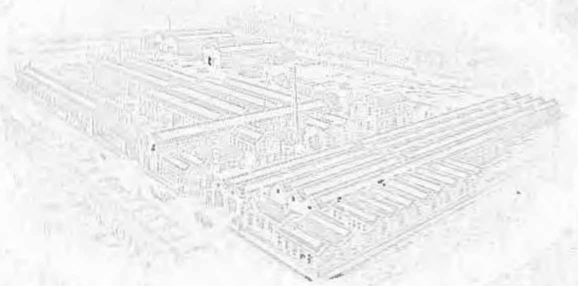
GARDNER ENGINES



BARTON HALL ENGINE WORKS PATRICROFT

T. TYPE

HEAVY OIL

ENGINES

for MARINE PROPULSION
ELECTRIC LIGHT &
GENERAL POWER PURPOSES

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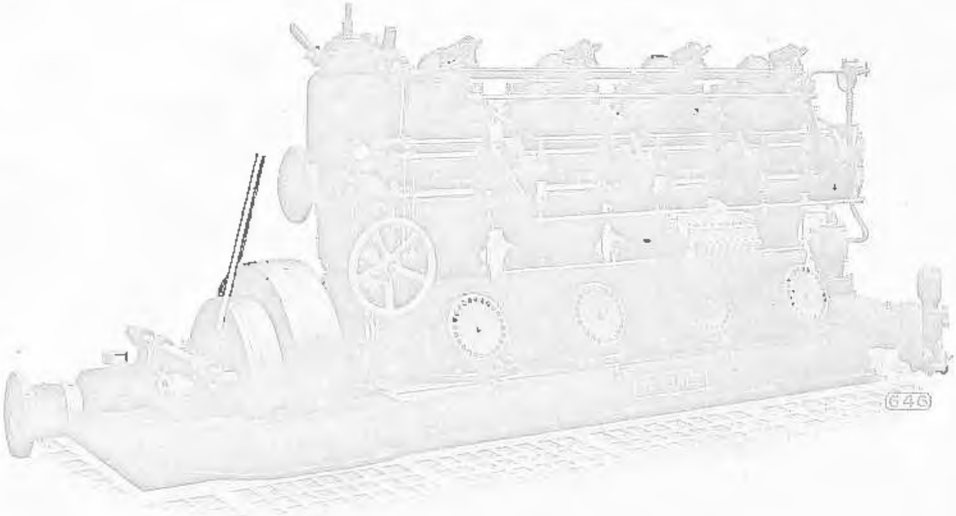


Typical 4-Cylinder Marine Engine

PRELIMINARY

THIS engine is of the type now generally known as the Semi-Diesel Engine. In effect, it is a Two-Cycle Vertical Engine designed to burn Heavy Oils. The principle on which such engines work is now so well known that a detailed description of it is hardly necessary. Condensed in a few words :

A charge of pure air is drawn into the crank case and thence is forced into the cylinder. Practically the whole of the charge is then compressed into a combustion chamber, part of which is formed in the cylinder breech and is water-jacketted; the other part is a small non-jacketted dome which, during work, remains at a " black hot " temperature. Just before compression is completed, a charge of fuel oil is injected in the form of a spray into the combustion chamber and is ignited by contact with the surface of the " black hot " dome in conjunction with the temperature of compression. The admission of the air charge to the cylinder and the expulsion of the products of combustion are effected by ports in the cylinder wall, which are covered and uncovered by the piston.

The present Gardner Heavy Oil Engine is the result of many years' original research, supplemented by the thirty years' experience which the makers have had in the building of, and the experimenting with, an enormous variety of types and sizes of Oil Engines.

PRELIMINARY *(continued)*

This research has been attended by complete and unqualified success, which has been amply confirmed by the experience of the many users.

Among the many desirable properties possessed by the Engine, the following may be mentioned :

It runs with the smoothness of a steam engine.

Starts from cold within three or four minutes from the word of command.

Will stand up indefinitely to the maximum load for which the engine is sold.

After having once been heated internally by a short run under load, the engine will run light for sufficiently long periods, ready to take up full load at any moment.

Runs equally well at all intermediate loads.

In the Marine type, of three or more cylinders, the reversals of the engine for manœuvring are performed with absolute certainty and precision, as quickly and as easily as in the steam engine.

The engine burns efficiently a variety of the heavier and cheaper grades of fuel oil, and with very low consumption per BHP per hour.

The consumption of lubricating oil is remarkably low, not exceeding that of $\frac{1}{10}$ of the fuel oil (actually it is much less than this).

It will be seen in the sequel that the T engine is a very perfect machine, in that it responds to so many desirable conditions and demands In appearance it is costly to build, yet the perfect administration of the works, together with very special methods of production, enable the engine to be put upon the market at an extremely low price.

GENERAL DESCRIPTION

In general, the following description applies equally to Stationary and Marine Engines : where necessary, a distinction is made between the two types.

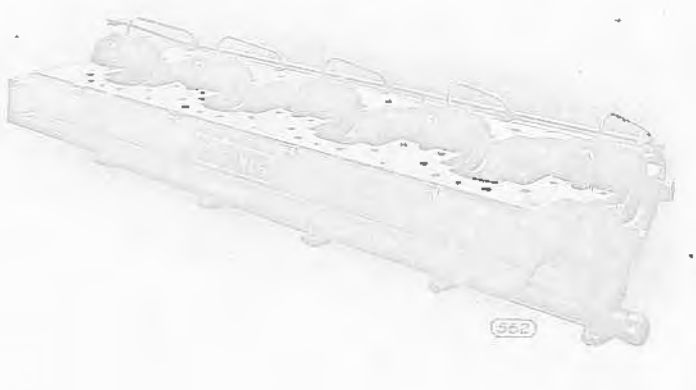
Engine Bed and Crank Cases.—The engine bed carries the main bearings and the general superstructure of the engine. In it are formed the lower part of the crank cases, one for each crank, from which the surplus lubricating oil is drained by a special device while the engine is running, the outlet of which drain debouches above the floor level. The upper crank cases are bolted on to the engine bed and each is provided with two large inspection doors. Situated in the doors are the air valves and inlet silencers for the supply of the air necessary for combustion.

Note.—In the T4, the smallest of the series, the upper crank case and the cylinder are in one casting.

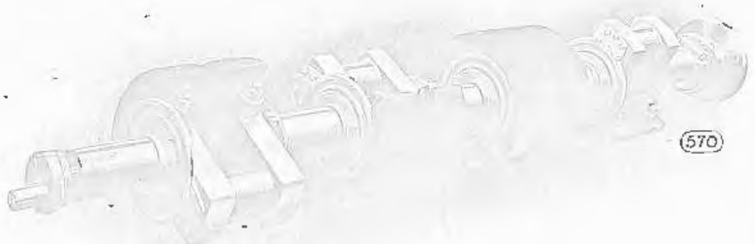
The air joints near the main bearings are made by massive, spring-loaded, sealing washers of large diameter positively driven from the crank webs.

A complete system of " Jigs " renders possible some rather remarkable feats of interchangeability of beds, crank cases, and cylinders.

Main Bearings.—These are housed in the engine bed, and are lined with upper and lower bearing shells of special anti-friction bronze. The caps and shells are readily dismantled for inspection without disturbing any of the structure of the engine. The lubrication is effected by a copious circulation of oil under pressure, just as is in the usual high class of 4-cycle engines. *See also under " Lubrication."*



Crank Shaft.—This is, of course, cut from the solid steel forging. The general dimensions are made to the latest issue of Lloyd's rules. Balance weights are fixed to each crank, sufficient for the balance of the crank and the proper proportion of the mass of the connecting rod. The diameter of the crank shaft is finished and sized by the modern process of grinding.


(570)

Cylinders.—The cylinders, as well as all other castings, are made in our own foundry from a blend of iron established by years of experience. Ample means of access are provided for examination of the water-jacket, the inlet and outlet ports.

The cylinder bores are finished and sized on Planet grinding machines.

Cylinder Breech.—This is a carefully designed, water-cooled structure in which is formed the lower part of the combustion chamber and the water-cooled duct through which passes the sprayer of the fuel injection.

Dome.—The dome is a light casting clamped on top of the cylinder breech and forms the upper part of the combustion chamber. It is maintained at a " black hot " temperature by the internal combustion, which temperature added to that of compression suffices to ignite the incoming spray of the fuel charge. Owing to the low working temperature, the life of the dome is indefinitely long.

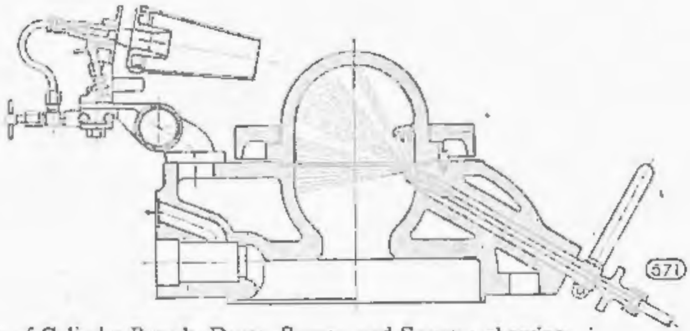


Illustration of Cylinder Breech, Dome, Burner, and Sprayer, showing three different positions of the Spray-form referred to on page 14.

Pistons.—The pistons are cast from the same metal as the cylinders. Considerations of heat-conduction and lubrication cause them to be of massive design. They are finished and sized on the grinding machine. The finished diameters of the pistons diminish in steps from the front to the back, to allow for varying diametral expansion when at work. The varying diameters, being accurately pre-determined by long experience, completely eliminate all "easing by hand," consequently the life of both piston and cylinder bore is immeasurably prolonged.

The gudgeon pins are of hardened steel, finished and sized by grinding. They are so fixed in the piston as to avoid distortion of the latter.

Connecting Rods.—The rods are made from steel forgings. The big end bearing is a bronze shell in two parts, lined with white metal. The small end is lined with a phosphor-bronze bush. The rod is bored throughout its length to carry a central duct for leading lubricating oil to the gudgeon pin. The lubrication for both ends of the rod is derived from a centrifugal oiler which is served by charges of oil measured by the Gardner Multi-Point Lubricator. *See also under "Lubrication."*

Flywheels.—These are machined all over. The mass and energy are of proportion sufficiently generous to smooth out the peaks of the torque diagrams and so reduce to a minimum the stresses on the clutch and propeller shaft. In Stationary Engines and Electric Generating Sets the energy of the wheel suffices to give any desired coefficient of cyclic variation.

Vertical Counter Shaft.—This is driven through helical gears by the crank shaft and serves to drive the cam shaft and the pump for the main lubrication system. It also carries the governor and the reversing gear of the engine.

Cam Shaft.—This is driven through helical gears by the vertical shaft. The gear on the vertical shaft is provided with a sliding motion along the shaft for reversing the engine and for varying the time of ignition if required. The fuel injection cams are of steel, hardened and ground to shape.

Governor.—A centrifugal governor is mounted on the vertical shaft and is entirely enclosed. It is of great power and responds to the fine regulation called for in the driving of Electric Generators. The whole of the working parts of the governor are enclosed and are lubricated from the main circulation system, described on page 12.

Variability of Speed.—For Electric Generation and Industrial Purposes the speed can be varied within certain limits by the usual external means, while the engine is running.

For Marine Engines, in addition to the governor, there is provided a hand-control whereby the speed may be instantly varied to anything between maximum and " just ticking round."

Auxiliary Crank Case.—This structure, situated at the forward end of the engine, carries the Air Compressor, the Circulation Pump, and, in the case of Marine Engines, the Bilge Pump, all three of which are operated by the one crank. The lubrication of all the parts in this crank case is derived from the circulation pressure system.

Compressed Air Starting.—All engines, whether Marine or Stationary, reversible or non-reversible, are started by Compressed Air. The machinery necessary for its generation, storage and distribution is supplied with each engine, and includes :

AIR COMPRESSOR built in with the engine and driven direct by the main crankshaft: it is water-jacketted and cooled by derivation from the main cooling system of the engine, and is provided with safety valve and unloading valve.

AIR RESERVOIRS, one or more, according to the size of the engine, each reservoir being supplied with stop valve, pressure gauge, safety valve, and scavenging valve.

AIR STARTING VALVES one to each cylinder, timed and operated automatically by the cam shaft. Each valve is connected to the main distribution air pipe fixed on the engine.

Circulation and Bilge Pumps (the latter for Marine Engines only). These are of the plunger type and are built in the auxiliary crank case. They are driven by a crank on the main crankshaft ; the motion work is lubricated by oil derived from the circulation system. Air chambers are fixed on both delivery and suction sides. The rams are of gun-metal, and the pump bore has a gun-metal liner. The air chambers and the special valves used eliminate every vestige of " water hammer."

Reversing and Starting Mechanism for Marine Engines.—This is somewhat analagous in its effect to that of a steam engine. The complete operation of reversing is performed by four turns of a handwheel, during which the following operations take place **automatically.**

The angular position of the cam shaft is changed from " ahead " to " astern," or vice versa. The first turn or so of the handwheel puts out of action the fuel injection pumps and the engine begins to stop. Towards the end of the third turn, the fuel pumps are brought into action again simultaneously with the compressed air starting valves, which latter give a puff of compressed air to the cylinders, causing the engine to start in the other direction. At the end of the fourth and last turn the air valves are put out of action and the engine now runs under full conditions in the desired direction.

The above operation, from beginning to end, takes only three or four seconds.

All engines, whether Marine or Stationary, are started by compressed air, but it is only in engines of three or more cylinders that starting will take place from any position of of the cranks. For engines of two cylinders the flywheel has to be " barred round," consequently, in practice, the reversing mechanism on the engine is not applied ; in its stead, the propeller drive is effected through a Gardner Transmission Reversing Gear.

Variable Ignition.—The reversing mechanism is used also to vary the time of fuel injection, and therefore, of ignition where fuel oils of varying qualities are used.

Stationary Engines, not being required to reverse, are fitted with a modification of the reversing mechanism for varying the time of fuel injection as above, but all engines are furnished with air compressors and compressed air starting gear.

Lubrication.—This is effected by two separate and distinct systems :

1. A Circulation Pressure System.
2. A Multi-Point Lubricator which delivers accurately measured charges of oil, under pressure, to various points about the engine.

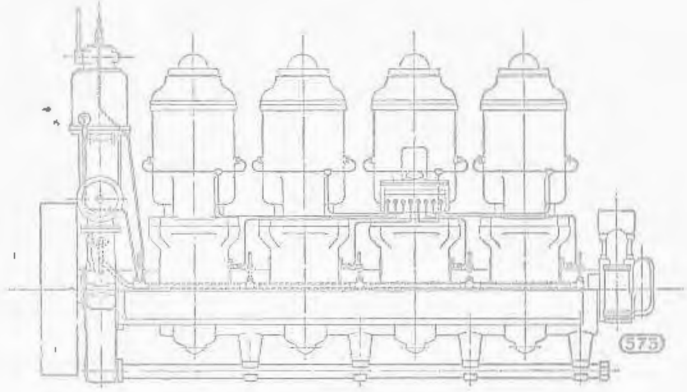
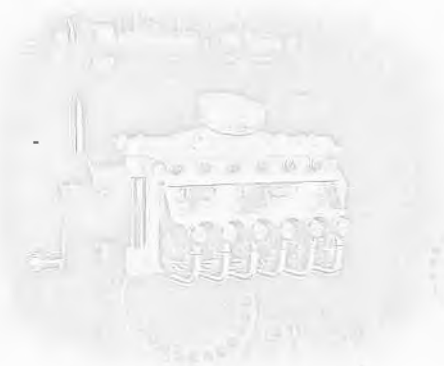


Illustration showing Lubrication Pipe System

1. THE CIRCULATION PRESSURE SYSTEM lubricates the crank shaft bearings and all other important parts external to the crank case and cylinder. The lubrication ram-pump, situated on the case of vertical counter shaft, delivers a continuous and copious supply of oil under pressure to a service pipe, which distributes it to each element to be lubricated, in such manner that a continuous flow of oil passes through each main bearing, or other element, from whence it passes back to the sump underneath the pump.

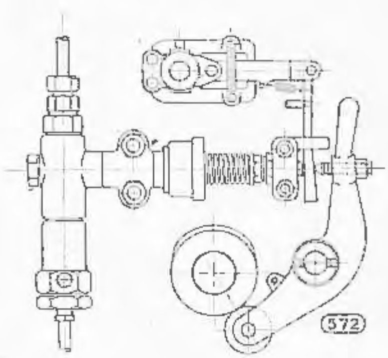
The pulsations of the pump are damped by an air chamber fixed on the suction side of the pump and an anti-pulsator valve on the delivery side. This valve serves also to control at will the pressure in the system.



2. A GARDNER PATENT MULTI-POINT LUBRICATOR delivers accurately-measured charges of oil to each cylinder for oiling the piston, and to each crank case for feeding the centrifugal oiler, which lubricates the crank pin and the gudgeon pin (*see under "Connecting Rod"*); the surplus oil collects in the bottom of the crankcase, from whence it is expelled periodically and filtered for use again.

This Patent Lubricator is fully described in the accompanying Lubricator Booklet.

Fuel Injection Pumps.—Each cylinder is served by a separate pump which accurately measures the charge of fuel corresponding to the load on the engine and forces it, under high pressure, to the fuel injection sprayer. The amount of charge delivered depends upon the position of a hard steel wedge interposed between the pump ram and the rocking lever, which position is controlled by the governor. The wedges are "flexibly" connected to the drop links from the governor, in such manner that the latter has always perfect freedom of action, notwithstanding that each wedge in succession is momentarily immovable while operating its pump.



The pump valves are of steel balls, carried in units separate and detachable from the pumps. The delivery valves are in duplicate, one covering the other.

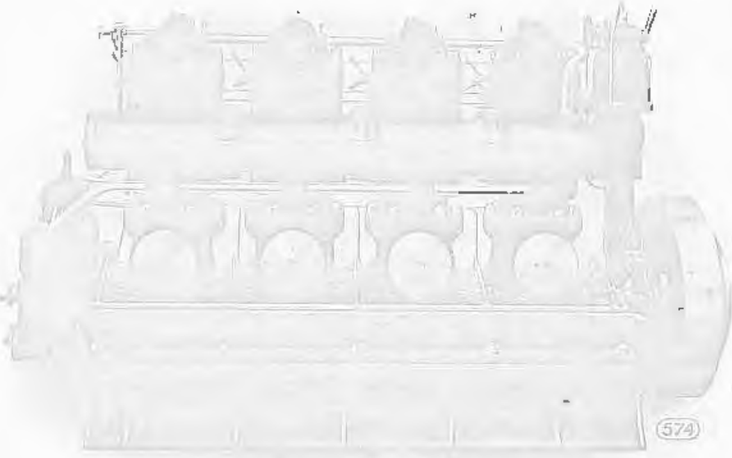
Fuel Injection Sprayer.—The Gardner Patent Rotable Sprayer forms an exceedingly important feature of the engine, in that it solves the well-known difficulty of running under varying conditions as regards load, kind of fuel, etc. Its function is to direct the geometric axis of the spray-form on to different parts of the surface of the Hot Dome, which is effected at will, either while the engine is running or at rest, and with the same facility as turning the lever of a cock. The result is that the engine, after having once been heated internally by a short run under load, will run light for sufficiently long periods ready to take up full load at any moment.

It is not, however, to be understood that the sprayer is to be continually adjusted as the load varies. In practice three positions suffice: no load and full load and an intermediate position for manœuvring or for mixed loads. (*Illustrated on page* 9).

Quick-Starting Burner.—These are small burners permanently attached to the engine, used for the preliminary heating of the Domes on the Combustion Chambers. In principle, the burner consists of a small spray of petroleum or gasoleum, across which blows a current of air derived from the compressed air system. The burners are lighted just the same as, and as instantaneously as, an ordinary gas burner, consequently the time necessary for starting is simply that of heating the domes, which takes about three minutes. In effect, the engine can be started from cold, ready for full load, in three minutes from the word " go." The burners are then instantaneously extinguished, no hand lamps are used. (*Illustrated under Cylinder Breech.*")

Exhaust System.—The exhaust gasses pass from the engine cylinder into a large water-jacketted manifold pipe built in sections, one to each cylinder, with special provision for the difference of expansion between the inner shell and the relatively cold outer shell. The gases then pass through an expansion chamber (commonly called a silencer) apart from the engine.

FOR STATIONARY ENGINES, the exhaust chamber is of cast iron of the usual type and is included in the price of the engine.



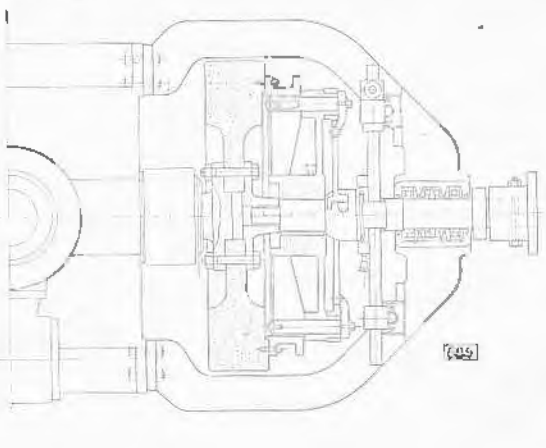
Rear View of Engine, showing exhaust manifold, pump, and service pipes of circulation lubrication

For Marine Engines the exhaust chamber takes a variety of forms to suit each installation. It is generally built of galvanised sheet steel, sometimes water-jacketted, sometimes provided with water injection, and sometimes made in the form of a ship's funnel. Under these circumstances the exhaust chamber is treated as being part of the installation and so is not included in the price of the engine.

Water Injection is NOT used on these engines.

Clutch and Thrust Bearing.—For Marine Engines. This is a unit used for all reversible engines; that is to say, for all engines of three or more cylinders. It consists of a clutch and a thrust bearing carried on one frame, bolted to the engine bed. The clutch case is bolted directly on the flywheel.

For engines of less than three cylinders the above is replaced by a Gardner Transmission Reversing Gear combined with thrust bearing.



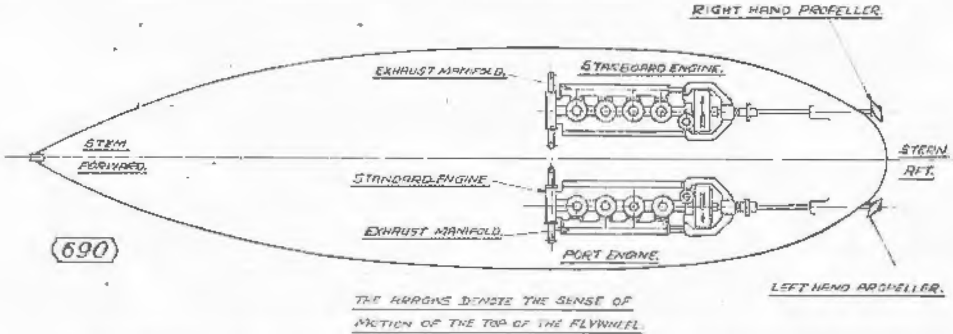
Pipe-Work.—All the pipe work on the engine is of polished copper or brass with brazed joints. Each engine is complete as regards its pipe-work and fittings. The pipe-work external to the engine proper is considered as forming part of the installation and so is not included in the price of the engine. External pipe-work means, for example, the compressed air pipe-work between the engine and air reservoirs, the pipe-work between the engine and the fuel tanks, and so on.

Lloyd's or Board of Trade Regulations.—All engines are built according to the latest rules of these surveys, whether they are to be surveyed or not. In case of complete survey the makers undertake all work in connection therewith, including tests of materials and inspections.

Sense of Rotation.—This is best described by saying that the sense of normal, or ahead, rotation adopted by the makers is such that the top part of the flywheel moves always from the injection (or admission) side of the engine towards the exhaust side as shown in the figure below and also on pages (38), (39), and (40).

Port and Starboard Engines.—All engines are built in two types, port and starboard (left or right hand), so that when engines are installed in pairs the motion work and manœuvring gear are situated in the one alley between the engines. This disposition is shown diagrammatically in the figure below.

As a consequence of the two preceding paragraphs it will be evident that the sense of rotation desired for dynamo or other drives determines the choice between port and starboard engines.



Diagrammatic Arrangement of Twin Marine Engines, showing Senses of Rotation

PROPELLING MACHINERY AND INSTALLATION.

This is designed and manufactured in our own works, in a department set aside for the purpose, directed by Marine Engineers of long experience, whose services are willingly placed at the disposal of our clients.

CYCLIC VARIATION OF SPEED.

This refers to the variations of speed which take place during one complete cycle of the engine, that is, during one complete revolution of the Gardner T Type Engine. Following the general practice in England and the Continent, the variation is measured as follows :

If N denotes the maximum speed at any moment during one revolution,
and n denotes the minimum speed at any moment during one revolution,
and C denotes the co-efficient of cyclic variation,

$$\text{then } C = 2\,\frac{N-n}{N+n}$$

Example.—N = 302 revs. per minute.
n = 298 revs. per minute.

$$C = 2\,\frac{302-298}{302+298} = \frac{1}{75}$$

All engines are "flywheeled" to suit the co-efficient demanded.

SPARE PARTS

Spare parts for engines of current types are kept in stock, ready for immediate delivery, and, as a rule, the same applies to engines of an earlier date. Spares for old types of engines are not, as a rule, kept in stock but are made at very short notice. We make it a principle never to "let down" a user of an obsolete Gardner Engine for want of spare parts, no matter how old the engine may be. It is quite a common occurrence for us to supply spares for engines that we sold thirty and more years ago.

LIQUID FUELS FOR HEAVY OIL ENGINES

The Heavy Oil Engine, in its earlier days, was commonly spoken of as a Crude Oil Engine, which often led to the erroneous idea that the engine burned crude oil in its natural state, just as it leaves the earth. In the first place, natural oil is of a very complex nature containing other things of greater value than heavy fuel oils and which will repay their separation ; and, in the second place, it contains impurities which render it unfit to burn in an oil engine without previous treatment, when obviously, it ceases to have any right to be called Crude Oil.

In order to make the best and most economic use of all its constituents, and, at the same time, to rid it of its impurities, the natural oil is subjected to distillation, the principle of which process is here briefly sketched.

The oil is heated in a retort to a certain temperature sufficient to volatilise the lighter constituents. The vapour is then led to a condenser where it is cooled to a liquid form and drawn off. When the oil in the retort has parted with all the vapour which it can give at this temperature the latter is increased by a certain amount and so gives off a vapour of a second order of heaviness, and this, in turn, is condensed and drawn off. And so the process goes on, in steps of increased temperature of the retort, until nothing is left in the retort but pitch, coke, ash, and other sediment.

Such is the process of distillation, shorn of all its technical refinements. Bearing in mind the infinitely complex structure of natural oils, it will now be evident that, by increasing the number of steps in the rise of temperature of the retort, the distiller can draw off a great variety of liquids, beginning with the lightest of all the petrols, passing through the range of lamp oils, and so on to what are called the Heavy Oils, which are used as fuel, or else, by further treatment, are converted to lubricating oils.

The preceding may be taken as a rough definition of the term Heavy Oils for use in Oil Engines. The specific gravity varies from about 0·85 to 0·95, while the calorific value varies from about 18,000 to 19,500 British Thermal Units. The lighter classes of heavy oils are known technically as Gas Oils. The heavier classes are denominated either by their origin or by trade names adopted by the Merchants or Distillers.

Owing to the enormous variety of fuel-oils current upon the market, it is not possible for any engine builder to make a general sweeping statement as to what fuels his engine will or will not burn efficiently : he must of necessity limit his assertions to the fuels that he or his customers have actually used. The accumulation of such experience is a long and arduous process, but, happily, the Distillers and Merchants have simplified the process very materially by putting upon the market fuel oils specially prepared for Heavy Oil Engines. It generally suffices now for the user to buy the fuel oil which is current in his part of the world, stating to the merchant the kind of engine he is running.

Viscosity.—Sometimes it happens that the fuel available is too viscous at normal temperatures to flow sufficiently freely through the injection pumps and sprayers. In this case, the engine has to be started on a more mobile fuel, such as gas oil, and run under load for a short time until the engine is "warmed up," when the engine is changed over to the viscous fuel. This, of course, applies to all Heavy Oil Engines, Diesel and Semi-Diesel. The Gardner Engines are provided with proper means of instantly changing over from one grade of fuel to the other in case a viscous fuel be met with. As a general rule, however, the modern fuels are sufficiently mobile at ordinary air temperatures.

The Purchase of Fuel Oil.—The cheaper and more convenient way of buying fuel oil is by bulk. This necessitates the consumer providing storage tanks into which the fuel is delivered direct by the Oil Merchants from their delivery tanks. This is the general practice for Marine Engines and is becoming general for Land Engines. It may also be bought by the barrel, but obviously this is dearer by reason of the handling and filling of the barrels and is also less convenient.

The price is generally quoted by the ton when bought in bulk, and by the gallon when bought by barrel. The relation between tons and gallons depends of course on the specific gravity of the fuel. The following table may prove useful :

Specific Gravity.	Gallons per Ton.	Pints per Ton
0·85	268·5	2108
0·86	260·5	2084
0.87	257·5	2060
0·88	254·5	2036
0·89	251·7	2014
0·90	248·9	1991
0·91	246·2	1970
0·92	243·5	1948
0·93	240·9	1927
0·94	238·3	1906
0·95	235·8	1886

Consumption of Fuel Oil.—This is usually and conveniently specified as a fraction of a pint per BHP per hour. For the engines mentioned in this catalogue, it varies from 0·520 pint to 0·480 pint per BHP per hour for a standard fuel of specific gravity of 0·86 and calorific value of 19,500 British Thermal Units.

For a medium size of engine this gives the convenient figure of 0·500 pint, that is, half a pint per BHP per hour at full load. From this, and the price per ton or per gallon, it is a simple calculation to determine the cost of fuel per hour burned by the engine when running at full load. For example, the present price of the above standard fuel is about 6d. per gallon of 8 pints, that is $\frac{3}{4}$d. per pint, which, at $\frac{1}{2}$ pint per BHP per hour, costs $\frac{3}{8}$d.=0·375d. per BHP per hour.

The makers will gladly quote guaranteed details of consumption on receipt of enquiry.

LUBRICATING OIL CONSUMPTION

THIS is a point of extreme importance and merits the closest attention of the purchaser when selecting an engine. It is well known that the cost of lubricating oil forms quite a considerable part of the running costs of the engine ; any material reduction in the consumption of lubricating oil is, therefore, a strong point in favour of the engine.

Low consumption depends very largely upon perfect combustion in the engine, as well as upon first-class workmanship and perfection of the methods used for lubrication. These form the basis of the extremely low consumption of lubricating oil in the Gardner T Type Engines, which is of the order of one-fortieth part of that of the Fuel Oil (actually it is much less than this).

It ought to be said that every engine undergoes proper tests for oil consumption, and that the low consumptions observed on test are amply confirmed by the logs of engines in actual service.

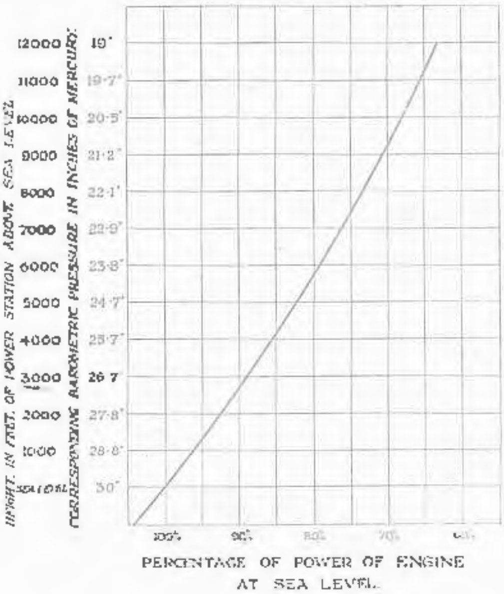
TESTING

THE test bay is equipped with all the appliances necessary for testing the engines from all points of view. The fundamental test for power developed is made by Hydraulic Dynamometers, the power which is recorded being that transmitted by the coupling on the crank shaft. All engines are tested for power, fuel consumption, consumption of lubricating oil, heat units carried away by cooling water, etc., etc. Tests are made at full load, overload, light and intermediate loads.

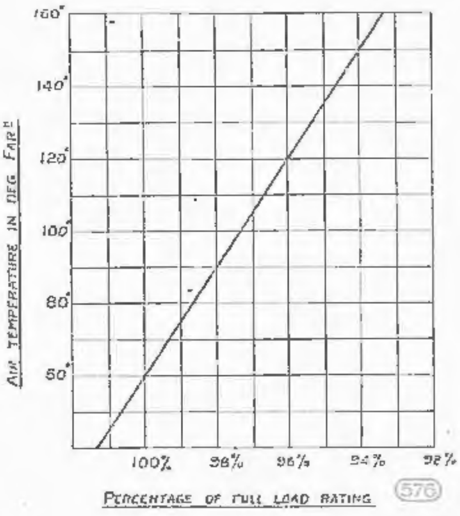
The powers quoted in the list are those measured by the Hydraulic Dynamometer, commonly called the Brake Horse Powers.

Customers or their representatives are cordially invited to attend the tests. All facilities are afforded to enable them to make independent tests. Electric Generator Sets are tested as such and the figures recorded are based on the measured electric output of the set.

ALTITUDE *and* AIR TEMPERATURE DIAGRAMS



ALTITUDE



AIR TEMPERATURE

THESE have been prepared for the purpose of enabling prospective users to arrive at the approximate size of an engine required to develop a given power under any conditions of altitude and air temperature. The resulting particulars may be taken as fully on the safe side.

The following example shows how to use these diagrams.

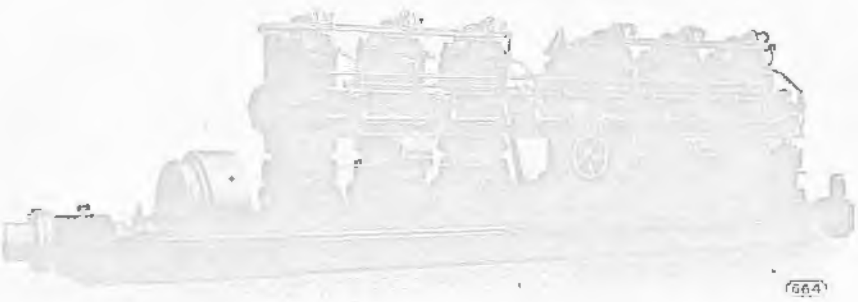
Given that an engine is to work at 3000ft. above sea level with an air temperature of 90°F.

From the diagram we read the following reduction coefficients :—

For Altitude : 88 per cent. or 0·88
For Temperature : 98 per cent. or 0·98
Combined coefficient = 0·88 × 0·98 = 0·86 or 86 per cent.

Thus an engine listed at 100 BHP, that is, at sea level, and with an air temperature of 60°F., will give 86 BHP at 3000 ft. and 90°F.

MARINE ENGINES



6T8 Marine Engine, 210 BHP

Mainly Historic.—The original Gardner Marine Engine came into being with the advent of the Motor-Boat, many years ago. Its design was preceded by a careful study of the conditions under which Internal Combustion Engines had to work when used for boat propulsion. Considerations of economy and safety led us to avoid the use of petrol, even for starting, and to adopt as fuel the heavy Russian Petroleums. This type of engine was, from the first, so successful that it remained our standard type of marine engine for many years until the coming of what is now termed the Heavy Oil Engine. During that period we installed many thousands of the Gardner M Type Marine Oil Engine varying from 10 BHP to 250 BHP. Their design was of course revised from time to time, as experience dictated. It is significant to add that we are still making this type of engine.

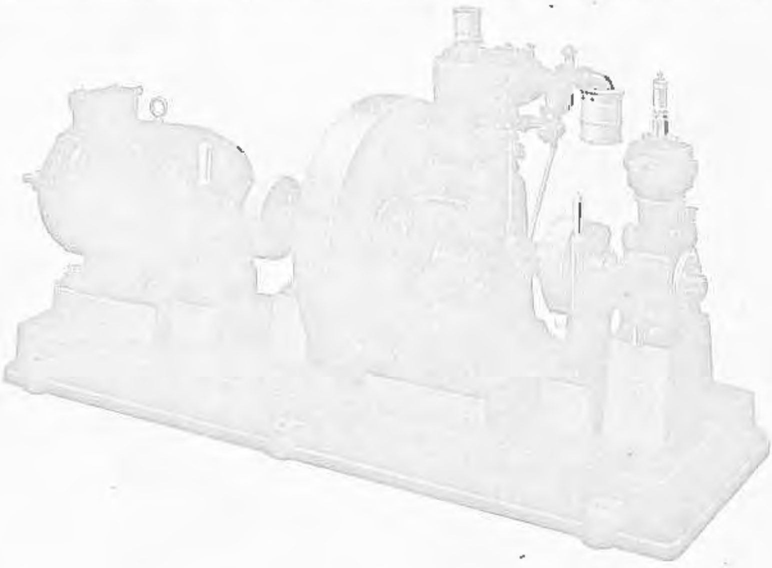
With the development of Magneto Ignition to its present state of perfection, and the lessening prejudice against the presence aboard of petrol, a demand arose for small power marine engines up to 40 BHP, to start on petrol and to run on petroleum (paraffin), which gave rise to the Gardner CR Marine Engine described in another catalogue.

Later, there came the development of the Heavy Oil Engine of two and four cycle types, which burn low grades of fuel cheaper than petroleum (paraffin) and much less of it. We chose the Two-cycle Engine by reason of its great simplicity, of the ease with which it can be reversed and of the consequent flexibility when manœuvring, a choice which experience has more than justified.

It will be gathered from the preceding that we have amassed an enormous amount of experience of Marine Practice, which we willingly place at the disposal of our friends.

Installation.—We have a department exclusively devoted to the construction of propelling gear and to the design of installation work. On receipt of the necessary data, accompanied by plan and section of the hull, showing the space available for the propelling machinery, we will, if desired, prepare a complete installation drawing. As these drawings involve considerable trouble, we trust to our friends to send the fullest possible details of their requirements so as to avoid the cost of amended drawings.

Small Stand-by Sets.—We have established a series of small paraffin engines coupled direct to dynamos or air compressors, or both, as auxiliaries to the propelling engines, for direct lighting or battery charging and for charging the compressed air reservoirs for the first start after installation, also as a stand-by in case of a loss of air pressure by inadvertence. One of these sets is here illustrated.

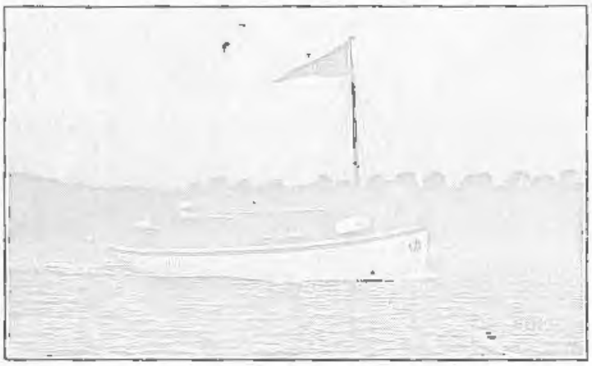


591.

In the absence of one of these stand-by sets, the air reservoirs are usually charged (for the initial start after installation) by means of a bottle of highly compressed air which is readily obtainable in most districts. Failing this, a hand pump is used, but this method of initial charging is both long and laborious.

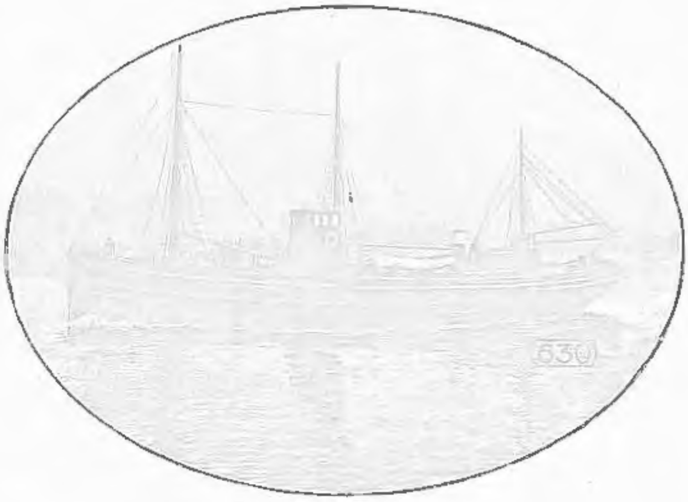
As a compromise between this and the use of one of the above auxiliary sets, we have designed a simple combination of a petrol engine and air compressor known as the OVC Compressor Set, which is described on page 34.

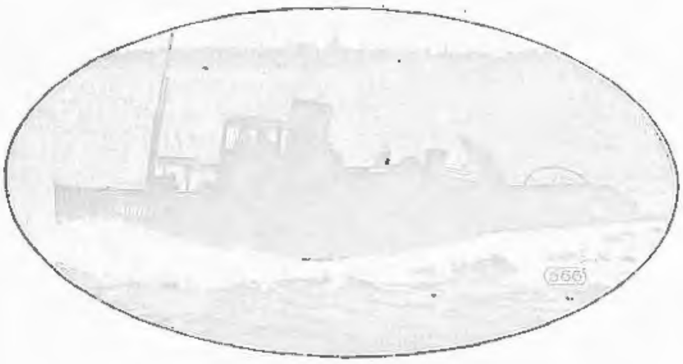
MARINE ENGINES *for* COMMERCIAL CRAFT



Motor Coaster
"*Rochester Castle*"
Two 4T6 Engines each of 96 BHP

Motor Coaster
"*Millrock*"
Two 3T7 Engines
each of 90 BHP

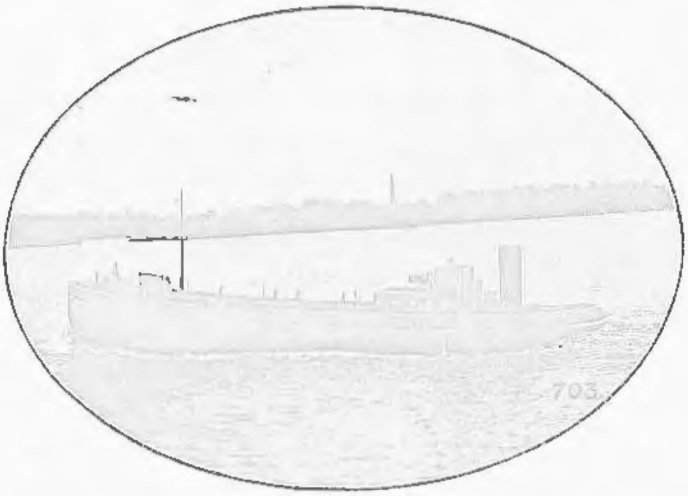




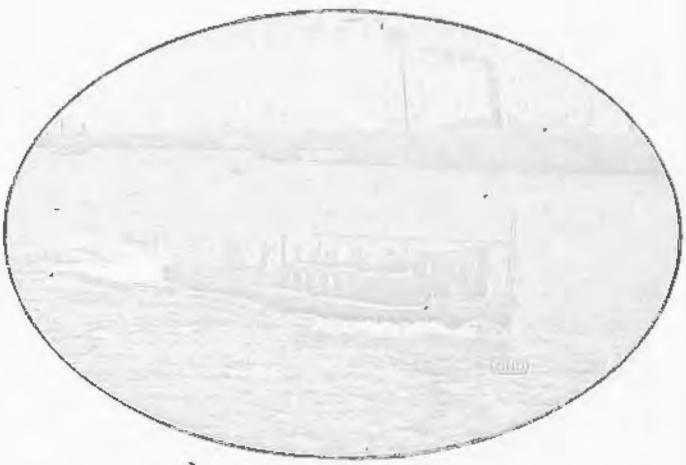
Motor Tug "*Pioneer*"
4T5 Engine: 72 BHP

MARINE ENGINES *for* COMMERCIAL CRAFT (*continued*)

Motor Tug
" *Motorman* "
Two 4T5 Engines each of 72 BHP



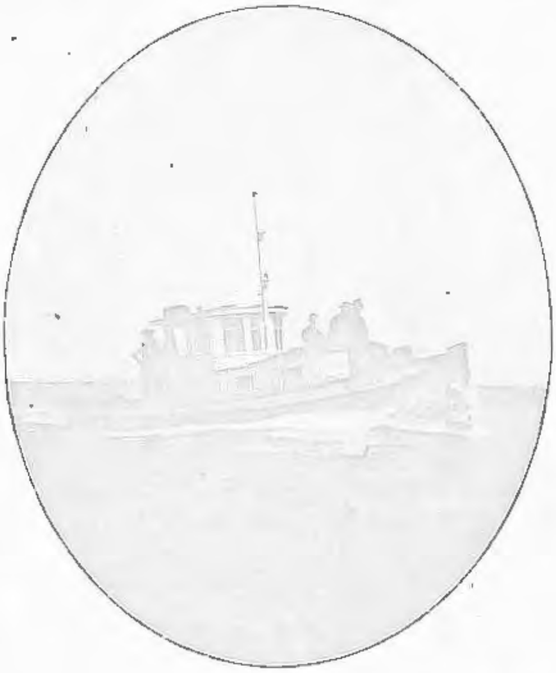
Oil Tanker
" *British Maiden* "
4T8 Engine : 140 BHP



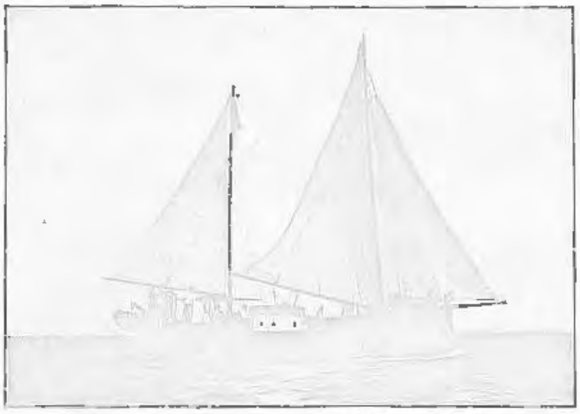
Vane Wheel Tug
Operating in Far Eastern Waters
4T6 Engine : 96 BHP

MARINE ENGINES *for* COMMERCIAL CRAFT (*continued*)

Motor Tug
"*Rodeo*"
4T7 Engine: 120 BHP



Vancouver Harbour Tug
"*Wee Giant*"
3T4 Engine: 36 BHP

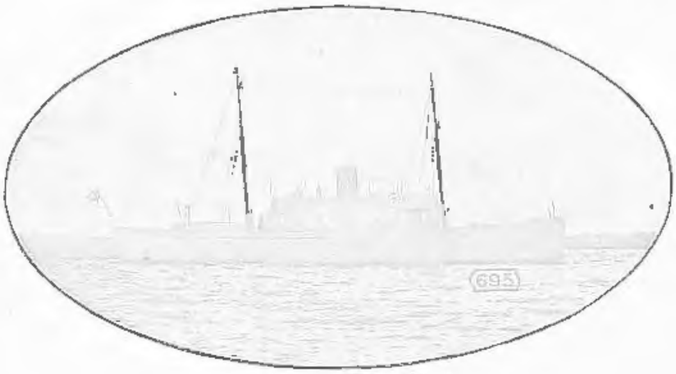


Fiji Motor Coaster "*Jan*"
3T4 Engine: 36 BHP

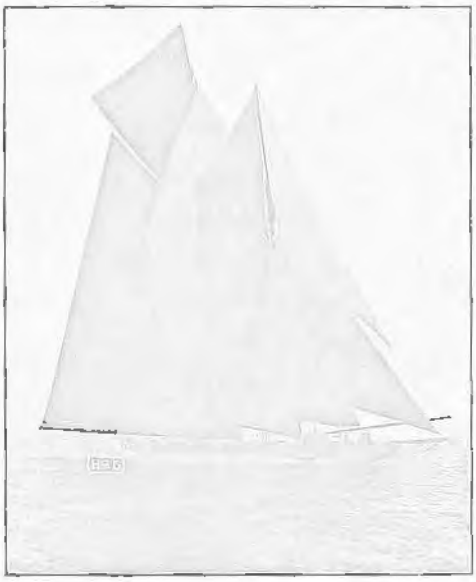
[*Photo, Caine's Studio, Suva*

GARDNER HEAVY OIL ENGINES

MARINE ENGINES *for* PLEASURE CRAFT

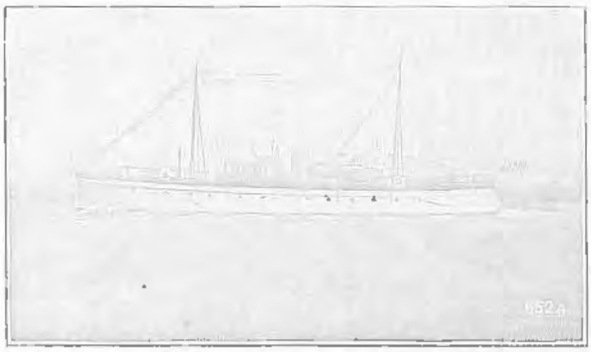


Motor Yacht "*Rhodora*"
Two 4T6 Engines
each of 96 BHP



Yacht "*Margherita*"
Two 4T4 Engines each of 48 BHP
(Auxiliary to Sails)

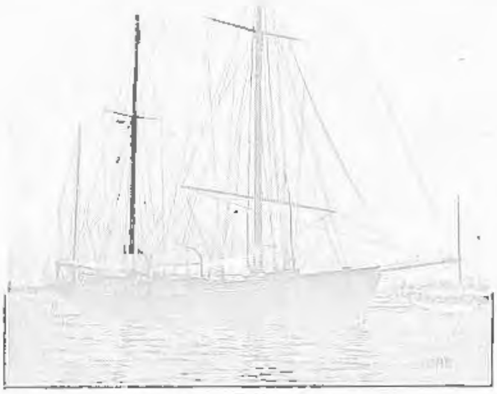
Motor Yacht
"*Swanhild*"
Two 4T5 Engines each of 72 BHP



MARINE ENGINES *for* PLEASURE CRAFT (*continued*)

Motor Yacht " *Aloha* "
Two 4T5 Engines each of 72 BHP

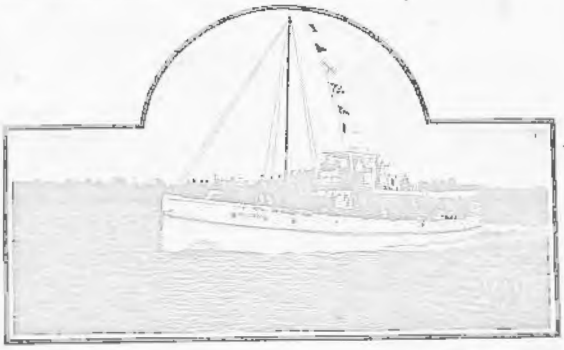
Yacht " *Lamorna* "
4T5 Engine: 72 BHP
(Auxiliary to Sails)



Yacht
" *Sylvia* "
4T6 Engine: 96 BHP
(Auxiliary to Sails)

GARDNER HEAVY OIL ENGINES

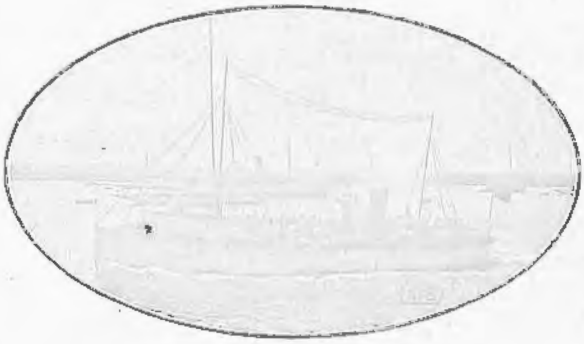
MARINE ENGINES FOR PLEASURE CRAFT *(continued)*



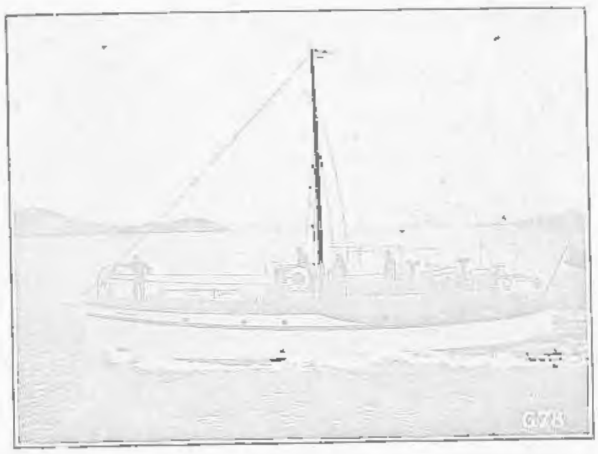
Queensland
Passenger Launch
"Malanda"

Two 4T6 Engines
each of 96 BHP

Passenger Launch *"Badoura"*
Two 4T4 Engines each of 48 BHP



Passenger Launch *"Unité"*
4T4 Engine 48 BHP

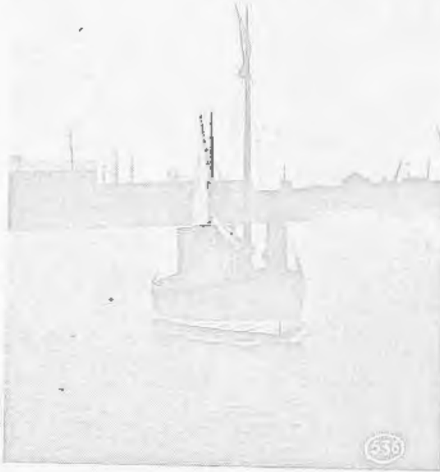


Passenger Launch
"Auld Reekie"

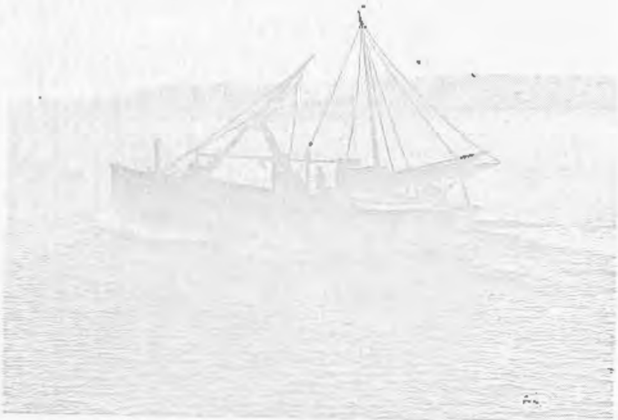
4T4 Engine
48 BHP

MARINE ENGINES *for* FISHING CRAFT

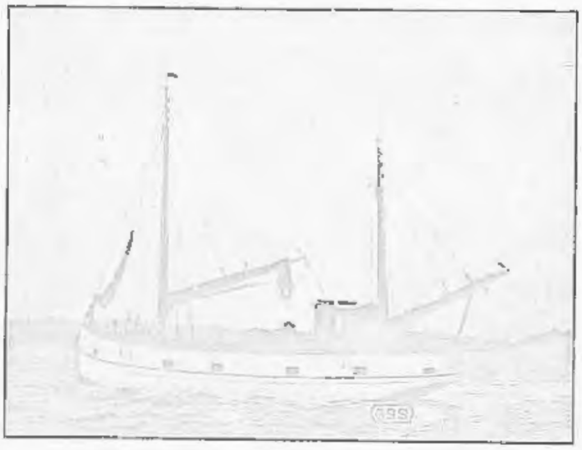
Fishing Boat
" Britannia "



2T4 Engine
24 BHP



Fishing Boat " *Ben My Chree* "
4T5 Engine : 72 BHP



Fishing Boat " *Tucan* "
3T4 Engine : 36 BHP

STATIONARY ENGINES

Electric Generator Sets.—The Gardner T Type Stationary Engine is extensively used for direct coupling to electric generators. The engines are " flywheeled " to suit the coefficient of cyclic variation of speed demanded and the governing is all that can be desired.

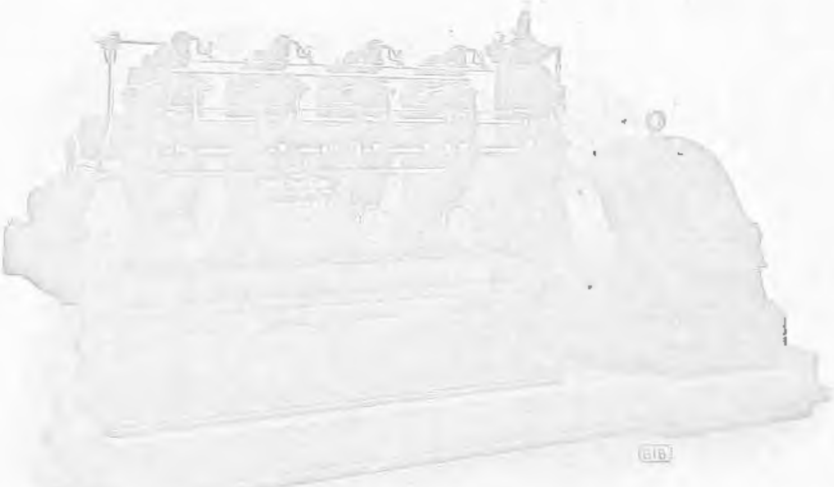
As a general rule, the engine and generator are mounted on a stiff bedplate as shown in the accompanying illustration. We hold in our pattern stores a goodly number of foundry patterns of bedplates which, in most cases, can be modified to suit each generator as it comes along.

These generating sets are also much used as auxiliaries to the propelling machinery of large vessels (*see under " Auxiliaries*)."

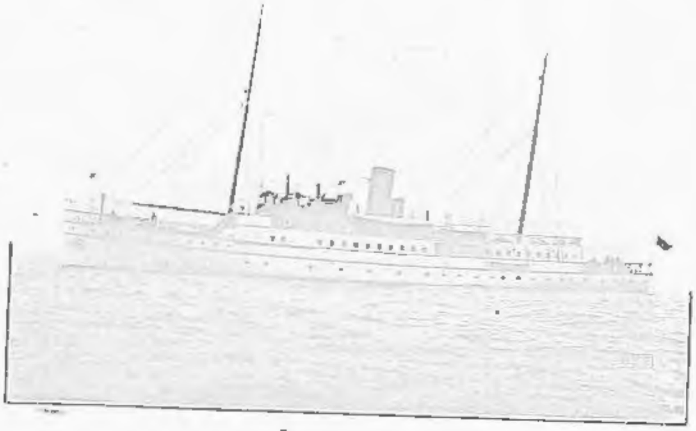
The Test Bay is equipped with all necessary appliances for the proper tests of Electric Generating Sets.

One of these generating sets of 150 BHP is in constant daily use in our own Power House, running at or about full load. The main object of this set is to give us authentic records of durability.

Industrial Engines.—By this is meant the class of engine from which the power is taken by a belt drive. The engine is the same as that used for electric generator sets, but the driving pulley is carried on an extension of the crankshaft supported by an outer bearing. The engine is " flywheeled " to give any desired coefficient of cyclic variation of speed.



As Auxiliaries.—These engines are admirably suited for ship auxiliary duties: lighting, pumping, and general transmission of electric power in vessels of large power driven by large Diesel Engines. The yachts "*Ara*" and "*Princess*" here illustrated form good examples of this use of the Gardner T Engine.

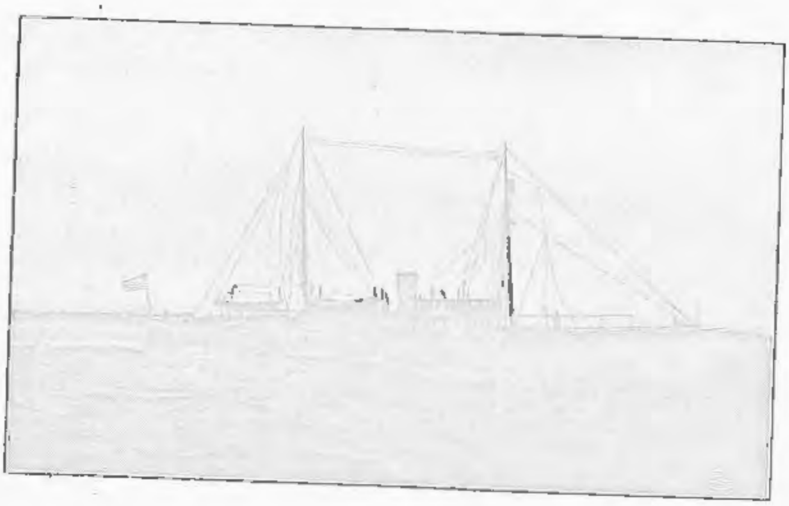


Yacht "*Princess*"

In the "*Ara*" there are two 3T5 electric generating sets each of 54 BHP which furnish energy for lighting, heating, wireless transmission, anchor winch, and refrigerating machinery, the main propelling engines being Polar Diesels.

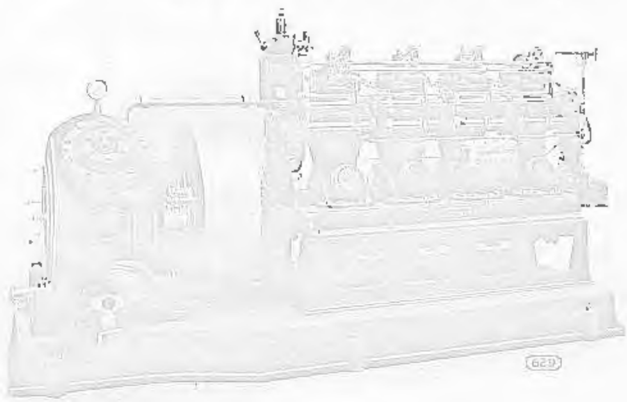
In the "*Princess*" there are three 4T4 electric generating sets, each of 48 BHP for duties similar to those of the "*Ara*."

Yacht "*Ara*"



STATIONARY ENGINES (*continued*)

Compressor Sets.—These engines are also used for direct coupling to Air Compressors. The accompanying illustration shows a typical set of a Reavell Air Compressor coupled to a T Type



Gardner Heavy Oil Engine, one of many sets that we have supplied to a Department of H.M. Government. The photograph shows a 4T4 engine of 48 BHP. This set, in particular, was subjected to an official test which included two separate non-stop runs of 100 hours each at full load.

4T4 Stationary Engine, 48 BHP, coupled to an Air Compressor.

THE GARDNER OVC AIR COMPRESSOR

THE primary object of this combined engine and compressor is the Initial Charging of the air receivers of Gardner Heavy Oil Engines after installation of the main engine, or in cases where the pressure in the receiver has been lost through inadvertence or other reason.

The compressor consists of an OV Gardner Engine of 1½ BHP at 770 r.p.m., into which is built a small single-stage air compressor, which is directly operated by the engine crankshaft. The OV Engine is fully described in our V Type Engine Catalogue.

The engine and compressor cylinders are water-jacketted and coupled with a copper circulation pipe, forming one circulation system.

The compressor has only one valve, the delivery valve, which is removable for examination without having to break any pipe joints. The air inlet is effected by ports in the cylinder wall, which are controlled by the moving piston.

The compressor is good for pressures up to 300 lbs. per square inch. The best idea of the capacity can be exhibited by saying that the compressor will charge a receiver of 4 cubic feet, from 0 lbs. to 250 lbs. per square inch, in 22 minutes.

Fuel for Engine.—Having regard to the fact that the compressor engine must be started on petrol, and that the whole operation of the initial charging of the receivers is so short, it is not deemed necessary to change over from petrol to paraffin ; consequently the engines are supplied only for petrol.

A WORD ABOUT THE PRICE

THE Gardner Engine seems to have got the reputation of being one of high price. Its appearance may be responsible for such impression, because of its high finish, its immaculate workmanship, and the exceptional completeness of all organs which experience has shown to be desirable, if not absolutely essential.

Notwithstanding these attributes, it will be found, on examination, that the prices compare most favourably with all other engines of this type, especially so when due regard is paid to all the things which are included or embodied with the engine, as enumerated and described in the next page or two.

WHAT THE MARINE ENGINE INCLUDES:

1. **Reversing Mechanism** (see page 11) for reversing the engine by compressed air and for varying the time of injection. This is standard for all T Type Marine engines down to the smallest size, but, as explained on pages 11 and 12, engines of two cylinders, the 2T7, 2T8, and 2T9, having only two cranks, will not start or reverse from every angular position of the cranks, therefore, when starting, the flywheel may have to be barred round into a starting position. For this reason, the reversing mechanism, although supplied with these engines, is not generally used for reversing and manœuvring. This is effected by a Gardner Reversible Transmission Gear.
2. **Air Compressor for Starting and Manœuvring,** water cooled, built in with the engine and drive from the main crankshaft, connected by copper pipe work to the main water circulation system of the engine.
3. **Compressed Air Starting Valves,** one to each cylinder, automatically operated by the camshaft, complete with all copper pipe-work, all ready to connect to the compressed air reservoirs.
4. **Compressed Air Reservoirs** for starting, manœuvring, and for feeding the quick-starting lamps, complete with all fittings ready to connect to the air distribution pipe on the engine. The fittings include for each reservoir a pressure gauge, stop valve, safety valve, and drain or scavenging valve.
5. **Quick Starting Burners** (see page 14) with all mountings, all connected by copper pipe-work to the main distribution fuel and air pipes on the engines, with small fuel tank and fittings for feeding the burners.
6. **Circulation Pump** (see page 11) built in with the engine and driven from the main crankshaft, connected by copper pipe-work to the water circulation system of the engine.
7. **Bilge Pump** (see page 11) built in with the engine and driven from the main crankshaft.
8. **Sectional Exhaust Manifold** (see pages 14 and 15) water jacketted, connected by copper pipe-work to the water circulation system of the engine.
9. **Governor** (see page 10).
10. **Lubrication.**—Two separate systems of lubrication as described on pages 12 and 13.
11. **Clutch and Thrust Bearing** (see page 15).

12. **Transmission Reversing Gear.**—Alternative to 11 (see page 15).
13. **Pipe-Work.**—As mentioned here and there in the preceding, all the copper pipe-work and fittings which belong to the engine proper are included in the standard price of the engine. The pipe-work and fittings external to the engine proper are not so included because they vary with each installation and therefore are taken as forming part of the installation.

Details not included in the Standard Price of the Marine Engine.

14. **Fuel Tanks and Exhaust Silencers.**—These vary so much in shape and size that they cannot be included in any standard price list. They are therefore taken as forming part of the installation and will be quoted for separately or with the installation.

WHAT THE STATIONARY ENGINE INCLUDES :

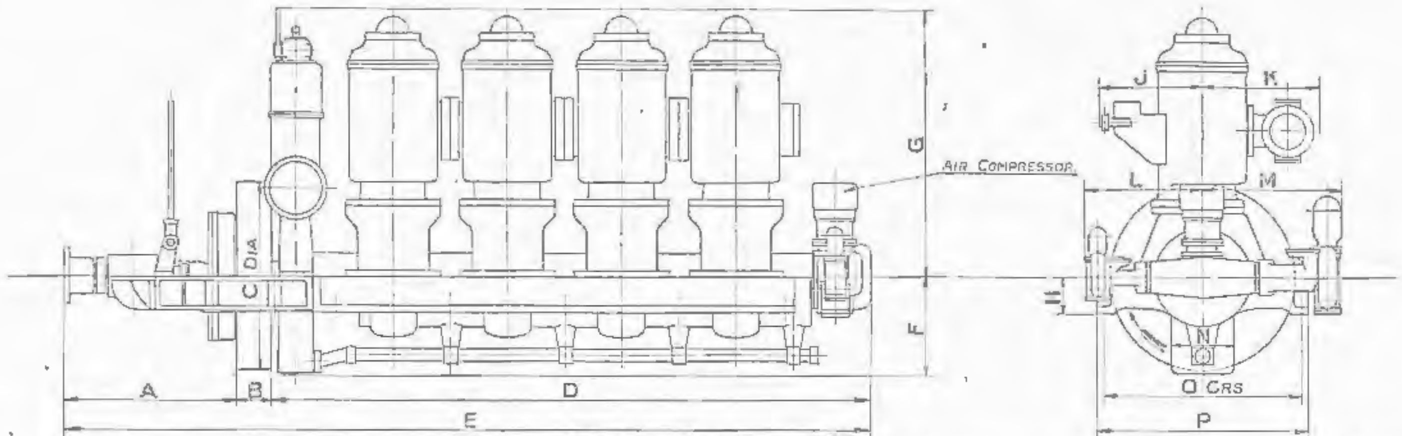
1. **Air Compressor for Starting**, water cooled, built in with the engine and driven from the main crankshaft, connected by copper pipe-work to the main water circulation system of the engine.
2. **Compressed Air Starting Valves**, one to each cylinder, automatically operated by the camshaft, complete with all copper pipe-work, all ready to connect to the compressed air reservoirs.
3. **Compressed Air Reservoirs** for starting, and for feeding the quick-starting lamps complete with all fittings ready to connect to the air distribution pipe on the engine. The fittings include for each reservoir a pressure gauge, stop valve, safety valve, and drain or scavenging valve.
4. **Quick Starting Burners** (see page 14) with all mountings, all connected by copper pipe-work to the main distribution fuel and air pipes on the engines, with small fuel tank and fittings for feeding the burners.
5. **Circulation Pump** (see page 11), built in with the engine and driven from the main crankshaft, connected by copper pipe-work to the water circulation system of the engine.
6. **Sectional Exhaust Manifold** (see pages 14 and 15), water jacketted, connected by copper pipe-work to the water circulation system of the engine.
7. **Governor** (see page 10).
8. **Lubrication.**—Two separate systems of lubrication, as described on pages 12 and 13.
9. **Timing Gear**, for varying the time of fuel injection ; a very useful adjunct where the quality of the fuel-oil is varied.
10. **Flywheel** of sufficient energy to give any desired coefficient of cyclic variation within reason.
11. **Exhaust Expansion Chamber**, commonly called a silencer.

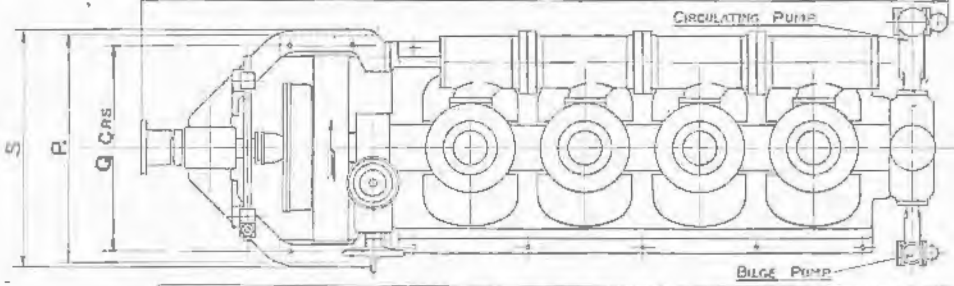
GARDNER HEAVY OIL ENGINES

TABLE OF DETAILS

POWERS, SPEEDS, &c.							WEIGHTS (in cwts.)					
Engine	B.H.P.	R.P.M.	No. of Cylinders	Bore	Stroke	Codeword	Engine with Ordinary Flywheel		Electric Light Engine and Bedplate		Marine Engine with Clutch or Reverse Gear	
				Inches	Inches		Gross	Nett	Gross	Nett	Gross	Nett
3T4	36	450	3	7	8	MACE . .	46	39	63	61	49	40
4T4	48	450	4	7	8	MADRE . .	62	48	84	72	63	49
3T5	54	400	3	8½	9½	MAGIC . . .	70	59	104	92	72	61
2T7	60	340	2	10½	12	MAKRA . .	97	86	162	149	103	87
2T8	70	320	2	11½	12½	MANOR . .	110	97	197	182	122	104
3T6	72	370	3	9½	10¾	MAILA . . .	85	76	139	128	84	74
4T5	72	400	4	8½	9½	MAGMA . .	80	70	118	108	82	71
3T7	90	340	3	10½	12	MALAS . . .	121	111	199	186	122	110
4T6	96	370	4	9½	10¾	MAJOR . .	103	94	173	156	107	92
2T9	100	290	2	13¼	15	MERIL . . .	156	136	264	244	164	144
3T8	105	320	3	11½	12½	MAORI . .	135	121	242	224	140	125
4T7	120	340	4	10½	12	MAMON . .	147	132	240	221	149	132
4T8	140	320	4	11½	12½	MARAT . .	164	148	286	267	167	151
3T9	150	290	3	13¼	15	MASTE . .	189	172	320	300	198	180
4T9	200	290	4	13¼	15	MAXIM . .	226	208	376	354	235	216
6T8	210	320	6	11½	12½	MATIL . . .	252	229	391	365	248	225
6T9	300	290	6	13¼	15	MALET . . .	339	311	515	483	341	312
						For Electric Light or Stationary Engines Prefix "EL"	The weights in this column include Engine, Receivers, Silencer, and ordinary Flywheel		The weights in this column include Engine, Receivers, Silencer, Bedplate, Stands, and Electric Type Flywheel		The weights in this column include Engine, Receivers, ordinary Flywheel, and Reverse Gear or Clutch	

NOTE: Although the above weights have been carefully compiled from our Shipping Notes, they should be taken as being approximate only.





THIS DRAWING SHOWS THE ARRANGEMENT OF A STANDARD (OR PORT) ENGINE. FOR A TWIN INSTALLATION THE ARRANGEMENT & ROTATION OF THE STARBOARD ENGINE IS THE OPPOSITE HAND.

ENGINE	CLUTCH	A	B	C	D	E	F	G	H	J	K	L	M	N	O	P	Q	R	S
3T4	Nº 4	19¾"	8¾"	24"	68¼"	96¾"	12½"	42⅜"	5"	16"	16¾"	22"	22"	9⅜"	25¾"	27½"	25¾"	30¼"	32"
4T4	Nº 4	19¾"	8¾"	24"	84"	112½"	12½"	42⅜"	5"	16"	16¾"	22"	22"	9⅜"	25¾"	27½"	25¾"	30¼"	32"
3T5	Nº 5	25½"	8¾"	29"	76¾"	111"	16½"	47¼"	6"	16"	18¾"	22"	22"	9⅜"	31"	33"	31"	36"	38"
4T5	Nº 5	25½"	8¾"	29"	96⅜"	130⅜"	16½"	47¼"	6"	16"	18¾"	22"	22"	9⅜"	31"	33"	31"	36"	38"
3T6	Nº 5	25½"	9"	33"	82½"	117"	16½"	51¾"	7"	16"	20⅝"	22¾"	22¾"	9⅜"	35"	37"	35"	40"	42"
4T6	Nº 5	25½"	9"	33"	102¼"	136¾"	16½"	51¾"	7"	16"	20⅝"	22¾"	22¾"	9⅜"	35"	37"	35"	40"	42"
3T7	Nº 6	29⅞"	10"	36"	92¾"	132⅝"	18½"	51½"	7"	20"	22⅝"	22¾"	22¾"	12"	38½"	41"	38½"	44"	46"
4T7	Nº 6	29⅞"	10"	36"	115⅝"	155½"	18½"	51½"	7"	20"	22⅝"	22¾"	27⅛"	12"	38½"	41"	38½"	44"	46"
3T8	Nº 8	34"	7½"	39"	103⅝"	145⅛"	19"	54"	8"	20"	24½"	23½"	28"	12"	40¾"	43½"	40¾"	47"	49"
4T8	Nº 8	34"	7½"	39"	127⅝"	169⅝"	19"	54"	8"	20"	24½"	23½"	28"	12"	40¾"	43½"	40¾"	47"	49"
6T8	Nº 8	33¾"	9"	39"	185¾"	228½"	19"	54"	8"	20"	24½"	23¾"	29¾"	12"	40¾"	43½"	40¾"	48"	50"
3T9	Nº 8	33¾"	11"	42"	110¾"	155½"	19¾"	65¾"	10"	20"	29"	23½"	28"	12"	43¾"	48"	43¾"	50"	53"
4T9	Nº 8	33¾"	11"	42"	141¼"	186"	19¾"	65¾"	10"	20"	29"	23¾"	29¾"	12"	43¾"	48"	43¾"	50"	53"
6T9	Nº 9	38¾"	11"	42"	207¼"	256½"	19¾"	68"	10"	24"	30"	30½"	30½"	14"	43¾"	48"	43¾"	51½"	54½"

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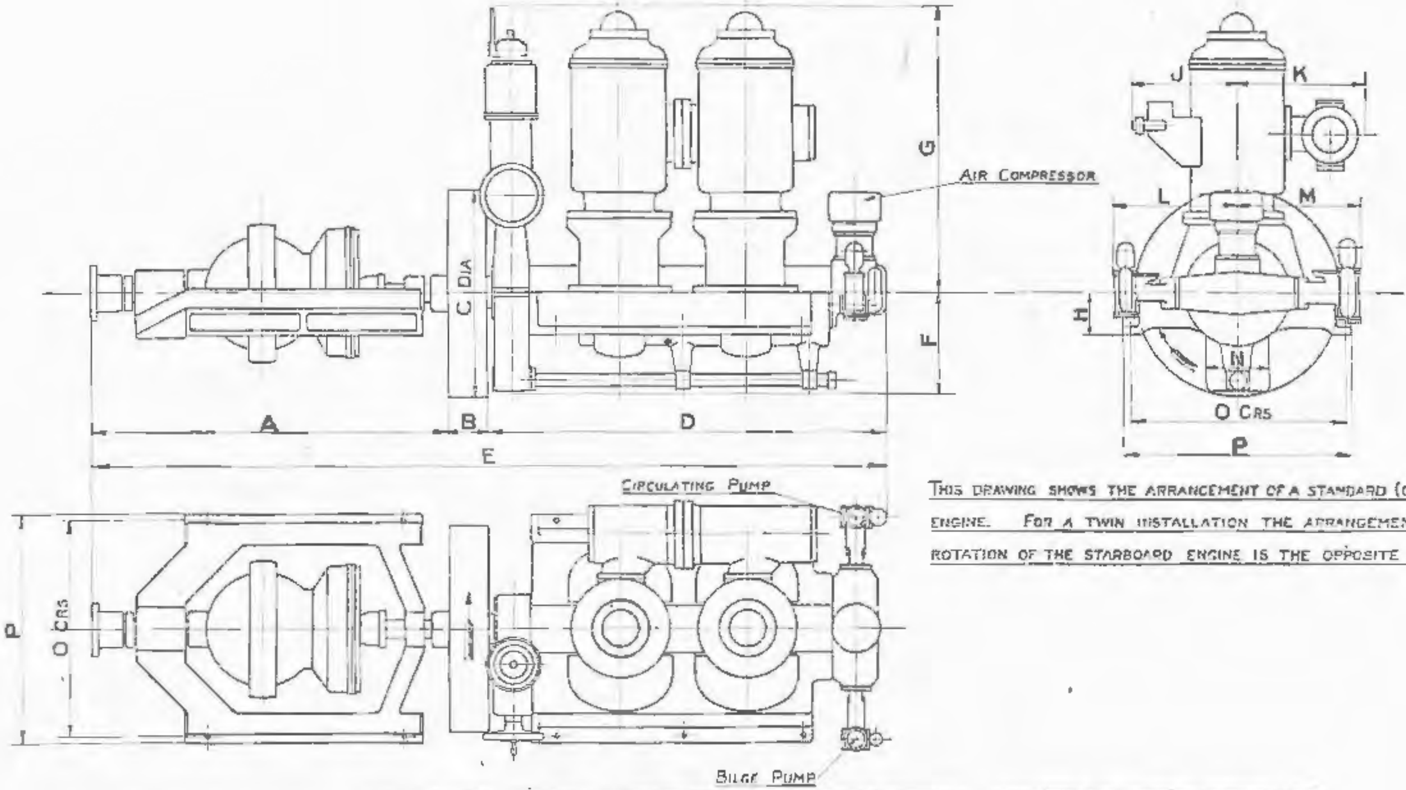
DIMENSIONS OF T ENGINES AND CLUTCHES

(3, 4, and 6 Cylinder Engines only)



THIS DRAWING SHOWS THE ARRANGEMENT OF A STANDARD (OR PORT) ENGINE. FOR A TWIN INSTALLATION THE ARRANGEMENT & ROTATION OF THE STARBOARD ENGINE IS THE OPPOSITE HAND.

DIMENSIONS A & E ARE SUBJECT TO CONFIRMATION.

ENGINE	REVERSE GEAR	A	B	C	D	E	F	G	H	J	K	L	M	N	O	P
2T7	Nº 5	59"	10"	36"	70¾"	139¾"	18½"	51½"	7"	20"	22⅝"	22¾"	22¼"	12"	38½"	41"
2T8	Nº 6	65⅝"	9"	39"	75¾"	150⅝"	19"	54"	8"	20"	24½"	23½"	23½"	12"	40¼"	43½"
2T9	Nº 7	63⅞"	11"	42"	110⅝"	185¾"	19¼"	65¼"	10"	20"	29"	23⅝"	28"	12"	43¼"	48"

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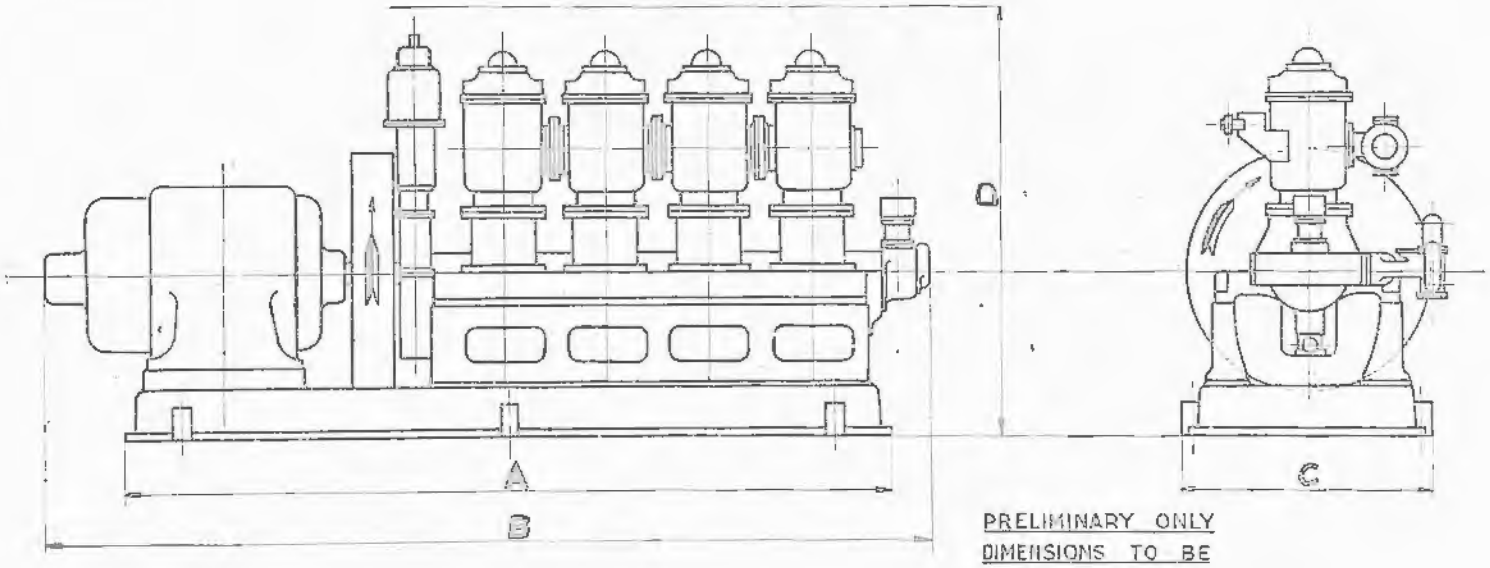
DIMENSIONS OF T ENGINES WITH TRANSMISSION REVERSE GEARS

(2-Cylinder Engines only)



PRELIMINARY ONLY
DIMENSIONS TO BE
CONFIRMED

	3T4	4T4	3T5	4T5	3T6	4T6	2T7	3T7	4T7	2T8	3T8	4T8	6T8	2T9	3T9	4T9	6T9
A	100"	121"	117"	138"	128½"	152"	115½"	146½"	173"	126"	151"	180"	260"	146"	173"	200"	310"
B	117"	138¾	135½"	160"	148½"	175"	138"	173"	203"	152½"	175"	204"	260"	160"	167"	214"	310"
C	39"	39"	39"	45¼"	46"	46"	52¼"	52¼"	52¼"	52¼"	66"	66"	66"	66"	66"	66"	72"
D	67¼"	68¼"	79"	79"	83"	83"	91"	93"	93"	96"	98"	98"	98"	98¼"	98¼"	98¼"	110"

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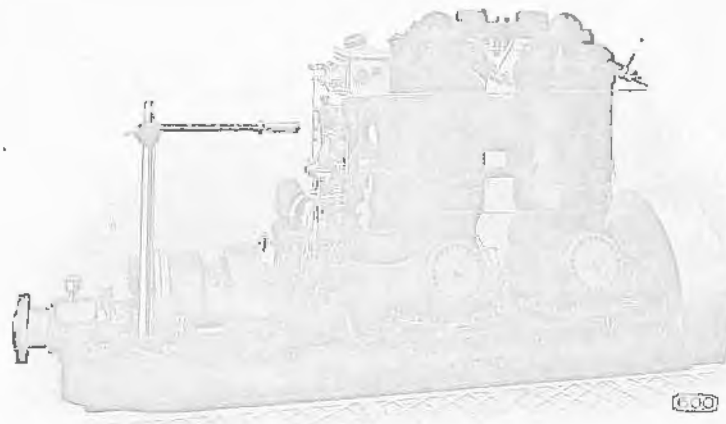
DIMENSIONS OF T ENGINES—DYNAMO COMBINATIONS

GARDNER HEAVY OIL ENGINES

EXTRACT FROM CATALOGUE OF VT ENGINES



Double VT Engine and Reverse Gear: from 13 to 48 BHP

In cases where smaller units than those shown in this catalogue are required we offer our VT Series of single and double cylinder engines, which are built in twelve sizes from 6 to 48 BHP. See separate VT Catalogue.

These engines use the same fuel and operate upon the same principle as those herein described, and vary only slightly in design. They form the subject of a separate catalogue, which will be sent free on application.

WHERE GARDNER PRODUCTIONS ARE MADE

L. Gardner
& Sons
Ltd.
Established
1868

Barton Hall
Engine
Works,
Patricroft,
Manchester

THE Barton Hall Engine Works, with their Recreation Grounds, cover about 25 acres. Though the firm is an old one, dating from 1868, its home is of the most modern description, constantly and continuously kept abreast with the enormous developments which have taken place in engineering practice during recent years. In it are lodged the

Iron Foundries,	Machine Shops,	Physical and Chemical Laboratories,
Brass Foundry,	Fitting and Erecting Shops,	Power House,
Forge,	Component Stores,	Research Bay,
Pattern Shop,	Test Bay,	Inspection Bay,
Pattern Stores,	Shipping and Packing Bay,	etc., etc., etc.

One of the features of the works is the huge Component Stores, where are kept in stock, under a "maximum and minimum" system, all the components which are required for the erection of engines. The primary object of this stores is to facilitate the administration of the works, but it will be conceded that it facilitates equally the expedition of spare parts and the delivery of engines.

Closely related to the Component Stores is the Inspection Bay, where every component is passed by an army of inspectors. This inspection applies to every operation and every component; in other words, a batch of components is not allowed to go for any one operation until the preceding operation has been inspected and passed.

The power throughout the works is distributed electrically from Generator Sets driven exclusively by Gardner Oil and Gas Engines, which, apart from their primary function of power generators, furnish valuable records as regards reliability, durability, wear and tear, consumption of fuel, and cost of maintenance. And, above all, their consistently satisfactory behaviour, year in year out, stands as most eloquent testimony of their high commercial value.

MATERIALS USED IN GARDNER PRODUCTIONS

LITTLE or nothing has been said on this subject in the general description herein, for the reason that the variety of materials now available is so great that a specification for each component would be wearisome to read. Suffice it to say that, for the most part, the selection of materials it entirely governed by the function that each component has to perform. For example, components made of steel, where hardness is of primary consideration, are made of steel which will harden, the components being afterwards finished and sized by grinding. On the other hand, the bolts in the big end of the connecting rod, for example, the failure of which would wreck the engine, have to withstand rapid variations of stress, and so are made of very special steel. Again, the iron used for cylinders and piston castings has to combine great hardness with strength, while that of the engine beds, flywheels, etc., is governed mainly by consideration of strength.

The various properties of all the important materials are verified by daily tests made in our Physical and Chemical Laboratories.

GARDNER
HEAVY OIL
ENGINES

OTHER TYPES OF GARDNER ENGINES

The following is a list of other types of Gardner Engines :

TYPE	DESCRIPTION	POWERS
VT	Heavy Oil, Single and Double Cylinder	$6\frac{1}{2}$ to 48 BHP
HF	Heavy Oil, Horizontal, Cold Start	13 to 82 BHP
CR	Petrol-Paraffin, Vertical, Multi-cylinder	9 to 48 BHP
F	Gas, Paraffin, and Petrol, Horizontal	$\frac{3}{4}$ to 14 BHP
V	Gas, Paraffin, and Petrol, Vertical, Single Cylinder	$1\frac{1}{2}$ to $12\frac{1}{2}$ BHP
H	Town and Producer Gas, Horizontal	16 to 94 BHP
M	Gas, Paraffin, and Petrol, Vertical, Multi-cylinder	10 to 180 BHP

We shall be pleased to send a catalogue describing any of the above types in which you may be interested post free on request.

SERVICE

We have, at the addresses given on page 2, Branch Offices, in charge of practical engineers, from which users of Gardner Engines can rely upon obtaining assistance and advice regarding their engines. These Branches will deal promptly and effectively with all requests made to them.

The Cloister Press Ltd., Heaton Mersey, Manchester

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