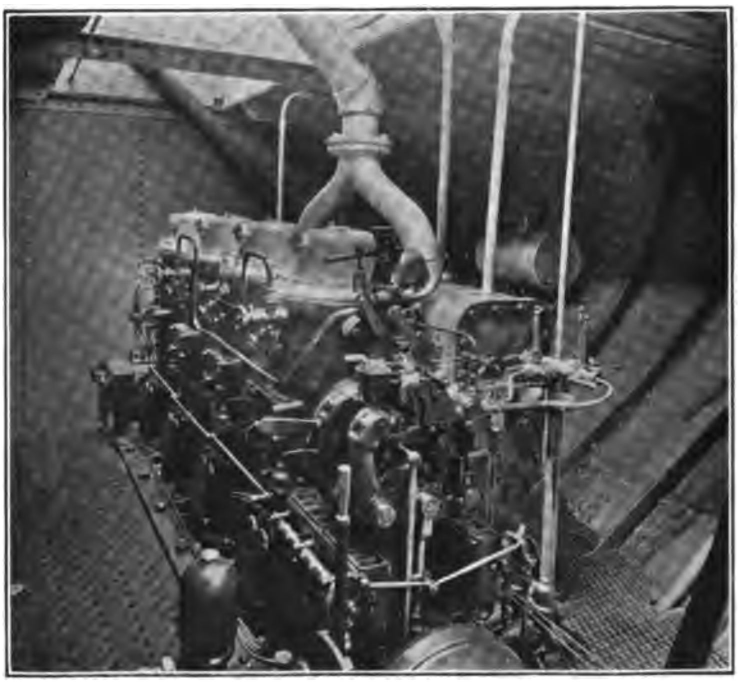


FIG. 312.—Motor Room of *Aquadon.*

in this chapter, the hot bulb oil engine has been fitted in practically every type of floating craft.

Passenger Vessels.—A design of motor passenger vessel is illustrated in Fig. 330.

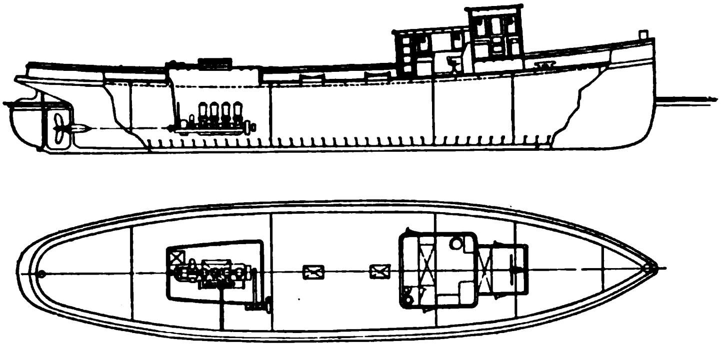


FIG. 313.—General Arrangement of Water Boat *Aquadon.*

It is only a question of time when these engines will be almost exclusively used for the purpose.

Water Boat.—Figs. 311, 312 and 313 illustrate the Water Boat *Aquadon*, fitted with a 100-B.H.P. engine.

FIG. 314.—*Huron.*

Lightships are specially suitable for this type of engine because full power can be obtained from cold in fifteen to twenty minutes in case the lightship gets adrift.

The American lightship *Buffalo*, 97 ft. long, is built of steel, and is fitted with a Mietz and Weiss, 3-cylinder hot bulb engine. Two smaller Mietz and Weiss paraffin engines are used in connection with the air compressors for furnishing the air for the fog signals.

FIG. 315.—*Quarken*, 120 B.H.P.

The *Huron*, 118 ft. × 26 ft. × 11 ft., was built of steel in 1892, and has two fixed red lights of 300 candle power, and a 12-in. air syren. In 1915 she was fitted with a three-cylinder Mietz and Weiss direct reversible engine of 100

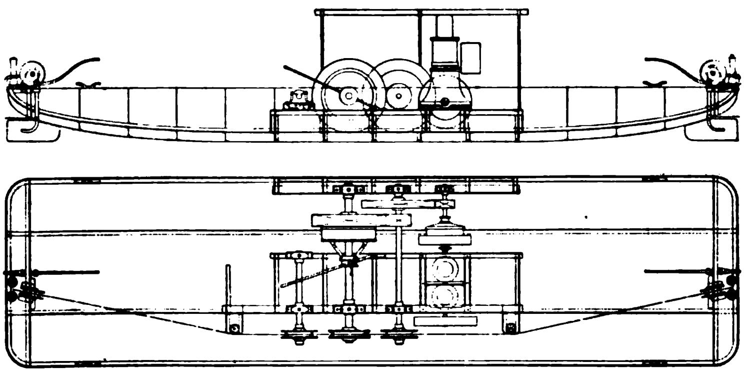


FIG. 316.– Chain Haulage Punt.

B.H.P., two 30 B.H.P. Mietz and Weiss hot bulb engines being fitted for the syren and auxiliaries.

The *Quarken*, Fig. 315, is a Swedish lightship fitted with a Bolinder engine of 120 B.H.P.

Chain Haulage Punts.—Various types of power boats have been used for towing cane punts in the West Indies. The one illustrated in Fig. 316 is fitted with a Dan engine. About four miles of chain are laid on the bottom of

FIG. 317.—Ferry Boat, 12 B.H.P.

the canal and the punt hauls the chain in forward and passes it out aft, thus hauling itself along together with any barges that it has in tow. The engine runs at 400 revolutions

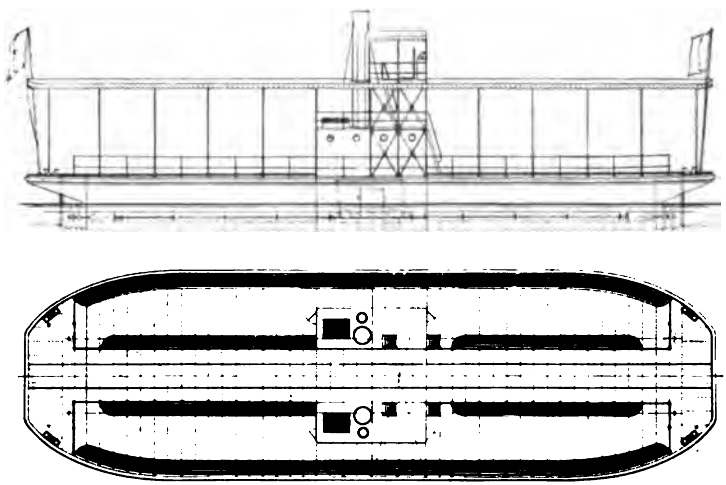


FIG. 318.—Double-ended Ferry.

and the chain sprocket wheel is geared down to 50 revolutions per minute. It is said that this towing punt cost only 0·4 pence per ton mile to work, as compared with 2·4 pence for the bullock traction along the bank, previously used.

Floating bridges and horse ferries can be economically run in the same way.

Ferry Boats can be driven at a very small cost with hot bulb engines. Fig. 317 shows a small vessel built for running across a dock and fitted with a Bolinder motor which has been doing the work satisfactorily for over three years.

Fig. 318 is a design of a ferry that is suitable for many parts of the world, and one that can be driven more economically than with any other form of machinery.

Lifeboats are also suitable for this type of engine since a heavy douche of water will not affect the running, which is hardly the case with a paraffin or petrol engine.

FIG. 319.—Motor Lifeboat *Leufsta.*

The *Leufsta*, Figs. 319 and 320, was probably the first hot bulb-engined lifeboat. She is fitted with a 30 B.H.P. Bolinder.

Pilot Boats.—Fig. 322 shows a modern pilot vessel. When waiting for steamers this craft can keep under weigh with sails alone, but when a steamer is sighted, the motor can be started to enable her to get near alongside, as handily as a steamboat would do. All stand-by losses are therefore eliminated which, together with the economy of fuel, reduced engine-room staff, etc., present great advantages over steamboats.

The *St. Helens*, is one of several pilot boats fitted with

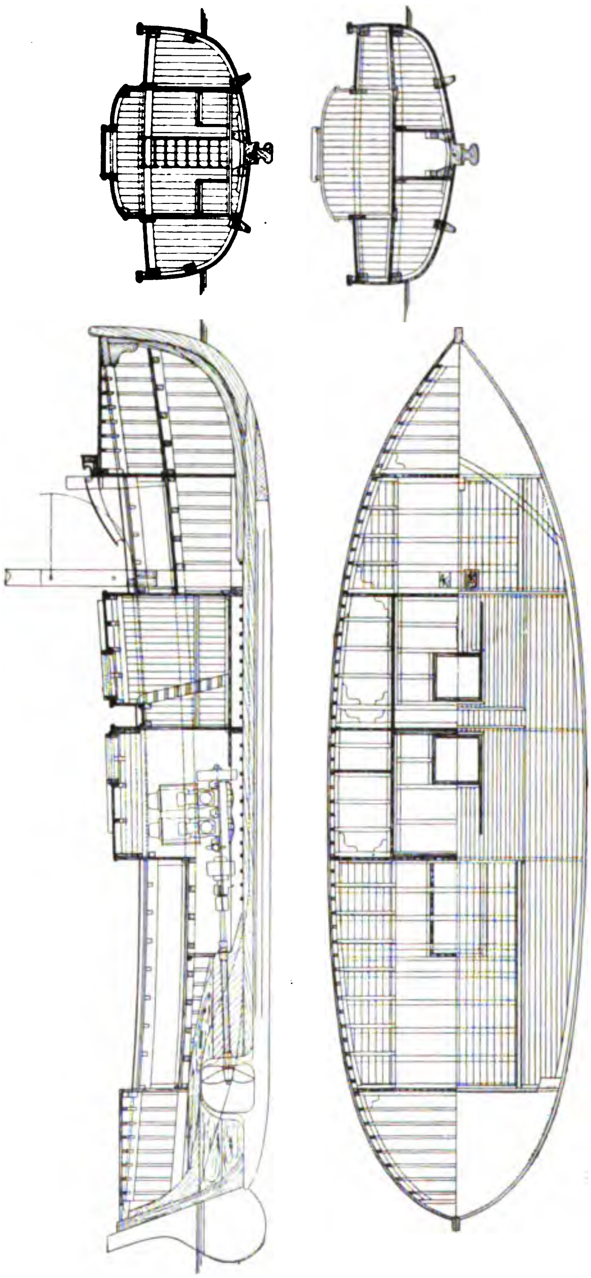


FIG. 320.—General Arrangement of Motor Lifeboat *Leufsta*.

Beardmore engines of 38 B.H.P., which are working in the English Channel.

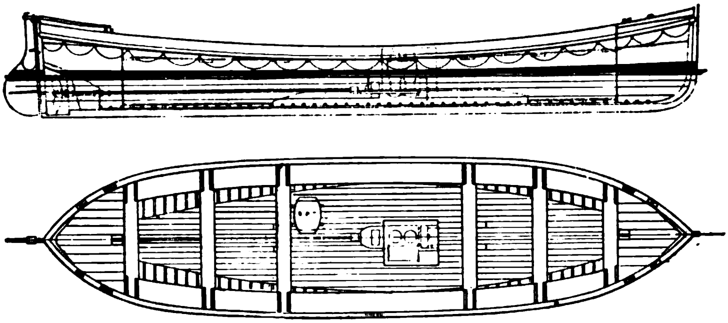


FIG. 321.—Motor Lifeboat.

The Cork Pilot Boat, Fig. 323, is fitted with a Dan engine, and has been at work for several years.

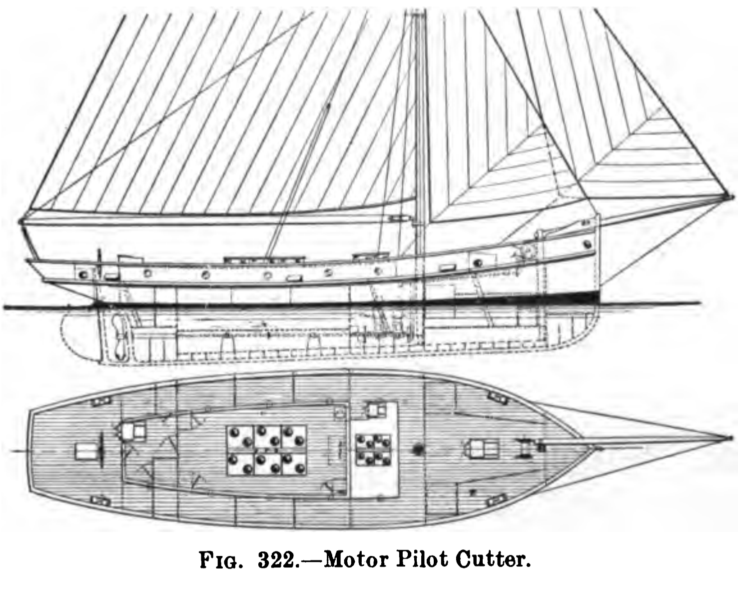


FIG. 322.—Motor Pilot Cutter.

Mission Vessels are frequently fitted with hot bulb engines, for instance the *Tamate*, p. 316.

FIG. 323.—Cork Pilot Boat.

FIG. 324.—*Evangelic.*

Fig. 324 shows the *Evangelic*, 70 ft. × 17 ft. × 7 ft., and of 30 tons displacement, which was built in Australia, and fitted with a 48 B.H.P. Skandia engine, giving a speed of about 8 knots.

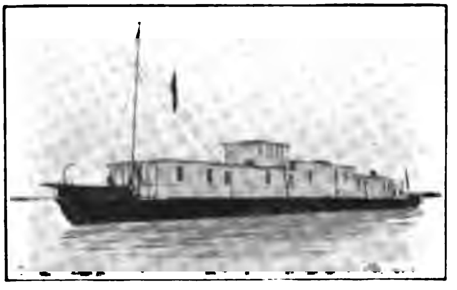


FIG. 325.—*Akmolinsk.*

House Boats.—The *Akmolinsk*, 171 ft. × 21 ft., drawing only 3 ft. 6 in., Fig. 325, is a house boat for working on shallow Russian lakes, and is fitted with two 40 B.H.P. Bolinder Engines.

FIG. 326.—*Heba.*

The *Heba* is another unusual type of vessel of 1,048 tons, and is fitted with two Avance direct reversing engines of 120 B.H.P. each.

CHAPTER VII

Notes on Working.

Engine Troubles Generally.—An engineer or driver who really knows his hot bulb oil engine, will agree that it is the simplest engine that he has seen and he would never think of going back to steam if he could avoid doing so ; this statement also includes captains or mate-drivers who have learnt to manage and handle hot bulb oil engines, and who have often had strong prejudices in favour of steam engines, but have now entirely overcome them.

At the present time there are not many men with experience in working these engines, but their number increases every year. In 1900 the motor car was in the same position, now there are probably 500,000 men and women in this country who can drive a motor car and do ordinary running repairs. The greater simplicity of the hot bulb engine, due to the absence of magneto, two-to-one shaft, valves, tappet rods, cam shaft and cams, geared wheels or chains, sparking plugs, etc., renders it possible for the drivers to be taught in a much shorter time, so that very large numbers of reliable men should soon be available for the purpose.

Thanks to this great virtue of simplicity, there is not a very wide range of difficulties likely to be encountered with hot bulb engines of first-class manufacture. All machinery in motion is subject to troubles of some sort, and it is to every one's advantage that those in charge should know how best to avoid them and how to put things right if trouble is allowed to occur. Most of the paragraphs of these " Notes on Working " have this as their direct aim, indicating both what to do and what not to do, though it is only possible here to deal somewhat generally with the subject as applying to the bulk of engines on the market. Each engine as delivered should be accompanied by a clearly-worded and illustrated catalogue of instructions, which must be applied to that particular make of engine.

Preparations for Starting Up.

See that the Fuel System is in Order.—The service tank and filter (if fitted) should be cleaned out in the first instance and filled with oil, and all air between the tank and

Fig. 327.—Fuel Priming Pump.
(2) is the priming pump on the three-way cock (1).

filter expelled. A little hand priming pump is usually supplied as part of the standard engine gear for fitting to the filter (or, if no separate filter is used, to the service tank), whereby the oil is primed through the pipes leading to the fuel pump on the engine. It is best to remove the delivery valves until all the air is expelled through these pipes and from the pump itself, more particularly where a rubber diaphragm "equaliser" or "compensator" is fitted to act as does the gas bag of the gas engine in damping the intermittency of the flow.

Now replace the delivery valves and leave the priming pump connections in position ready for running, and work the fuel pump on the engine by hand until the oil reaches the top of the delivery valves, and all bubbles have ceased to appear. Then connect the delivery pipes and continue working by hand until the oil passes the nozzle in the form of a sharp jet. Every trace of air must be expelled before starting up the engine.

When first starting up after the engine has been installed, the tanks, pipes, etc., may not have been sufficiently well cleaned out, in which case the nozzle and the fuel pump valves may have to be removed and cleaned of grit once or twice. The valves should in that case be taken apart, soaked in clean paraffin and when all grit has been removed, carefully reassembled. This is rather a tedious job, as the priming and expelling of air has to be repeated each time, so it pays well to be particular in cleaning out the tank, filter, pipes, valves and pump in the first place. A good, if unpleasant, way of seeing whether a valve is tight is to try holding it to the tongue by suction; this is quite easy with the usual form of valve and seat which can be unscrewed as a whole.

Air Lock.—If the air has not been completely expelled from the fuel pump and pipes there is a cushioning effect felt when the fuel pump is worked with one hand with the thumb of the other hand pressed on the nozzle, and also when the thumb is removed and the pump worked, the jet does not finish sharply but tails off and dribbles as the locked air expands after its compression by the pump strokes. The engine will not then run satisfactorily, and quite likely will even fail to start, and if it does run, very bad carbonisation will take place in the cylinder, bulb and nozzle. It is obvious from these remarks that not only must the oil be well filtered and the pipes and valves properly cleaned, but all the suction joints must be absolutely airtight and should, of course, be coned metal to metal, care being taken that they are kept clean during the brazing operation.

Attend to the Lubrication.—To avoid the chance of trouble from dirt or small bits of waste, the lubricating pipes and the lubricator box should be washed out with clean paraffin before they are first fitted to the engine. A permanent but portable strainer should be fitted in the lubricator box. When the pipes are in place, the oil should be worked through to each separate point and examined for cleanliness before the pipe is finally connected, means for flooding oil through the pipes by hand being always provided for. When connected up a little oil should be pumped by hand to each point to ensure efficient lubrication at the outset.

Attention to Crank Chamber.—The crank chamber doors should be taken off and any waste, rag or dirt carefully removed, and at the same time the bottom-end bearings should be tried for freeness on the pin by levering them with a spanner to see that there is a small amount of movement sideways from web to web. This should always be done after laying up for some time, and always after opening up the cylinders for cleaning. It is a wise precaution to syringe the inside of the crank chambers with clean paraffin, running it away through the crank chamber cocks. This prevents grit or carbon deposit finding its way to the all-important banjo-ring used to lubricate the crank pin.

Clutch.—Bar the engine round one complete revolution with the clutch lever thrown out, to see that the clutch is free, and that there is no binding from bad adjustment, dirt between the friction surfaces, or springing of the bedplate by careless bedding of the engine on its chocks. Leave the clutch lever out for starting.

Check the Fuel Pump Stroke by means of the gauge supplied or by direct measurement. The instructions for working almost invariably state in detail the best way for the particular engine.

Light the Pressure Lamps and open the compression cocks on the cylinders. These lamps are well known in the form of the familiar painter's blow lamp and as cooking stoves, and do not require detailed mention here. It should be remembered however, that troubles with details can be very annoying, and that it pays over and over again to keep these lamps clean and in good working order by using good clean paraffin and following the detailed instructions which are provided by the lamp makers. Above all, the lamps should not be allowed to burn at low pressure and with a luminous flame (which causes carbonisation and choking of coil and nozzle), but either worked with a good blue flame or turned out.

Always have one or more good spare burners aboard so that a troublesome lamp can quickly be replaced and the faulty one cleaned out at leisure without delaying the job.

The lamps have to be lighted from eight to fifteen minutes prior to starting, according to the size of the engine; an engine of 160 B.H.P. has, as a matter of fact, been started within eight minutes of lighting up. The method of ascertaining whether the bulb is hot enough to start up, naturally varies according to the engine, but a fairly uniform test is to inject fuel by giving a stroke to the fuel pump by hand and seeing if flame issues from the compression cock; keep clear of the cock when doing this. In some makes, when the heat is enough for starting, a red spot is seen on looking through the nozzle seat with the nozzle removed.

Circulating Water.—After opening the sea cock, it is as well to fill up the cylinder jackets before starting up, if the engine is to be run for the first time after installation, so as to save shutting down again if the pump cannot be got to deliver in a very few minutes. It is usually quite easy to fill the jackets, by simply uncoupling the eccentric rod from the fuel pump rocker and working it by hand. When the pump is driven by an independent eccentric, the process is more tedious. At the outset, grit may have been allowed to get into the pump or into the pipes, or there may possibly be a rough edge on the wings of the valves which will prevent proper delivery, in which case the grit should be removed, and the valve wings eased and smoothed with emery and paraffin and replaced clean.

Tighten Cylinder Head when Hot by "following up" the nuts evenly round the head. This should always be done before starting up the engine, after a new joint has been fitted, so as to prevent the joint leaking at the start, which damages the joint and makes it less easy to get it to hold well subsequently.

Bar round to Starting Position with the nozzle removed or, at least, with the fuel pumps definitely out of action, so as to avoid a back fire. If the starting position has not been clearly indicated by the makers, remove the cylinder head (corresponding to the starting cylinder) and bar round till the piston is on the top dead centre, then chisel a good mark on the flywheel to correspond. The starting position is slightly over the top dead centre, say 3 in. over on a 30-in. flywheel.

Starting Valve.—Whenever air starting is fitted (*i.e.*, for any engine above 20 B.H.P. or so), see that there is plenty of air in the container and close off the stop valve. Then make sure that the starting valve on the engine is quite free and can be opened and closed off sharply by hand. If it is stiff, free it with paraffin, and if it has been lying about and becomes gritty it must be dismantled and thoroughly cleaned. Failure to make this valve free involves possible loss of all air from the container and considerable annoyance and delay in recharging.

Release the Fuel Pumps from being held out of action by the hand lever for stopping.

Replace the Nozzle in position when it has been ascertained that the bulb is hot enough for starting, taking care to seat it properly to prevent damage to the seat and cone.

Close the Compression Cocks on the cylinders.

STARTING UP.

Open the stop valve on the air container. Slack back the hand wheel on the starting valve and then open the starting valve for a fraction of a second, closing off again before the engine makes half a revolution.

The engine will now pick up speed. If any difficulty is experienced, especially if the air pressure is low, it may help to give one smart injection with the fuel pump trigger at the same moment as the starting valve is opened. This injection should only be given to the starting cylinder.

Some small engines are not provided with the air starting apparatus, in which case a spring handle is usually fitted in the fly wheel and, when all the preparations for starting up

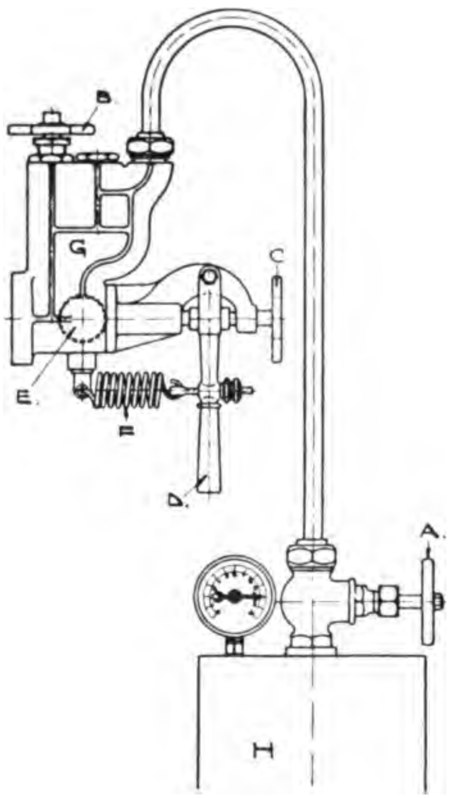


FIG. 328.—Air Starting System.

have been attended to, the engine is started by "cranking" by means of this handle. The flywheel may have to be rocked to and fro several times before the engine starts up, and should be swung round as far as possible each way. A hand injection of oil is of assistance just before cranking.

Recharging Container.—In some engines a non-return valve is fitted on the cylinder communicating with the air starting pipe and leading back to the container. This valve incorporates also a screw-down valve, which has to be slackened back before the non-return valve comes into action to recharge the container from the working cylinder itself.

In some engines recharging is done by the starting valve automatically when the hand wheel is slacked back. The pressure in the cylinder opens the valve against the pressure of the spring and when the pressure drops in the cylinder the spring holds the valve closed. This has the disadvantage of "gumming up" the valve frequently.

On larger installations a small air compressor is driven by the engine, which keeps the containers charged when demands are made upon them by the air-blown whistle, as well as for starting up.

Stopping the Engine.

This is accomplished by simply putting the fuel pumps out of gear, which is usually done by a small lever which can depress the plungers, out of the way of the strikers.

Before stopping in every case, except of course in an immediate emergency, attend to the following :—

(1) Make sure you have got the air container full and the stop valve closed.

(2) If water drip is fitted, see that it is shut off before shutting down.

(3) Give by hand, a small amount of extra lubrication to each point served by the lubricator box. This usually amounts to giving a turn to a ratchet wheel or working a small lever three or four times.

Careful attention to this makes the engine easier to start up again.

After shutting down for the day the sea cock for the circulating water should be turned off as a precaution, *but on no account must it be left shut when starting up again.*

It is always a good plan after shutting down to fill up the paraffin containers for the lamps so as to be ready to get the engine under way again in the shortest time, if desired. Also open the cylinder compression cocks and keep the fuel pump plungers held up so that the engine can be barred round the next morning without injecting fuel.

Attention while Running.

Fuel System and Filtering.—The effect of either air lock in the system, or grit choking the nozzle, or water in the fuel is a slowing down of the engine—or if running declutched on the "hit-and-miss" governor, the proportion of "hits" to "misses" will increase noticeably and then, possibly, the engine will slow down when the trouble has become more pronounced.

Grit is, of course, due to imperfect filtering arrangements, except after recent assembling when it may be due to grit which has got into the pipes and pump not properly protected when dismantled. On any but the smaller installations a special filter is permanently fitted, and is usually placed on the system between the daily service tank and the engine. If grit has lodged in the nozzle, it will be detected by the greater resistance offered when working the fuel pump by hand, and also by the jet itself being abnormal, *i.e.*, a shapeless spray in place of a clean jet in plain nozzles, and a distorted spray with nozzles, fitted with a spraying device.

Special prickers are supplied to remove any such grit, and only these prickers should be used for the purpose, as otherwise the nozzle may get damaged.

On one occasion when trouble was reported with an engine, the fuel oil was found to be thick and dirty at the nozzle ; on close examination of the oil tank, nearly half an inch of sediment was found in the bottom which explained the cause of the trouble.

On another occasion the sale of an engine was lost owing to dirt getting into the fuel pipe, and the would-be purchaser was convinced that it was a defect in the engine.

Fuel oil, bearing and cylinder oil should be filtered through 45 mesh wire gauze.

The following is a description of some of the most common types of filters in use :—

Gauze and Cloth Independent Filter.—Fig. 329 has a cast iron or brass body or reservoir with the fuel introduced

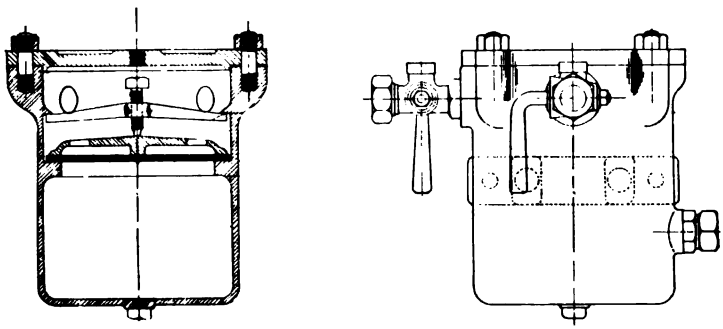


FIG. 329.—Gauze and Cloth Independent Filter.

at the bottom. At a position half way up the casting there is a ridge cast, to support the filtering medium which consists

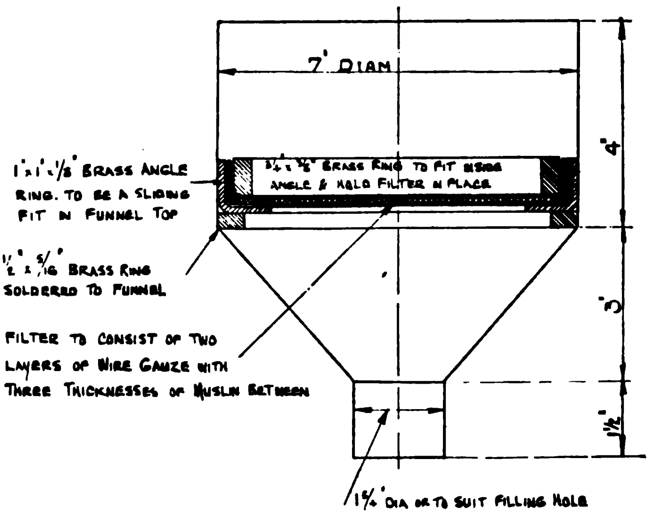


FIG. 330.—Funnel Filter.

of three layers of different grades of felt and one layer of about 45 mesh gauze. The fuel outlets are arranged near the top, and an air cock or pipe is fitted in the cover. If the fuel comes through this cock sluggishly, or does not run at all, it is a sure sign that the filtering medium is clogged and requires cleaning out at once. By making the fuel flow upwards in the filter, most of the trapped dirt falls to the bottom and so does not clog up the filtering medium. The drain plug is right at the bottom.

Funnel Filter.—Fig. 330 should always be used when filling the fuel tanks. The funnel is made of extra large size, but with a spout to fit the tank filling pipe. At its largest section a removable wire gauze of 45 mesh is fitted.

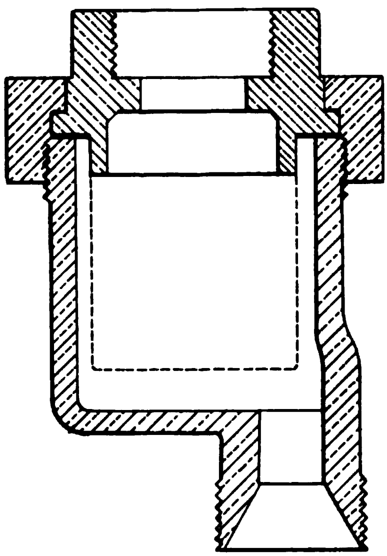


Fig. 331.—Pipe Filter.

Pipe Filter.—Fig. 331 is sometimes fitted in the pipe line of small engines. It is in two halves connected by a nut. In the middle is a piece of fine gauze, which can be removed and cleaned when desired.

Air Lock. — If the trouble has been air lock, proceed as indicated, p. 341. The causes of air lock are (1) faulty lead of fuel pipes, see Fig. 348, p. 382; (2) level of oil in daily service fuel tank allowed to fall below the outlet cock; (3) leaky joints in suction pipes, compensator box or suction valves on fuel pump; (4) suction valves leaking. In case (3) when the engine is shut down and the pipe primed, wipe the various joints carefully and watch for weeping. In case (4) replace the suction valves by spares and wash the old ones in clean paraffin when taken adrift.

Water in Fuel.—If water has found its way into the fuel it can be quickly detected by spraying some from the nozzle on to the outside wall of the cylinder, when characteristic water drops can be seen sliding over the oily surface. To overcome the trouble, open the cock or plug at the bottom of the filter and keep it open until pure oil only comes. Then drain off any water in the same manner from the daily service tanks and main fuel tanks, in each case from the bottom where water, being heavier than oil, always collects. The cause of this trouble will probably be found to be faulty vent pipes to the tanks, see p. 380. Drive out all the watery oil still in the pipes, before starting up the engine again.

Lubrication.—On first-class makes of engines, forced feed lubrication is almost invariably employed for the cylinders, gudgeon pins and crank pins, and on the larger engines, also the main bearings, the latter being wisely adopted on engines above 100 B.H.P., or so.

Notes on Mechanical Lubricators will be found on pp. 166 to 170.

It is the business of the driver to make sure that the lubricator box is kept filled, that the oil is very carefully strained (a permanent but portable strainer should be fitted to the top of the lubricator box and never removed when filling), and that the little pumps are all in working order. He should thoroughly understand the mechanism and each part of it, and follow conscientiously the printed directions of the makers of the engine.

The pipe for the crank pin has often a sight feed glass which enables the driver to see at a glance that this point is receiving proper lubrication, which is an advantage, as this bearing is enclosed and cannot be felt. If the crank pin should heat up, the heat spreads to the main bearings on each side, so that if two main bearings show signs of heat one on each side of any one crank chamber, it is a warning that probably the corresponding crank-pin bearing is heating up and requires flooding by hand operation of the mechanical lubricator and, if the heat does not subside, inspection is necessary.

Wick feed or ring oiling is often employed for the main bearings and thrust block, and these should be inspected and filled up periodically and the wicks removed after shutting down, care being taken that they are replaced before starting up.

The internal bearing in some clutch designs is also wick fed, lubrication being required when running declutched. The clutch friction faces do not require lubricating oil but only clean paraffin occasionally, to free the surfaces from grit, the clutch being temporarily disengaged for the purpose about once a day; the paraffin should be injected by a syringe, into a groove cut in the surface and driven to the friction faces by centrifugal action.

The minor points, such as the fuel pump actuating gear, etc., are lubricated by feeder-can, say, once every hour, or once every two hours.

The Stern Bush and Gland should be fitted with large grease lubricators and should be attended to once an hour or once in two hours, just as regularly as the feeder-can oiling of the engine.

Heat of Bulb.—Notes on the material and design of bulbs and the various forms they take will be found on pp. 127 to 133.

To generalise on the proper regulation of the heat is difficult owing to the many different shapes and designs, but the subject is one of great importance. In each and every case the driver should read carefully the printed instructions issued by the maker, and if anything is not clear the makers or their agents should be written to.

When no part of the cylinder head is cooled it is safe to say that the bulb should show a dull glow but not become a really bright red. Overheating makes for inefficiency, short life of bulb, carbonisation due to "cracking" the oil, and usually makes itself known by a bumping noise. On the other hand, if the bulbs are run too cool inefficiency will also follow, due to incomplete combustion, and ultimately the engine stops when combustion is insufficient to drive it. When the bulbs are too cool the exhaust shows very blue and smoky.

When part of the cylinder head is cooled, and only the small bulb proper (or small plate) is unjacketed, then in some cases the uncooled portion is to be kept at a dull glow, *e.g.*, **Avance** and **Skandia**, but this is not necessarily the case.

Various means are adopted for the regulation of the heat.

(1) Water injection is employed and means provided to regulate the amount, *e.g.*, **Bolinder** "E" types and **Avance**.

(2) In bulbs so designed that overheating does not ordinarily take place, but only if the load is very heavy or if the particular fuel used makes the little bulb too bright red, the direction of the nozzle can be altered by hand to overcome the trouble, *e.g.*, **Skandia**.

(3) Throttling of scavenge air is used when the engine is running light, to keep the bulb hot enough without recourse to lamps, *e.g.*, all **Bolinder** engines since about 1913.

(4) Messrs. Bolinders on their new "M" types of engine use compressed air for injection with the fuel, which gives more complete combustion, and a smokeless exhaust. A most ready means of controlling the heat of the bulb is obtained by the hand regulation of the amount of air injected.

In each case the makers' directions should be carefully followed.

Circulating Water.—On small vessels the circulating water as it is discharged overboard can be felt by the hand, and it should be possible at any time to hold the hand in it for some time. The temperature should never exceed 150° F., and if it does, there is something not quite right; if attempts to put it right do not succeed in the first three or four minutes, the engine should be shut down. Whenever the position of the discharge overboard does not admit of the hand being held under it for trial, a tap should be fitted in the engine room to test the water after its passage through the cylinder, and preferably again after its passage through the silencer jacket. These taps are usually brazed on the standard copper pipes as sent out by the makers with the engine.

The troubles most likely to cause failure or undue heating of the circulating water are:—

(1) *Choked Sea Cock or Strainer.*—In this case clean out the strainer, if any, and see that the water runs into it properly. If not, the sea cock itself must be cleaned out.

The engine must, of course, be shut down for this unless two sea cocks or one sea cock and two strainers are fitted, so that the engine can utilise one line while the other is being inspected and cleaned.

(2) *Air Lock due to Leaky Joints.*—See whether all suction joints are tight by wiping, and watching for weeping.

(3) *Leaky Suction Valve due to Dirt, Rag or Waste, Rough Finish of Valve Wings, Faulty Spring, etc.* If the water is heating up abnormally but not dangerously and rapidly, remove the cap of the pump and the delivery valve, prime the pump from a bucket and then hold the delivery valve in place by hand, when the pump may come into action again and discharge the offending dirt or waste, after which the cap can be replaced and screwed down bit by bit so that at first the delivery valve will only have a light tension behind it; this is a wet job and a certain amount of hot water is also apt to drain back from the cylinder. If this fails the engine must be shut down and the valves taken out of the pump, dirt or waste removed, rough or tight valve wings eased and finished smooth, and bent or broken springs replaced by spares.

(4) *Air Leaking in*, due to the absence of, or a defect in, the packing in the stuffing box. Tighten the gland, and if it still passes air, shut down the engine and repack the gland.

(5) *Inefficient Suction Pipe* of too small bore or of great length with awkward bends. If everything else is in order examine the suction pipe and see if there are reverse bends causing air lock, or if any joints are blanked off or partially blocking the free passage of water. If the pipe is unduly long it may have to be replaced by one of larger bore.

Crank Chamber Drain.—It is most important that lubricating oil should not collect in an enclosed crank chamber, as it is then blown into the bulb and cylinder with the scavenge charge and causes excessive carbonisation. Makers usually state in their directions that the drain should be opened for a minute or so every so often or else left permanently partially open. The latter is far better as the occasional opening is liable to be forgotten altogether, whereas quite inappreciable power is lost even when the cocks of the size usually fitted are left permanently full open. Every couple of hours or so it is wise to see that they are blowing properly.

Governing.—Notes as to methods of governing appear in Chapter IV., pp. 145 to 149. In all makes of hot bulb engines there is some simple provision to prevent racing when in rough weather the propeller leaves the water, or when the clutch is withdrawn for manœuvring, waiting or shutting down. In almost every instance this takes the form of a spring of which the tension is overcome when the speed exceeds a certain number of revolutions per minute. The speed at which this tension is overcome and the fuel thereby diminished by the governing action, depends upon the amount of tension which in turn is immediately regulated by a small hand lever. The driver should satisfy himself that this hand lever is not in a position to allow of racing, which is easily tested by simply withdrawing the clutch for a few moments. A stop is usually furnished to prevent the lever being put far enough over to allow racing, but if not the driver can easily fix up something for himself, or at least make a good mark. Also a stop or mark is required so that the lever cannot go far enough the other way to stop the engine altogether. Sometimes an automatic gear is arranged so that the lever is moved back as the clutch is withdrawn which makes the governing instantaneous when manœuvring. The driver should see that this is in proper adjustment, say, once a day.

In cases where an independent hand adjustment of the fuel pump stroke is provided together with the automatic hit-and-miss cut-out governor, the speed should be regulated by cutting down the stroke (except when manœuvring) until the desired revolutions are obtained without the hit-and-miss governor coming into operation, or only very slightly so, as this leads to much smoother running and less vibration. It is good practice when running at anything below absolute full power just after an overhaul or repair has been made to get the stroke lever in such a position that the cut-out comes into operation say once in ten, to once in eight revolutions. This has the advantage that if the bulbs get too hot or too cold, or if a bearing is giving trouble, or if there is anything slightly out of order with the fuel system, the "missing" will cease altogether, as more fuel will be required to do the work, thus giving warning.

This only applies in still water such as riverways and canals and in smooth seas. In any but smooth seas the rising and dipping of the propeller with the boat's motion makes this adjustment impossible by changing the load on the engine continuously.

If the engine reverses by pre-ignition cushioning, *e.g.*, the **Bolinder**, the stroke lever should be kept at the normal full load notch when manœuvring.

All moving parts of the governor should be lubricated every hour or every two hours in the oil round by feeder-can, so that all spindles or little bearings or pin joints are quite free.

Manœuvring and Running Light.

The driver should very quickly feel himself master of a hot bulb engine and respond to the telegraph with as great, or greater, ease and speed than with a steam set.

When reverse gears are fitted, "ahead," "free engine," and "astern" are obtained by three positions of one single lever. When pre-ignition reverse is fitted, the clutch is thrown out for "free engine," and this must always be done before moving the reverse lever over to go from "ahead" to "astern" or *vice versâ*.

If a considerable period of manœuvring or waiting with "free engine" is expected, care must be taken to keep the bulbs at sufficient heat. In the older designs this required lighting the lamps, but newer types avoid it by various devices, such as throttling down the scavenge air, using compressed air to spray the fuel injection, or by special design of bulb or plate enabling it to keep hot when the engine is running without load. Whenever water drip is employed, it must, of course, be shut off when manœuvring or running light for an appreciable time.

When manœuvring, and continuously in riverways, fog, etc., the driver should see that the air containers are kept full, so as to meet the demands which the whistle makes upon them.

Overload.—The best advice a driver can have is not to use the overload at all except when absolutely necessary. This applies to all makes even when a certain overload is guaranteed and can be developed continuously.

Sparing use of overload is repaid by long life and cheap maintenance of the engine, but its use may be of great advantage on occasion to catch a tide or obtain a place in dock, etc.

In this connection it might in fact be said that whenever it is quite immaterial whether the vessel does normal full speed or whether she does half a knot less, it is a good plan to reduce the engine speed by a few revolutions, but, naturally, this is only recommended if the earning capacity is not materially affected.

Crank Chamber Air Valves.—Reference to these with illustrations appear on pp. 151, 152. Very little trouble is ever experienced with these light valves. After many months or years one might break, and then attention is called to it by the outrush of air on the down stroke of the piston. If it is inconvenient to shut down, a piece of cardboard held in position over it will serve for a while. As a rule about eight are used on each cylinder so that the other seven can easily do the work. The least number per cylinder is two, and in that case the area of air inlet is halved with one out of action, but even that will not seriously affect the power developed. When the engine can be shut down it is the work of a minute to replace it by a spare. After laying up a while the valves may stick a little, in which case they should be taken off and wiped over with paraffin. If they have been allowed to get rusty they must be cleaned with oil and emery, but if they leak much, spares should be fitted.

In the case of leather valves, which are still used on some engines, trouble may be experienced by the leather getting stiff and brittle, in which case a spare should be fitted.

Dirt also causes leakage, so that a periodical cleaning is recommended, and this can conveniently be done in a few minutes when the cylinders are opened up.

Crank Chamber Seal Rings.—Notes on these appear on p. 151. These parts are not likely to require attention except after first installing or complete dismantling, when they may leak air when first started up through not being pressed home properly on the faces, but they will probably right themselves in the first few minutes. If not, shut down, take off crank chamber door and tap them with the wooden handle of a hammer gently and evenly, and they will get into position.

If assembling has not been carried out cleanly, grit may have got in, in which case syringe with paraffin, draining the paraffin away through the crank chamber cock before replacing the door.

Maintenance and Overhauling.

Care of Engine when Shut Down or Laying Up.—The driver should always take a real interest in keeping his engine in good clean working order. When shutting down for the day or for the trip, he should wipe the engine down, and see that the skylights are closed before leaving, as a precaution against rain. Where the engine is fitted in the open, he should take great care to cover it well, particularly the fuel pumps and gear, clutch, etc., and see that in doing so he avoids shaking dirt or grit on to these parts. A little care of this sort makes a great deal of difference to the engine in a year or two. When laying up for some time the bright parts should be oiled over and inspected periodically, or else well greased. The clutch faces and parts should be syringed with paraffin and the clutch left engaged, and then on periodical inspection disengaged, to see that it is clean and free from rust and then left again engaged. The sea cock should always be closed on leaving the engine room in case of leakage which might, if left a long while, flood the engine room and do very serious damage.

In the event of an engine not being in use for a long period, it should be barred round by hand every few weeks to keep it easy and free.

Life of Working Parts.—The statement that the working parts of a hot bulb oil engine will have as long a life as those of the marine steam engine cannot be maintained. The life of the hot bulbs when water injection is employed does not appear to be greater than two years for steel bulbs, although the cost of renewal is not great. The life of the later type with partially water-cooled heads cannot yet be ascertained, although they will no doubt be found to last much longer, as must be the case with cast iron, even when totally unjacketed.

The cylinders could hardly be expected to have as long a life as those of the steam engine, because the crude oil used is likely to leave some sort of deposit in the cylinders, although this should not be very much with proper combustion and a moderate use of approved lubricating oil.

Besides the lamps, bulbs, piston rings, springs, balls for valves, or such like insignificant items, there should not be any renewals required within, say, five years. Even if in five years it is found necessary, in addition to reboring the cylinders, to renew the fuel pump plungers and their strikers, crank shaft seal rings, as well as to reline main bearings, bottom end bearings and thrust block, ease the halves of gudgeon pin bearings and rebore and scrape them, the expense is not a large item in the balance sheets of so many years working.

Carbonisation.—Carbonisation, which is caused by imperfect combustion and/or too much inferior lubricating oil, takes place in the bulbs, cylinder exhaust ports and in the piston ring grooves. The imperfect combustion may be due to very inferior fuel, air lock in the fuel system, excessive fuel pump stroke or wrong timing, such as, for instance, when the pipe from one fuel pump is connected to the nozzle of the wrong cylinder. To prevent this, it is a good plan for new users of hot bulb engines to consult the makers regarding lubricating and fuel oil, and to check the fuel pump stroke and timing with the makers' information.

The engine will soon wear if the carbon deposit is allowed to accumulate to any extent.

Overhauling.—Once a year or at least once in two years the engine should be taken down and carefully overhauled, and the makers or their agents may with advantage be called in to inspect. The driver should most certainly be present during the overhaul and more, especially, when the makers inspect, so that he may ask questions and give any information about the behaviour of the engine since the previous overhaul.

Cleaning of the Engine.—It is very important to give careful attention to the cleaning of the various parts of the engine, which should be done periodically and at regular intervals. The periods will depend on the make of engine, the class of fuel and lubricating oil used, and the amount of intermittent work done by the engine.

A suggested period is—

Item.	Time.
Lampburners	1 month.
Fuel filter	1 ,,
Ignition bulb and combustion chamber	2 months.
Crank chamber	2 ,,
Cylinders and pistons	2 ,,
Air compressor	4 ,,
Silencer (main)	4 ,,
Lubricating system	4 ,,
Silencer (secondary)	6 ,,
Thrust block	12 ,,
Cylinder jackets	12 ,,
Fuel tanks and fuel pipes	12 ,,
Tail shaft drawn	12 ,,
Air containers	12 ,,
Fuel pumps	12 ,,

These are average times and should not be exceeded, though it is advisable that the cleaning should take place more frequently at first until the men in charge have ascertained how long the various parts will run ; they can then prepare a list to be hung up in the engine room with dates filled in as the items are attended to. It is better to clean too often than not often enough.

Bulbs.—The bulbs will be the items of the engine proper to require most frequent overhaul and cleaning; it is advisable to take them down every eight weeks for cleaning. After taking down, they should be carefully examined to see that they have not been overheated or distorted, any scale or coating found inside being removed.

The jointing should be carefully prepared. Thin copper and asbestos joints will be efficient, but as they are somewhat expensive, Palmetto packing or stoutly plaited asbestos cord dipped in black lead will sometimes answer the purpose, providing it is sufficiently thick to equal the thickness of the jointing as fitted by the makers. To keep a good tight joint, the nuts should be tightened up finally while the engine is hot whenever a new joint has been fitted.

FIG. 332.—Piston of Skandia Engine.

Cylinders.—When the bulb and cylinder head have been removed, the cylinders and the exhaust ports should be examined, and thoroughly cleaned, care being taken to prevent the carbon deposit passing down the side of the piston and getting on to the piston rings.

Pistons will not usually require to be taken out every time the bulb is removed and the cylinder cleaned; it is, however, advisable to take the piston out on every alternate occasion, say, every sixteen weeks; the man in charge will soon learn how frequently it is necessary.

The crank chamber must always be kept clean so that no dirt can clog the hole in the ring which lubricates the crank pin, or the drain cock and pipe fitted in the bottom of the crank case.

When the eyebolt is screwed into the top of the piston and the lifting tackle properly attached, the bottom half of the crank-pin brass can be removed. When the piston is being lifted, be sure that the top half of the crank-pin brasses is lifted off immediately the connecting-rod bolts are clear of the crank pin. If this is not done, the brass may fall and damage the crank pin.

Clean the piston, the recesses and the piston rings thoroughly. If the rings are not free in the recesses, soak them with paraffin and then tap lightly all round with a piece of hard wood until they come free. Then insert a packing knife at each end of the slot between the body of the piston and ring and work it round slowly until the ring springs free from the recess. When replacing rings, each ring should be put back into the recess it came out of.

In replacing the piston, put oil on the cylinder walls.

Refitting Brasses.—The man in charge should be sure that the number markings on the crank-pin brasses are in correct position when reassembled. He should also make sure that the brasses are free on the pin. A spanner can be used for levering the crank-pin brasses side ways from each crank web in turn. This movement, though small, can be seen and felt, and is the only satisfactory way of feeling the freedom of the brasses on the pin.

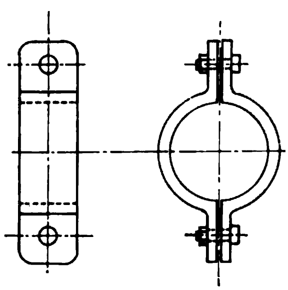


FIG. 333.—Method of polishing Crank Pin.

Use of Waste.—Never use waste on an oil engine, stray pieces of waste in the crank chamber may lead to serious trouble. Use mutton cloths or similar material.

Crank Pins.—When inspecting crank pins, care must be taken to see that the surface is free from scratches and marks. Should the pin be badly scored it will be necessary to remove the cylinder and crank-chamber casing, and file up the pin carefully, first with a smooth file, then by the application of a "wooden lathe" or an iron one, as shown in Fig. 333, care being taken when filing the pin to see that there are no flats and that the pin is absolutely parallel. None but an experienced fitter should attempt this, except in a real emergency, for a good job is essential.

To ensure the lubricating oil hole in the pin being clear, paraffin should be forced to the oil ring by means of a small sprayer until it comes through quite freely and clean.

The oil ring can be wiped out with a piece of clean rag soaked in paraffin, and the set screws holding the ring in place should be examined to see that they have not slackened back.

Clutches.—To ensure the clutch being kept in good running order a little paraffin should be poured in between the inner and outer drums once a day when the clutch is in the disengaged position, so as to keep the frictional surfaces smooth and free from rust; no lubrication oil should be used on these surfaces. The toggle joints connecting the wedge piece fitted to the inner member should be given a few drops of lubricating oil once every day. If strict attention is paid to keeping all working parts clean and in good adjustment there will be no occasion to disconnect the clutch from the crank shaft, except at the yearly overhaul and inspection.

Reverse Gears and Direct Reverse.—As there is a large variety of reverse gears as well as a few types of direct reverse, it is advisable to get the makers' instructions and follow them accurately when adjusting and overhauling. See also pp. 95 to 117.

The Fuel Pump should be taken out about every twelve months, and the pump plunger, spring, suction and delivery valves and pump barrel examined.

When reassembling care should be taken to reset the stroke by means of the gauge supplied by the makers. The stroke of the fuel pump should be stamped on the pump to prevent any misunderstanding and to enable the stroke to be checked easily.

Air Containers should be taken down for examination every twelve months and deposits of foreign matter should be cleaned away by filling them with a hot solution of caustic soda and draining out. This is very much easier when the container has proper doors.

Opportunity should also be taken to wash the air starting pipe through with hot caustic soda solution.

When remaking joints, make quite sure that they are *perfectly airtight again.*

Silencers.—A drain cock is fitted in well-designed silencers, and it greatly assists in keeping the silencers clean if this cock is opened periodically, say, once a day, to drain off any oil or water that may have collected inside. Small manhole doors are also fitted at each end to enable the silencer to be inspected and cleaned out quickly.

If the secondary silencer should unfortunately consist of perforated plates, these should be examined and cleaned at least every three months, or oftener, if the perforations are under half an inch in diameter.

Circulating and Bilge Pumps.—Examine the suction and delivery valves and see that they have their proper lift. If springs are fitted on top of the valves, they should be examined to see that they have not weakened: the wear on the valve faces and seats should also be noted, and if it appears to be excessive the valves should be taken to the shop and made good in the lathe. It would also be wise to have the lift stamped on the pump.

Water Injection Pump.—The same procedure should be adopted as when overhauling the fuel pump.

Air Compressor.—The piston, suction and delivery valves should be taken out and thoroughly cleaned at least once every four months. The greatest care must be taken to see that any oil residues are drained off from the compressor.

Tail Shaft.—It is advisable to draw the tail shaft for inspection purposes once a year. Careful note should be made of the size of the shaft and stern bush. If the liner on the shaft and/or stern bush have worn extensively, it will be advisable to have spare ones fitted, and the stern gland made to suit.

Whistle.—If the air for the whistle is supplied through a reducing valve, it is advisable to try all joints leading to the whistle periodically, to see that they are tight.

The Mason Automatic Reducing Valve, and other good makes have been found to be very effective, and require little or no overhauling when properly adjusted.

Engineers' Log.—An Engineers' Log Book should be kept on all vessels and should be properly entered up to enable the owners in a few minutes to compare their oil-engined vessels with steamers and see the economy and advantage they have gained.

The log should include the runs made, the starts and stops of the engine, the fuel and lubricating oil consumption, fresh water consumption (when used), and also the time of periodical cleaning and examination of any of the principal parts, and any repairs or fitting of spare parts. The name of the firm who undertake any repairs, and the authority upon whose advice the repairs were done should also be entered, and in the case of fuel or lubricating oil taken aboard, the name of the firm supplying, and the price as well as the brand and any remarks as to quality.

Tools, Etc.—Adequate tools should be part of the engine-room equipment and should be kept under lock and key, and should include :—

Spanners of all the sizes required.
One adjustable spanner in case of eventuality.
One good hammer and perhaps also a heavier one.
Two good bent scrapers.
A pair of pliers.
A brass syringe.
A soldering iron, solder and spirits of salts.
A large and a small screw-driver.
Jointing material.
Other items according to size of vessel and nature of service.

Spares for Engines.—In the case of steam machinery the necessary spare engine parts which should always be carried on board ship are now well recognised, but in the case of oil engines it is more difficult to draw up a list because of the varied designs, especially of parts such as hot bulbs, fuel pumps, governors, etc.

It would be advisable to have two standard lists for each make of engine, one for sea- or ocean-going vessels and a modified one for river vessels.

Where the items apply the following is a suggested list for sea-going ships.

1 unjacketed hot bulb for each cylinder.
1 water-cooled head for each engine.
1 pair bottom end brasses for each engine.
2 bottom-end bolts for each engine.
1 gudgeon pin for each engine.
1 pair gudgeon-pin brasses for each engine.
2 gudgeon pin bolts.
1 fuel pump complete.
1 set piston rings for each cylinder.
1 spare propeller and possibly a spare tail shaft.
2 studs for cylinder covers.
1 stud for main bearings.
1 set coupling bolts.
1 blow lamp for each cylinder.
6 ,, ,, nozzles.
2 air valves.
12 cleaning needles.
2 injection nozzles for each cylinder.
2 speed regulator springs.
1 set of all small springs on engine.
1 ,, reversing pinions.
2 compensator diaphragms.
1 complete set of small parts on lubricator box.
6 glasses of each size used for sight feed lubrication.
1 complete set of gauge glasses.
Small quantity of thin sheet steel, muntz metal and tin will always be found useful for making temporary springs and washers.

Keep spare joints for cylinder heads and bulbs ready for use : do not have to stop on a lee shore to cut them out.

The spares for river and harbour vessels would be somewhat less and would depend upon the nature of the service and the facilities for overhaul.

In every case, purchasers should satisfy themselves that an ample supply of spares is procurable at short notice and should have sufficient lists and information so that they can, in case of necessity, order what is necessary by telegraph without the possibility of mistake.

Makers should try in position on the engines, all important spare parts ordered with engines, such as pistons, fuel pumps, bulbs and cylinder heads, bearings, etc., even although they are made to gauge, especially when the engines are going out of their hands and perhaps to a remote part of the world. After these spare parts have been tried in place they can be marked and put in a case marked "spares," the original parts being replaced on the engine. Another way is to test with one set of fittings which can be removed, and then put on another set of fittings for completing the test, and allow these to remain with the engine ; if this latter suggestion is adopted the makers should inform the purchasers of what they have done, to prevent the suggestion being made that second-hand parts have been sent out as new spares.

Owners should ascertain from makers the names of the agents who stock spares, nearest to every port of call which the vessel is intended to make.

Superintendence.—Owing to the comparative newness of internal combustion engines for marine work, it is well to have a keen and careful superintending engineer with experience of modern hot bulb machinery to supervise the engine-room department of the fleet, if the number or size of the vessels justifies the expense of a good man.

Makers are only too pleased to instruct superintendents in the details of their engines and the points that should be watched and attended to.

If a suitable superintendent is not available owners might, with advantage, arrange for the makers' expert to visit the ship and inspect the engine, say, three or four times a year for the first year, and then once a year afterwards.

For vessels large enough to warrant the expense, an engineer of good intelligence and mechanical ability should be carried, whereas for smaller boats a good conscientious attendant is what is wanted. It is far better to have a conscientious man of even only mediocre ability than a careless one of greater ability with, perhaps, his own ideas as to how the engine ought to have been designed.

Notes on Installing.

The importance of efficiently installing hot bulb oil engines on board ship cannot be too strongly emphasised.

In order to obviate vibration, special care should be taken to ensure a rigid seating, by which the strains on the engine and shaft are reduced, and the good behaviour of bearings ensured.

The Shaft Line should be as nearly parallel to the keel line as possible, the propeller being kept well down so as to get greater immersion and efficiency and enable the vessel to make better voyages when light.

In the case of existing vessels it is frequently better to fit twin screws and two shaft lines, as only a few frames have to be scarphed and a few plates bossed. The stern post, rudder and deadwood need not be touched.

Shaft Alignment.—It is important, if the engine is fitted before launching, to check the alignment after launching, and in the case of a cargo vessel when loaded also, to see that all the shafting is in line, otherwise there is sure to be trouble with bearings, etc. Engineers whose experience is derived mostly from slow-running steam engines in cargo boats should not grudge the little extra care and time which is required when oil engines are being lined up.

Engine Bearers or Seating. *For Steel Vessels.*—When installing oil engines in a steel boat, care should be taken to adopt substantial bearers to ensure rigidity.

Suggested scantlings are given on p. 369.

The most economical and most efficient construction is that illustrated in Fig. 334, where the floors are carried across in one piece for the full depth, as transverse length is important: while the longitudinal plates are intercostal the top angles are continuous.

In well-designed engines the flywheels are within the line of the longitudinal holding-down bolts, which allows the intercostals and top angle to be carried well forward and aft of engine. If possible, the length of the bearers should be twice the length of the engine. If the top angles have to be cut to take the flywheel, angles should be fitted on the oppo-

SUGGESTED SCANTLINGS FOR BEARERS OF STEEL SHIPS.

B.H.P.	25	50	100	200	300	500
No. Cyls. . . .	2	2	2	4	4	4
Frames . .	1½ × 1½ × ·18	2½ × 2½ × ·25	3½ × 2½ × ·35	4 × 2½ × ·35	5 × 2½ × ·35	6 × 3 × ·40
,, spacing .	16	18	20	21	22	23
Reverse frames .	2 × 2 × ·25	2½ × 2½ × ·25	3 × 2½ × ·30	3½ × 3½ × ·40	4 × 4 × ·40	4 × 4 × ·50
Floors, thickness .	·25	·25	·28	·34	·40	·45
Top plates, each .	6 × ·375	10 × ·40	12 × ·50	12 × ·75	15 × ·75	16 × ·85
Top angles . .	3 × 3 × ·35	3½ × 3 × ·35	3½ × 3½ × ·35	4½ × 3½ × ·40	4½ × 4½ × ·40	5 × 4 × ·50
Intercostal plate .	·18	·25	·30	·35	·40	·45
Intercostal angles.	1½ × 1½ × ·18	2¼ × 2¼ × ·25	2½ × 2½ × ·25	3 × 3 × ·34	3½ × 3½ × ·40	4 × 4 × ·45

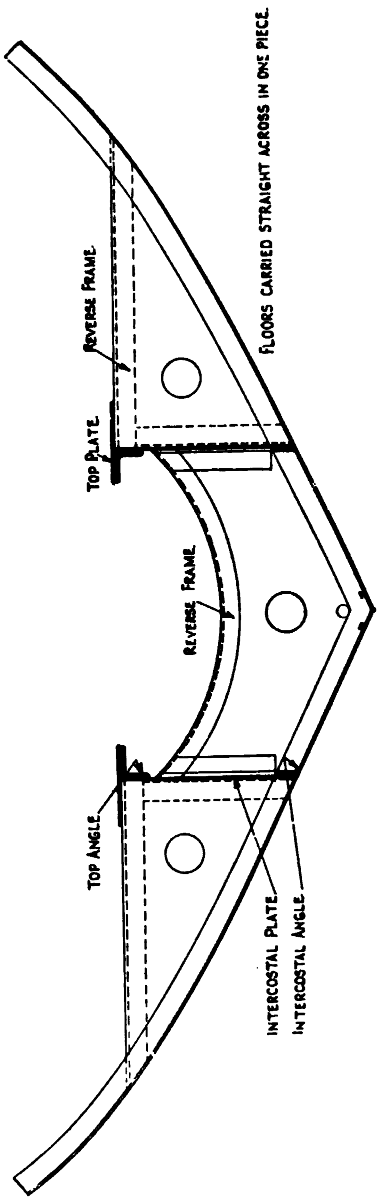


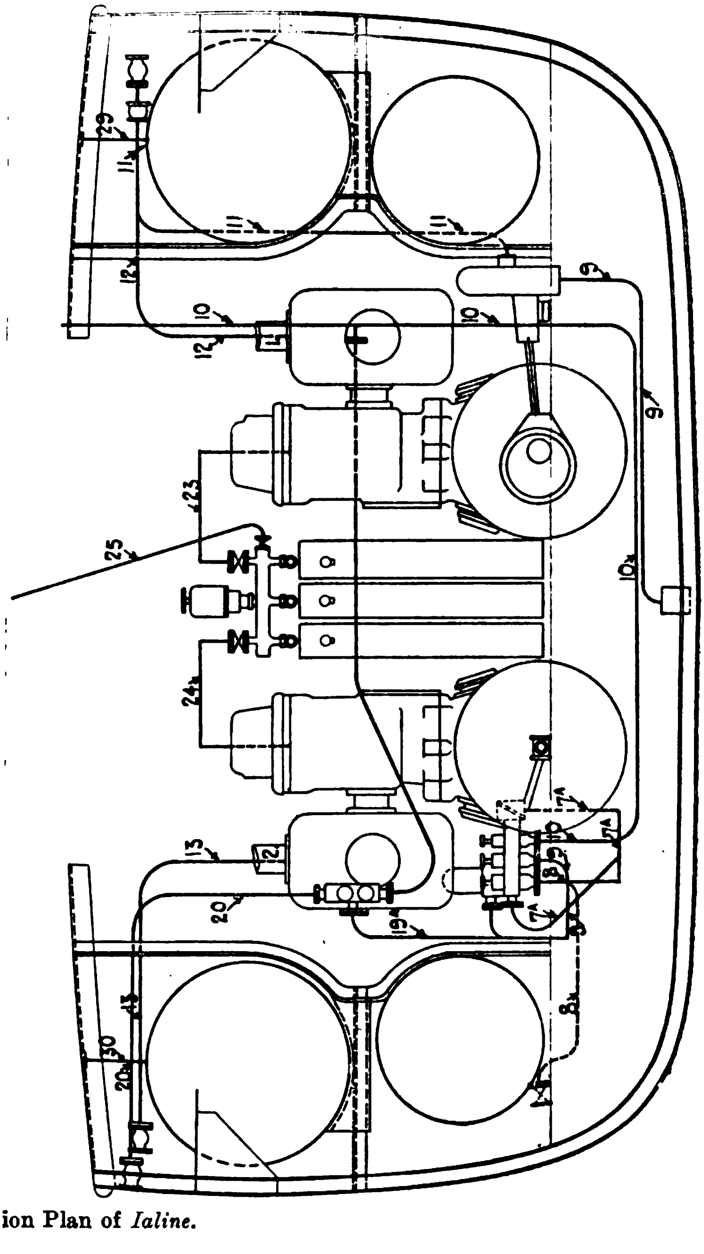
FIG. 334.—Steel Motor Seatings.

site side of the intercostal plates well overlapping the top fore and aft angles.

The recommended design and construction is as a rule only possible on new vessels. For old vessels or vessels not originally constructed for oil engines it is usually necessary to build up on the existing floors and frames and over a centre keelson, but even then the same construction can be adopted, and the additional floors carried right across in one piece, and connected to the frames; the longitudinal plates may be fitted intercostally and carried right down and connected to the skin of the ship and well forward and aft of the ends of the engine. Rivets, not bolts, should be used in these bearers.

Bearers for twin-screw installations would have a similar arrangement, but four lines of longitudinal intercostals.

For Wooden Vessels the bearers should be of pitch pine, two and a half times the length of the engine



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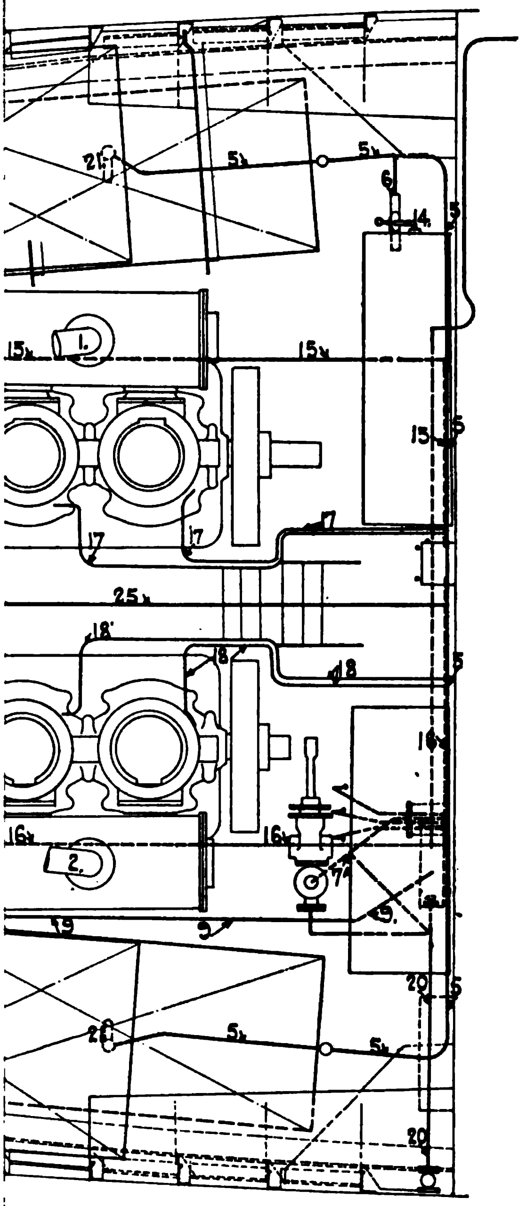

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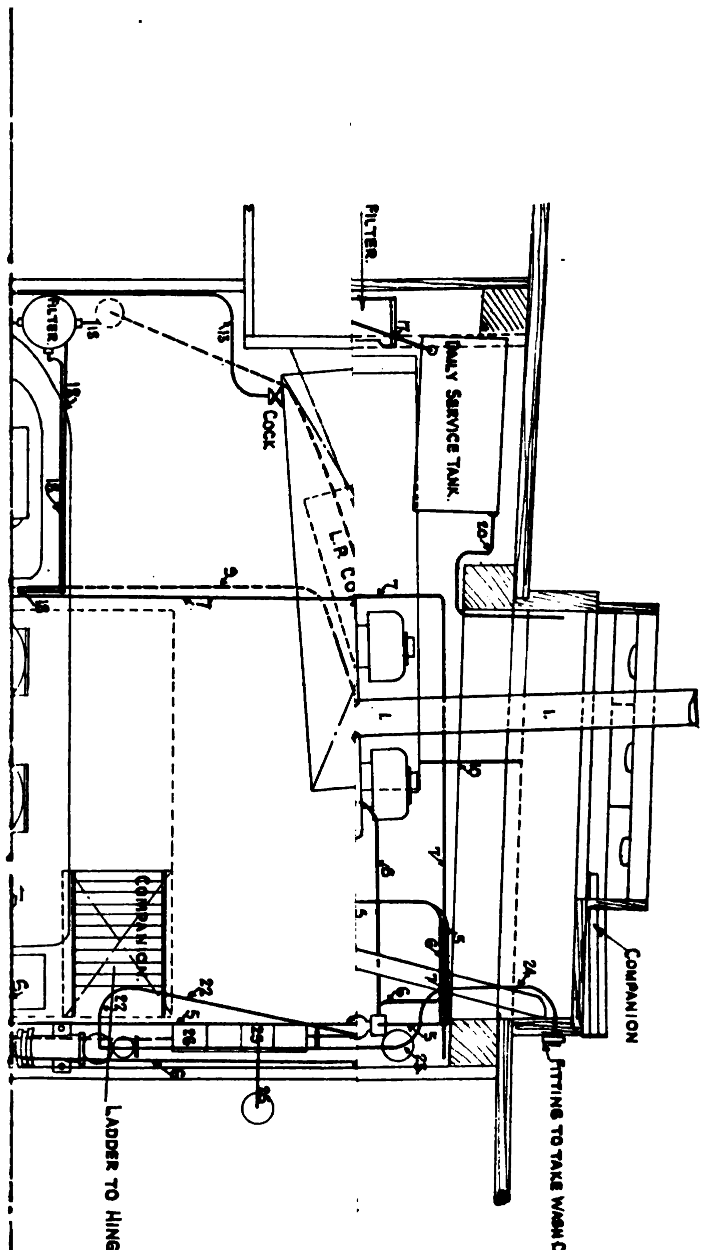
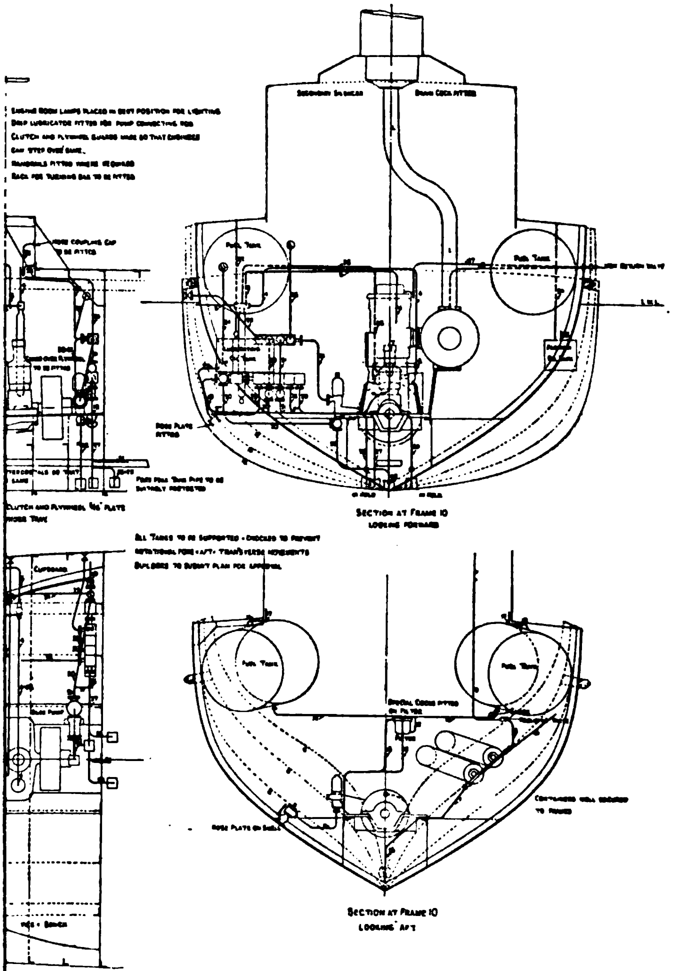


FIG. 339.—Installatio



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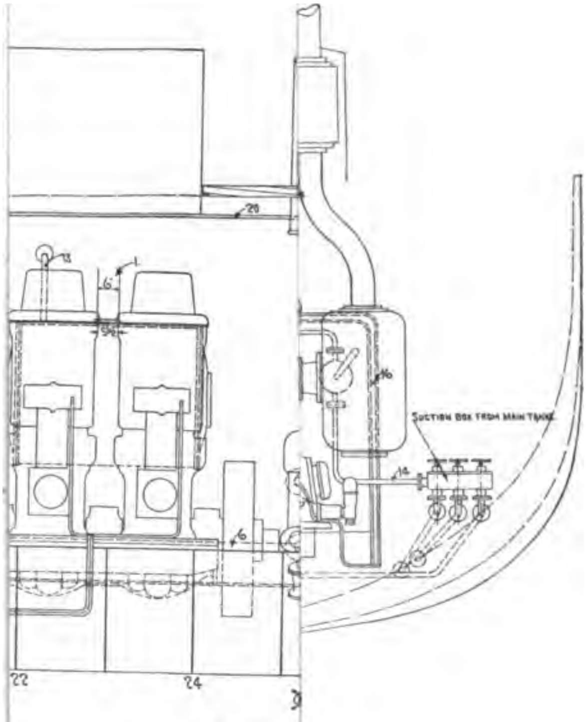


FIG. 341.-

SUGGESTED SCANTLINGS FOR BEARERS OF WOODEN SHIPS.

B.H.P.	25	50	100	200	300	500
No. Cyls.	2	2	2	4	4	4
Floors	—	—	6 in. × 6 in.	8 in. × 8 in.	9½ in. × 9½ in.	11 in. × 11 in.
Frames	2½ in. × 2½ in.	4 in. × 4 in.	5 in. × 5 in.	7 in. × 7 in.	8¼ in. × 8¼ in.	9 in. × 9 in.
Spacing	14 in.	16 in.	18 in.	20 in.	23 in.	26 in.
Fore and aft bearers, width	4½ in.	5 in.	8 in.	9½ in.	10½ in.	12 in.
Length of bearers in feet	13	17	25	40	50	60
Transverse bearers, width	4 in.	4½ in.	6 in.	7½ in.	9 in.	10½ in.
Bolts through bearers, dia.	⅞ in.	1 in.	1¼ in.	1½ in.	1¾ in.	2 in.

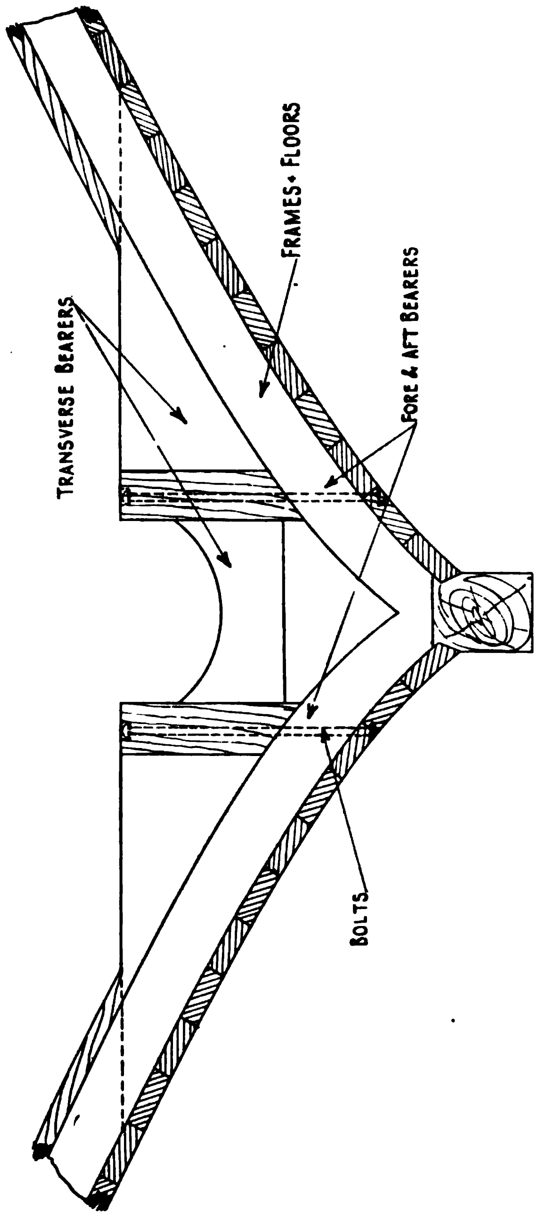


FIG. 335.—Wooden Bearers.

bedplate. The height of the bearers will depend upon the diameter of the propeller and the diameter of flywheel.

Substantial oak or other hardwood chocks should be fitted transversely, and occur *at least* on each side of, and close to every engine holding-down bolt, and more frequently if possible.

Suggested scantlings are given on p. 371.

It is essential that these engine bearers should be securely and solidly fixed in the boat, and for this purpose through bolts (*i.e.*, bolts right through to the outside of the skin) should be used rather than screws or coach screws.

The engine bearer bolts apart from the engine should be fixed, say, every 12 in. or 15 in.

The Skin Fittings should consist of a sea cock for circulating water and an inlet cock or valve for the bilge pump when required by specification; both these cocks should have rose plates fitted and placed on the round of the vessel at the bilge to prevent them from becoming choked, if the vessel should take the ground. For specially shallow-draft vessels a box or tank can be fitted inside with a door on the top.

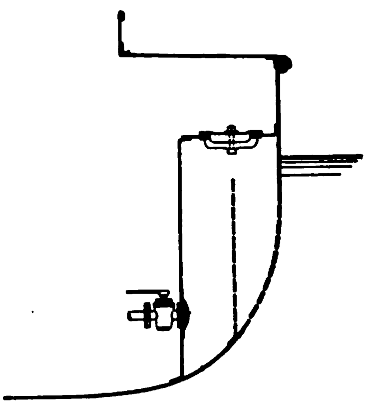


Fig. 336.—Weed Box.

A non-return valve is also required for the circulating water discharge and a non-return valve for the bilge discharge overboard, the last two valves being placed as high as possible.

Packing Strips.—For sizes up to 100 B.H.P. hard wood strips, preferably teak, $\frac{7}{8}$ in. to $1\frac{1}{4}$ in. thick, and laid transversely, should be fitted between the engine and the engine bearers, or, if preferred, longitudinal chocks running the length of the bedplate, space being allowed for these in the lining up of the shafting. For larger-powered engines a straight edge should be used on the top of the bedplate to check alignment and prevent trouble with the crank-shaft bearings. Cast-iron chocks are usual on engines of over 100 B.H.P., and these should be fitted with precision by an experienced fitter, one at every holding-down bolt, and teak chocks in between.

The Drain Cocks on the bottom of the crank case should be fitted before the engine is lowered on to the bearers.

The Drip Tray underneath the engine bedplate, and reverse gear or clutch, should be of zinc or galvanised sheet steel and fitted with drain cocks in accessible positions, and should be placed in position before the engine is lowered on to the bearers.

Silencers.—The main silencer, which is practically always furnished with a water jacket, is bolted direct to the cylinder, and to ensure further rigidity should be supported by stays from the bedplate. Great variations are possible in the installation and design of the secondary silencer ; examples of the latter will be found on p. 176, and the methods of fitting will be found on installation plans, in this chapter. For yachts and important passenger vessels these silencers should have water jackets.

All silencers should have man or hand holes for cleaning purposes, and both silencer and jacket should have drain cocks, the secondary silencer being fitted with a sump also, if possible.

If the secondary silencer is fitted in the funnel, the drain cock should be fitted on the bottom so that it may be kept free from oil residues.

Exhaust Pipes.—There are several ways in which exhaust pipes may be fitted in motor vessels, among which may be mentioned :—

(*a*) The exhaust led up a funnel.
(*b*) The exhaust led out at the stern.
(*c*) The exhaust led through the casing top.
(*d*) The exhaust led through a mast or through a pipe led alongside the mast.

(*a*) *The Exhaust led up a Funnel.*—This is undoubtedly the best for all-round purposes, as it prevents rain or sea water getting into the silencer, allows the secondary silencers to be fitted conveniently in the funnel, and gives the vessel at once the appearance of a vessel fitted with power, thus enabling the motor ship to obtain "steamer's turn" on entering the dock. If required the funnel can easily be arranged to lower with a cone joint between the portion of the exhaust pipe in the funnel and that immediately below.

(*b*) *The Exhaust led out at the Stern.*—This system is frequently fitted in small vessels. The exhaust pipe can be carried above the deck and out through the bulwark, or below the deck and out through the counter; in either case the pipe should be efficiently lagged and fitted with iron plates in way of bulkheads, and means should be provided to prevent the water coming back into the silencer should the vessel be in a seaway. This can be accomplished by making a high bend in the pipe in the engine room and turning the pipe downwards before it goes aft.

(*c*) *The Exhaust led through the Casing Top.*—The most inexpensive arrangement is to carry the exhaust pipe straight up through the casing top, with a small cowl above so that it can be turned round to suit the direction of the wind. This method has been successfully adopted in many fishing boats, where it would not be advisable to fit the exhaust under the counter, over the side or up a funnel; the former is objectionable in a seaway, while a funnel interferes with the working of the sails and gear.

An excellent arrangement showing the exhaust through the casing as fitted in a tug and tender is illustrated in Fig. 341, where each of the exhaust pipes for the twin-screw engines is carried straight up through the awning, with a light steel air casing round. This arrangement enables the captain to see right aft and observe the vessel in tow.

(*d*) *The Exhaust led through a Mast or through a Pipe led alongside the Mast.*—This method is very popular for sailing ships, auxiliaries, etc., and has been fitted with much success on large auxiliary sailing ships, such as the ***Fingal***, Fig. 228, p. 266, the *Caracas*, Fig. 229, p. 267, and the

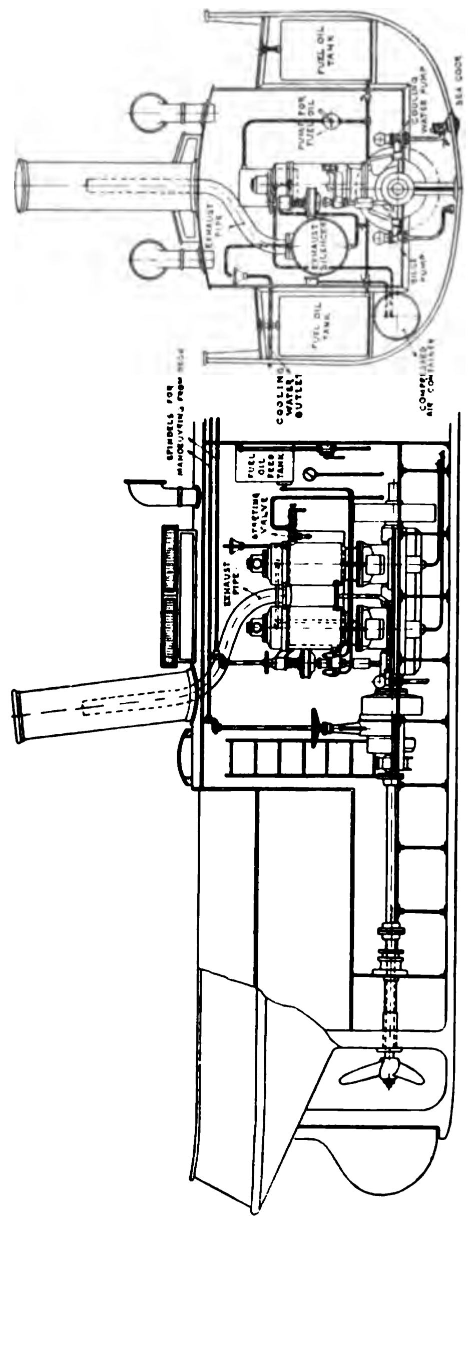


FIG. 342.—Installation Plan of Tuxham Motor Barge.

Goodwin, Fig. 231, p. 269. The outlet pipe should be at least 20 ft. above the deck of the vessel.

Notes on materials for exhaust pipes and the method of fitting will be found on p. 382.

Fitting Air Containers.—One or more air containers, as described on p. 178, can be fitted as desired. If secured horizontally against the aft engine-room bulkhead by clips, or against the vessel's side, they do not obstruct the engine room at all.

If two or more air containers are being fitted a brass or cast-iron branch piece should be arranged so that any one of the air containers can be removed for cleaning whilst the others remain in use, and for this purpose it is necessary to have a valve between each container and the branch piece. This branch piece also requires to have connections to the engine starting valve, the compressor if fitted, the whistle, the hand compression pump and a safety valve (when a compressor is connected), while a pressure gauge is required on each container.

FIG. 343.—Bilge Pump.

Whistle.—The position of the whistle should be so arranged that there is no impediment to the sound, say, just in front of the wheel-house. The connection is taken from the air container, in which the pressure is maintained by an air compressor, or by a charging valve on the engine. A reducing valve, placed between the air container and the whistle is an advantage, and also a stop valve where the air pipe joins the container.

Bilge Pumps.—Nearly all makers of engines arrange for a bilge pump to be fitted if ordered, on the bedplate, and worked from an eccentric on the main shaft; the objection to this arrangement is that the stroke is very small, and consequently the pump is not very efficient for marine work, except for launches, small barges and fishing boats.

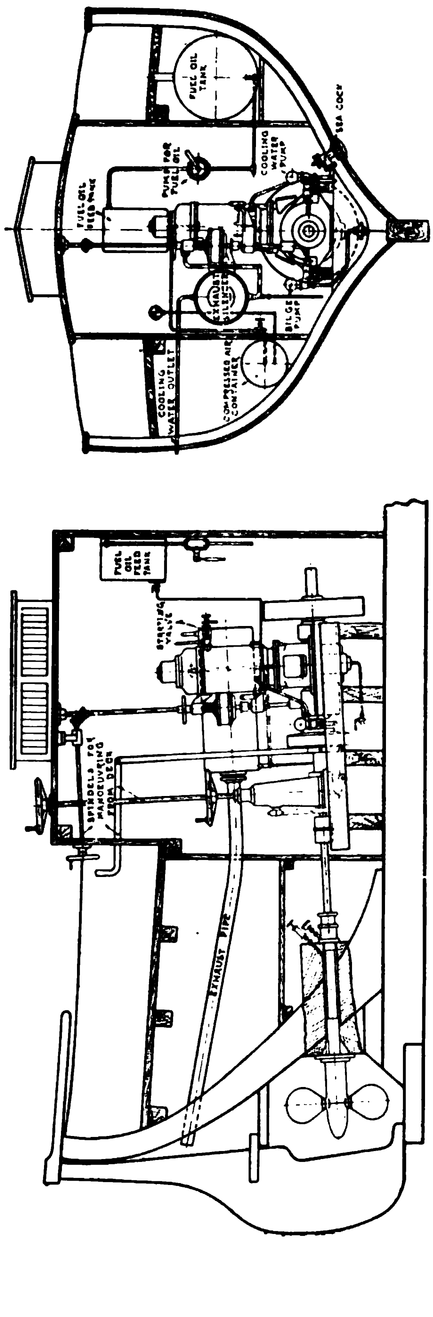
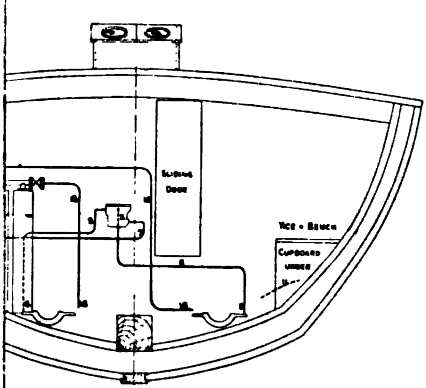


FIG. 344.—Installation Plan of Tuxham Fishing Boat.



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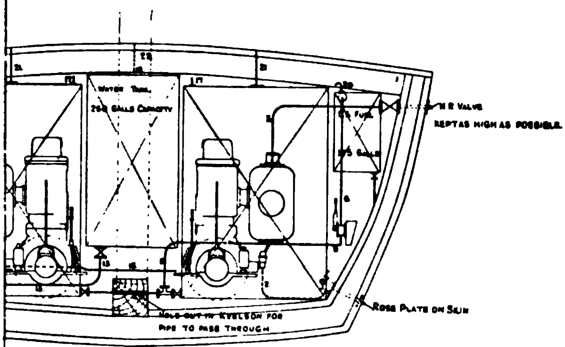

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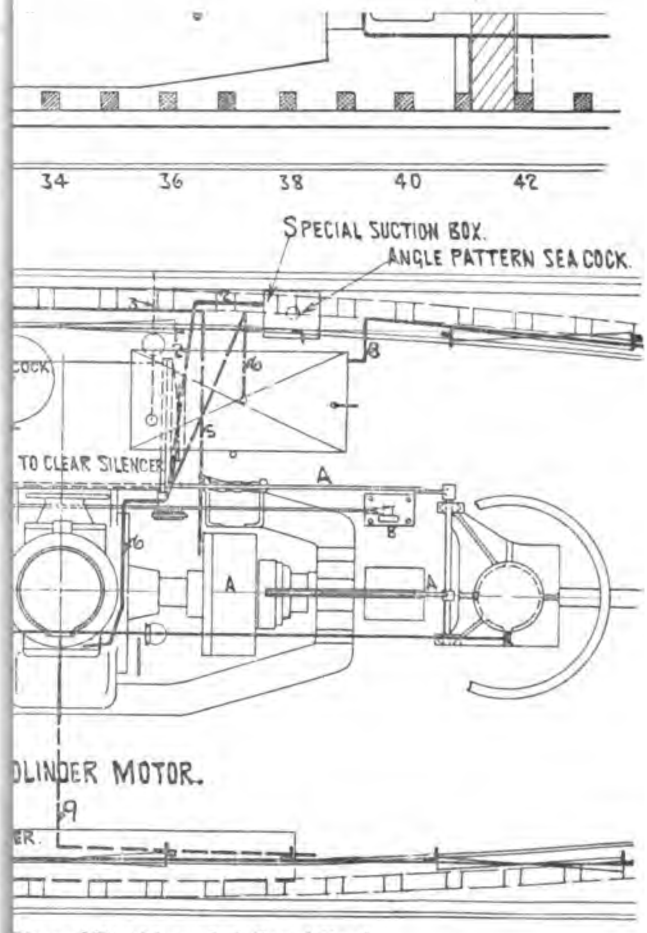
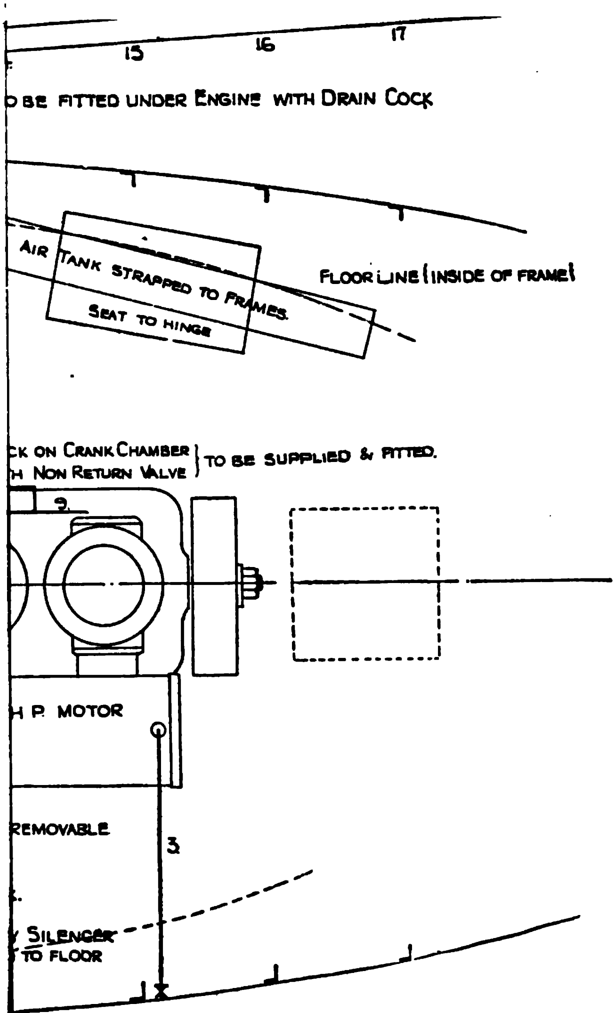


Plan of Double-ended Canal Boat.



'lan of 30 H.P. Launch.

Bilge pumps are sometimes arranged to be driven off a pin carried on the forward end of the crank shaft, and often by a pin on a cast-iron cap bolted on the flywheel boss, which gives satisfaction and can be made of any size.

Such a special bilge pump is required when vessels are to be classed to Lloyd's and Board of Trade, whose latest regulations must be studied as they are subject to constant change in these early years of oil engine development.

Reference to bilge pumps is also made on pp. 170 and 410.

Tanks.—Main Tanks for both fuel and water should, if possible, be cylindrical with dished ends, as being less likely to leak from the surge of the oil in a heavy sea when the tanks are only partly full, and they are also more efficiently drained in cleaning operations.

For smaller sizes, shaped or rectangular tanks may be preferred.

The suggested scantlings are :—

Capacity.	Cylindrical Tanks.	Shaped or Rectangular Tanks.
	Thickness of Plating.	Thickness of Plating.
Below 80 gallons	$\frac{1}{8}$ in.	$\frac{1}{8}$ in.
100 to 300 ,, ...	$\frac{1}{8}$,,	$\frac{3}{16}$,,
300 to 600 ,, ...	$\frac{3}{16}$,,	$\frac{1}{4}$,,
Above 600 ,, ...	$\frac{1}{4}$,,	$\frac{5}{16}$,,

	Number of Wash Plates.
3 ft. to 6 ft. long	1 transverse.
Above 6 ft..	2 transverse.
Under 5 ft. diameter	No longitudinal.
Above 5 ft. ,, ...	1 longitudinal.

Every tank should have a manhole if it is large, or a hand hole if it is small. The filling pipes to the deck for the larger tanks should be not less than 2 in. diameter, and should have a portable gauze filter fitted in the pipe at the deck level. A drain cock should be fitted at the lowest part of the tank in an accessible position. The pipe connections for drawing off fuel or water should be about 2 in. above the bottom, so that any sediment may be left in the tank, and drained off when the drain cock is opened periodically, say, before each refilling.

For tropical work the tank should be designed so that the required capacity only fills 95 per cent. of the tank, the remaining 5 per cent. being left for expansion of the oil.

All tanks should have ventilating or overflow pipes carried up to the deck and so arranged with sawn necks that sea or rain water will not enter the pipe.

Small tanks including all service tanks, lubricating oil tanks, etc., should be galvanised.

The capacity of the tanks will depend on the power of the engine, and the conditions of service of the vessel. All makers will supply particulars of consumption, so that the size of the tanks most suitable for any given service can be calculated from the owners' requirements.

Arrangement of Fuel Tanks.—The main tanks should have connections which will allow the oil to be pumped from these tanks to a daily service tank by means of a semi-rotary or other suitable pump. A filter is placed between the service tank and the engine, and cocks are fitted on each main tank for shutting off the tanks so that the pump and pipes can be inspected and cleaned at any time. It is also advisable that pipes with cocks or valves should be so arranged in the engine room that fuel can be used from any one main fuel tank, independently of any other.

Under no circumstances should fuel tanks be used for water or filled with water ; if cleaning is necessary it should be done with paraffin.

Manhole door joints should be made of leather, as rubber or rubber material deteriorates with the action of the fuel. The studs require to be close spaced, relatively large and tightly fitted to prevent leakage. A stiffening ring should always be fitted behind the opening.

The Daily Service Fuel Tank should be so fitted that the bottom of the tank is above the fuel pumps on the engine, but preferably by only a few inches. It should have connections from the semi-rotary pump, test cocks or a protected gauge glass, vent pipe, drain cock, and a cock with a connection to the engine or the filter if fitted.

Where a special cock is supplied by the engine builders, see Fig. 327, p. 341, it should be fitted about 3 in. from the bottom of the tank (or of the filter if installed).

Position of Filter.—The filter should be placed in a convenient position, say, on the after bulkhead with its top a few inches below the outlet of the daily service tank. When fixed in position all pipes and cocks and drains must be accessible and it must be quite easy to dismantle the filter for cleaning while in place. In selecting its position it should be borne in mind that the shorter the pipe and the fewer the bends between filter and engine, the better, and a rise and second fall of the pipe must be strictly avoided as giving rise to air lock.

The Water Drip Tank, if required, may be placed in any suitable position, but if a small water tank is not used in conjunction with it, it should be placed about on a level with the cylinder cover and fitted with a cock for each cylinder, placed about 3 in. from the bottom of the tank, a copper pipe being led from the valve to the water drip valve on the engine.

With a large installation it is advisable to fit a small water drip service tank fed from the main water tank by a semi-rotary pump, the service tank being fitted about on a level with the cylinders.

Pipes.—Copper pipes should be used for all engine work and connections between the engine, and the fuel tanks, filters, air containers, lubricating boxes, all circulating water pipes, from the pump to the various parts of the engine, and overboard, the bilge pump to overboard, the water service to deck, etc. The copper pipes should be solid drawn, the smaller sizes having union connections and the larger sizes having couplings brazed on, not soldered. These couplings may be round or lozenge shaped, but all should be of the spigoted type.

Fuel Pipes.—If crude oil is used for fuel, steel pipes, especially for tropical vessels, are preferable to copper, which may be damaged by the sulphuric acid formed in oil which contains sulphur.

The lead of the fuel-pipe connections from the tanks to the filters, and the filters to the pump to avoid any inverted bend, and so air locks, is very important. That is to say, the pipe must rise continuously, in each direction, from the lowest point, thus :—

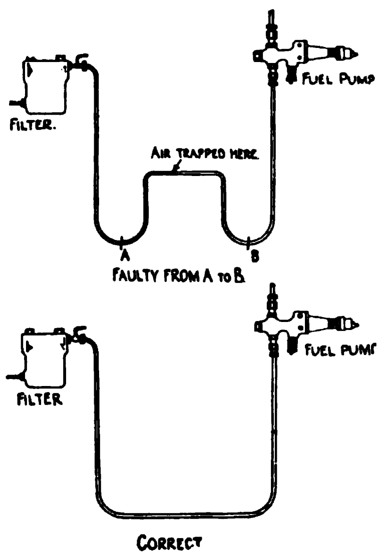


FIG. 348.—Lead of Fuel Pipe.

Lubricating Oil Pipes.—These are probably fitted to the engine by the makers at the works, and when the engine has been installed, the correct place should be found for them without the need for bending them in any way. These pipes should all have paraffin passed through them before they are fitted to ensure their being thoroughly clean, and when connected to the lubricating box, should have the oil pumped through them by hand before they are connected to the various parts of the engine, so as to ensure the oil actually passing to the engine.

Circulating Water Pipes.—See p. 353.

Exhaust Pipes should be of steel and, where possible, standard bends and connections should be used in no case with a mean radius of less than three times the diameter of the pipe, elbows being, of course, absolutely prohibited. Where water cooled pipes are required it will be advisable to make them of cast iron or of riveted plates and flanges for very large sizes. The diameter of the exhaust pipe should be made larger than the usual diameter of the exit hole in the silencer, by at least half an inch in smaller engines and one inch in the larger engines to prevent back pressure.

Bilge Pipes, ballast tank and water service pipes should be of galvanised steel or iron, steam quality, although cheaper pipes and cast-iron lengths can be used. The objection to the use of lead piping is that it is somewhat costly, and after years of use usually gets flattened in places with consequent loss of area and efficiency.

Deck Tanks and Pipes.—If the vessel is to work in cold climates, the water drip or water circulating tanks for the main engines or motor winches should be protected, if on the main deck, by a casing, space being provided for a small lamp to prevent the fresh water from freezing.

All deck pipes should have a cock at the casing or on the tank to shut the water off, and drain cocks where necessary.

For self-contained winches with circulating water suctions from the sea, only drain cocks are necessary.

Pipes Generally.—It is important that the leads should be so arranged that all pipes are accessible, and yet out of the way, and in no case should they be fitted in such a way that a strain is likely to come on them, either through expansion, vibration or carelessness on the part of the driver when overhauling parts of the engines. Supports and clips should be fitted so that the pipes will not get chafed or worn, and will not shake or vibrate.

Engine Room Equipment.—Lubricating Oil Tanks of substantial make should be fitted in a convenient place with savealls under the cocks. These cocks should be extra large, the one for the lubricating oil being say $\frac{3}{4}$ in. and the one for the cylinder oil 1 in.

The capacity of the lubricating oil tank might be 5 per cent. and that of the cylinder oil tank .3·5 per cent. of the capacity of the main fuel oil tank. In the case of double purpose oil, the percentage would be 8·5 per cent. These percentages should give good margins for emergency.

The name of the oil should be clearly painted on the tank.

Connections from the deck to the tanks, when they are of more than 20 gallons capacity, will be found convenient for filling, little vent cocks or vent pipes to the deck being then required, the latter making the filling a one man job.

Paraffin Tanks should be fitted in the engine room for supplying the oil for the blow lamps, and the same tanks could be used for the navigation lights on deck, cabin lamps, etc. The capacity of these tanks should be 5 per cent. of the total fuel tanks.

Engine Room Floors are best made of chequer plates on iron bearers, which should be made portable for access to the bilge, with hinged plates in way of all bilge strums or rose boxes.

Ladders to the engine room should be of iron, with cast-iron steps, or preferably with three square bars on edge to form each step, and should have two portable hand rails secured in place by bolts.

Lockers should all be of iron, with the exception of the seat portion, which may be of wood. They should be arranged to take the various tools and small spares and have good locks and duplicate keys.

Vice.—A 6-in. parallel vice should be fitted on an iron bench, secured by bolts, so that it can be taken up and bolted to the casing on deck if required at any time. For small boats with little available engine-room space, a smaller vice would usually answer.

Guards.—Iron guards or stanchions of round bars should be fitted in way of the flywheel, the clutch, and across the front of the engine, etc., so that the man working the engines can hold on and protect himself in a seaway.

In arranging these guards, consideration should be given to getting at the flywheel, clutch and other parts. In engines of larger power it is necessary to have steps and hand rails fitted on the engine, so that the men in charge can easily see whether the bulbs are sufficiently hot.

Sand Box.—A box filled with sand is imperative for every engine room where light or volatile oils are used for fuel purposes, as that is considered to be one of the best means of putting out a fire, although oils having a flash-point of 200° F.

and above, cannot in their ordinary condition be ignited with a lighted match even if poured out on to wood.

It is advisable to have a sand box of, say, 4 cubic ft. capacity per hundred brake horse-power, of sheet iron inside and fitted with a lid, and provided with a scoop which should be kept in the box, and in an accessible position in case a fire should occur from other causes, such as the methylated spirit sometimes used for heating the lamp burners, or the woodwork catching fire from an overturned lamp.

If light paraffins are frequently used for fuel purposes, it is advisable to have this sand box on deck near the engine-room entrance.

Fire Extinguishers.—It is also advisable to carry one or more portable fire extinguishers, hung in a convenient place outside the engine room and accessible to any member of the crew.

Ventilation.—Leakage of fuel and other oils may find its way from the tanks and connections into the bilge, and under the hot conditions of the engine room, especially in the tropics, will throw off smelly fumes ; if this gas can be distributed along the engine-room floor it will in all probability disappear by being drawn into the crank case through the air valves. It is therefore advisable to fit a down cast ventilator from well above the casing top, right through the engine room and for a few inches below the floor level with ample ventilating holes in the bearers and ship's floors, etc., longitudinally and transversely to ensure proper ventilation of the bilges.

With the adoption of the hot bulb engine the ventilation is greatly facilitated, and in a well-designed vessel fitted with a two-cycle engine of, say, 120 horse-power the air required for the engine will cause the displacement of the air in the engine room eighteen to twenty times an hour.

Classification.—Some owners prefer to have their engine inspected by one or other of the Classification Societies. The first class Swedish makers from their early experience have really set the standard for scantlings and strengths for the simple two-stroke hot bulb engine, and many other makers have based their designs on this standard. It is somewhat difficult for any Classification Society at the present time to prepare hard and fast rules that are entirely applicable to all hot bulb oil engines.

It is necessary to have some standard rules for the crank shafts and some other important details, and the Classification Societies are doing good work in that direction for all types of internal combustion engines for marine work.

For small powers and small installations it is doubtful whether much is gained by having the engines tested and passed by the Societies referred to, as the expense at present is somewhat heavy. For larger power installations and for sea-going ships it is often a considerable advantage to the owner to have the vessel properly classed, not only as to the engine but the ship and also the installation work, especially if he does not happen to have an expert consulting engineer who has special experience in this work. It will also be an advantage on the score of insurance, and will probably enable a better price to be obtained should a sale be desired.

In the case of some builders the classification means altering their methods of construction and the routine of their works, because special test pieces have to be provided for and, consequently, specially ordered from the makers of the forgings, but in time these objections and difficulties will automatically disappear.

Lloyd's Scantlings.—The rules of Lloyd's Register of Shipping for the year 1917 that are applicable to hot bulb engines are :—

Crank Shaft.

For smooth water service.

Diameter of crank shaft in inches $= C \sqrt[3]{D^2 \times S}$.

Where D = diameter of cylinder in inches.

S = stroke of piston in inches.

Two cycle.	Bearing between each crank.
1 or 2 cyl.	$C = \cdot 34$
3 ,,	$C = \cdot 36$
4 ,,	$C = \cdot 38$
6 ,,	$C = \cdot 44$

For open sea service add ·02 to C.

Intermediate and Screw Shafts.

Diameter of intermediate shaft and screw shaft in inches $= C' \sqrt[3]{D^2 \times S (N + 3)}$.

Where D = diameter of cylinder in inches.

S = stroke of piston in inches.

N = number of cylinders of a four-stroke cycle engine

and N = **twice** the number of cylinders for a two-stroke cycle engine.

For smooth water services.	For open sea services.
$C' = \cdot155$ for intermediate shafts.	$C' = \cdot165$
$C' = \cdot170$ for screw shafts fitted with continuous liners.	$C' = \cdot180$
$C' = \cdot180$ for screw shafts fitted with separate liners or with no liners.	$C' = \cdot190$

Thrust Shafts.—When ordinary deep thrust collars are used the diameter of the shaft between the collars is to be at least $\frac{21}{20}$ths of that of the intermediate shaft.

The above rules apply only to engines in which the initial pressure does not exceed 250 lb. per square inch. In the case of Semi-Diesel, Diesel and other engines, in which higher initital pressures are employed, particulars should be submitted for special consideration.

Port Authorities and Harbour Boards were a few years ago very averse to the entrance into their docks of vessels fitted with internal combustion engines using a pressure lamp and a naked flame to heat the bulb owing to the supposed danger. It was difficult to follow their reasons, especially if heavy and crude fuel oils were used, as these could not catch fire, and the risk of fire from the pressure lamps with a steel skylight and deck above, is considerably less than from a steam boiler, where there is the possibility of sparks coming out of the funnel when "firing up" to get out of dock, or from winch boilers.

The objections have been almost entirely overcome, and the good and safe working of these engines if properly installed, and the advantages of the quick handling of barges at the dock entrances when fitted with these engines now pleases the Harbour and Dock Masters and facilitates the work of the Port.

The Port of London Authority will not allow barges carrying petroleum in bulk, fitted with internal combustion engines, having a naked flame for heating the bulbs or vaporisers, to work on the River Thames, and a set of rules was issued by them in May, 1915. It is difficult to see why such stringent rules should be made and why these engines, if designed to use heavy and crude oils, should not be approved. If the engines are installed properly with steel decks and skylights, no woodwork allowed in the engine room, with proper ventilation and efficient secondary silencers, and also cofferdams between the tanks and the engine room, there can be no more risk from fire than with any other engine.

Passenger Certificates.—All British Motor Passenger Vessels that are intended to carry more than twelve passengers are required to have a licence which is generally known as a Board of Trade Passenger Certificate. The hull and machinery have to be inspected annually, and the certificate renewed usually for from three to twelve months.

The limits of this book prevent detailed reference to the hull, but copies of the regulations can be obtained for a few pence.

The position is somewhat vague with regard to hot bulb oil engines intended for such vessels, because detailed regulations have not yet been prepared as to the design and installation. However, the basis of all such rules is that the engine shall be sound, substantial, reliable and as safe as it is possible to make it, and these remarks more particularly apply to the installation, and the fitting of fuel tanks, drip trays and fire extinguishing apparatus.

Many authorities appear to be nervous of the small naked flame of the pressure lamp for heating the bulbs, but overlook the fact that there are only a few pints of paraffin in the lamp containers, the bulk being stored on deck in a tank, that can easily be smothered ; the fuel oil, which is used in considerable bulk, is usually of a high flash-point and very safe. The engines and fuel used are therefore much safer than is the case with ordinary paraffin and petrol engines. In the case of wooden vessels, the latter type are a source of danger, and for that reason are not used by the Admiralty for driving launches. It is convenient to have half a pint of methylated spirit in the engine room for lighting up the lamps, but in any case of objection, waste soaked in paraffin answers quite well.

The Board of Trade usually require scale drawings showing the design and construction of the engines, with detailed dimensions of the working parts and the materials used, in order that they may check the strength. Tail shafts are also gone into, fuel tanks tested for strength and oil tightness, all tanks arranged to fill from the deck if possible, and if not, the arrangements for filling are made to prevent oil getting into the bilges and so on.

Most of the regulations will be covered by an observance of the recommendations contained in this book regarding installation work, tanks, pipes, and ventilation, and it is not therefore necessary to reiterate them.

It is necessary to communicate with the Board of Trade if a passenger certificate is required, and this should be done immediately the order is received, so that the makers' designs and proposals can be approved at the start and right through. The fees are ascertainable on application to the Board of Trade, and are moderate.

CHAPTER VIII

Auxiliary Machinery.—Auxiliary machinery for hot bulb oil-engined vessels and the method of driving it has not received the attention that the importance of the question deserves.

The outstanding feature of the hot bulb engine for the purpose named is that it does not require any of the power of the main engine, although for small powers it may be more economical to drive the pumps, winches, and electric lighting sets from the main engine. In steam-engined vessels as much as 7 or 8 per cent. of the power of the main boilers is used in driving auxiliary machinery, electric light engines, pumps, steering gear, etc., and in the case of Diesel engines as much as 6 to 8 per cent. of the power of the main engines is required for driving air compressors, although in some cases these machines are driven by separate oil engines.

A thousand-ton vessel in these days may require mechanical power for :—

Steering gear.	Bilge pumps.
Cargo winches.	Ballast pumps.
Windlass.	Discharging pump for tankers.
Electric light.	Air compressors.
Wireless.	

Trawlers also will require several of the above and in addition a trawl winch and a winch for discharging fish.

The auxiliary power may be obtained by any of the following methods :—

(*a*) A separate oil engine with direct drive.
(*b*) An electric generating set.
(*c*) The main engine, by a connecting rod.
(*d*) ,, ,, ,, ,, belt.
(*e*) ,, ,, ,, ,, silent chain.
(*f*) ,, ,, ,, ,, bevel gearing.
(*g*) Steam donkey boiler.

If the main engine is used with the methods shown in (*c*), (*e*), and (*f*) a clutch can conveniently be fitted between the main shaft and the driven shaft, so that the auxiliary machinery can be declutched and left at rest when not in use.

If a belt drive (*d*) is adopted, it will probably be advisable to fit a jockey pulley to take up the slack, see p. 290.

Steam machinery should be avoided on oil-engined vessels, because of the dirt, the necessity of carrying coals (unless oil-fired boilers are adopted) and the heavy stand-by losses, and therefore steam donkey boilers are not dealt with in this book.

Deck winches and capstans of fishing vessels are frequently driven from the main engines on small vessels and are operated by the winchman on deck, for designs see pp. 288 to 290.

Small tank vessels may have their powerful pumps on deck, driven by silent chains from the main engine in a similar manner to that shown on p. 289.

Anchor capstans and windlasses may be driven by a separate engine below deck or by a messenger chain from the cargo winch.

Trawler winches that require from 70 to 120 B.H.P. may be conveniently driven by a shaft and bevel gear, with a clutch on the main shaft. The operating gear should be on deck, as it is necessary when pulling on a trawl wire to be able to ease or stop the pull at a moment's notice. The main engine is probably the best drive for this purpose, because generally 20 per cent. of the power is required to haul in the Otter boards and, say, only 50 per cent. or 60 per cent. for propelling the ship during that operation. Illustrations showing drives from the main engines are given on pp. 288, 289, and 290.

One objection to using the main engine is that when only a small power is being developed it is necessarily inefficient and wasteful of fuel, because the mechanical friction of the engine is just as much as when full load is developed, but for relatively short periods this is not serious.

On a multi-cylinder engine working at a quarter load or under, more even running is obtained by cutting off the fuel from half the number of cylinders, in which case these idle cylinders only absorb the unavoidable friction. There is, of course, no need to open release cocks or crank case doors, as any negative work done in compressing air is returned in the outward stroke giving almost a pure line curve for an indicator card.

Separate hot bulb engines for auxiliary machinery are advantageous because they generally consist of self-contained units. In the case of shallow-draft gunboats, self-contained

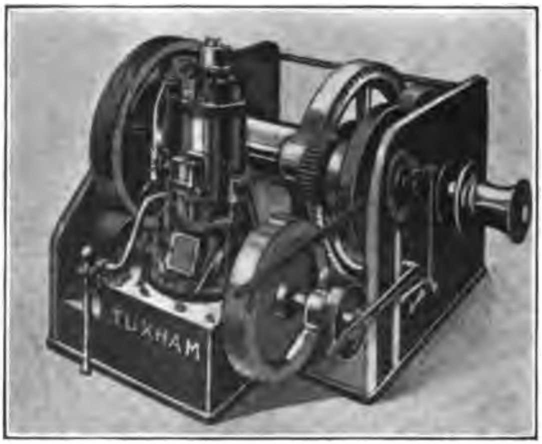


FIG. 349.—Tuxham Oil Engine Winch.

engines and pumps can be fitted in watertight compartments and started just before going into action, and should a compartment be holed, the water is automatically pumped out without detracting from the power of the main engines and the speed of the vessel.

A similar advantage is obtained for wireless telegraphy installations in ocean liners and naval vessels, where it is of the utmost importance to have a self-contained unit well above the water line, and to dispense with the objections of steam pipes or cables from the main engine room below the water line.

Motor Winches.—It is rather surprising that a larger number of cargo winches driven by hot bulb oil engines are

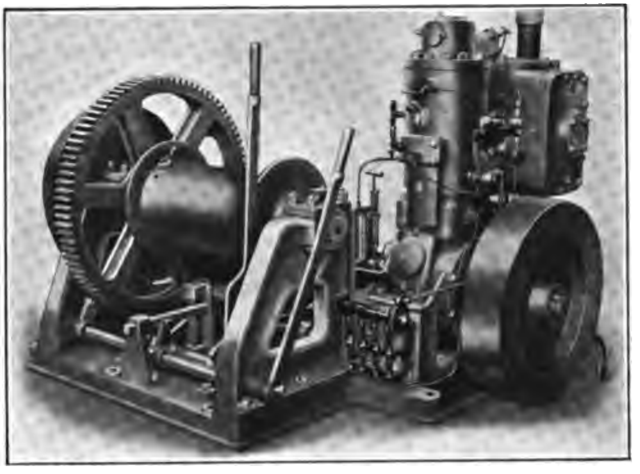


FIG. 350.—Bolinder-Cyclops Winch.

not in use; it may be due to the fact that a number of motor winches were placed on the market a few years ago,

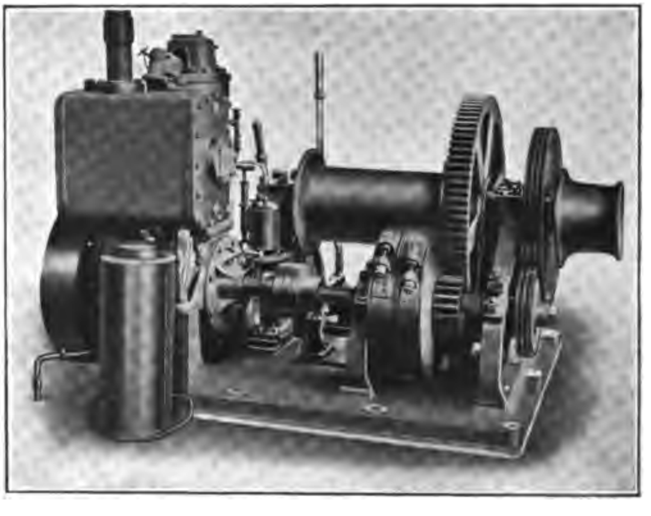


FIG. 351.—Bolinder-Cyclops Winch, back view.

some with paraffin engines and others with petrol engines which were of too light construction. The conditions that usually exist on board ship especially in rough and stormy weather are not conducive to the successful use of anything but the strongest and most substantial type of engine and winch. Recently a number of good winches have been available.

An excellent winch, although somewhat expensive, is the **Bolinder-Cyclops,** illustrated in Figs. 350 and 351; being constructed on a self-contained cast-iron bedplate, it can be fitted on the deck of any ship.

The outline particulars of this winch are :—

Lifting Weight.	Lifting Speed.	B.H.P. Motor.	Floor Space Occupied Overall.	Weight Approx.
Cwts.	Ft. per Minute.		ft. in. ft. in.	Cwts.
20	80	8	6 11 × 3 9	40
20	100	10	6 11 × 3 9	45
30	75	12	7 5 × 4 0	50
40	70	15	8 5 × 4 6	60
60	65	20	9 5 × 5 0	84

The winch is fitted with cast-iron barrel and messenger chain wheel and double purchase spur gearing with machine cut teeth throughout. One control lever only is required. When in mid position the engine is free; when in forward position it lifts the load, and when in the aft position, it lowers the load on the brake. A special gear is fitted, worked by a friction clutch, for lowering the empty hook at a rapid speed, and also a band brake lined with Ferodo Strips.

These winches are also made with two speeds, so that the lighter loads can be handled more quickly and easily, and at less running cost.

The winch is arranged to take a special bilge pump to meet Lloyd's requirements as an "auxiliary driven bilge pump." This pump is fixed on the same bedplate out of the way of the chains and tackle.

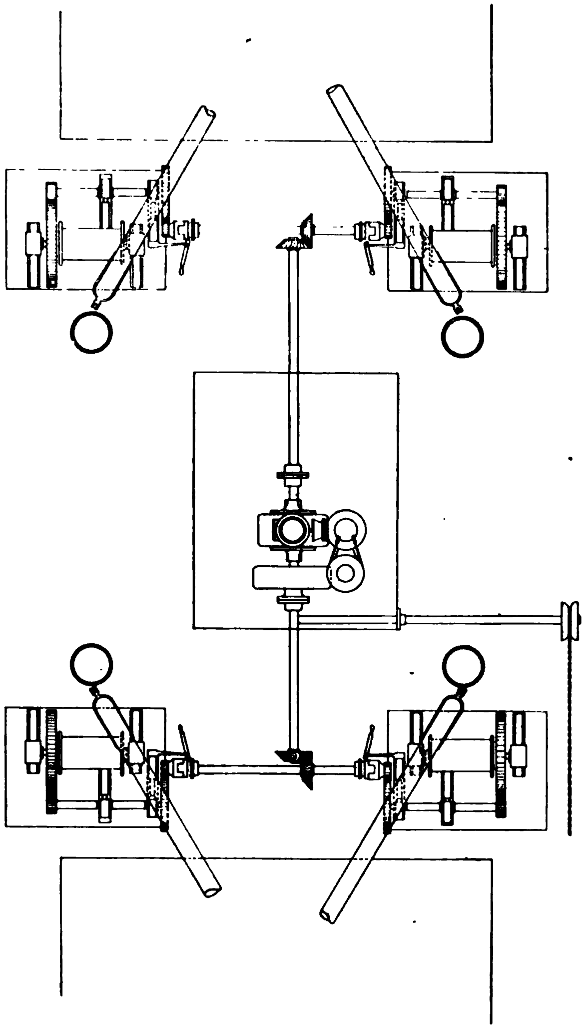


Fig. 352.—Four Winches, one Engine.

The circulating water pump which is arranged to draw the cooling water from the sea is fixed on the base of the engine, where it is easily accessible.

An economical winch installation is illustrated in Fig. 352, where four cargo winches and the messenger chain to the windlass are driven by a single-cylinder engine which can be conveniently fitted in a deck house.

Another example for small lifting capacities is the oil engine winch illustrated in Fig. 353, which shows the front view of a 10-cwt. cargo winch direct coupled to an engine of 5 B.H.P. The winch has a lifting speed up to 70 ft. per minute and is fitted with centre barrel, two warping ends

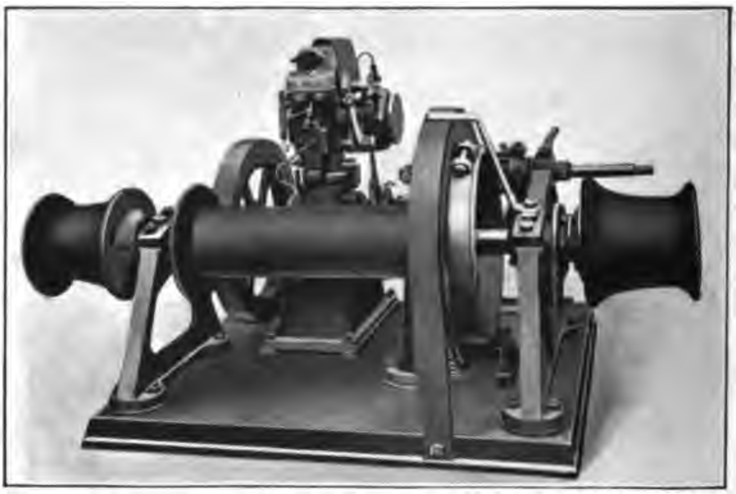


FIG. 353.—Bolinder-Pollock Winch.

and messenger chain wheel, and a strong expanding ring friction clutch whereby the load can be easily manipulated, as well as a clutch for lowering if necessary, and a powerful foot brake.

Hand power is fitted and worked with winch handles. This winch can be ready for use in ten minutes, starting from all cold.

The remarkable economy of this winch is illustrated by the fact that it lifts out of a ship's hold on to the quay 1,000 sacks of flour weighing 120 tons in 1,000 lifts in eight working hours with a total fuel consumption of one gallon of gasoleum, which costs in ordinary times 4*d*. per gallon. The cost of discharging 120 tons was :—

	s.	*d.*
Fuel	0	4
Lubricating oil, say	0	2
One winch driver	5	0
One man in hold	5	0
Depreciation and interest	3	6
Total	14	0

which equals 1·4 pence per ton.

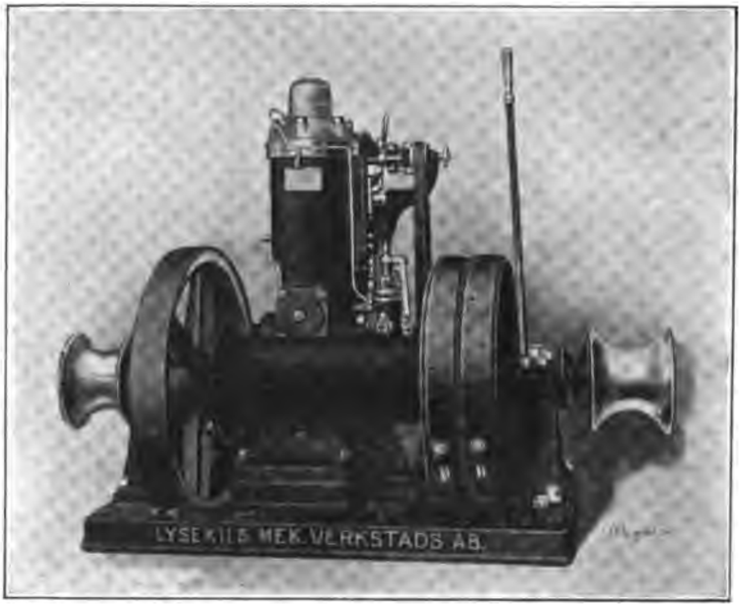


FIG. 354.—Direct-coupled Skandia Motor Winch.

	£	*s.*	*d.*
If the cargo were discharged by hand labour the cost would be . . .	1	4	0
Loss in time of, say, 4 hours, which at £2 10*s*. per working day	1	0	0
Total	£2	4	0

or 4·4 pence per ton, an increase in cost of over 300 per cent.

Steering Gears.—There are five different systems of power steering gears used in motor ships.

(1) Hydraulic.
(2) Electric.
(3) Compressed air.
(4) Steam.
(5) Electric hydraulic.

(1) *Hydraulic.*—This system generally consists of a hydraulic ram coupled direct to the quadrant on the rudder head, worked by an engine, and operated and controlled by

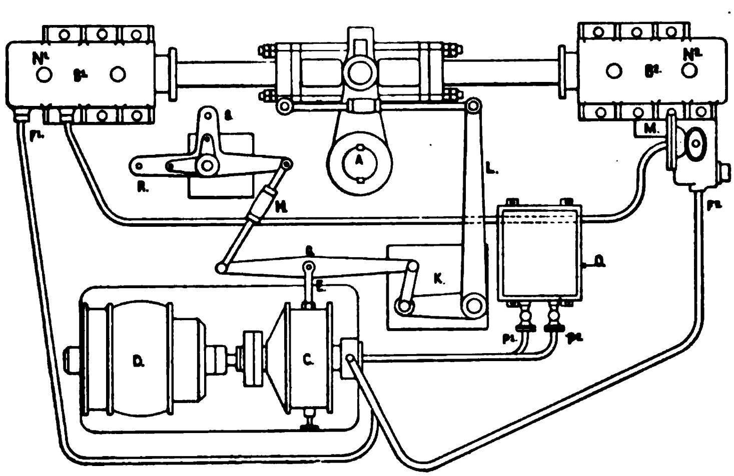


FIG. 355.—Hele-Shaw Electric Hydraulic Steering Gear.

a telemotor from the bridge. The only objection to this arrangement is the loss of power through the transmission, but otherwise it is both simple and reliable.

(2) *Electric.*—The motors are generally direct coupled to a gear drive on to the quadrant head with an electric control arranged from the bridge, the current being taken from a separate generating set in the engine room.

(3) *Compressed Air.*—An auxiliary engine and air compressor are arranged in a suitable position near the steering gear and the action of the gear is controlled from the bridge. The objection to this system is, of course, the loss of effi-

ciency, and the difficulty in preventing the expanding air and moisture from depositing ice, etc., in the pipes in very cold weather.

(4) *Steam Steering Gear.*—For objections, see p. 391.

(5) *Electric Hydraulic.*—This gear consists of two opposed cylinders B and B1, with a common ram forming a piston in each cylinder. The ram is connected to the rudder head A in its centre, and should the ram be moved in either direction the rudder has a corresponding movement.

A special rotary plunger pump C driven by an electrical

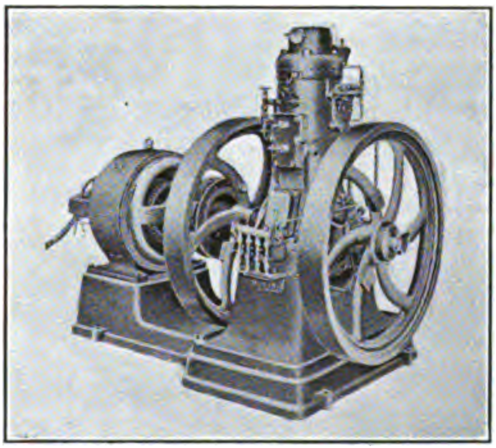


FIG. 356.—Electric Generating Set.

motor D delivers oil to either of the cylinders. This flow of oil is controlled by a spindle E and it is so arranged that no flow takes place when the spindle is in the neutral position.

The telemotor from the bridge controls the spindle E, so that the pump delivers oil to one of the two cylinders when the rudder is to be moved in either direction. An arrangement of levers L and K from the rudder head automatically shuts off the delivery of oil when the rudder has moved the required distance. A pipe M connecting the two cylinders has a safety valve on it which enables the rudder to give way when the strains are abnormal.

Electric Generating Sets.—The hot bulb oil engine is particularly suitable for marine electric lighting sets as the same fuel can be used as for the main engine. The engine is neat and compact, with an excellent fluctuation coefficient, in some cases as low as 1 in 200, being easily started and having all the other attributes of this simple design.

Particulars of the various sizes of the **Bolinder** sets illustrated are as follows :—

B.H.P.	Output K.W. 110 Volts.	Overall Dimensions.			Approximate Weight Complete Lbs.
		Length in Inches.	Width in Inches.	Height in Inches.	
5	2·5	66	44	44	2,070
8	4·5	75	51	53	2,700
10	6·0	80	59	59	3,400
12	7·0	88	65	63	3,970
15	9·0	93	65	67	5,130
20	12·0	107	67	75	6,360
25	15·0	120	71	83	8,560

The **Kromhout** set illustrated includes an electric generator, an air compressor and bilge pump, and either one or both the engines can be used according to load requirements.

Air Compressors.—The great majority of small and medium power hot bulb engines do not require a mechanically driven air compressor at all. In these engines the scavenge air is automatically compressed in the crank chamber by the underside of the piston, and the starting bottle is charged during each run from the engine cylinder by gases passing through a non-return valve. A motor car type hand pump or a hand driven compressor may be used to charge the bottle in the first instance.

When the starting medium is gas obtained direct from the engine cylinder, a certain amount of solid matter is deposited in the bottle, and this must be inspected and the deposit cleaned out periodically, say, once a year ; the need for perfect cleanliness in the whistle emphasises the necessity of this frequent cleaning.

These conditions have led to the use in larger installations of a special air compressor which, in some cases, is driven from the main engine, or it may be driven by a small auxiliary engine or electric motor installed for the purpose. With such a compressor a supply of pure air to the container is

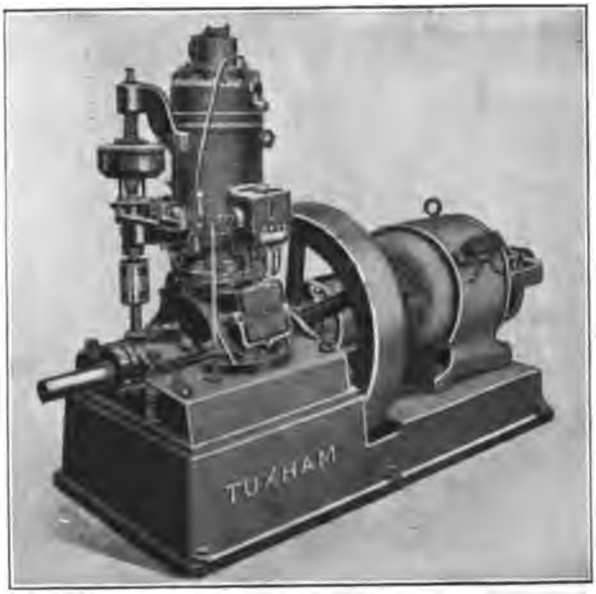


FIG. 357.—Tuxham Electric Generating Set.

assured, and this air can be used for the following purposes :—

(1) Starting the engine.
(2) The whistle.
(3) Reversing the engine.
(4) Atomising the fuel.
(5) Scavenging.
(6) Driving the auxiliaries.

(1) *Starting the Engine.*—For starting purposes alone a pressure of 200 lb. generally suffices, but the bottles or

receivers should be large enough for, say, five or six failures without having to recharge.

(2) *The Whistle.*—The supply of air for the whistle is obtained from the starting bottles, but should pass through a reducing valve so that the pressure at the whistle is not more than 40 to 60 lb. Any pressure in excess of this does not increase the effectiveness of the whistle and only spells waste.

(3) *Reversing the Engine.*—If air is required both for starting and reversing it is better to charge the bottles to a higher

FIG. 358.—Combined Air Compressor and Electric Generating Set, with Kromhout Engines.

pressure, say, 400 lb. per square inch or more, so as to keep the receiver down to a reasonable size, whilst at the same time allowing an ample margin in case it may be necessary to reverse several times in so short a period as to allow no time for the compressor to recharge the bottles.

(4) *Atomising the Fuel.*—As the size of hot bulb engines increase compressed air at a pressure of about 400 lb. per square inch is becoming used for atomising the injection fuel, which gives better combustion, better scavenging, and an almost smokeless exhaust over a wide range of load. Another

advantage is that the air injected prevents overheating at heavy loads so that water injection is eliminated without any sacrifice of power.

(5) *Scavenging.*—A separate air compressor for scavenging purposes is necessary in double-acting engines or in single-acting engines with an open crank case. These compressors which deliver their air at 5 to 8 lb. per square inch are necessarily cumbersome, owing to their large displacement, but they are essential when the usual method of compressing the scavenge air in the crank chamber cannot be adopted. They are usually driven from the main engine by side levers attached to the cross-head.

FIG. 359.--Roman Air Pump.

(6) *Driving the Auxiliaries.*—Deck winches, the capstan and the steering gear can be operated by compressed air.

A number of tests have been carried out which show that it is unnecessary to compress the air for deck winches to a greater pressure than 40 or 50 lb. per square inch, and that the pressure in the steam chest of the deck winches at their ordinary duty, rarely, if ever, exceeded 20 lb. per square inch, the usual pressure being about 14 lb. per square inch.

DESCRIPTION OF AIR COMPRESSORS DESIGNED OR SPECIALLY SUITABLE FOR THE ABOVE-MENTIONED PURPOSES.

Hand-driven Compressor.—Machines of this type are shown in Figs. 359 and 360, and in both cases the air is compressed in two stages which is of advantage even in such small compressors. In the first place, leakage and clearance losses are very much reduced, and secondly, the work done is much more evenly spread over the revolution than is the case with single-acting single stage machines.

Two-stage Mechanically-driven Compressor.—The trunk piston (see Fig. 361) has two diameters, the air being first compressed in the low-pressure cylinder above the piston

FIG. 360.—Reavell Air Pump.

and then in the annular space below the main piston and above the trunk guide.

This compressor is suitable for supplying air for the starting bottles and auxiliary purposes such as blowing a whistle, and as such it would be designed for a delivery pressure of 200 lb. per square inch. It should also be used in small engines for fuel injection as well, but for this purpose the delivery pressure would be 400 lb. per square inch or thereabouts, and the size of the compressor would have to be adjusted to meet the double demand.

If this machine is driven from the main engine, it may either have a friction clutch (see Fig. 362) or else be driven

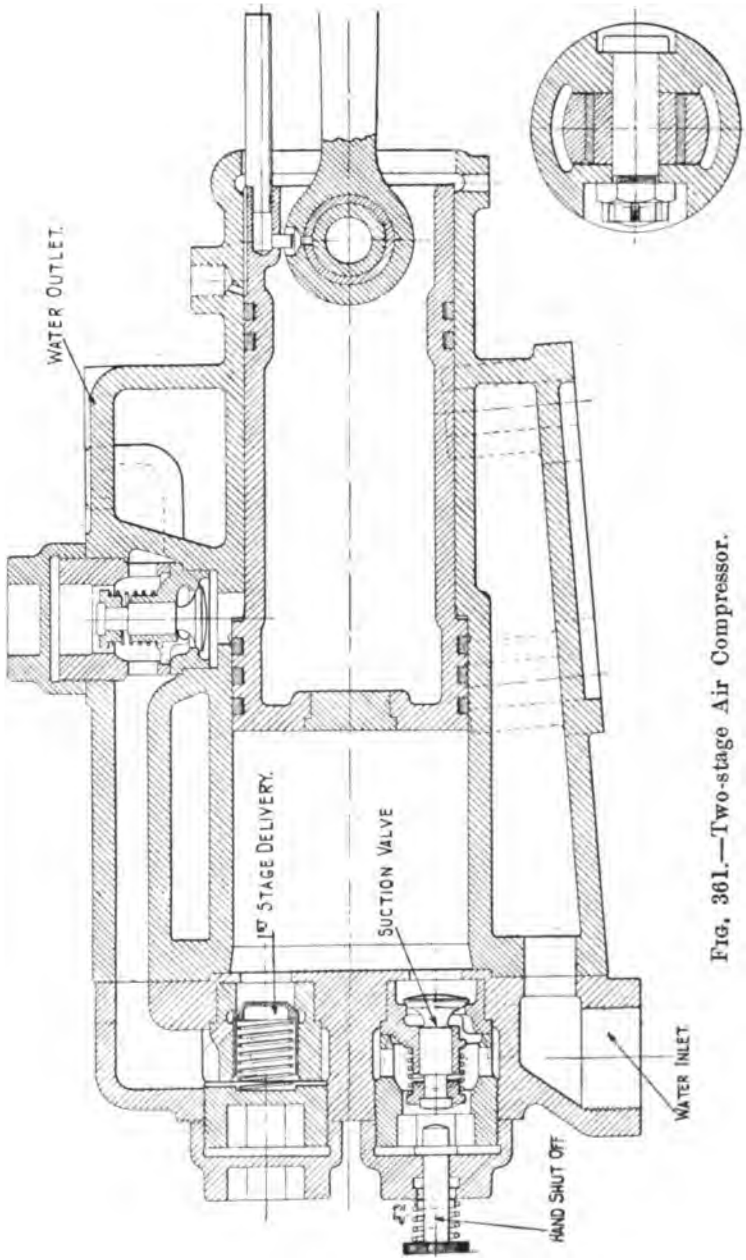


Fig. 361.—Two-stage Air Compressor.

from a crank attachment on the end of the flywheel (see Fig. 363). In the latter case the compressor is running whenever the engine is running, and it is therefore usual to fit an automatic unloading device on the compressor so arranged that no air is compressed and the machine runs light as soon as the bottles are fully charged, but comes into operation again as soon as the bottles are appreciably emptied. When the compressor is used for fuel injection, it would not be so fitted, and any excess air would generally be bye-passed to the atmosphere. It is essential that there should be

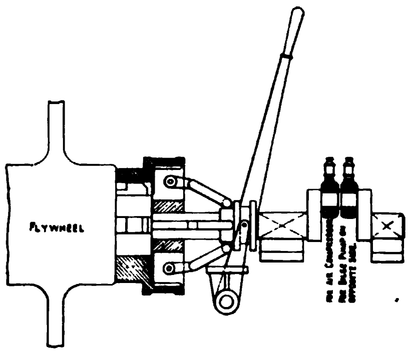


FIG. 362.—Drive with Clutch.

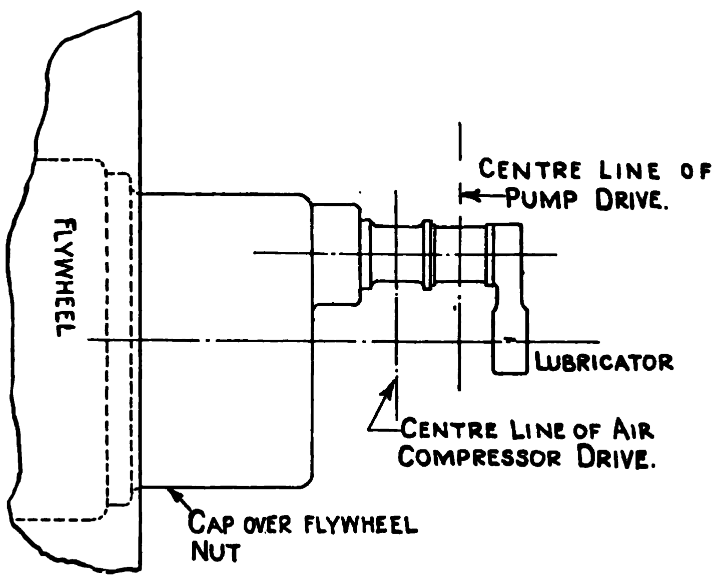


FIG. 363.—Drive from Flywheel.

a slight excess, because if all the air is used for fuel injection it would not be possible to re-charge the starting bottles. A safety valve is always fitted to blow off at a given pressure.

For deck auxiliaries it may sometimes be convenient to drive a compressor from the main engine by means of a belt-and-jockey tensioning arrangement, so as to allow the compressor to be started up when required and remain idle when there is no demand for air. In this way a

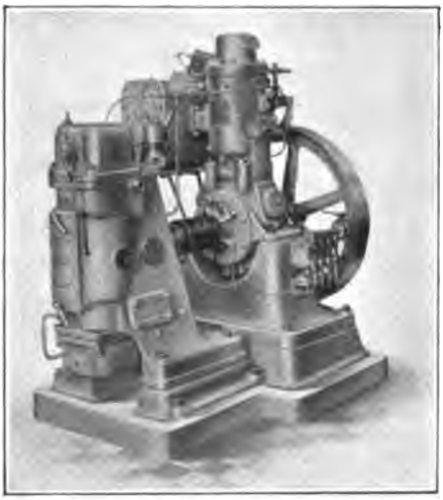


FIG. 364.—Reavell Bolinder Air Compressor.

clutch between engine and compressor shafts is rendered unnecessary.

Compressor Driven by Auxiliary Engine.—It is often most convenient to have a compressor driven by a separate engine so that the starting bottles can be charged when the main engine is not running.

An example of this type is shown in Fig. 364, which illustrates a two-stage duplex machine direct coupled to a hot bulb engine, the two shafts being connected by a muff coupling.

The compressor illustrated is admirably adopted for Diesel engine work, but is equally efficient for the lower duty

FIG. 365 – Compressor and Electric Generator, driven by Paraffin Engine.

called for by the hot bulb engine. It is capable of filling a starting bottle of, say, 10 cubic ft. free air volume to 200 lb. per square inch in about ten minutes.

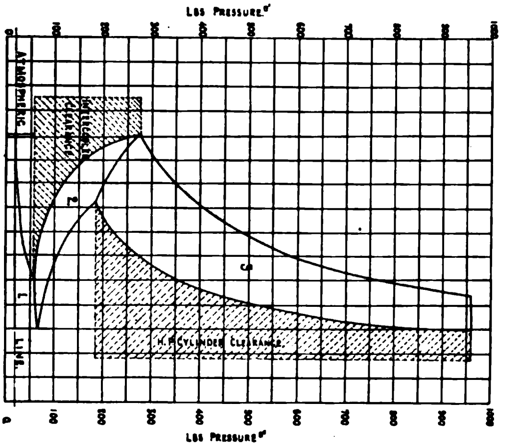


FIG. 366.—Theoretical Indicator Diagram.

In smaller installations the plant illustrated in Fig. 365 is often very convenient. This shows a two-stage compressor driven by a paraffin engine through gearing. On the other side of the engine a small electric lighting dynamo is direct coupled, and when the dynamo alone is required, the pinion which drives the compressor can be moved along the shaft so as to disengage from the compressor spur wheel and thus throw it out of action.

Compressor for Direct Coupling to Large Main Engines for Fuel Injection and Charging Starting Bottles.—The compressor illustrated in Fig. 367 is similar

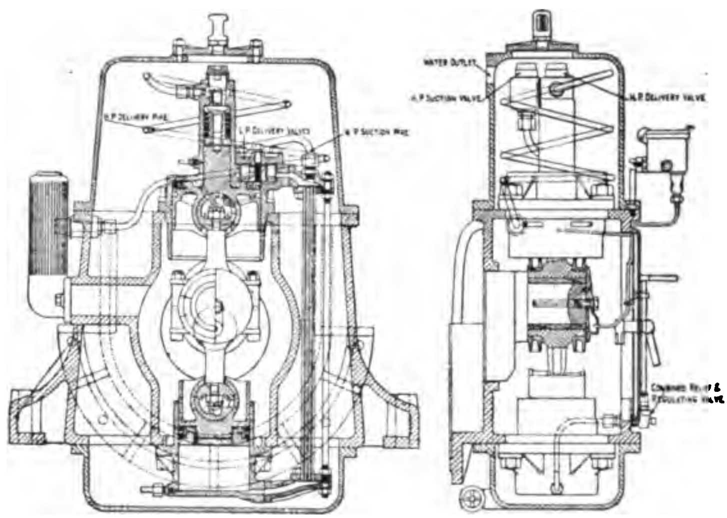


FIG. 367.—Three-stage Air Compressor.

in construction to the well-known machine used for the same purposes and driven from the crank shaft of smaller sizes of Diesel engines.

The compressing pistons are driven from an overhung crank pin attached to, or solid with, the crank shaft of the engine. The air is compressed in three stages, the first and third stages by the upper piston which has two diameters, and the intermediate stage by the bottom piston.

The delivery valves of the low-pressure cylinder also perform the function of suction valves for the intermediate cylinder; the suction valve of the high-pressure cylinder is also the delivery valve for the intermediate stage. This simple construction allows all the valves to be at the top, and another good point is, that the compression in the intermediate stage takes place to a large extent in the intercoolers themselves.

A combined theoretical diagram showing how the air is compressed in this machine is shown in Fig. 366, where the final delivery pressure is 960 lb., but a special feature of the design is that the compressor correctly divides its total range of compression into three stages whatever the delivery pressure may be, so that it would be equally efficient when running at the lower pressures called for in hot bulb installations.

FIG. 368.—Centrifugal Pump.

The size of the cooling water passages allows sea water to be used for cooling purposes, so that there is no necessity for carrying a fresh water supply for this purpose.

Bilge and Deck Service Pumps.—The most popular methods of pumping out bilges and supplying water on deck for wash-down and fire purposes are :—

(*a*) A direct driven centrifugal pump with a self-contained engine.

(*b*) A gear driven plunger pump with a self-contained engine.

(*c*) A large pump driven off a pin on the flywheel of the main engine, or from an eccentric fitted on the crank shaft.

(*d*) A special pump driven from a self-contained deck winch.

(*a*) Centrifugal pumps (Fig. 368) have the advantage when large quantities of water are to be dealt with at a low " head," such as emptying bilges, emptying and filling ballast tanks and supplying wash-deck service.

(*b*) Gear driven pumps are more particularly useful for fire purposes, although they can also be used for dealing with smaller quantities of water for bilge, ballast tanks, etc.

(*c*) A large pump, driven off a pin on main flywheel (Fig. 369), or by an eccentric strap off the shaft, has the advantages that its first cost is small and that it can deal with all water services.

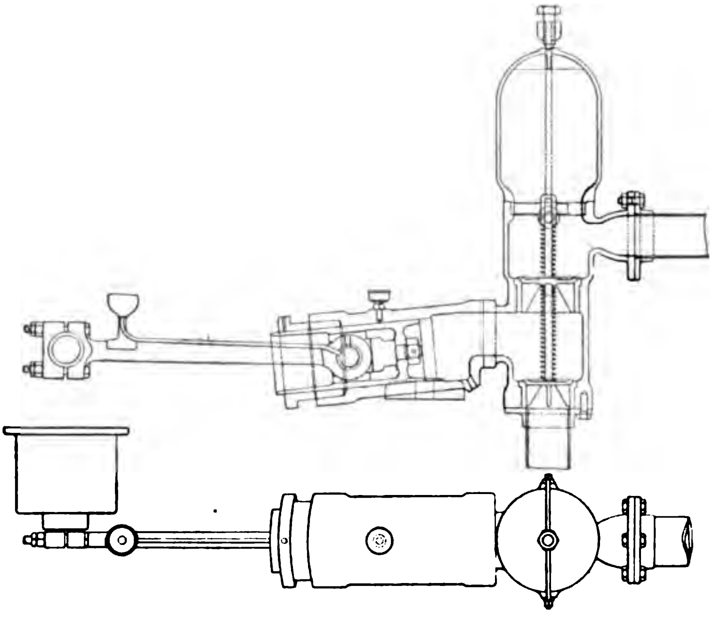


FIG. 369.—Bilge Pump driven off Pin on Flywheel Cap.

(*d*) Where a separate self-contained pump such as (*a*) or (*b*) are not fitted, it is advisable to have an auxiliary pump that can be driven off the deck winch, as sea-going vessels should have a mechanically driven bilge pump independent of the main engine.

There are many other types such as the deck hand-pumps connected to the bilge, the centrifugal, the reciprocating, or the drum pumps driven by a belt from the main flywheel.

Reference to bilge pumps is also made on pp. 170 and 379.

The author recognises the great difficulties of the task he has undertaken in endeavouring to present such a mass of information in a readable, and yet concise form without omitting material points. He would therefore be glad to receive any suggestions for alterations, and would specially welcome contributions of photographs, details and plans, or interesting data for inclusion in future editions.

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