# L3 TYPE

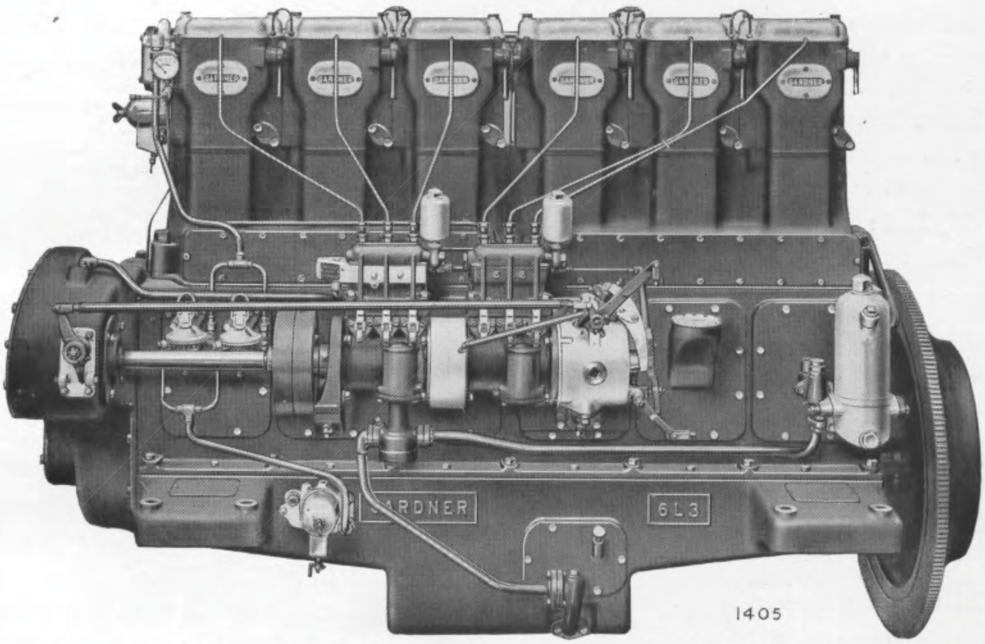
# GENERAL DIRECTIONS

## for the Management and Care of

# GARDNER

# OIL ENGINES

Vertical Four-Cycle Compression-Ignition
Airless Fuel Injection




**NORRIS, HENTY & GARDNERS LTD.**

(Proprietors: L. Gardner & Sons Ltd.)

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# INDEX

(The numbers refer to the paragraphs).

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# ILLUSTRATIONS

# Altitude and Combustion

As is well known, air at an altitude is rarer than it is at sea level, so that, a cylinderful of air at an altitude weighs less than the same cylinderful at sea level. On the other hand, the weight of a given charge of fuel remains comparatively constant at all habitable altitudes ; hence, when considering the amount of air necessary to burn a given charge of fuel, it is the weight or density of the air which counts rather than its volume.

The makers' works at Patricroft are situated at practically sea level where a cylinderful of air has its maximum weight and, during test, the engine is so adjusted that the maximum charge of fuel is that which is capable of being completely burned by this weight of air. It will therefore be readily realised that if the same engine be taken to work at an altitude, there will not be enough weight in a cylinderful of air to burn the maximum charge of fuel for which the engine was set during test, consequently, combustion of this maximum charge will be imperfect and there will be a smoky exhaust and excessive deposit of carbon in the cylinder.

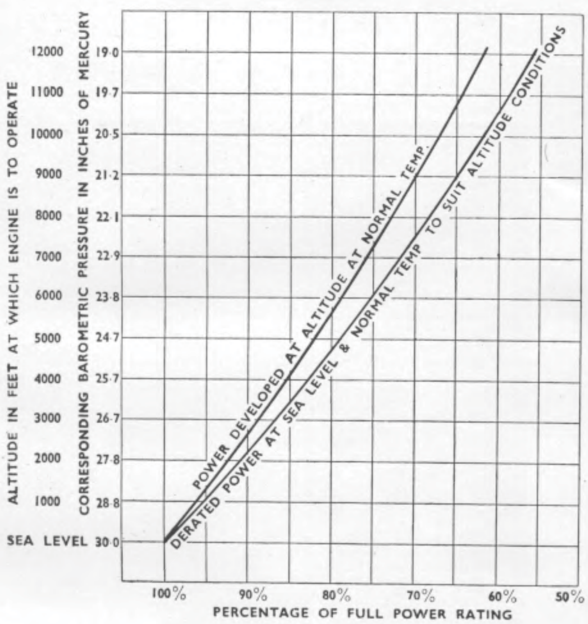
The preceding may perhaps be better understood by taking as an example the 4L3 engine, which gives a maximum of, say, 102 B.H.P. at 1,200 r.p.m. at sea level. At 3,000 feet altitude, the power that the engine will give will be only 87% of 102 B.H.P., say 89 B.H.P., because the weight of a cylinderful of air at that altitude is only 87% of its weight at sea level. The consequence is, that if the engine were adjusted to give 102 B.H.P. at sea level, the driver could give the engine considerably more fuel than the air can burn. This excess of fuel would be lost and, moreover, trouble would follow due to excessive deposit of carbon in the cylinders, a smoky exhaust and other evils.

When, therefore, it is intended to work the engine permanently at an altitude greater than, say, 2,000 feet, notification of this fact should be given to the makers, as also the approximate altitude, in order that the engine may be set during test for the maximum fuel charge which can be burned at that altitude.

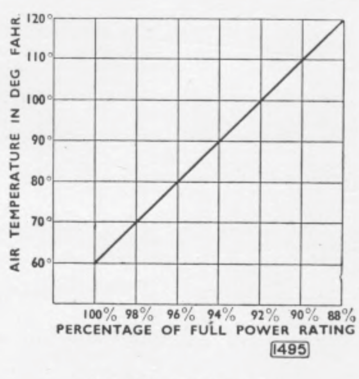
The actual power developed at the altitude is in excess of this setting, thus in the above example the engine would be set at sea level to 87% of 102 B.H.P., say 89 B.H.P., but would develop at this setting 89% of 102 B.H.P., say 91 B.H.P. when operating at 3,000 feet altitude.

# Altitude and Air Temperature Diagrams

The powers shown on the graphs are those which the engines give at sea level with the barometer standing at 29 or 30 inches of mercury and with a normal air temperature of 60° F. or 70° F. At higher altitudes and temperatures, the power of all heat engines falls away according to the diagrams given below, the use of which can best be explained by the numeric example which follows.




ALTITUDE




AIR TEMPERATURE

**Example.**—Given that the engine has to work at an altitude of 3,000 feet above sea level with an air temperature of 90° F. From the diagrams, we read the following coefficients of reduction :—

For altitude—89% or 0·89, *i.e.*, Power Developed at normal temperature.
For temperature—94% or 0·94.
Combined coefficient of reduction—0·89×0·94 = 0·84 or 84%.

Thus an engine having a full power rating of 100 B.H.P. at sea level will be good for 84 B.H.P. at 3,000 feet and 90° F.

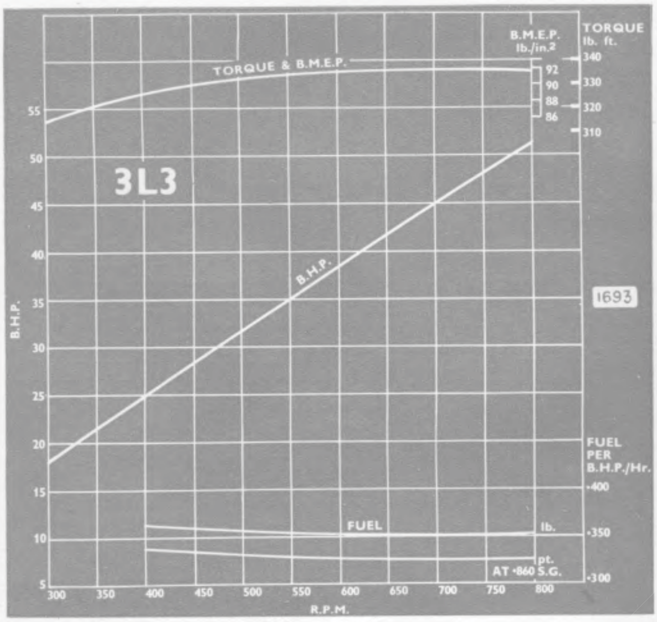
# Performance Curves

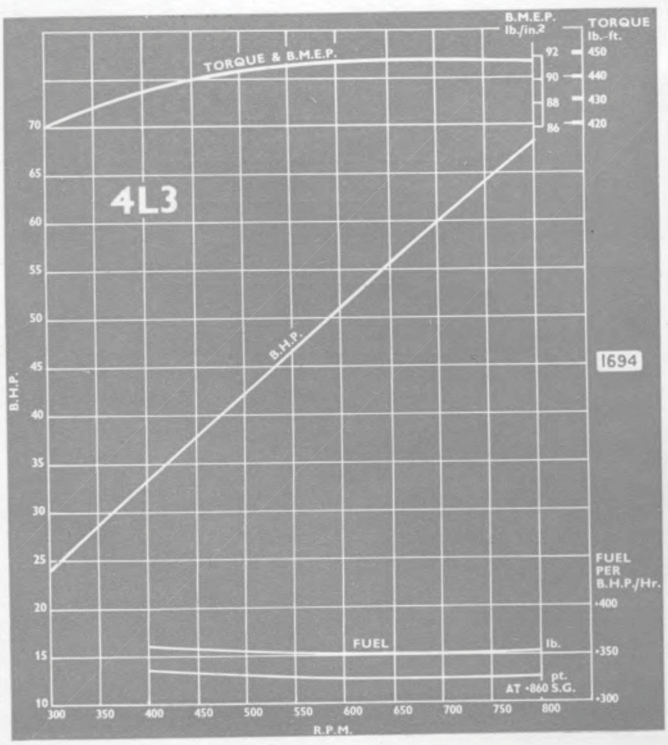
**INDUSTRIAL DUTY**

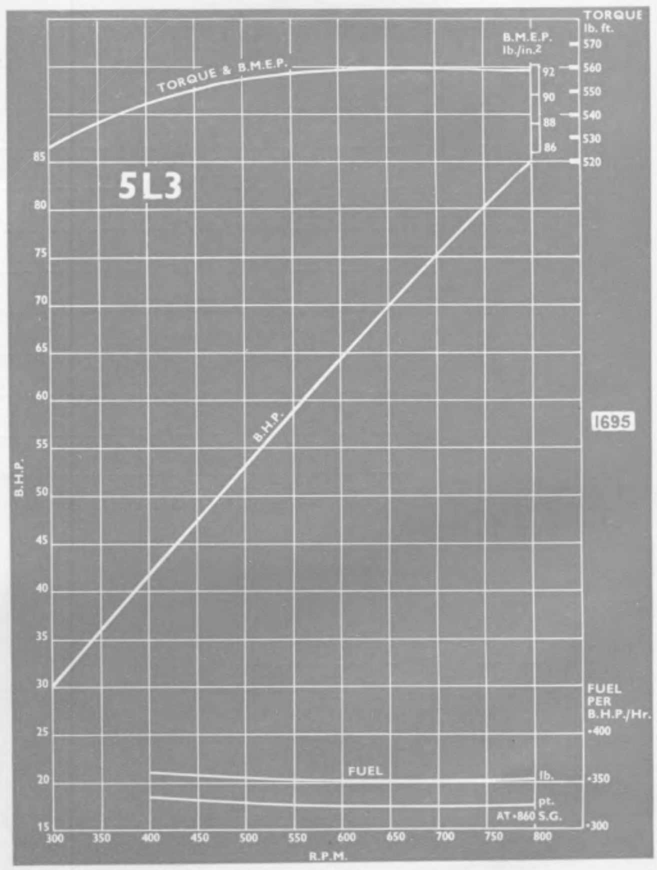
Engines running at a Maximum Speed of 800 r.p.m.

**Swept Volumes.**

3L3 .. 9 litres.
4L3 .. 12 ,,
5L3 .. 15 ,,



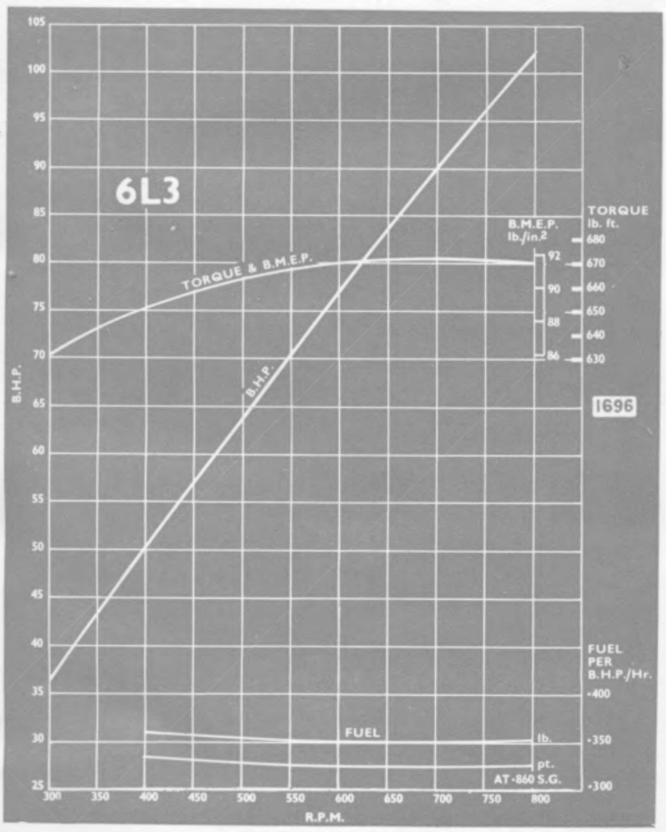

These graphs are made from figures regularly observed during the ordinary tests of the engines ; they are in no sense mere laboratory results. Large scale prints of the graphs are available on application.

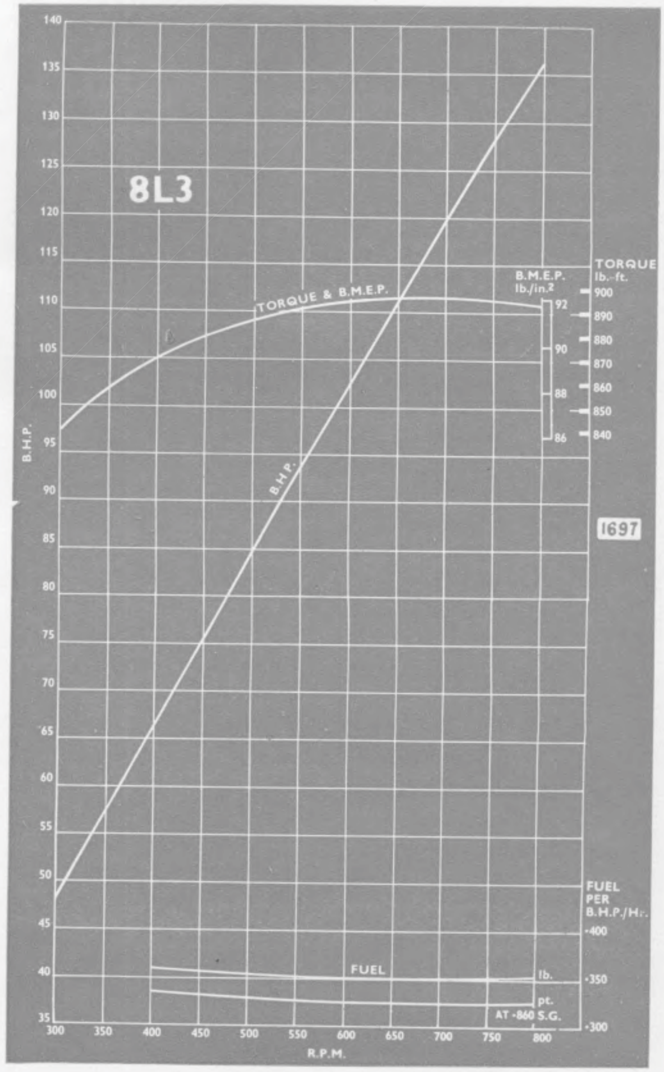
# Performance Curves

## INDUSTRIAL DUTY

For Engines running at a Maximum Speed of 800 r.p.m.

**Swept Volumes.**
6L3 .. 18 litres.
8L3 .. 24 „

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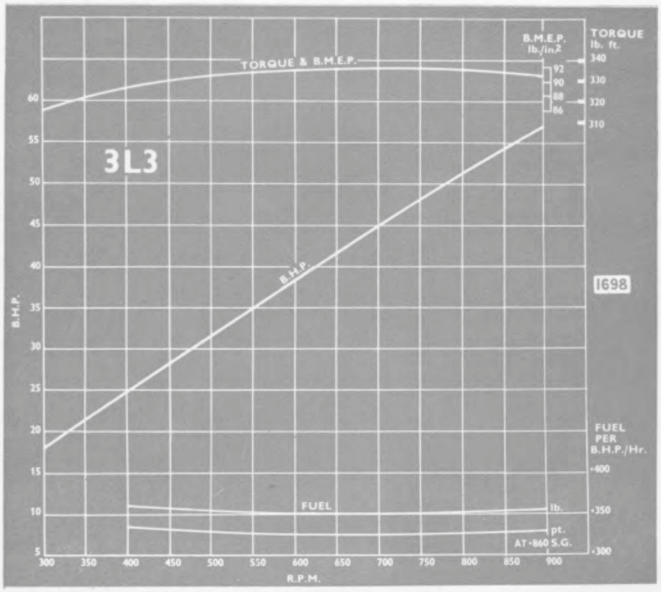
# Performance Curves

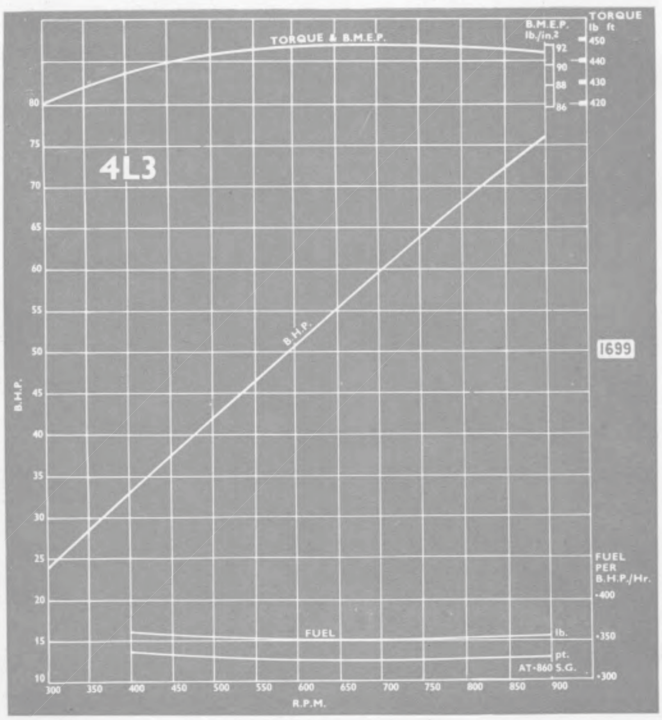
**MARINE DUTY**

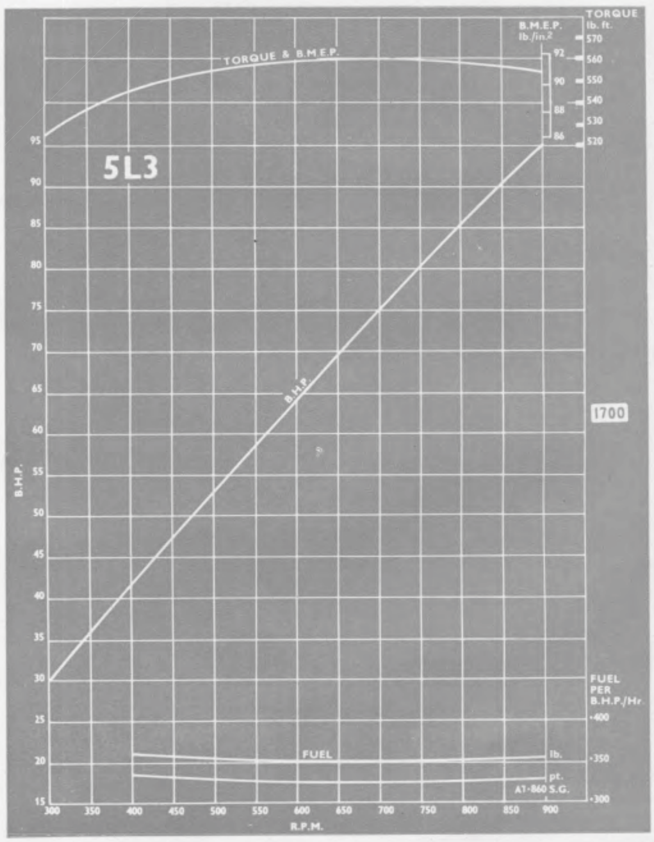
Engines running at a Maximum Speed of 900 r.p.m.

**Swept Volumes.**

3L3 .. 9 litres.
4L3 .. 12 ,,
5L3 .. 15 ,,

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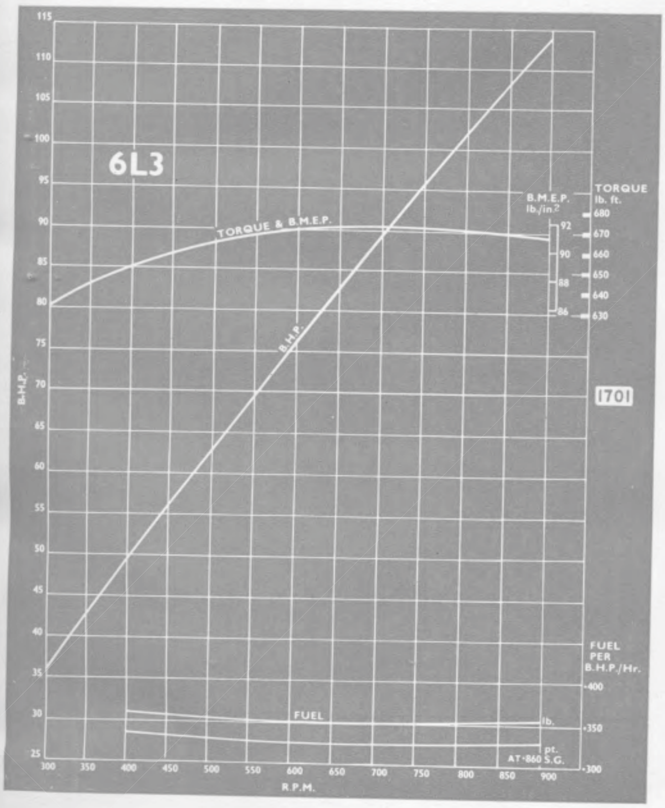
# Performance Curves

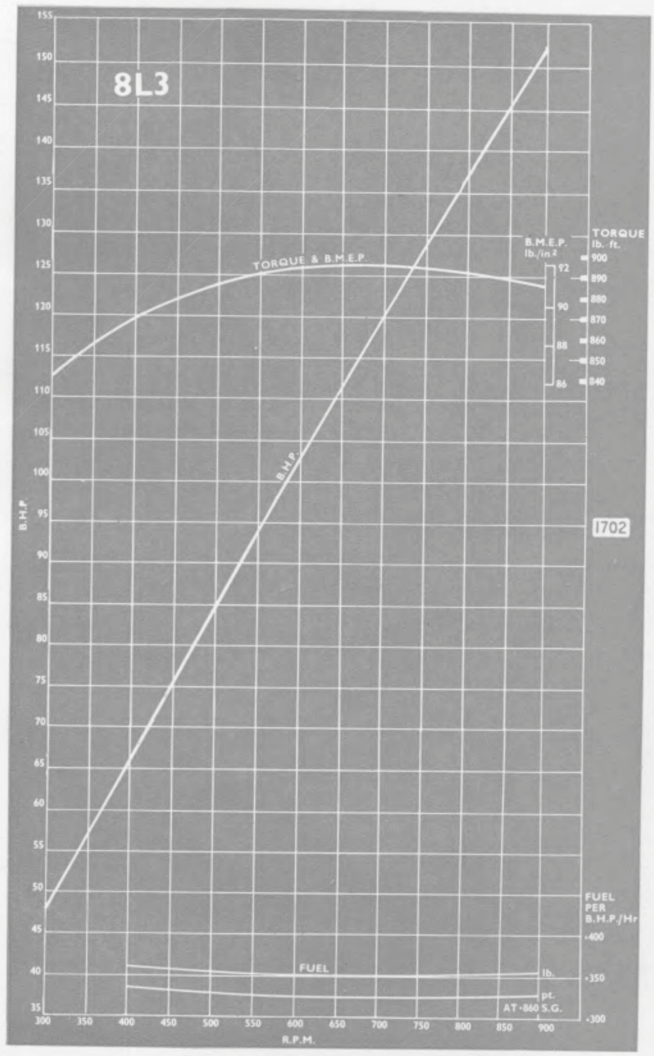
## MARINE DUTY

For Engines running at a Maximum Speed of 900 r.p.m.

**Swept Volumes.**

6L3 .. 18 litres.
8L3 .. 24 ,,




These graphs are made from figures regularly observed during the ordinary tests of the engines ; they are in no sense mere laboratory results. Large scale prints of the graphs are available on application.

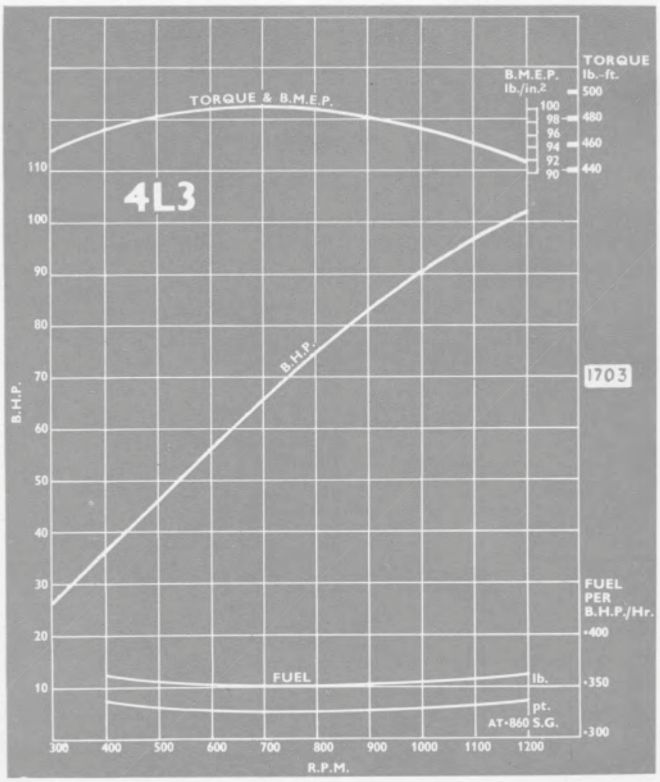
# Performance Curves

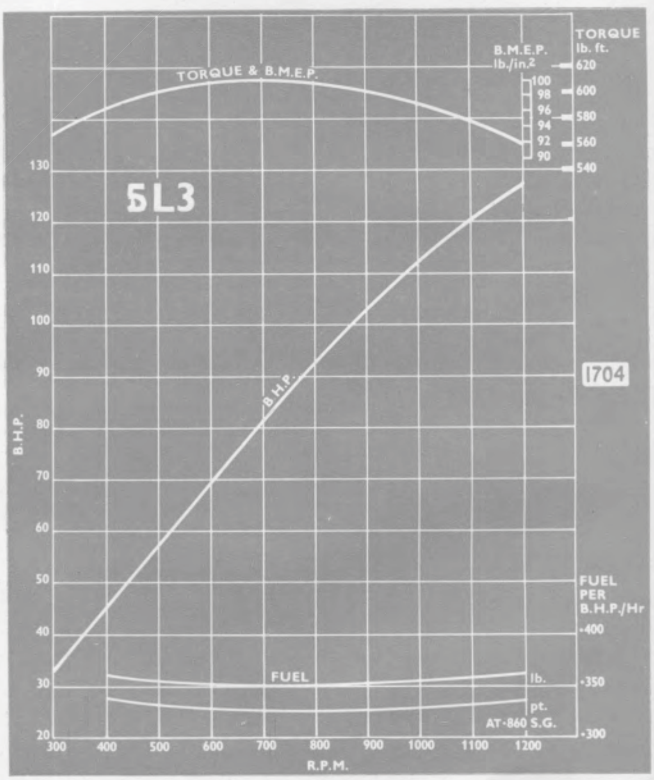
**INTERMITTENT DUTY**

For Rail-Car Engines running at a Maximum Speed of 1,200 r.p.m.

**Swept Volumes.**

4L3 .. 12 litres.
5L3 .. 15 „



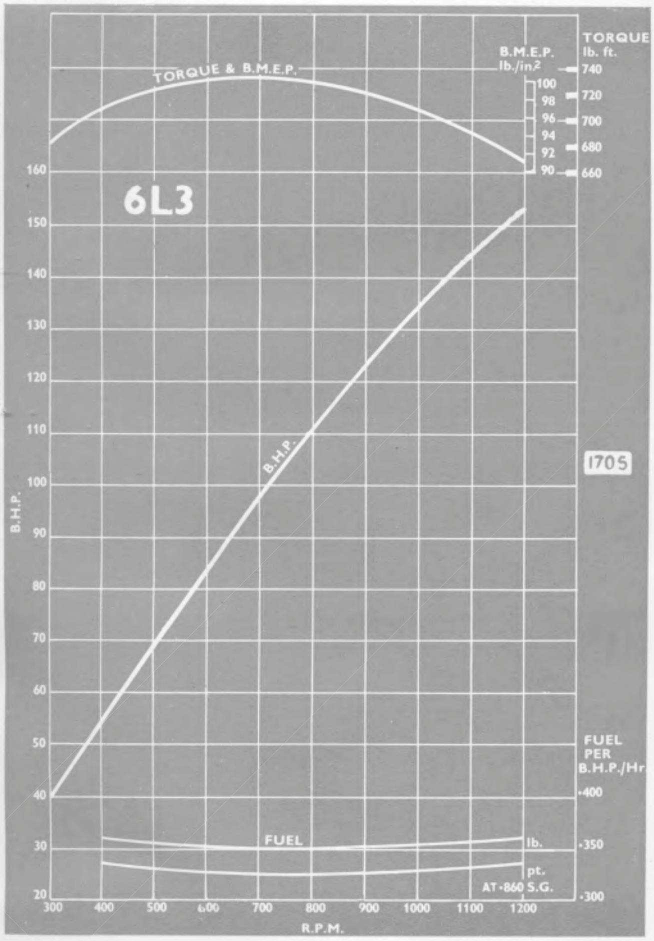



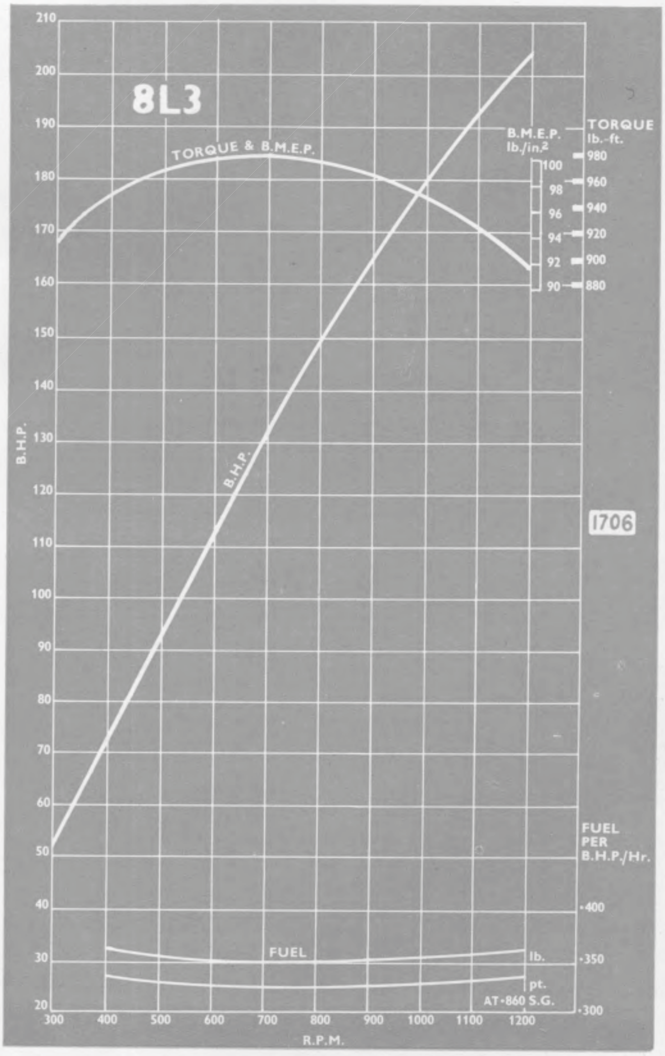

These graphs are made from figures regularly observed during the ordinary tests of the engines ; they are in no sense mere laboratory results. Large scale prints of the graphs are available on application.

# Performance Curves

**INTERMITTENT DUTY**

For Rail-Car Engines running at a Maximum Speed of 1,200 r.p.m.




These graphs are made from figures regularly observed during the ordinary tests of the engines ; they are in no sense mere laboratory results. Large scale prints of the graphs are available on application.

# GENERAL INTRODUCTORY NOTES

1. The complete working cycle of the engine requires four strokes of the piston, that is, two complete turns of the crankshaft. During the first stroke, a charge of air is drawn into the cylinder and is compressed during the second stroke. At or towards the end of this stroke, a charge of fuel is injected into the combustion space in the form of spray which is at once ignited solely by the temperature of the compressed air charge. The resultant combustion causes a rise of pressure and a store of energy to be expended during the third stroke, or the power stroke. During the fourth and last stroke, the burned gases are expelled and this completes the cycle.

2. It is well-known that when air is compressed, its temperature rises, and if the compression be high enough, the resultant temperature suffices to ignite readily the liquid fuel charge. This is the principle of the L type, compression-ignition engine : to repeat, ignition is effected solely by the temperature of the compressed air charge, and this applies equally while the engine is running or while it is being started by hand when all is cold.

3. The injection of the fuel into the combustion chamber is effected by an injection pump, one to each cylinder, which forces the fuel through a sprayer situated at the summit of each combustion chamber. Each fuel charge is accurately measured by the injection pump, the amount of the charge being varied and controlled by the automatic governor to correspond with the load carried by the engine at any given moment.

4. **Fuel Injection Pumps.**—These are built in units each containing as many pumps as there are cylinders on the engine. The 5-cylinder engine, however, has a 2-pump unit and a 3-pump unit, the 6-cylinder engine has two 3-pump units, and the 8-cylinder engine two 4-pump units. Each pump is operated by its own cam on the camshaft, and in addition, is furnished with a hand lever and latch enabling the pumps to be worked by hand for priming the injection system. The latches enable any pump to be put into or out of action. For fitting of spare pumps, see para. 117.

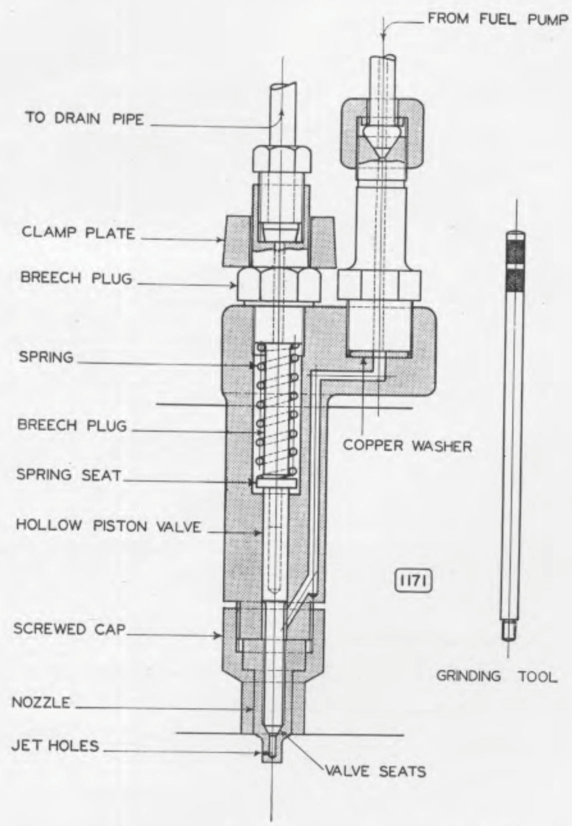
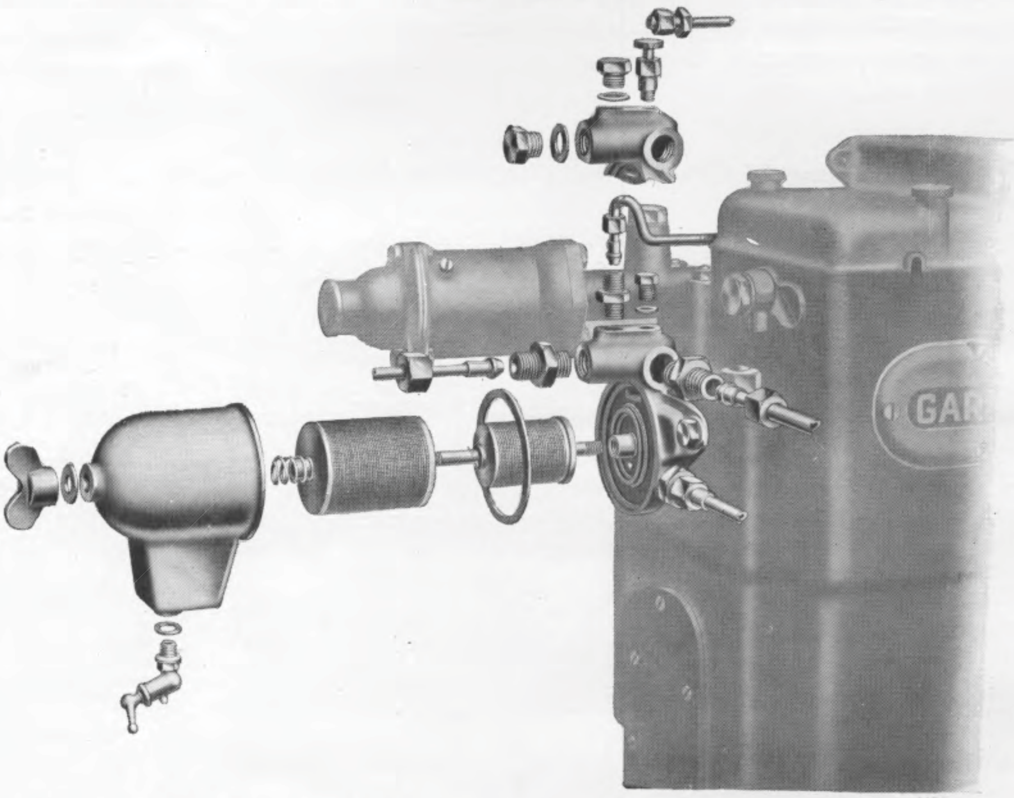



Fig. I

GENERAL INTRODUCTORY NOTES—*continued.*

5. **Fuel Sprayers.** (See Fig. 1.)—The sprayer will be seen to be a very simple and robust piece of apparatus, and is designedly made non-adjustable, meaning that when the sprayer is reassembled after taking to pieces for cleaning or examination, it requires no adjustment of any kind. The sprayer may be said to be the life and soul of the engine : its function is to receive the minute fuel charge and to convert it into a fine spray. To this end, the fuel charge is forced through fine passages which would be liable to become choked with any foreign matter which may find its way into the fuel were it not for the ample precautions taken by the makers to avoid this contingency. These are mentioned under the next head but one.




SHOWING THE SECOND FUEL FILTER TAKEN APART FOR EXAMINATION (ALTERNATIVE ARRANGEMENTS FOR GRAVITY AND OVERFLOW RETURN SYSTEMS) **Fig. 2**

6. **Sprayer Drain Pipe.**—A minute quantity of fuel is allowed to leak past the piston valve of the sprayer which leak is properly piped from each sprayer into a 'bus-pipe, whence it may be piped back to the fuel tank. The pipe should be led into the **top** of the tank, **not** the bottom ; this is in order to avoid the necessity of using a cock or valve on the pipe which, if inadvertently closed, would impair the efficient working of the engine.

7. **Fuel Filters.**—In circuit with the fuel system are two fuel filters of very special design. Both filters are alike. One is mounted on No. 1 cylinder head. The other is intended to be fixed near the fuel tank in such

GENERAL INTRODUCTORY NOTES—*continued.*

a position that it is perfectly accessible for cleaning and inspection. As this is the first filter through which the fuel flows it is called the **First Fuel Filter,** the **Second Fuel Filter** being that mounted on No. 1 cylinder head. See Fig. 2. Each contains two gauze elements, an inner and an outer, which are removable for cleaning.

Both filters are provided below with a sump and a drain cock. For gravity feed systems, the second filter is fitted with a vent cock, but this is omitted with the overflow return system, which is vented automatically through the fuel return pipe—See para. 116.

8. **Lubrication.**—This is effected by a circulation-pressure system fed by a gear type pump located in the fuel cam box, driven by the fuel camshaft (see Fig. 11), and regulated to deliver oil at the pressures stated in paras. 9, 29 and 51. The oil is carried in a sump formed in the crankcase. The arrangement of filters is such that all lubrication oil is filtered before delivery to the various bearings. On the forward side of the delivery strainer is a spring-loaded by-pass valve for regulating the oil pressure.

9. **Lubrication.**—Practically all parts of the engine are lubricated by a circulation-pressure system fed by a gear pump driven by the camshaft of the engine. In a sump built into the lower crankcase is a strainer with foot valve external to the sump, through which the pump draws oil and delivers it through a second strainer fixed on the engine to a main service pipe, from which it is distributed to various parts of the engine —the main bearings, the crankpins, the gudgeon pins, the camshaft, the gears, the governor, the valve rocking levers on the cylinder head, etc. After passing through all these organs the oil is led back to the sump to be again put into circulation. Incorporated with the delivery strainer is a **by-pass valve for regulating the oil pressure.** See paras. 29 and 51 and Fig. 12. On the delivery side of the system is fixed a pressure gauge which, when the engine is running, should show the following pressures :—

Industrial Engines, 35 lb./sq. in. at 800 R.P.M.
Marine Engines, 35 lb./sq. in. at 900 R.P.M.
Rail Traction Type Engines, 35 lb./sq. in. at 1,200 R.P.M.

These pressures are set when the temperature of the oil is about 135° F. (57° C.)

10. **Water Circulation.**—This is forced in all cases : thermo-syphonic circulation is not used nor can it be used, as the engines are not designed for it. Each engine is fitted with a circulation pump driven from the half-speed shaft. A plunger type pump, fitted with air vessel, drain tube, snifting valve and safety valve is used for " open " circulation systems or " closed " systems incorporating a water-cooled heat exchanger. For closed circulation systems incorporating cooling tanks or air-cooled radiator, a gear-driven centrifugal pump is fitted. Normally the plunger types of pumps are of bronze and the centrifugal are of aluminium.

11. **Bilge Pump.**—This is built into the engine and is driven through the intermediary of a friction clutch, so that it may be started and stopped at will. The pump is the exact counterpart of the plunger type circulation pump, except, of course, for the friction clutch. See Fig. 15.

Engines are not supplied with bilge pumps unless expressly ordered : they are then the subject of an extra charge.

GENERAL INTRODUCTORY NOTES—*continued.*

## STARTING AND VALVE GEAR.

12. An essential feature of these engines is that starting can be effected by hand cranking handles, but compressed air or electric starting (whichever has been ordered) is fitted as standard to all engines. As already explained, the ignition of the fuel charge is effected solely by the temperature of compression, therefore all extraneous devices such as pre-heating, cartridges, electric plugs and such like, often used for starting from cold, are entirely dispensed with.

Having regard to the high degree of compression necessary in engines of the compression-ignition type, starting by hand power is quite an achievement and depends among other things upon the Gardner Patented Valve Gear by which (1) the engine is relieved of all compression during the first stage of hand starting and (2) during the second and last stage, the timing of the air valve is altered so as to obtain maximum compression during the slow turning at starting. Even this latter facility is only necessary under extremely cold conditions.

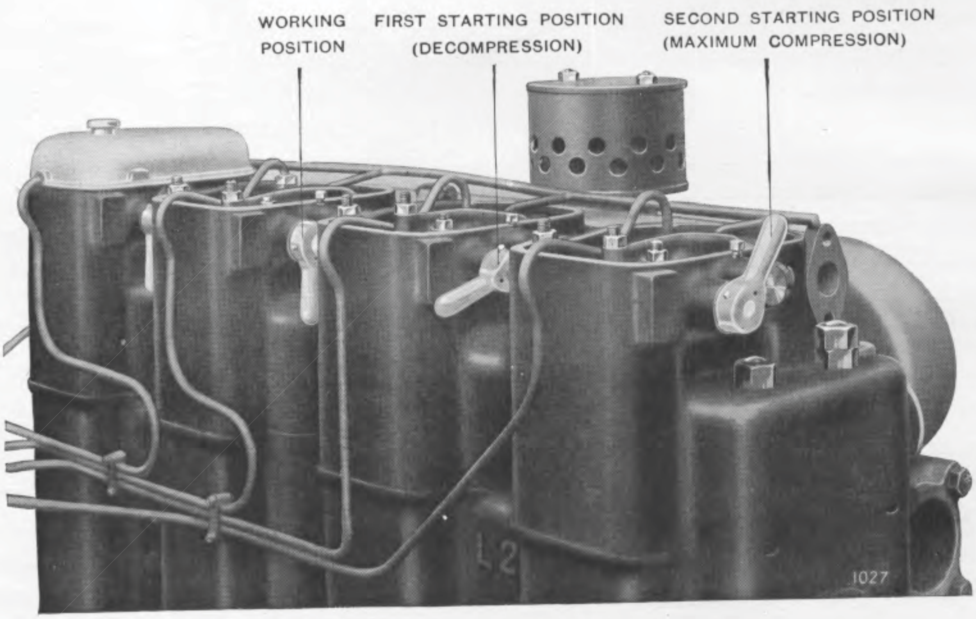



Fig. 3

STARTING LEVERS, SHOWN IN THEIR THREE DIFFERENT POSITIONS

On the valve gear box of each cylinder head is a small starting lever which normally rests vertically downwards while the engine is running, in which position it is inoperative. In the horizontal position it prevents the air inlet valve from entirely closing and so prevents compression. When the starting lever is turned vertically upwards, past the top centre, it causes the inlet valve lever to slide along the rocker shaft so as to re-engage with the air inlet valve, but now, the time of opening and closing of the air valve is altered so as to obtain

GENERAL INTRODUCTORY NOTES—*continued.*

**Starting and Valve Gear**—*continued.*

maximum compression while the engine is being turned slowly by hand. To recapitulate, the starting levers take in turn the following three positions :

No. 1—First starting position. Horizontal. De-compression.

No. 2—Second starting position. Over the Top. Maximum compression. (This step only necessary when extremely cold.)

No. 3—Running position. Vertically down. Out of action.

The operation of starting is described further on : See 36 and 37.

13. **Starting Fuel-Plunger.**—Underneath and at the end of the aluminium box attached to the front of the fuel pumps will be found a vertical spring-loaded plunger which, on being pressed up, as far as it will go, releases the governor-control bar of the pumps and allows it to slide towards the flywheel, in which position the pumps deliver an increased charge of fuel for starting from cold. As soon as the engine is started, the governor-control bar automatically retakes its normal working position in which the pumps cannot give an excessive charge of fuel.

This plunger is to be used only when starting from cold : it must on no account be used when the engine is running, for the purpose of increasing the power of the engine. If the plunger be held or propped up while the engine is working, the pumps may deliver more fuel to the engine than it can burn and serious trouble may occur.

14. **Variable Speed.**—The speed of Marine and Industrial engines can be varied while the engine is running, from 250 r.p.m. to the maximum running speed, including all intermediate speeds by adjustment of a friction controlled lever and knurled knob (Fig. 11) respectively on the governor case. In the case of the Rail Traction type of engine, the speed is controlled from an idling speed of 350 r.p.m. to the maximum of 1,200 r.p.m. by a lever which is also mounted on the governor case (Fig. 12). See paras. 90·2, 90·3. It is here to be observed that the engine is under complete control of the governor at all speeds. Apparatus for the remote control of the speed can be added at an extra charge for marine installation.

## ASSEMBLING AND INSTALLATION.

15. **Packing.**—Unless expressly ordered otherwise, the engines are packed in their assembled state with only the flywheels removed. Before packing, all bright parts are varnished with a rust preventive which is soluble in paraffin.

16. **Unpacking.**—When unpacking, lay out all the loose parts in a suitable, clean place, free from dust and grit and sheltered from the weather. These parts should be at once checked and identified by the Contents List, which is sent by post with the Advice Note of dispatch. In case these parts have to lie for any length of time before assembling them, it is not wise to remove the protective varnish.

17. If there is any work being carried on in the neighbourhood of the installation, it is advisable to keep the engine sheeted up as much as possible, and to retain the protective varnish till the last moment.

GENERAL INTRODUCTORY NOTES—*continued.*

18. **Assembling.**—To remove the protective varnish, use clean, cotton cloths, soaked in paraffin (kerosene). Do not use cotton waste as it is rarely free from dust and particles of fluff. When assembling engines at the Works, we make free use of clean cloths and paraffin baths, and strongly recommend this practice when assembling on site. Clean Gas Oil (from petroleum) is nearly as effective and is, in general, much cheaper than paraffin. Take care that all oil holes and such places are thoroughly cleaned out during assembling.

19. **Fuel Service Tank.**—A suitable service tank is included in the accessories of all stationary engines but not for marine engines or other engines requiring special tanks. Special tanks differ so much in size, shape and construction that they are regarded as coming under the head of installation work.

20. **Fuel Service Tank.**—After piping the fuel tank to the first fuel filter mentioned in para. 7 and from this filter to the second fuel strainer on the engine, and after charging the fuel tank it is advisable to uncouple the union at the engine second fuel filter and allow a copious flush of fuel to pass in order to clear out from the pipes any dirt that may have found its way in. After re-coupling to the filter, open the vent tap on top of the filter and allow another flush of fuel to pass. Do the same at the screwed plug in the flywheel end of the fuel pumps. These last two flushings are to expel all air from the system. This is very important.

21. **Exhaust System.**—Due to the very many different conditions, under which these engines are used, and to the varying number of cylinders, it is impossible in the compass of this book to give full particulars of individual exhaust systems. The works will, however, be pleased to give their recommendation for any installation.

In all cases the system should be as short as possible, with the minimum number of bends, which should be of maximum radius.

Whenever possible the " straight-through " type of silencer should be used and in no case must pipe or silencer bore be less than 3 in. for the smaller and 3½ in. for the larger engines of the series.

## PREPARATION FOR STARTING AFTER INSTALLATION.

22. **Lubrication System.**—To charge the sump in the lower crankcase, remove the cover of the oil filter box (Fig. 12) and pour in lubrication oil until the sump level reaches the maximum mark on the dip rod which will be found in the lower crankcase on the governor side. See Fig. 4, page 19.

23. The **Dip Rod** passes obliquely through a hole in the crankcase and is withdrawn by a knurled knob (Fig. 11) marked " Oil Level." The lower end of the rod is marked " Max. Level " and " Min. Level."

24. Remove the screwed plug (Figs. 11 and 12) on the suction pipe of the lubrication pump and, by the aid of the large syringe supplied with the engine, fill the pipe with oil until it overflows at the plug hole. The object of this is to prime the pump and suction pipe from the foot valve upwards. This plug will be found on the left-hand side of, and within an inch, or so of the oil pump.

25. After a first run after installation, a certain amount of oil will be used to fill all the oil pipes and to wet all the internal surfaces. This will, of course, reduce the oil level in the sump, hence the necessity of an additional make-up charge of oil after a first run.

**Addition to Para. 28 Lubrication.—Suitable Oil.** *Jany. 1950*

The use of detergent oil to Specification 2·104—B Supplement 1, is desirable but not essential. Its use is particularly desirable when any or all of the following conditions obtain :

(1) The fuel oil in use contains more than ·3% sulphur

(2) The engine is operating under continuous load (e.g., stationary electricity generating plant)

(3) The gross laden weight of a road vehicle in tons (2240 lb./ton) per litre of engine swept volume is in excess of 1·6 approximately.

(4) High atmospheric, coolant and lubricant temperature.

The Works will be pleased to make recommendation upon enquiry for any particular duty.

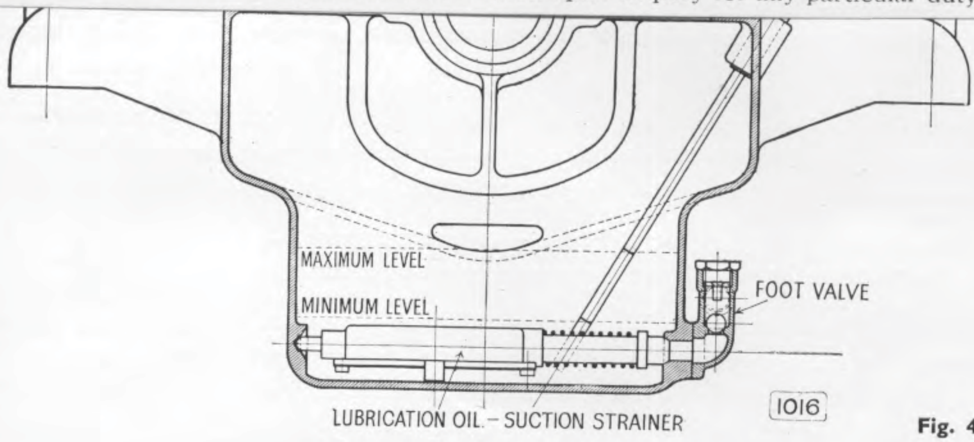



**Fig. 4**

26. Formed in the crankshaft are oblique ducts which lead lubrication oil from the main bearings to the crank pins and hence to the gudgeon pins by way of a central duct in the connecting rod.

27. When starting for the first time or after a prolonged stop, see that the oil pressure gauge registers pressure ; if it does not, shut down at once and investigate—see para. 30.

28. **Lubrication.—Suitable Oil.**—This is supplied by any of the well-known makers.
As a general rule a lower viscosity lubricant should be used during cold weather or in cold climates, than is used during hot weather or in hot climates.
The following tables show our recommendations for this purpose based on the mean ambient temperature prevailing during the operation of the engines.

VISCOSITY REDWOOD No. 1

| Temp. °F. | **Specification BS.** 55° — 90° F. *e.g.* British Isles June, July, Aug., Sept. | **Specification BW.** 30° — 55° F. *e.g.* British Isles March, April, May, Oct., Nov., and Dec., Jan., Feb., Normal Winter. | **Specification KW.** 10° — 30° F. *e.g.* British Isles Dec., Jan., Feb. Severe Winter. |
|---|---|---|---|
| 70 | Not exceeding 1600 sec. | Not exceeding 1250 sec. | Not exceeding 780 sec. |
| 100 | ,, ,, 600 ,, | ,, ,, 420 ,, | ,, ,, 300 ,, |
| 140 | Not less than 160 ,, | Not less than 120 ,, | Not less than 112 ,, |
| 200 | ,, ,, ,, 64 ,, | ,, ,, 54 ,, | ,, ,, ,, 52 ,, |
| | | Cold Test—Not higher than 5° F. | Cold Test—Not higher than 5° F. |

**Note.**—The Works will be pleased to advise in any case where operating conditions are particularly arduous or where temperature conditions are not covered by the above table, as for instance severe tropical and arctic conditions where oils heavier and lighter respectively than those quoted above should be used.

PREPARATIONS FOR STARTING—*continued.*

29. **Lubrication Oil Pressure.**—The pressure gauge should read not less than 35 lb./sq. in. at 800 r.p.m. for Industrial type ; at 900 r.p.m. for Marine type, and at 1,200 r.p.m. for rail traction types. If the pressures shown on the gauge are more than 5 lb./sq. in. less than the above, stop the engine and investigate. Do not run any engine with the pressure less than 25 lb./sq. in. See paras. 51 to 53.

**Note.**—When a cold engine is started, a higher pressure than the above will be recorded, due to the higher viscosity of the oil.

30. **Lubrication Oil Pressure.**—After starting the engine, an interval of ten to fifteen seconds is necessary for the pipe and filter system to become filled by the lubrication pump, consequently, during this interval the gauge will not be expected to record any pressure.

31. **Water Circulation Pump** (Centrifugal Type).—See that the grease cup of the gland is fully charged with a good quality ball-bearing grease and before starting give two or three turns to the greaser.

32. **Liquid Fuels.**—The following is a laboratory specification of a typical example of the type of Fuel Oil which should be used in these engines. Whilst a selected fuel may conform to these figures, before it is finally approved it should be the subject of an actual trial in an engine.

| | | |
|---|---|---|
| Specific Gravity at 60° F. | Not exceeding .. .. .. | ·850 |
| Initial Boiling Point | ,, ,, .. .. .. | 180° C. |
| Distillation Test | Not less than | 85% at 350° C. |
| Flash Point (Pensky-Martin) | ,, ,, ,, .. .. .. | 170° F. |
| Viscosity Redwood No. 1 at 100° F. | Not exceeding .. .. .. | 45 secs. |
| Sulphur | ,, ,, .. .. .. | ·7% |
| Ash | ,, ,, .. .. .. | ·01% |
| Water | To be free from visible water. | |
| Calorific Value : B.Th.U./lb. .. .. .. .. .. .. .. .. | | 19,400 |

**Note.**—Paraffin, as used in lamps and heating appliances, is an excellent fuel, having a high ignition quality, and, therefore, particularly suitable under conditions of extreme cold, but, if blended for use in spark ignition engines, is unsuitable for compression ignition engines, since it has low ignition quality.

32·0. **Ignition quality**.—This is an extremely important factor. An accepted criterion of ignition quality of a Diesel Fuel is its Cetane Value expressed as a number.

The majority of good quality fuels in use have a Cetane Value of not less than 57 and it is desirable that the Cetane Value of the fuel used should not be less than this figure and should not in any case fall below 52. Other figures in use are the Cetene and Diesel Index Numbers. These are always several points higher than the Cetane Number for any given fuel. The above figures if quoted in Cetene and Diesel Index Numbers are :—

Cetane 57—Cetene 65—Diesel Index 62

Cetane 52—Cetene 60—Diesel Index 56

Generally speaking, the higher the ignition quality, the better will be the startability, operation and general maintenance of the engine.

Fuels corresponding to the above specification are readily obtainable and are supplied by :—

Anglo-American Oil Co. Ltd.

Shell Mex & B.P. Ltd. and Overseas Branches of the Shell Organisation, and others.

PREPARATIONS FOR STARTING—*continued.*

32·1 **Lubricating Oil Additions to Fuel.**—It is permissible for a small quantity of lubricating oil, up to a maximum of 2%, to be added to the fuel. If paraffin is used as a fuel, this addition of lubricating oil is desirable. Used sump oil may be employed, disposing of it usefully in this way. It must be allowed to stand for a few days so that carbon and solid matter may settle, the oil then being drawn from near the top of the container. Periodically the container must be drained, to remove the accumulating sediment. Alternatively, the used oil may be cleaned by filtering or centrifuging. Whichever method is employed, cleanliness is essential.

33. **To Prime the Fuel System.**—It is here assumed that arrangements have been made to supply fuel to the injection pumps by any of the following means :—

(*a*) Gravity Feed Tank.
(*b*) SU. Electric Petrolift Fuel Pump.
(*c*) Amal Fuel Lift Pump and Gardner Patent Overflow return system. Fig. 12 and para. 116.
(*d*) SU. Electric Diaphragm Pump and Gardner Patent Overflow return system.
(*e*) Auto. Pulse Pump and Gardner Patent Overflow return system.

It is necessary now in a new installation and desirable after dismantling the pipe system for any reason to allow a copious amount of fuel to wash through the pipes in order to clear them of any foreign matter and to rid the system of air.

**Note.**—For systems incorporating the Amal Fuel Lift Pump and Gardner Overflow Return, delivery of fuel for the following steps is obtained by hand operation of the Lift Pump Priming Lever.

The engine should be rotated by hand into a position at which it is felt that the Priming Lever imparts maximum stroke to the Lift Pump.

**Step No. 1.** Unscrew the aluminium air chamber from the injection pumps and allow a flush of fuel to emerge from the orifice ; then replace the air chamber.

**Step No. 2.** Slacken the special vent screws and allow a further flush of fuel to emerge, then re-tighten the vent screws.

It may be necessary to repeat this step, while the engine is running, owing to liberation of further air from the fuel.

After this operation it will be found that the Priming Lever of the Amal Lift Pump (if fitted) ceases to operate the Pump, after the first or second stroke. This indicates that the system is fully primed up to the elements of the Injection Pump.

The delivery valve holders (union stocks) should not be disturbed as this may move the plunger barrels and so interfere with the calibration of the pump.

**Step No. 3.** Uncouple the unions of the Sprayer Pipes on the Pumps. Taking each pump in turn, work the priming lever until fuel emerges from the unions without the slightest trace of air bubbles. This completes the priming of the system up to the summit of the pumps. Recouple the Sprayer Pipe unions and tighten firmly.

PREPARATIONS FOR STARTING—*continued.*

**Step No. 4.** Work each priming lever until the elastic feeling, if any, has vanished, that is, until a " solid feel " is obtained. This completes the operation of priming. The object of Step No. 4 is to clear out the air from the sprayer pipes. Each stroke of the priming lever forces some of the imprisoned air through the sprayer into the cylinder. When the last vestige of air has been forced out, the " feel " of the lever suddenly becomes " solid." It is important to cease working the priming levers as soon as the " solid feeling " is attained, otherwise, one is liable to inject a harmful amount of fuel into the cylinders.

**Caution.**—Do not inject fuel into the cylinders by means of the priming levers.

34. **Sprayer Pipe Connections.**—After the preceding priming operations are complete, make quite sure that the union nuts of the sprayer pipes are tight, particularly at the sprayer end, because any leakage from these unions would fall into the crankcase and contaminate the lubrication oil. This, by the way, applies equally to the unions on the drain pipes of the sprayers. It is easy to inspect for leakage, all that is necessary is to remove the valve chamber covers one at a time, while the engine is running and wipe the said unions dry. If there be any leak it shows itself at once on the top face of the sprayer bodies.

**Note.—It is of the utmost importance to avoid such leakage.**

35. **Lifting Eye-Bolts.**—For convenience of lifting the engine, certain of the nuts which bolt down the cylinder head are temporarily replaced by eye-nuts. Before attempting to run the engine, see that these eye-nuts are removed and replaced with the permanent nuts which will be found attached to their respective studs.

## STARTING BY HAND FROM " ALL COLD."

The six cylinder L3 engine is the largest of the series which it is practicable to start by hand. The 8L3 engine requires either compressed air or electric starting. It is opportune to mention that when an engine is fitted with a very light flywheel as is often the case in a rail traction engine, where maximum acceleration is desirable, the ability to hand start has to be sacrificed.

36. **Step No. 1.** Turn the stopping cam upwards as far as it will go.

**Step No. 2.** Press up the maximum fuel plunger as far as it will go : this will release the fuel pump slider bar and allow it to move towards the flywheel. If it be sluggish in sliding, help it by pressing on the governor lever.

**Step No. 3.** Turn up all the starting levers to the horizontal for decompression. (Fig. 3.)

**Step No. 4.** Crank smartly round the starting handle.

**Step No. 5.** When maximum speed is attained, turn up quickly any one (the nearest, preferably) of the starting levers as far as it will go, for maximum compression : this cylinder should immediately give power.

**Step No. 6.** Turn up the remaining starting levers : all cylinders will now be at work.

STARTING—*continued.*

**Step No. 7.** Turn all the starting levers vertically downward into the final running position This completes the operation of starting.

**Note.**—Only when conditions are extremely cold is it necessary to use the maximum compression position of the starting levers. Under normal conditions they may be turned direct from " decompression " to " running position."

## HAND STARTING A WARM ENGINE

37. Proceed as in para. 36 but omit Step No. 2, and do not use maximum compression position of the starting levers.

## TO START BY COMPRESSED AIR.

37·1. The minimum air pressure required to start from cold is approximately 220 lb./sq. in., when hot this figure may be reduced to 160 lb./sq. in.

**Step No. 1.** Decompress all cylinders. (Fig. 3.)

**Step No. 2.** Bar the flywheel round until any one of the lines marked " Air Start No..." is at the top, *i.e.*, in line with the white mark on the aft end of the crankcase. In a 3 or 5 cylinder engine the cylinder which corresponds to the number on the air start line must be on its firing stroke, this can be ascertained by feeling which fuel pump ram is lifted by means of the fuel pump priming lever. *E.g.*, suppose that in a five cylinder engine air start No. 3 has been turned to the top, then if this cylinder is on its firing (correct) stroke, No. 3 fuel pump priming lever should have a lot of free movement. If not, No. 3 cylinder is not on its correct stroke for starting. The flywheel must be barred round one complete revolution until the air start No. 3 line is again opposite the white mark on top of the crankcase.

**Step No. 3.** Put all decompression levers into running position (Fig. 3), [unless extremely cold weather, when they should be turned to " Maximum " (Fig. 3) position].

**Step No. 4.** Turn the stopping cam upwards as far as it will go.

**Step No. 5.** If engine is cold lift the starting fuel plunger (Figs. 11 and 12) to allow the fuel pump slider bar to move to its maximum towards the flywheel.

If the engine is warm it is unnecessary to lift the starting fuel plunger.

**Step No. 6.** Undo the locking screw (Fig. 14) on the air covering valve which is situated at the aft end of the crankcase.

STARTING—*continued.*

**Step No. 7.** Lift the covering valve by means of the air starting lever (Fig. 14) as far as it will go. The crankshaft will now revolve, and after about one revolution the engine will start. Immediately release the starting lever. If the decompression levers have been turned to maximum compression they must at once be turned downwards to running position.

**Step No. 8.** Screw down the covering valve. On the air supply 'bus pipe is fitted a small vent cock. This cock should be left open when engine is running to relieve the air pressure on the starting valve stems and so permit of their lubrication.

## AIR CHARGING.

37·2 On each engine which is equipped with air starting there is one cylinder to which is fitted a charging valve. The maximum pressure to which air can be charged satisfactorily by this method is 260 lb./sq. in. To charge the air receiver proceed as follows :—

**Step No. 1.** Set the engine running light (without any load) at a speed of about 600 or 700 r.p.m., or about twice the idling speed.

**Step No. 2.** Stop the fuel injection to whichever cylinder is fitted with the charging valve (this varies according to the number of cylinders an engine possesses) by pulling back the fuel pump priming lever and latching in this position. This in effect merely turns the cylinder in question into an air compressor.

**Step No. 3.** Undo the screw down valve (Fig. 14) on the pipe from the charging valve.

**Step No. 4.** Unscrew the charging valve about two turns. The air receiver will now be charging. It is not advisable to use the charging valve for periods longer than five to six minutes at a time, as over-heating will occur. After five or six minutes the charging valve should be screwed up and the valve on the pipe closed until the pipe and valve have cooled, when charging may be continued. This procedure will only be found necessary when large quantities of air have to be stored as in the case of the initial charging of the receiver, or, if all the stored air has been inadvertently lost.

Under no circumstances must the air charging valve be operated without first cutting off the fuel injection to the cylinder to which the charging valve is fitted. If attempt is made to charge the air receiver with fuel still being injected into the cylinder, serious damage will result, apart from the grave risk of an explosion.

37·3. **Air Charging Valve Gland.**—In this valve is incorporated a gland which will require adjustment from time to time. After long use the gland may even require repacking, in which case a heat resisting asbestos and graphite type of packing should be used.

## TO START BY ELECTRIC STARTER MOTOR.

37·4. **Step No. 1.** Make sure that all cylinders are on full compression (Fig. 3) or maximum compression (Fig. 3) if conditions are extremely cold.

STARTING—*continued.*

**Step No. 2.** Turn the stopping cam upwards as far as it will go.

**Step No. 3.** If engine is cold lift the starting fuel plunger to allow the fuel pump slider bar to move to its maximum towards the flywheel.

If the engine is warm it is unnecessary to lift this plunger.

**Step No. 4.** Press the starter button, the crankshaft will commence to revolve, and after the first or second compression the engine will start. Immediately release the starter button.

## AFTER STARTING.

38. **After Starting.**—See that the circulation pump and lubrication pump are operative and that the pressure gauge of the latter registers the pressure quoted in para. 9, if not, shut down at once and investigate : probably the suction pipe from the foot valve to the pump will need re-priming.

39. **After Starting,** the engine is at once able and ready to take up full load, but a careful engineer will recognise that, in all heat engines, it is better practice to apply the load as gradually as circumstances will permit, especially after starting from cold, in order that the internal parts may become heated gradually and so expand gradually, and to permit the lubrication system to assume proper circulation.

## STOPPING THE ENGINE.

40. **To Stop.**—Turn the stopping cam (Fig. 11) downwards as far as it will go : in this position the fuel pumps immediately cease to inject fuel and so the engine stops.

41. When the engine stops, the flow of circulation water naturally stops : it is therefore recommended that the engine be allowed to run light for a minute or two just before stopping.

42. The engine may also be stopped by pulling forward all the pump handles to engage with the lifting latches. This puts the pump rams out of action with the cams, but, of course, the use of the stopping lever is obviously preferable, and should always be used except under emergency conditions.

43. On no account should the engine be stopped by turning off the fuel supply, because this would empty all the fuel pipes and so would necessitate re-priming of the whole fuel system before the next start.

44. It is neither necessary nor advisable to turn off the fuel supply when the engine is standing idle.

## GENERAL OPERATIONS AND MAINTENANCE.

45. **Lubrication System.**—The lubrication system of any internal combustion engine is of such importance that we would impress upon the users of our engines the necessity of exercising every care in rigorously following the recommendation and instructions set forth hereunder.

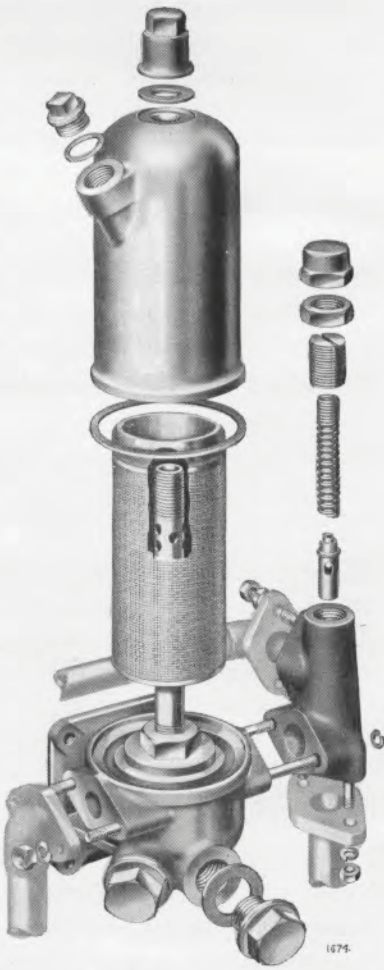
STARTING—*continued.*

46. **Suitable Oil,** as mentioned in para. 28, can be obtained from any of the well-known makers, and should approximate to the viscosities mentioned in para. 28. If any doubt should exist as to the suitability of any oil, we are always pleased to test a sample and report upon it. See also para. 51·1.

47. **The Lubrication System** is such that the whole of the working parts of the engine are automatically lubricated from the main pressure system which is maintained by a gear pump (Fig. 11) carried by the fuel cam box immediately adjacent to the crankcase. The pump is driven by a vertical shaft from the fuel camshaft. The oil is delivered from the pump to the delivery filter (Fig. 12) and pressure regulator. It now passes into the feed pipes of the main bearings and thence, by drilled passages, to the crank pins and gudgeon pins. From the same pressure system, oil is fed under pressure to the valve gear in the cylinder heads. The surplus oil rejected by the pressure regulator is separately circulated through the governor unit, the fuel injection pump cams, the tappet mechanism, and finally through the main timing drive of the valve camshaft. This surplus oil pipe is situated on the near side of an external to the engine. It runs along the base of the cylinders from the pressure regulator to the casing of the main drive. This pipe should be dismantled and examined for signs of stoppage every 1,500 hours see paras. 113 and 114. It is of interest to note that the oil pump is of such large capacity that approximately 50% of the output from the pump is surplus, and this ensures of the copious lubrication of the timing chain, etc., in addition to allowing for wear in the bearings.

48. **Delivery Filter.**—As will be seen, this unit is situated on the near side of the crankcase at the flywheel end (Fig. 12). It is of very simple yet special construction, comprising a vertical cylinder in which is a special gauze element instantly detachable by removing the filter cover which is secured by a single nut. In the base of this unit is a sludge sump, provided with a proper plug for drawing away any foreign matter extracted by the filter element. The whole of the lubrication oil passes through this filter before going to its work, so that it is of the greatest importance that the filter be kept clean as in the next paragraph.

49. **Delivery Filter, Cleaning of.**—This unit **must** be thoroughly cleaned after every 100 hours. To this end, first remove the drain plug (Fig. 12) of the sludge sump and so drain away the contents. Next remove the filter cover, take out the gauze element and wash it thoroughly in clean paraffin or fuel oil.



TYPICAL DELIVERY FILTER **Fig. 5**

GENERAL OPERATIONS AND MAINTENANCE—*continued.*

49·1 After decarbonising or otherwise disturbing the engine an increased collection will be found on the gauze. Anticipate this by early and frequent inspection.

50. **Delivery Filter. Reassembling.**—In doing this, it is recommended that the cover of the filter be gently rotated upon the face joint in order to minimise the chance of any foreign matter causing a leak. It is recommended also to replenish the filter with clean oil through the orifice closed by the square headed plug.

50·1 **Suction Filter.**—This is situated in the oil sump (Figs. 4 and 13), and can be removed by reaching down to it with the arm through the crankcase door on the exhaust and air manifold side of the engine. The filter is on the centre line of the suction flange which can be seen on the outside and near the bottom of the sump on the fuel pump side of the engine. This enables one to select the correct crankcase door to remove for access to the filter, which should be taken out and cleaned each time the sump is drained.

The filter itself is a shallow rectangular box, the open and lower side of which is covered with gauze. At one end of the strainer a spherical ended pipe projects, and has a certain amount of free movement to slide in and out. On this pipe is a spring and collar which holds the pipe in an extended position. At the end of the strainer remote from the pipe, a small spherical ended peg projects. The pipe end fits in the countersunk opening of the suction pipe hole in the sump. The peg engages with a small countersink in the opposite side of the sump.

From the foregoing it will be seen that to remove the filter it will have to be pushed towards the fuel pump side of the engine to release the peg from its countersink ; this end of the strainer can now be lifted up and the strainer withdrawn from the sump. When refitting, the pipe must be entered in its countersink first, the spring compressed, and then the peg entered in its countersink. The above will be more readily understood if reference is made to Fig. 4.

When refitting the suction strainer make absolutely certain that the gauze faces downwards and that both the spherical end pipe and peg are seated properly.

51. **Pressure Regulation Valve** (Fig. 12).—The function of this unit is to maintain within certain limits the pressure of oil in the lubrication system. It consists of a spring-loaded valve. The correct amount of spring-loading is effected by an adjusting screw. It will be easily understood that varying the spring-load will correspondingly vary the pressure at which the valve permits the surplus oil to escape through the surplus oil pipe described in para. 47.

The adjusting screw is set during test to the pressure indicated in para. 9 with lubrication oil at a temperature of about 135° F. It is well to mention here that in certain installations, or until the engine has attained maximum working temperature, the oil in the sump may not attain so high a temperature as 135° F., consequently, the pressure recorded may be about 2 lb./sq. in. higher than mentioned above. Therefore if this regulation valve be dismantled for any reason it should be re-set to give 37 lb./sq. in. at 800 r.p.m., at 900 r.p.m. or at 1,200 r.p.m. as the case may be when the engine is thoroughly warmed.

A useful guide to the setting of the adjusting screw during test is to count and record the number of screw threads that stand above the hexagon locknut. This, of course, should be done before dismantling.

GENERAL OPERATIONS AND MAINTENANCE—*continued.*

If correctly counted, this should prove a useful aid when reassembling. On no account should the engine be run if the oil pressure is less than 25 lb./sq. in.

51·1 **Lubricating Oil Temperature.**—Just as in some installations the lubricating oil temperature may not rise above 135° F., in others it may rise very considerably above this figure. A safe maximum is about 145° F. An engine should not be run with the sump temperature higher than this. It is only possible to fit a water jacketed oil cooler on a marine engine, as usually only in this case is the water of sufficiently low temperature to be effective, and it is most unlikely that the oil temperature in these engines will rise anywhere near the above maximum.

In some stationary installations the problem is somewhat different, and if the oil tends to rise to or above the maximum of 145° F., endeavours should be made to create a draught about the engine either by doors or windows in the engine room, or even a small fan to circulate air around the oil sump.

Should the oil temperature in a rail traction engine rise to 145° F., the engine casing should be adequately ventilated and full use made for this purpose of the draught created by the motion of the car or locomotive. Should there be difficulty, in spite of the above, in keeping the oil temperature below 145° F., an oil radiator should be fitted. The Works will be pleased to make recommendations for this purpose.

The oil temperature may be recorded by inserting a thermometer into the oil, access to which may be obtained by way of the oil level dipstick hole ; alternatively, this temperature can be ascertained by fitting to the lubricating oil strainer filling plug (Fig. 12) a thermometer similar to that fitted to the water outlet.
In conclusion, we would emphasise that the value of a draught around the engine is very great and often avoids costly and complicated oil cooling systems, also it is very beneficial for the air drawn into the engine to be as cool as possible.

52. **Oil Pressure Too Low. Possible Causes.**

(1) Delivery filter requires cleaning.

(2) Foreign matter under the seat of the pressure regulation valve.

(3) Fracture of the spring of the regulation valve.

(4) Sprayer pipe unions slack or pipe broken allowing fuel to reach the crankcase.

(5) The gauze filter in the sump is choked by sludge deposit.

(6) Shortage of oil in the sump.

(7) A pipe fracture somewhere in the system.

(8) Worn bearings.

(9) Bearing failure.

(10) Defective pressure gauge or stoppage in the pipe line.

GENERAL OPERATIONS AND MAINTENANCE—*continued.*

53. **To Remedy the Above Defects.**

(1) Dismantle, clean and reassemble as in paras. 49 and 50.

(2) If foreign matter prevents the proper seating of the regulation valve, this is usually indicated by the pressure gauge recording normal pressure when the engine is running at maximum r.p.m. and too low a pressure at slow speeds. Sometimes a light tap on the body of this unit suffices to dislodge the obstruction ; if not, the valve should be withdrawn, wiped clean and replaced, making the correct spring-load adjustment as described in para. 51.

(3) Replace with spare spring.

(4) Drain the crankcase sump and replace with new oil of the correct grade. In any case, this operation should be carried out after about every 500 hours. See para. 54.

(5) Remove and clean the suction filter and read para. 49.

(6) The oil level in the sump should not be allowed to fall below the minimum mark on the dipper rod, nor, in passing, should it be allowed to rise above the maximum mark. Read para. 23.

**Note.**—If the small oil pipe from main bearing oil feed pipe (Fig. 16) is led to the pressure gauge on the instrument panel or bulkhead, it is important to secure the pipe from all vibration and consequent possible fracture, and use the flexible pipe provided with the engine to the best advantage, *i.e.*, it should be fitted between the first fixing clip on chassis or bulkhead and the engine, or, expressed in another way, the flexible pipe should be used so as to accommodate any movement there may be between the engine and chassis, or between engine and hull.

54. **Crankcase Sump. Renewal of Lubrication Oil.**—It is recommended that the sump oil be completely drained after periods of about 500 hours. This should be done after a long run while the oil is warm and fluid. It is not recommended to wash out the sump or crankcase with paraffin as this is liable to disturb particles which might re-enter the lubrication system.

As the duty of an engine has considerable bearing on the desirable length of time between renewal of sump oil, the Works will be pleased to report on any samples of used oils which are submitted, and make recommendations as to whether it is fit for further use or has already been used for a longer period than is desirable.

By this means it will be possible to arrive at the most economical periods between sump oil renewal.

If advantage is taken of this offer please supply the following information :—

(1) Make and grade of the oil. If possible send also a sample of the oil before it was used in the engine.

(2) Number of hours (or miles) for which the oil has been in use.

55 **Gauging the Sump Oil Level.**—This is described in para. 23.

56. **Correct Oil Level.**—This is indicated on the dip rod which shows the minimum level at which it is safe to run the engine. The maximum level is also shown on the dip rod. This is the level to which the sump should be charged and also the level which should be maintained.

GENERAL OPERATIONS AND MAINTENANCE—*continued.*

57. **Oil Filler Box.**—This is mounted on one of the crankcase doors on the fuel pump side of the engine (Fig. 12). The filler box opening to the crankcase is protected by a diaphragm in the form of a gauze filter. The sump is charged through the mouth of the filler. If, when charging, the oil does not flow freely, it will probably be found that the gauze diaphragm needs cleaning, which is readily done after removing the filler box from the crankcase.

58. **Fuel System. Filters.**—Each engine is furnished with two fuel filters, a first filter and a second filter as described in para. 7. The first filter is placed in circuit between the fuel tank and the second filter, due regard being paid when fixing to its accessibility for cleaning. The second filter is permanently attached to the head of No. 1 cylinder.

59. **Fuel Filters.**—These are readily opened and contain an inner and an outer element (Fig. 2) which are removable for cleaning. Both filters are provided with a sump fitted with a drain cock and in gravity feed systems, the second filter is provided with an air vent.

59·1. **Testing Fuel Filters for Stoppage.**—We have had certain fuels through our hands which have shown a tendency to choke both the inner and outer elements. This, of course, necessitates the removal of both for cleaning purposes. Sometimes it is impossible to remove the obstruction, and it is then necessary to renew the elements or re-cover them with copper or monel metal cloth. This chokage is more liable to take place in cold weather, and therefore more particularly to the first filter which is usually fitted on the chassis frame in an exposed position. A more suitable place for this unit is low down on the dashboard under the bonnet where it may derive some heat from the engine.

The filter elements can be tested for obstruction, either by uncoupling the feed pipe from the filter to the fuel pump, and observing the flow, or, alternatively : take the filter elements one at a time, and hold in a vertical position, open end uppermost, close the small hole in the bottom with the finger and pour fuel oil into the element. If fuel collects and does not run through the gauze almost as quickly as it is poured in, the filter is probably choked sufficiently to cause erratic running if not complete stoppage of the engine. Our experience tells us that a large percentage of service calls are due to choked or partially choked supply. Therefore, we recommend the user to make quite sure that a copious flow is obtainable beyond all filters.

60. **Cleaning of Fuel Filters and Re-Covering.**—The frequency of this operation depends among other things on the type and quantity of the fuel used. It is recommended that the outer elemen in each filter be taken out and examined after 100 hours and replaced if it be found to be almost free from foreign matter. Then re-examine after, say, 300 hours ; if it is still found to be clean, the interval can be further increased. Repeated examination will show the user when cleaning becomes really necessary. When cleaning the elements,

GENERAL OPERATIONS AND MAINTENANCE—*continued.*

it is not possible to be quite sure that particles of foreign matter do not get into circulation, therefore, the idea intended to be conveyed by this paragraph is for the user to find by inspection how seldom he may, with safety, clean the elements. Spare elements are supplied with each engine.

The gauze elements are most conveniently cleaned by brushing them in clean fuel-oil or paraffin. If brushing fails to make the elements pass the tests mentioned in para. 59·1, they should be re-covered by four layers of metal cloth of the following mesh. First one layer of 50's, on top of this, two layers of 140's, and finally the last and outer layer of 80's mesh. Both inner and outer elements have the same covering. If the elements are returned to us or any of our service depots this work will be carried out promptly and at a nominal charge by a system of exchange.

61. **When Replacing the Filter Covers** gently rotate them on their joint faces so as to minimise the chance of foreign matter causing an unsound joint. Do not use a spanner or hammer to tighten the nut on the cover : hand tightening is all that is needed.

62. **Fuel Filters. After every 100 hours.**

(1) Open the vent cock (Fig. 11), if fitted on the second filter in order to make sure that the filter is full of fuel oil.

(2) Open the drain cock (Fig. 11) of the filter sumps in order to draw off any water or sediment.

63. **Fuel Sprayer.** — This is described in para. 5. Efficient running of the engine depends very largely upon the perfect working of the sprayers. They should be withdrawn every 500 hours and the carbon deposit, if any, wiped from around the jet holes, at the same time making sure that the needle valves do not leak and that each jet hole in the nozzle is delivering the same amount and form of spray, also that none of the jet holes is stopped up. It should be noted that some fuels, more than others, possess the characteristic of forming this deposit around the jet holes. The nature of duty performed by the engine can also have an effect on this. If an engine continues to operate with a clean exhaust this period of 500 hours may be exceeded.

64. **To Test for Stoppage of the Jet-Holes.**—Remove the sprayer from the cylinder head and re-connect with its sprayer pipe in such a position that the fuel jets are visible while the hand lever of the pump is being worked by hand. See Fig. 7. The jets of fuel emitted from the jet-holes should all travel the same distance and should appear alike.

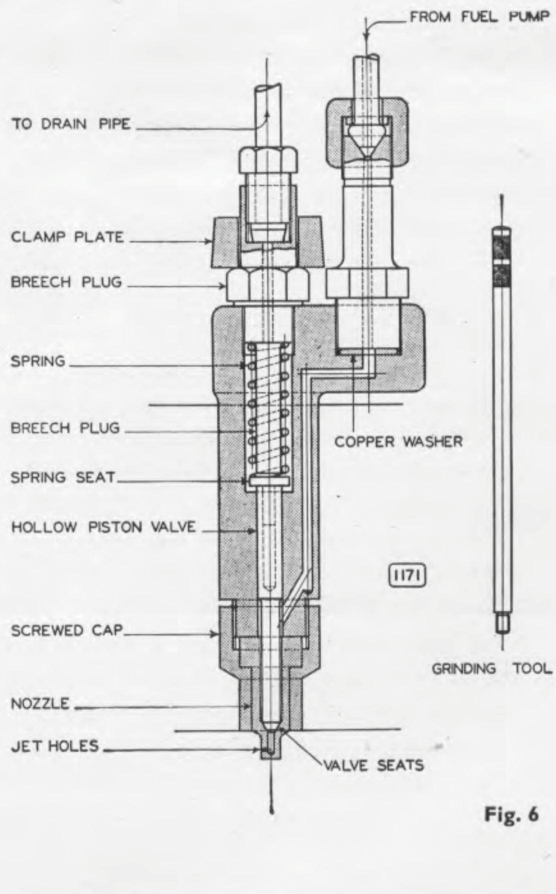


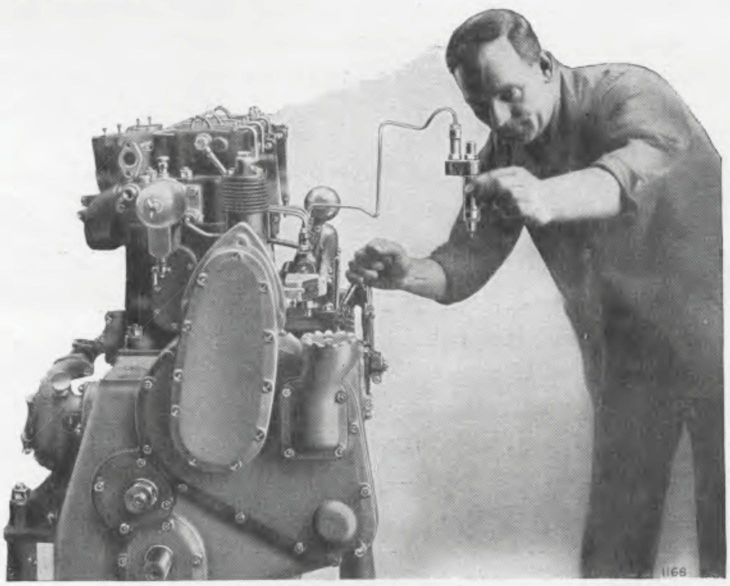

Fig. 6

GENERAL OPERATIONS AND MAINTENANCE—*continued.*

If they do not, take the sprayer to pieces and prick and clear the jet-holes by means of the prickers supplied with the engine, and at the same time clear out the central bore of the nozzle. The size of these jets **is of the utmost importance,** therefore it is imperative that prickers of the correct diameter be used. In case of loss or damage of prickers, the makers will be glad to supply new ones at a nominal charge.

65. **To Clean the Sprayer Nozzle.**—Having pricked the jet-holes (from the outside, of course), it will be realised that any obstruction so removed will fall into the central bore. Obviously, the only effective way of cleaning the central bore is to force a liquid through the jet-holes **from the outside of the nozzle to the inside,** which is done in the following manner :—

Take the utility syringe supplied with the engine and change the ordinary nozzle in favour of the special one made to fit the sprayer nozzle. (This special nozzle is also supplied with the engine.) Draw into the syringe some clean paraffin and insert the sprayer nozzle into the special syringe nozzle, pressing it in place by the fingers. A pressure now applied to the plunger of the syringe will force a flush of paraffin through the jet-holes and the central bore in a direction opposite to that of the fuel when the sprayer is in work. See Fig. 8.




TESTING A SPRAYER Fig. 7

To repeat, it is obviously futile to attempt to clear the central bore by flushing through in the same direction as the fuel flow when the sprayer is in work.

66. **To Test for Leak of Sprayer Valve.**—Remove the sprayer from the engine and recouple it to its sprayer pipe as directed in para. 64 with both unions tight. Give the fuel pump handle a few strokes in order to expel all air from the sprayer. Now press on the pump handle with a force just short of that required to lift the sprayer valve from its seat. If the valve be unsound, fuel will emerge from the jet-holes and run down the nozzle. A certain amount of leak is inevitable in the best of valve seats. (See Fig. 7.)

The following will be a useful guide : If, when pressing on the pump handle with about one-half of the force necessary to lift the sprayer valve from its seat, no more than two drops per minute fall from the sprayer nozzle, the valve seats may be passed as being sound.

When the priming levers are worked rapidly a sprayer valve and seating in reasonable condition, will make a noise due to rapid opening and closing of the valve. This noise can be described as a squeak, and sprayers will vary considerably in this characteristic. It should be noted that sprayers which make most noise are not of necessity better than those which make only a moderate noise.

GENERAL OPERATIONS AND MAINTENANCE—*continued.*

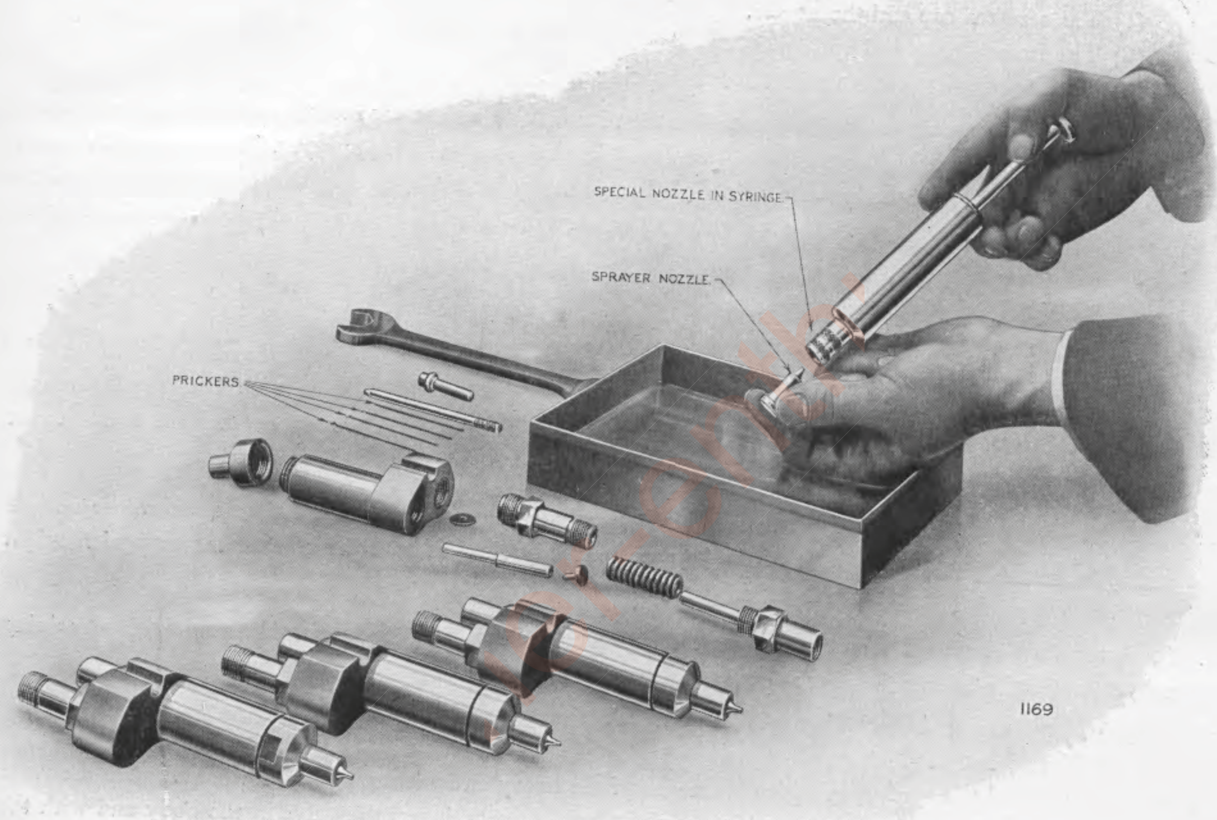



**Fig. 8**

66·1 **To Check Sprayer Valve Spring.**—It is very unusual for this spring ever to require any attention. When compressed to 1·320 in. long it should exert a load of 60 lb. If a spring has " sunk " so that the load measured as above is less than 56 lb., thin packing washers or shims may be inserted at the top end of the spring until the required load is obtained.

67. **To Correct a Leaking Valve.**—Remove the sprayer from the engine and screw off the cap nut which retains the sprayer nozzle. Examine minutely the valve seat on both the nozzle and the piston for dirt or anything which may prevent the proper seating of the valve faces. Whether or not any obstruction has been found, wash the parts in paraffin and replace without wiping, assembling the parts so that the nozzle is in correct alignment with the valve as instructed in para. 69. If, on further trial, the valve be still defective, the seats may require grinding in, but grinding should be done only as a last resource, and as seldom as ever possible.

GENERAL OPERATIONS AND MAINTENANCE—*continued.*

68. **To Grind the Sprayer Valve Seats.**—Take the sprayer to pieces in the following order :—

(1) The screwed cap and the nozzle.
(2) The breech plug and spring.
(3) The hollow piston valve with the small spring seat.

Remove the spring seat from the hollow end of the piston valve and screw into the hollow end the knurled grinding tool supplied with the engine and replace the piston valve in the sprayer. Then smear the valve seat **with the most minute possible dab of flour emery and oil, taking the utmost care that no emery gets anywhere but on the valve seat, otherwise it will destroy the close fit which is so essential for the piston.**

Hold the sprayer nozzle, with finger and thumb, up against the end of the sprayer body. Apply very light end load to the sprayer valve and slowly rotate both valve and nozzle in opposite directions.

The absolute minimum of grinding should be performed, as excessive grinding will seriously damage both valve and seat. This will be realised readily when it is understood that the best seat is formed by little more than line contact and that the more a valve is ground into its nozzle the wider becomes the seat. A seat which has become too wide is very prone to leak and can be rectified only by the makers.

69. **Screwed Cap and Nozzle.**—Before assembling after grinding or after examination, see that the outside surface of the nozzle and the bore of the cap are perfectly clear of carbon or other matter which might interfere with the alignment mentioned in para. 70.

70. **To Assemble Sprayer.** Wash every part scrupulously clean with clean paraffin, and without wiping reassemble in the following order :—

(1) Piston valve with grinding spindle attached.
(2) Nozzle and cap.
(2) (*a*) Hold the sprayer in a vice by means of the heavy end with the body horizontal, take the valve with grinding spindle attached in the right hand fingers, insert the valve in the body and with the left hand fingers on the cap nut gently tap the valve on the nozzle seat, gradually tightening the cap nut from slack to finger tight. This action will be found to align the nozzle with the valve. If correct alignment is obtained the valve will be perfectly free to be lifted from the seat. If incorrect alignment is obtained the valve will be found to stick in the seat. Finally, tighten the cap nut with spanner and re-check. This instruction is of the utmost importance.
(3) Spring pad.
(4) Spring and breech plug.

71. **Reconditioning of Sprayers.**—If all the preceding instructions fail to enable the mechanic to correct the sprayers we strongly recommend that they be sent to our works for re-conditioning which will be carried out at the least possible expense to the customer.

71·1 **Service Sprayers.**—We are very strongly in favour of an operator having a spare set of sprayers to enable him to return those which have had long use to the Works, where they will be exchanged for a thoroughly reconditioned set. This work is carried out for a small charge, and ensures that the sprayers when returned are equal to new.

GENERAL OPERATIONS AND MAINTENANCE—*continued.*

72. **Lift of Piston Valve.**—This dimension is 0·012, and is very important, therefore, when dismantling sprayers, do them one at a time, so that the parts be kept to their own sprayer bodies and not interchanged with those of another sprayer. This happens to be one of the few cases where interchangeability is not practicable.

73. **Sprayer Pipe Unions.**—It is imperative that these unions do not leak, especially those in the valve gear chambers on the cylinder heads. Please read paragraph 34.

74. **Defective Sprayers.**—If a sprayer is known to be defective, do not run the engine any longer than is absolutely necessary as this will cause undue wear accompanied by other evils.

75. **Replacing a Sprayer in the Cylinder Head.**—The nose of the sprayer body is slightly taper, whereas the hole in which it fits in the cylinder head is parallel, consequently, the space thus left becomes, in the course of time, filled with carbon, which of itself is quite negligible. When, however, the sprayer is withdrawn, it leaves a conical liner of carbon which must be removed before replacing the sprayer ; otherwise the carbon liner is liable to become disturbed and so prevent the sprayer body making a true gas-tight joint on the conical seat. The carbon liner is easily removed by the aid of the fluted reamer supplied with all engines.

76. **Replacing a Sprayer in the Cylinder Head.**—When clamping a sprayer in the cylinder head, do not tighten up the nuts more than is necessary. The feeling of tightening up against the spring of a clamp is very different from that of bolting two surfaces together, and so is liable to deceive the engineer into screwing harder down than is necessary. It requires but comparatively little screw pressure to make a tight joint on the conical seat.

The special box key and short tommy bar, supplied with each engine, should be used to tighten the sprayer clamp nuts.

77. **Routine Cleaning of Sprayers.**—It is an excellent practice to have a complete set of spare sprayers which may be changed every 800 hours. This permits of systematic, leisurely cleaning and examination without loss of running time. If they were returned to the makers they would be examined, cleaned and tested for a merely nominal charge. See para. 71·1.

78. **Withdrawal of Sprayer.**—Should the sprayer have become fast in the cylinder head, there is supplied with each engine special drawing tackle, consisting of a flat bar, passing through which is a screwed rod and nut. The end of the rod should be screwed into the union on the sprayer, the bar set to bridge the top faces of the cylinder head, and the nut screwed down, when the sprayer will be drawn out.

79. **Water Circulation.** Engines, which draw cooling water from large or unlimited supplies or are equipped with a water cooled heat-exchanger, are fitted with ram type pumps for this purpose. (See Figs. 13 and 15.) They are driven through an eccentric and clip from the valve camshaft. On the outward end of the pump body will be found a small vent valve (Fig. 15). This consists of a bronze ball resting on a seat, and limited in lift by a knurled headed screw. The purpose of this valve is to admit a small amount of air together

GENERAL OPERATIONS AND MAINTENANCE—*continued.*

with the water during the suction stroke of the pump and so prevent water hammer. To set the valve correctly the knurled screw should be screwed down as far as it will go (by hand), and then unscrewed approximately quarter of a turn and locked in this position. If the valve is set too wide open too much air will be drawn into the pump and so reduce the amount of water delivered.

Engines which have a " closed " circulation system, *e.g.*, tank or air-cooled radiator, are fitted with a centrifugal type of pump (see paras. 80, 81 and Fig. 16), gear driven, also from the valve camshaft.

79·1 **Operating Temperatures.**—The desirable maximum temperature of the water outlet is 140° F. (60° C.) (see para. 79·2).

79·2 **Water Temperature Control.**—Engines fitted with ram type pumps have a temperature control (Fig. 13) which " Shunts " or " by-passes " warm water from the discharge pipe to the suction pipe of the circulation pump, thus raising the temperature of the water going into the cylinder jackets. It will be readily understood that the by-pass cock serves as a means of controlling, within limits, the temperature of the water in the cylinder jackets and at the point of discharge, which is of special utility when the engine is running at light loads during which the temperature of the discharged water should be maintained at about 130° or 140° F. that is, when it is just about as hot as the hand can momentarily bear.

**Note.**—When starting the engine or idling, it is important that the control cock be closed, otherwise air may get into the circulation pump and interfere with its operation.

On engines fitted with centrifugal water pumps the water temperature is controlled by a thermostat arrangement, which automatically maintains the outlet water at or about 140° F. (60° C.) (provided the radiator, pipes and bonnet ventilation are adequate).

79·3 **Operating under Conditions of Extreme Cold.**

**Closed Fresh Water Cooling Systems.** Under these conditions it is necessary that an " Anti-freeze " preparation, in sufficient quantity to prevent freezing, be added to the cooling water.

A suitable anti-freezing agent is Ethylence Glycol, and this should be used in the following proportions :—

To be safe down to 17° F.—10% by volume.
" " " " " 7° F.—15% " "
" " " " " 3° F.—20% " "

Use only well-known brands since many solutions used for this purpose seriously corrode the cooling system.

**When an Anti-Freeze Agent is not Available, or Open Fresh Water Cooling Systems.**

When an engine has to stand idle for any period sufficiently long for the cooling system to approach freezing point, drain away the water from the system (see para. 81) as soon as possible after stopping the engine, and leave the cocks open until the system is to be refilled. Take precautions to ensure that the engine is not inadvertently put into service with a dry water system.

When filling the water system preparatory to service, use hot water, since the combination of cold water and engine parts below freezing point may generate ice before the heat generated by running the engine is sufficient to prevent this.

GENERAL OPERATIONS AND MAINTENANCE—*continued.*

In the case of radiator cooled sets, the risk of freezing the radiator whilst the engine is running may be greatly minimized by causing all the water circulation to pass through the radiator by removing the thermostat unit from its housing and plugging with cork bung or blank packing the by-pass pipe between the housing and the water pump suction. In addition, aud in order to further reduce the risk of freezing, and to enable the engine to attain a suitable operating temperature, blank off from the bottom upwards 50% or more of the radiator frontal area, until a temperature of 140° F. to 160° F. is attained in service.

79·4 **Marine Ram Type Water Pump Valves and Cup Washers.** These valves which are disc-like in form, are made of a special oil-resisting compound. If, after long use they buckle or become " saucer-shaped " they may be reversed so that what was originally the upper face becomes the lower.

If, in emergency, valves, not of Gardner manufacture have to be used, it is important that they are of the same thickness for which the stop plates were designed ; if they are thicker the edges will turn up when the through bolt is tightened. This, of course, will prevent them from seating.

The cup washers, of which there are two per pump, are fitted back to back.

The design of the ram is such that when the cup washers and distance washers are fitted and the castle nut screwed up, it first of all clamps up the cup washers, etc., and finally tightens up solidly on the brass washers. If this were not done and the nut only tightened up on the cup washers, it would soon become slack and rapidly wear away the thread.

80. **Centrifugal Water Pump. Gland and Greaser.**—This is of the spring loaded carbon gland type, in which the carbon ring is fixed in the pump case and forms a spherical seating for the sealing ring which revolves with the impeller. The impeller spindle is carried on a self-aligning ball bearing which, together with the spherical sealing ring, permits of slight mal-alignment between the pump and its driving member. The only attention which the pump requires is the lubrication of the ball bearing. This should be carried out once a week by two or three turns of the greaser which should be kept filled with a good quality ball bearing grease.

81. **Centrifugal Water Pump—Draining of Cooling System.**—As the pump is exposed and is not in all engine installations automatically drained with the rest of the system, it may be necessary to drain it separately. The drain cock will be found at the lowest point on the pump body and an inspection of the shape of the pipe connecting the pump with the bottom of the radiator will reveal whether or not emptying the radiator will suffice to empty the pump. There is a small drain from the periphery of the water pump body into the pipe and in an installation where the pipe has a continuous fall from pump to radiator, separate draining of the pump may be omitted.

When the pump is dismantled this small drain hole will be found crossing the joint face of the cover to the body and care should be taken to avoid blanking this hole with any packing or jointing used. If the engine installation is such that the engine is inclined rearwards, the water manifold from the water pump to the base of the cylinders will require separate draining by means of the cock provided at the rear end. If water became frozen in the pump it is obvious that serious consequences would follow any attempt to start and run the engine. In order to guard against this contingency so far as it is possible, the diameter of the impeller spindle is reduced for a short length near the driving square so that any undue load will fracture the reduced spindle by twisting and thus prevent more serious consequences in the form of damage to the driving gears. In this event the driving square can be withdrawn from the driving member after the water pump has been removed, by inserting a stud extractor or other implement, into the hole provided for this purpose in the centre of the square. A piece of wire or wood screw may also be effectively used.

82. **Centrifugal Water Pump.—Service.** Spare parts for the water pump may be obtained at our Service Depots and the Works. The Works can also supply complete service pumps when required.
Special tools are used for the fitting of impellers to the spindles. For this reason impellers and spindles cannot be supplied separately.
When fitting a new impeller and spindle the sealing faces of the carbon gland and impeller should be lightly lapped together with pumice powder and water.
Should it become necessary to replace the carbon gland it is desirable that the pump be returned to the works as a special tool is necessary for this purpose. Under certain circumstances this procedure may be impracticable, in which case we will be pleased to supply the necessary tool and instructions to enable the operator to carry out this work.

83. **Water Circulation.**—Inspection should be made regularly in order to ascertain if circulation be taking place.

83·1 It must be remembered that, in closed systems, circulation does not take place until the temperature rises sufficiently to open the thermostat valve. Above 135° F. it should always be possible to observe this circulation. The operation of the thermostat unit can be readily observed by removing it from its case and raising its temperature when immersed in water. In the event of the thermostat bellows becoming damaged the valve assumes a full open position, so that dangerously high temperatures cannot occur through this cause.

83·2 On engines fitted with the Automatic Temperature Control, it is necessary to inspect the water level a few minutes after filling the water system. This precaution is necessary since there is of necessity only a small air release hole in the thermostat valve.

84. **Cylinder Heads, Water and Oil Joints.**—These are made by a series of small, inexpensive rubber rings. It is good practice to renew them whenever the cylinder heads are removed.

84·1 **Cylinder Water Jacket.**—After lengthy periods of use the water jackets will accumulate a certain amount of sediment, the amount and time taken to accumulate vary considerably according to the condition of the water used for cooling.
In marine engines there is always a likelihood of sand accumulating in the water jacket.
On account of this sediment and sand collecting it is always advisable to observe from time to time that it has not accumulated sufficiently to impede the flow from the water inlet holes near the base of the cylinder. Each time a cylinder is removed from the engine the water jacket should be flushed out from the top.

## GENERAL OPERATIONS AND MAINTENANCE—*continued.*

85. **Cylinder Heads. Removal. Decarbonising.**—In order to obtain the best results from the engine and

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84·2. **Water Jacketed Exhaust Manifolds.**—In this design of water jacketed exhaust manifold, cleaning holes are provided in the lower side of the jacket, for the removal of silt and scale. Means are also provided whereby the manifold sections may be readily dismantled when this is desired.

For cleaning purposes, a piece of $\frac{3}{16}$ in. or $\frac{1}{4}$ in. diameter steel rod suitably bent and worked through the cleaning holes will enable the silt and scale to be loosened sufficiently for flushing away with water.

For dismantling of the sections, it will be found (after removal of the bolts) that the bolt holes in the flanges are tapped $\frac{7}{16}$ in. Wh. to receive jacking screws. These will be found in the standard tool box supplied with each engine.

When dismantling is desired, remove the manifold from the engine and lay it on a flat surface. The bolts and nuts should be removed from each pair of flanges in rotation and replaced by the short set screws in one of the flanges. The jacking screws should then be screwed into the other flange and gradually tightened in diametrically opposed pairs, until the flanges are thus jacked apart.

Transfer of the set screws and jacking screws will enable all the sections to be dismantled in a similar manner.

duty, decarbonising and piston withdrawal may probably not be necessary more frequently than say every 1,200 hours. To repeat, this can only be found by experience. See para. 94. Any ring removed during this operation must be returned to its own groove with the same face upwards as before removal.

86. **To Avoid Damage to the Sprayer Nozzles,** which project from the flat surface of the cylinder head, it is strongly recommended that the sprayers be withdrawn before removing the heads. See para. 78.

87. **Replacing the Inlet Valves.**—These valves are formed with patent deflectors and are prevented from turning round by the specially formed valve collars and split pins. It is **absolutely essential** that the valves be replaced in their correct position, that is, with the deflectors on the same side of the valve spindle as are the manifolds, and they must be definitely positioned by the split pin in the valve collar. To ensure this, the slot for the split pin in the collar and also the pin hole in the valve stem do not pass through the centre line of the valve stem. It will be realised that this device makes it impossible for one to screw the valve into the collar and to thread in the split pin with the valve half a turn wrong.

When the inlet valves are replaced care must be taken to see that there is a minimum clearance of 0·003 in. between the stems and guides. Should the valve stems be a closer fit than this, the guides must be reamered out until the 0·003 in. clearance is obtained.

87·1 **Replacing the Exhaust Valves.**—When the exhaust valves are replaced, care should be taken to see that the carbon is removed from the holes in the guides, and that there is a minimum clearance of 0·004 in. between the stems and guides. Should the valve stems be a closer fit than this the guides must be reamered out until the 0·004 in. clearance is obtained.

GENERAL OPERATIONS AND MAINTENANCE—*continued.*

85. **Cylinder Heads. Removal. Decarbonising.**—In order to obtain the best results from the engine and to maintain it in an efficient and economical state, it is recommended that the heads be lifted off and the valves and other parts cleaned not less frequently than every 800 hours. These intervals have, to our knowledge, commonly been doubled and trebled, but we do not recommend such intervals, because, unless the engines be running under proper conditions, undue wear of parts takes place. Little need be said about the removal of carbon deposits which will be found chiefly in the valve ports ; the deposit on the piston and cylinder heads being of little consequence. The operation of removing the heads is very simple and straightforward. The holding down nuts are accessible by means of the box spanner from the top of the head. Those which cannot be so reached are accessible by an ordinary spanner after removing the small aluminium doors from the near side of the cylinder head.

85·1 **Withdrawal of Pistons and Cleaning Ring Grooves.**—At the same time as the above operation (para. 85) it is recommended that, in the case of a constant load and speed installation, the pistons are withdrawn to examine for piston rings which may have become fast in their grooves. The pistons may be withdrawn by uncoupling the big end bolts, access to which is gained through the crankcase doors, and drawing the piston and connecting rod complete upwards through the cylinder bore. It may be found from experience that the period of 800 hours between these operations (piston withdrawal and decarbonising) may be increased with safety. In any case, for an engine which is used for very varying loads, such as rail traction duty, decarbonising and piston withdrawal may probably not be necessary more frequently than say every 1,200 hours. To repeat, this can only be found by experience. See para. 94. Any ring removed during this operation must be returned to its own groove with the same face upwards as before removal.

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GENERAL OPERATIONS AND MAINTENANCE—*continued.*

88. **Re-fitting Inlet and Exhaust Valve Spring Collars.**—Particular care should be taken to make sure that the spring collars are not screwed further down the valve stems than is necessary to thread in the split pin, otherwise the valves would not have sufficient lift and the operating mechanism would suffer damage. Always use a new pin which should be sprung open previously to prevent movement in service and firmly locked by thoroughly spreading the ends.

89. **Replacing a Cylinder Head.**—The gas joint of head to cylinder liner is made by a metal to metal joint, *i.e.*, there is no joint washer. When replacing a head it is therefore only necessary to see that all the rubber rings are in correct position and that the gas joint faces are absolutely clean and smeared with a little lubricating oil. Screw up all the nuts evenly and a little at a time.

90. **Tappet Clearance.**—After replacing a cylinder or after every 800 hours, adjust, if necessary, the clearance between the toe of the lever and the end of the valve stem. The correct clearance for inlet and exhaust valves is as follows:

| DUTY | MARINE AND STATIONARY ENGINES | RAIL TRACTION ENGINES |
|---|---|---|
| Inlet | ·005″ | ·005″ |
| Exhaust | ·012″ | ·015″ |

When tightening the lock nuts, it is quite unnecessary to use great pressure. The adjustment should always be made with the piston at the top of the compression stroke. To find this position, decompress all the cylinders and turn the flywheel until the inlet valve under consideration just closes, then turn the flywheel a further half turn ; the piston will now be at or near the end of the compression stroke. This position may also be verified by observing the injection pump belonging to the cylinder in question, the priming lever of this pump will show that the pump tappet is in the lifted position. Turn the decompression lever to the running position.

90·1 **Slow Running. Adjustment.** As the speed of these engines is always under the control of the governor, the idling speed which is set by the makers during test remains sensibly the same and does not vary with climatic conditions.

In the case of a rail car or locomotive type of engine, advantage may be taken by the user, of the above mentioned stability, to set the idling speed to such as will give him the smoothest running for his particular case. This adjustment is effected by a knurled screw (Fig. 12) and lock nut adjacent to the accelerator lever.

During test at the Works, the idling speed is set to 350 r.p.m.

Marine engines are set by us during test to idle at their slowest, and no attempt should be made to reduce this speed, which is about 250 r.p.m.

During service it will be found that slight wear in the governor and control mechanism will cause the idling speed to reduce slightly and the running to become erratic. This should be corrected by screwing in the slow running screw. **This adjustment should be the subject of regular inspection.**

90·2 **Accelerator Control (Rail Traction Type Engines only).** This should be inspected from time to time to make sure that the remote control mechanism is working the accelerator lever through its full range, that is, from idling to maximum speed. An inspection of the lever on the accelerator spindle will reveal the limiting stops, the one for idling being the " slow running " screw, while that for maximum speed consists of two $\frac{5}{16}$ in. diameter pegs at the end of the Governor spring lever. Do not under any circumstances alter or interfere with these $\frac{5}{16}$ in. pegs.

GENERAL OPERATIONS AND MAINTENANCE—*continued.*

90·3 **Position of Accelerator Lever** (Fig. 12).—In order that the remote control may be as light as possible, it is necessary to arrange the geometry of the accelerator linkable so that the rods and levers are mutually at an angle of 90° when the accelerator lever is in a position 40° from the idling speed position. This clearly gives the greatest leverage when the greatest effort is required.

90·4 **Advance and Retard of Injection (Rail Traction Type Engines only). Adjustment.**—The accelerator lever being a speed control and not a torque control, is coupled by a connecting rod to the lever of the advance and retard mechanism, consequently, the timing of the moment of injection is varied automatically as the speed of the engine varies. The mechanism consists of a small lever adjacent to the accelerator lever which is coupled by a horizontal, forked-end, connecting rod to the lever of advance and retard mechanism located on the chain case at the forward end of the engine. Should this mechanism become deranged for some reason or other, it is a simple matter to re-adjust it when it is known that the maximum advance mark on the index plate corresponds to the maximum speed position of the accelerator lever. Occasional inspection should be made to see that this position is maintained.

90·5 **Advance and Retard Device (Rail Traction Type Engines only).**—The advance and retard mechanism controls the axial position of a helical gear capable of sliding along the splined camshaft of the injection pumps, consequently, there is a slight reaction of the cams on the mechanism. To provide against this being transmitted to the accelerator lever and so wearing the connecting links, etc., an adjustable friction device is fitted. This consists of a cork washer clamped between the case and the advance pointer lever loaded by a castle nut and a spring washer. See Fig. 13.

This should be inspected every 800 hours, and if, while the engine is idling, the pointer lever is seen or is felt to move slightly backward and forward, the castle nut should be tightened by the minimum amount required to damp out the vibration. If the friction device be over-tightened, it will make the accelerator lever stiff to move and will prevent it returning to the position of slow running. The amount of friction applied in this way can be judged by operating the accelerator lever, but if this be done with the engine stopped, it is necessary to pull back all the priming levers on the injection pump so as to liberate the pump cams from all spring load.

91. **Governor-Control Slider Bar.**—This slider bar (Fig. 12) is operated by the centrifugal governor, and its function is to vary the amount of fuel injected into the cylinders and thus vary the power of the engine. It is connected to the governor lever by the governor-bar connecting link. The effect of moving the slider bar towards the flywheel is to increase the amount of fuel injected into the engine and *vice versa.* If the bar is moved to the full extent towards the timing case, there is no injection. The correct setting of the slider bar with relation to the governor is such that when the governor weights are parted to their full extent by inserting the fingers through the inspection opening in the governor case, the length of the governor-bar connecting link is so adjusted as to give the slider bar a position approximately $\frac{1}{32}$ in. from its maximum stroke towards the timing case. If the link has thus to be adjusted at any time, care should be exercised in seeing that the holes of the joint pins are parallel and that the slider bar moves freely.

GENERAL OPERATIONS AND MAINTENANCE—*continued.*

91·1 **Governor-Control Slider Bar Sticking.**—If at any time the slider bar shows a tendency to stick or only move sluggishly, it may cause the engine to stop when the speed control is moved from full speed to idle.
There are five possible causes for this trouble, as follows :—

(1) The unions on top of the fuel pumps may have been tightened excessively and so distorting the fuel pump elements.

(2) Fracture of one of the fuel pump plunger springs. This should at once be replaced by the spare spring supplied with the engine. For this purpose the pump has to be removed from the engine and the particular plunger withdrawn from the pump. The plunger is retained by a spring circlip or ring which has to be removed before the plunger can be withdrawn.

(3) The idling screw has been unscrewed too far (para. 90·1), so preventing the governor from having control of the speed when the engine is set to idle.

(4) The use of a fuel which has poor lubricating properties, in which case a small quantity of lubricating oil should be mixed with the fuel as recommended in para. 32·1.

91·2 It is of the utmost importance that the governor bar connecting link (Fig. 12) be adjusted as above. Should the link be adjusted to such a length as to leave no clearance in the above position there is a grave risk of the small centre ball race sustaining damage with serious consequences. This will be readily understood when it is realised that the governor weights are provided with a substantial abutment at their fulcrum to determine their maximum extended position and so relieve the connecting link and small ball race of this duty. To amplify this further, if $\frac{1}{32}$ in. clearance is not allowed, the full power of the governor weights is transmitted through this small bearing, which, normally, carries only the load applied by the governor-bar return spring.

92. **Timing-Chain Drive. Adjustment for Slack.**—It is not good to run the engine with the chain unduly slack (see para. 109) : on the other hand, it is imperative that it runs with a certain amount of slack as defined as follows. The chain is correctly adjusted when it is possible to move the middle of the nearly vertical run through approximately a distance of $\frac{1}{4}$ in. on either side of its mean position. The adjustment is effected by an idler sprocket (Figs. 13 and 15) running on a stud eccentrically housed in the timing case. The method of adjustment is obvious.
The chain should be inspected for slack every 800 hours. To repeat, do not on any account run the chain with less slack than that indicated above.

92·1 **Timing Chain. Renewal and Re-Fitting.**—After long use the timing chain will require renewal (see para. 109). The following will be useful as a guide for this purpose. Thoroughly wash the chain in paraffin and stretch it out on a flat surface. Through the last pin hole in each end of the chain insert fitting pins about 2 in. long. (Detachable link, of course, removed.) Now when the chain is stretched by hand to its maximum the length between the inner sides of the fitting pins must not be greater than $47\frac{9}{16}$ in. If the length is greater than this, the chain has had a useful life and must be renewed. Expressed in another way, the length quoted above is that which would be read by an " inside " micrometer or " inside " callipers. The useful life of a chain is about 10,000 hours, but the detachable link should be renewed once during this time. When fitting the detachable link great care must be taken to see that the spring clip is not over stressed and retains its grip in the groove on the pin when fitted. The clip should be fitted so that the closed or rounded end is leading, that is to say, the pointed or open end is trailing when the chain is running. *e.g.* In Fig. 9 the clip is shown fitted correctly for an engine running in a clockwise direction.

GENERAL OPERATIONS AND MAINTENANCE—*continued.*

93. **Decompression. Adjustment of Valve Lift.**—The act of turning a starting lever into position No. 1 (decompression) causes a cam to bear upon an adjustable screw fixed in the heel of the inlet valve rocker lever which cam lifts the heel and consequently holds open the inlet valve, *i.e.*, it cannot now close. The amount of opening is determined by the adjustable screw. In case of derangement, adjust this screw so that it lifts the inlet valve 0·040 in. (forty thousandths of an inch) from its seat.

93·1 **Summary of Attention by Running Time.**

**Daily.**

(1) **Water Pump—Centrifugal Type.**—Give one turn of the grease cup as directed in para. 31.
—**Ram Type.**—Fill cup with engine oil, regularly.

(2) **Engine Controls.**—Oil all the joints and link pins.

(3) **Fuel Pump Slider Bars.**—Oil the ends of these slider bars where they project from the fuel pump bodies.

(4) **Fuel Pump Driving Shaft Damper.**—Give one turn to each of the two greasers situated one on either side of the damper.

**Note.**—This damper is not fitted to the 3L3 engine.

(5) **Lubricating Oil Sump.**—Inspect level and add oil if necessary.

(6) **Crankshaft Damper.**—8L3 only—Give two or three turns to each of the two greasers.

**Every 100 Hours.**

(1) **Lubricating Oil Delivery Filter.**—Clean as directed in para. 49.

(2) **Fuel Filters.** Open vent cock (if fitted) and sump drains as directed in para. 62.

**Every 500 Hours.**

(1) **Lubricating Oil Sump.**—Drain off the oil and replenish with new oil as directed in para. 54.

(2) **Lubricating Oil Suction Filter.**—Remove and clean. See para. 50·1.

(3) **Fuel Sprayers.**—Remove and wipe around jet holes as directed in para. 63.

**Every 800 Hours.**

(1) It is recommended that, in the case of continuous duty engines where they are called upon to deliver high power for long periods without relief, the cylinder heads are lifted for decarbonising and the valve seats ground in, also the pistons should be withdrawn to examine for stuck piston rings. It is impossible to say definitely that this work is imperative at this period, as only experience of the particular case will prove if it is necessary. See paras. 85 and 85·1.

(2) **Valve Tappet Clearance.**—Inspect, and if necessary, adjust the clearance as directed in para. 90.

(3) **Timing Chain.**—Inspect, and if necessary, adjust the amount of slack as directed in para. 92. See also para. 92·1.

(4) **Injection Timing.**—Inspect and adjust if necessary as directed in para. 108.

(5) **Advance and Retard Friction Mechanism** (Rail Traction Type Engines only).—Inspect and adjust if necessary as directed in para. 90·5.

(6) **Sprayers (Injectors).**—Routine cleaning. Note paras. 64 to 78.

**Every 12,000 Hours (Approx. only).**

General examination and overhaul.

## MISCELLANEOUS NOTES ON THE OVERHAUL OF THE ENGINE.

94. **Drawing the Pistons and Connecting Rods.**—These can be drawn in either of two ways : 1, through the bore of the cylinders, after removing the heads ; or 2, by lifting the cylinders from the crankcase. A piston ring guide is sent with the engine in case method 1 is preferred. The gudgeon pin is free to turn in the piston and in the connecting rod ; in other terms, it is fully floated. To remove the pin it is sometimes necessary to use a wooden drift and so lightly drive it out. See para. 85·1.

95. **Fitting New Piston Rings.**—If at any time new piston rings are fitted to an engine, the cylinder liners of which have not been renewed, the top outer corner of the top ring should be filed at 45° to produce a bevel of about $\frac{3}{64}$ in. wide. This is to prevent the new and unworn ring fouling the unworn step in the bore which will have been left by the old ring. Also when new piston rings are fitted to an engine see that when inserted in the mouth or lower end of the cylinder liner, they have a gap clearance of ·016–·023 in.

95·1 **Relinering.**—The wet liners are fitted with dry liners. This enables the wet liner to be re-claimed and so assist servicing. To this end the Works operate a system of exchange whereby credit is allowed for worn liners in exchange for re-lined ones.

95·2 **Removing and Refitting Cylinder Wet Liners.**—The liners (Fig. 11) are only a push fit in the cylinders (water jackets) and held in place by the cylinder head. The water joint at the lower end is made by two rubber rings, each one of which is fitted in the outer of three grooves turned in the liner, the centre groove forms a drain and communicates with a small hole in the water jacket. The purpose of this hole is to give visible warning, on the outside, if at any time the first or top joint ring should leak. The top water joint is metal to metal, and is made with the addition of a little paint or jointing compound.

To remove a liner without dismantling the cylinder from the engine proceed as follows : Lift the cylinder head and remove the crankcase doors of the cylinder in question, draw the piston and connecting rod together by uncoupling the four big end bolts and drawing through the upper end of the liner. With the aid of a baulk of timber and heeling off the edge of the crankcase door opening, lever the liner upwards. If the cylinder complete has been removed from the engine the liner will have to be tapped out of the cylinder with a lead hammer or mallet, etc.

To refit a cylinder wet liner proceed as follows :—

(1) Remove any sediment or deposit which might restrict the water space, particularly at the top and bottom of the cylinder block.

(2) The bore and recess in the top face and the bore in the bottom face of the cylinder block must be scraped clean with a blunt tool which will not cut the metal.

(3) Lap the top flange of the liner into the block, using a small amount of very fine abrasive. Wash the two faces with paraffin or fuel oil and dry off. Avoid fouling the cylinder stud threads with grinding compound.

(4) Fit new rubber rings into the upper and lower grooves on the liner.

(5) Paint the bore and recess in the top face and bore in the bottom face of the cylinder block. Paint the external machined portions of the liner at the upper end and adjacent to and including the rubber rings towards the lower end.

(6) Fit the liners into the block whilst the paint is still wet.

(7) Wipe away any paint present on the cylinder head joint face of the liner.
The painting of these machined surfaces materially reduces corrosion and assists in making the joint water tight, in fact, if the cylinder blocks can be thoroughly dried, the whole of the inside surfaces of the water jacket should be painted before the liners are fitted, to reduce corrosion of this area. A good quality slow drying enamel may be used, or, when ordered, the Works will supply paint suitable for this work.

96. **Big-End Bearings. Main Bearings.**—Whenever new bearing shells have to be fitted to any of these bearings, the following things should be observed. The bearing shells must be a perfect fit in their housings. Both the big-end bearing and the main bearing are so designed that, when bolted up, the halves of the bearing shells butt against each other, metal to metal, as also do the cap of the bearing and its housing and the fitting is such that, when bolted up, the bearing is perfectly free on the crank pin or journal. In order to ensure

MISCELLANEOUS NOTES ON THE OVERHAUL OF THE ENGINE—*continued.*

that the bearing shells are tightly held in their housings, the whole is so fitted that, when the bolts are only slightly more than finger-tight (just before finally tightening), there remains a gap of 0·002 in. between the cap and the housing.

Main bearing shells should be carefully hand-scraped so that, when bolted up, they are perfectly free on the journal and have 0·0025 in. clearance. Do not make any attempt to " burn in " a bearing by running the engine, as this will destroy the white metal.

The big-end bearings should have no end slack between the crank webs but should have 0·002 to 0·003 in. clearance, *i.e.*, vertical slack. Observe that the oil grooves in the main bearings are in correct alignment with the feed holes in the crankshaft.

There is a right and a wrong way round for these shells. Bearings are so fitted that the numbers lie on the governor side of the engine for big-end bearing and on the exhaust manifold side of the engine for main bearings.

97. **Crankshaft.**—This is located endwise between the two main bearings nearest to the flywheel and should have an end-play of 0·004 in.

All the other bearings should have an end-play of 0·040 in. (forty thousandths of an inch) to allow of expansion. Before assembling the crankshaft, thoroughly clean and wash out all the feed passages and carefully examine all the bearing surfaces for any signs of abrasion : a scratch or a dinge can usually be detected by rotating the half of a bearing shell on the shaft.

98. **Valves.**—Directions for assembling the valves have been given in para. 87 (very important) and 87·1. See also para. 88.

99. **Valve Camshaft.**—Little need be said about this organ since an inspection will readily reveal the method of construction. When assembling, take care that the cams come under the correct tappet, *e.g.*, that the exhaust cam is under the exhaust tappet and not under the inlet tappet or *vice versa*. The exhaust cam, it will be noticed has a less rise than the inlet cam but is of longer period. Make sure that the binding screws are thoroughly tightened home. A special, square box key is supplied with the engine for this purpose. This also applies to the air starting cams when an engine is so fitted.

100. **Clearance Between Valve Heads and Piston.**—It will be seen that shallow recesses are formed on the top of the pistons to give clearance to the valve heads and to allow of an over-lap timing diagram. The diameters of the inlet valves and their recesses differ from those of the exhaust valves, therefore this must be taken into account when fitting the piston on the connecting rod so that the recesses shall fall underneath their corresponding valves. The correct way in for the piston is clearly indicated by the lettering, " TAPPET SIDE " on the top of the piston.

101. **Timing of Valves.**—When reassembling an engine after an overhaul, it is of the utmost importance to pay special attention to the timing of the valves with relation to the crankshaft, for if the timing be not in accordance with the timing marks on the flywheel and the timing gears, the valves will foul the pistons and **serious consequences will result.** For this reason, it is desirable, during timing to place the lower end of the tappet rod (Fig. 11) in the cam-tappet socket and not to push the upper end under the valve rocker

MISCELLANEOUS NOTES ON THE OVERHAUL OF THE ENGINE—*continued.*

until all is verified. In this way, one can observe the vertical motion of the free end of the tappet as the flywheel is rotated to and fro. This motion should be such that when the piston is towards the top of the exhaust stroke, if all is correct, the inlet valve will be on the point of opening while the exhaust valve will be on the point of closing. In other words, the centre of the overlap between the inlet opening and the exhaust closing should occur when the piston is approximately on the top dead centre, after the exhaust stroke.

102. **Timing Marks of Fuel Injection (Rail Traction and Marine Type Engines).**—Drawn across the periphery of the flywheel will be found timing lines for each cylinder. A short line will also be observed on the aft cylinder foot flange at the base of the cylinders, called the **zero line.** Taking, for example, the lines for No. 1 Cylinder, when the longer line, marked " No. 1 T.D.C." registers with the zero line, crank No. 1 is exactly at top dead centre (T.D.C.), and when the shorter line marked " No. 1 cylinder injection " registers with the zero line, on the compression stroke, the timing lines on the fuel pump should coincide, as described in para. 104. The number denotes the number of degrees before T.D.C. and the line marked is the position of maximum advance. These advance figures are liable to be varied slightly to suit individual engines. See para. 108 and Fig. 10.

It goes without saying that while checking the timing in this way, the pointer (Fig. 12) of the advance and retard device must be turned to point to position of maximum advance.

**Note.**—No. 1 cylinder is that situated at the forward end of the engine remote from the flywheel.

103. **Timing Marks of Fuel Injection (Industrial Type Engines).**—The point of injection of these engines is fixed, that is to say there is no maximum and minimum advance.

On the periphery of the flywheel of these engines there are marks in the same way as those in para. 102. The advance and retard mechanism is set and fixed during test and should not be moved in any way.

104. **Timing of Fuel Injection.**—Each fuel pump is provided with a sight hole or window through which can be seen a plunger moving up and down when the crankshaft is rotated. On the sides of the window is a horizontal line, also one on the plunger.

When the flywheel is turned in its running direction and these two lines (the one on the window and the one on the plunger) coincide, the corresponding injection line on the flywheel registers with the zero mark on the cylinder as described in para. 102. When so checking the timing be careful not to be misled by turning the flywheel in the wrong direction. Also if the engine is of the variable injection type care should be taken to see that the injection control pointer is at maximum advance, and observe the corresponding line on the flywheel. On the fuel pump operating tappets are locked screws which should not be disturbed. See para. 111.

105. **Timing of Valve and Injection Pump Camshafts.**—Remove the cover from the chain case at the front end of the engine ; this will give access to the chain, camshaft chain wheel and fuel pump driving gears (Fig. 9). The chain wheel and valve camshaft gear are bolted together, face to face, by three studs. The stud holes in the chain wheel are elongated to permit a certain small amount of rotation, relative to the camshaft gear, for the purpose of accurate timing. When this timing position has been set by the makers, a marker is inserted in the sight hole and a line forming an arc of a circle inscribed on the camshaft gear.

MISCELLANEOUS NOTES ON THE OVERHAUL OF THE ENGINE—*continued.*

Turn the flywheel until No. 1 crank comes to the T.D.C. after the compression stroke as directed in para. 102. If the timing is correctly set the following events will take place :—

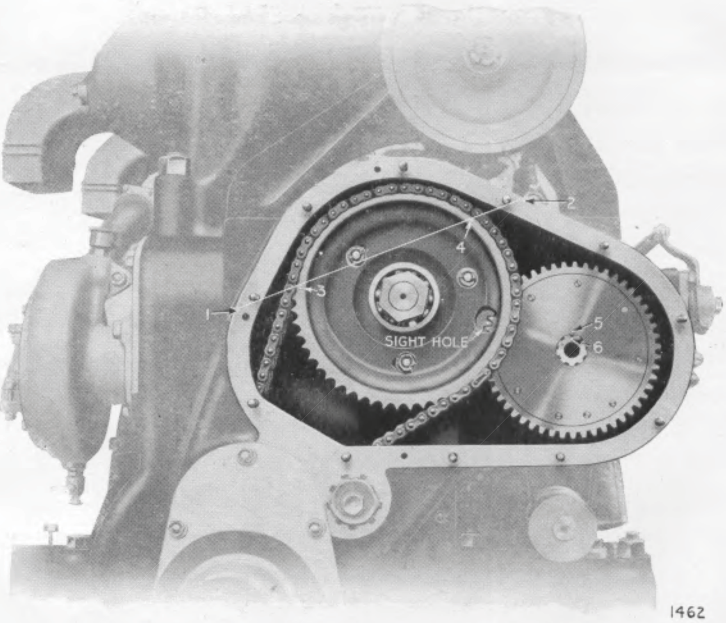


**Fig. 9**

(1) The dots 1 and 2 on the gear case and the dots 3 and 4 on the periphery of the camshaft chain wheel will all lie on a straight line as indicated by the stretched cord in Fig. 9.

(2) Through the sight hole in the large chain gear will be visible the teeth of the gears of the valve and fuel-pump camshafts, and it will be found that the dotted tooth of the gear of the valve camshaft lies between the dotted teeth of the fuel-pump camshaft.

(3) Through the same sight hole will be verified that the lune on the edge of the gear of the valve camshaft (described above) is in its correct position, in which case the lune will not be very conspicuous but should the gears be incorrectly bolted together, the lune will exhibit the defect very conspicuously.

(4) The dotted spline on the camshaft of the fuel pump will register with the dot on the camshaft gear, see dots 5 and 6 in Fig. 9.

**Note.**—All the dots referred to in the above are countersinks made by the point of a drill.

MISCELLANEOUS NOTES ON THE OVERHAUL OF THE ENGINE—*continued.*

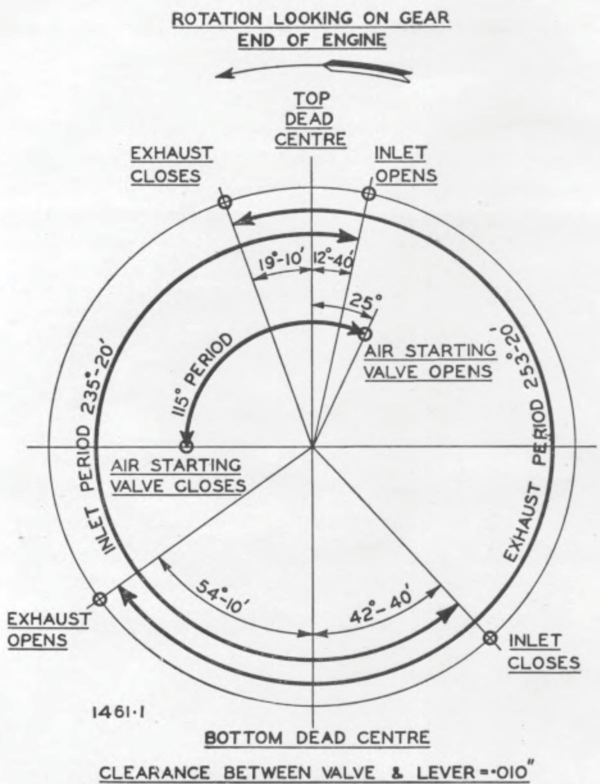


Fig. 10

**Fuel Injection Timing.**—For engines set to a maximum speed of . –

| | 800 *r.p.m.* | 900 *r.p.m.* |
|---|---|---|
| 3 & 4L3 | 18° before T.D.C. | 19° Max. before T.D.C. |
| 5 & 6L3 | 19° ,, ,, | 20° ,, ,, ,, |
| 8L3 | 20° ,, ,, | 21° ,, ,, ,, |

| | 1200 *r.p.m.* |
|---|---|
| 4, 5, 6 & 8L3 | 24° Max. before T.D.C. |

**Note.**—When an engine is set to some maximum speed below 1200 r.p.m. but greater than 900 r.p.m., reference must be made to actual timing figure stamped on the injection control plate, adjacent to the injection control pointer, figs. 12 and 13.

106. **Air Starting Valve Timing and Tappet Adjustment.**—These valves are set to open 25° before T.D.C.s of the cylinder to which they are fitted. They close 90° after T.D.C. (see Fig. 10). The correct clearance between the small bell crank lever and the end of the valve is 0·015 in. This must be checked or set when the cylinder in question is on its exhaust stroke, *i.e.*, the exhaust valve open and the starting hand lever in it. starting or lifted position (see para. 38·1, Step 7).

MISCELLANEOUS NOTES ON THE OVERHAUL OF THE ENGINE—*continued.*

107. **Timing of Inlet and Exhaust Valves.**—The cams are so fixed on the camshaft that they cannot be displaced, except that, when re-assembling the camshaft, care must be exercised that the cams are not placed in the reversed position, *i.e.*, inlet valve cam under the exhaust valve tappet. The inlet valve cam, which is more pointed than the exhaust valve cam, must be assembled to the right hand side, viewed from the fuel pump side of the engine.

The clearance between the toe of the rocking levers and valve stems should be carefully adjusted (see para. 90) and has an important influence in the maintenance of correct valve timing.

108. **Correction of Injection Timing for Stretch (Wear) of Timing Chain.**—In the course of time, the timing chain wears and consequently increases in length (para. 92), which causes the timing of the valves and the fuel injection to become slightly retarded, therefore compensation should be made when required. To this end inspect the timing as indicated in para. 102, after, say, 800 hours working, and if it be found that the timing is retarded, proceed as follows : Turn the flywheel until the injection timing line is in line with the zero line on the cylinder, then slacken the three hexagon nuts on the main chainwheel shown in Fig. 9, and rotate the fuel pump camshaft or the valve camshaft until the lines on the windows of the fuel pump coincide as indicated in para. 105. Check the timing again after tightening the nuts (see also para. 109).

For the correct injection settings see para. 105.

109. **Timing Chain Wear.**—Wear or stretch of a chain can give rise to noisy running and unsteady governing. Generally speaking it has a useful life of about 10,000 hours (see para. 92·1), but the detachable link should be renewed once during this time.

110. **Air Inlet Valve.**—It will be noticed that the spring collar of the valve has a flat side which is located by a flat bearing surface on the inside of the gear box on the cylinder head. The object of this device is to ensure that the valve head with its patent baffle shall not run out of its correct position. As a further precaution, the split-pin hole is drilled slightly away from the centre line of the valve so that, when replacing the valve after cleaning, should it be half a turn wrong, it will not be possible to thread the split-pin through the hole. This, of course, forms a clear indication whether or not the valve is in its correct position.

111. **Fuel Pump Tappets.**—As mentioned in para. 104, the adjustment of these fuel pump tappets should not be deranged. They are adjusted during the engine test and will not require any further attention. Should this adjustment be inadvertently upset or a new part have to be fitted, through an accident or other cause, re-set as follows :—

Turn the flywheel round until a tappet has lifted to its maximum, then turn the flywheel one more exact revolution, this tappet will now be resting on the base of the cam. Place on top of the tappet screw a small disc or washer of 0·140 in. thickness. Refit the fuel pump and tighten the holding down nuts, the lines in the windows of the fuel pump should now coincide as in para. 104, if they do not, adjust the tappet screw either up or down until this condition obtains. Remove the disc or washer, firmly lock the screw, and refit the pump. This operation must be carried out on each tappet in turn.

**Important Note.**—Under no circumstances must the engine be revolved whilst the 0·140 in. gauge is in position on any of the tappets. Very serious damage will occur to the pump if this is not observed.

MISCELLANEOUS NOTES ON THE OVERHAUL OF THE ENGINE—*continued.*

112. **Bilge Pump Friction Clutch (when fitted).**—Outside the gear case of the pump is a large hand-nut with a central locking screw. The hand-nut is attached to a sleeve which screws in and out of the gear case cover. To engage the clutch, screw in the sleeve as far as it will go. To disengage the clutch, unscrew out the screw as far as it will go.

For the purpose of adjusting the spring load on the clutch, the hand-nut is screwed on to the sleeve and locked by the central screw, so that when this screw is slackened, the hand-nut is free to turn upon the screwed sleeve. To increase the spring load on the clutch, first, disengage the clutch as above, then slacken the central screw and **unscrew,** by a fraction of a turn, the hand-nut on the sleeve and lock again. It will be evident that unscrewing the hand-nut relative to the sleeve increases the stroke of the sleeve and therefore the spring pressure.

113. **Fuel Pumps. Camshaft Case.**—The parts enclosed in this case are continuously lubricated from the main pressure system. As, however, owing to convenience of construction, this oil does not pass through the delivery strainer, and as a precaution against the remote contingency of the nozzle of the feed pipes becoming choked, it is advisable to make sure that the parts are receiving an adequate supply of oil (see para. 47). This may be verified by opening the inspection covers (Fig. 12) and looking into the vertical well on the side of the case. (There are two of these wells on engines with five and six cylinders). This inspection should be made while the engine is running in order to see the oil splashing from the moving parts.

114. **Governor Case.**—The preceding paragraph applies equally to the governor case, inspection being made through the opening which is closed by the large screwed plug (Fig. 12) while the engine is running.

115. **Crankshaft Damper.—(8L3 Engines** fitted with external damper on the crankshaft.) The damper, fitted outside the timing case on the projecting portion of the crankshaft, will occasionally (about once a week) require a small quantity of lubricating oil ; this should be poured into the gap between the two discs.

116. **Diaphragm Type Fuel Lift Pumps and Gardner Overflow Return Feed System.**—These pumps (Fig. 12), of which the " Amal " is a typical example, are driven from the valve camshaft and arranged so that they will deliver about 60 per cent. more fuel than the engine demands on maximum load. The fuel from the pump is delivered into a chamber embodied in the base of the fuel strainer on No. 1 cylinder head (Fig. 12) at a pressure of about $1\frac{1}{2}$ lb./sq. in. Out of the chamber, fuel, and any air there may be, is allowed to return through a ·025 in. dia. hole to the tank (along with the leak fuel from the sprayers). By this means it is ensured that any air which finds its way into the fuel on the suction side (at joints, taps, etc.) is separated from the fuel which feeds the injection pumps on the engine.

The above type of fuel lift pumps are provided with a lever for operating by hand in order to initially fill the pipe system and prime the fuel injection pumps.

MISCELLANEOUS NOTES ON THE OVERHAUL OF THE ENGINE—*continued.*

117. **Instructions for Fitting Spare Fuel Pumps on 5, 6 and 8L3 Engines.**—In the event of this being necessary, due to a failure in either block of pumps, it is essential that **both** pumps are replaced by the spare pair, *i.e.*, one pump of the spare pair will **not** replace one of original pair. This is necessary because the pumps are set when in pairs.

To replace, proceed as follows :—

No. 1. Fit the pumps after having checked and corrected where necessary the tappet setting on each pump line as directed in para. 111.

No. 2. Fit the pumps, but before finally tightening down set the pumps on their respective cam boxes so that the distance piece supplied will just pass between the facings on the inner ends of the pumps at a point just below each control bar, and see that the ends of the control bars are in line with each other.

No. 3. Fit the centre link which connects the control bar of one pump to that of the other.

No. 4. Fit the eyed rod connecting the control bar of the " aft " pump to the vertical governor lever. The length of this rod may have to be adjusted to suit the new pumps. The correct setting of the control bar with relation to the governor weights is such that when the governor weights are parted to their full extent by inserting the fingers through the inspection opening in the governor case the length of the eyed connecting rod is so adjusted as to give the control bar a position approximately $\frac{1}{32}$ in. from its maximum stroke towards the timing case. Should it be necessary to make adjustment to this rod great care should be exercised to see that the holes for the joint pins are parallel when the nuts are locked and that the control bar moves freely.

No. 5. When the stopping lever is in the " stop " position the control bars should still have a movement of $\frac{1}{32}$ in. before reaching their maximum " in " position (as in No. 4). To obtain this, adjust the screw in the lower end of the governor lever.

No. 6. Fit the pipe-work and the return spring behind the " forward " pump.

When pumps are supplied fitted to a common insertion plate, item No. 2 should be omitted.

For fitting the spare pump to 3 and 4L3 engines, proceed as above but omit items Nos. 2 and 3.

**Important Note.**—The aluminium fuel limiting box fitted to the pump must only be used on the pump to which it was fitted when delivered. The number of the pump to which a limiting box has been set is stamped on the box itself as is also the engine number.

118. **Air Filters.**—When an engine is fitted with air filters it is most important to clean them when and as stated on the instruction plates attached.

It is highly injurious to run an engine with choked or partially choked filters.

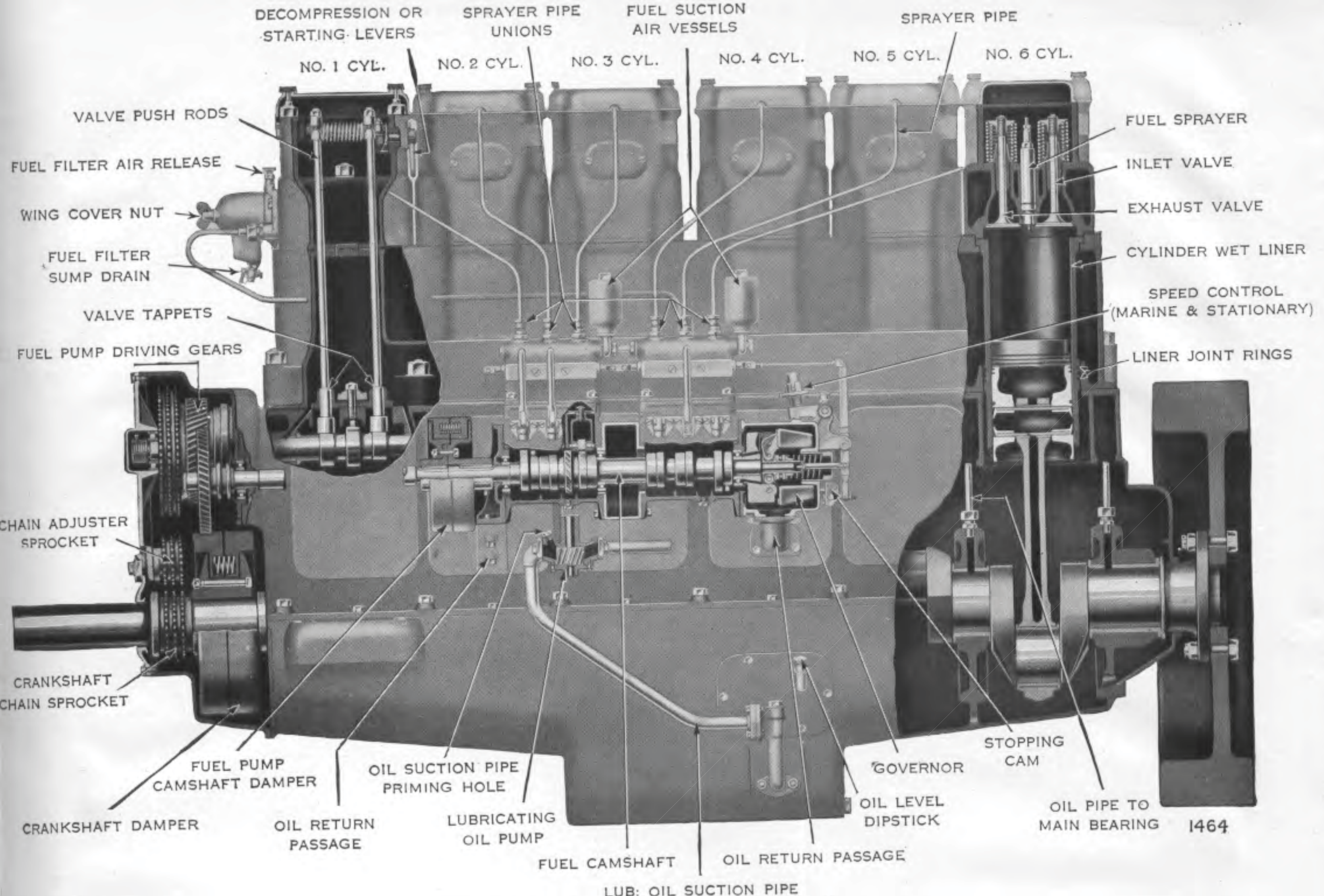


**Fig. 11** PART SECTION OF 6L3 ENGINE

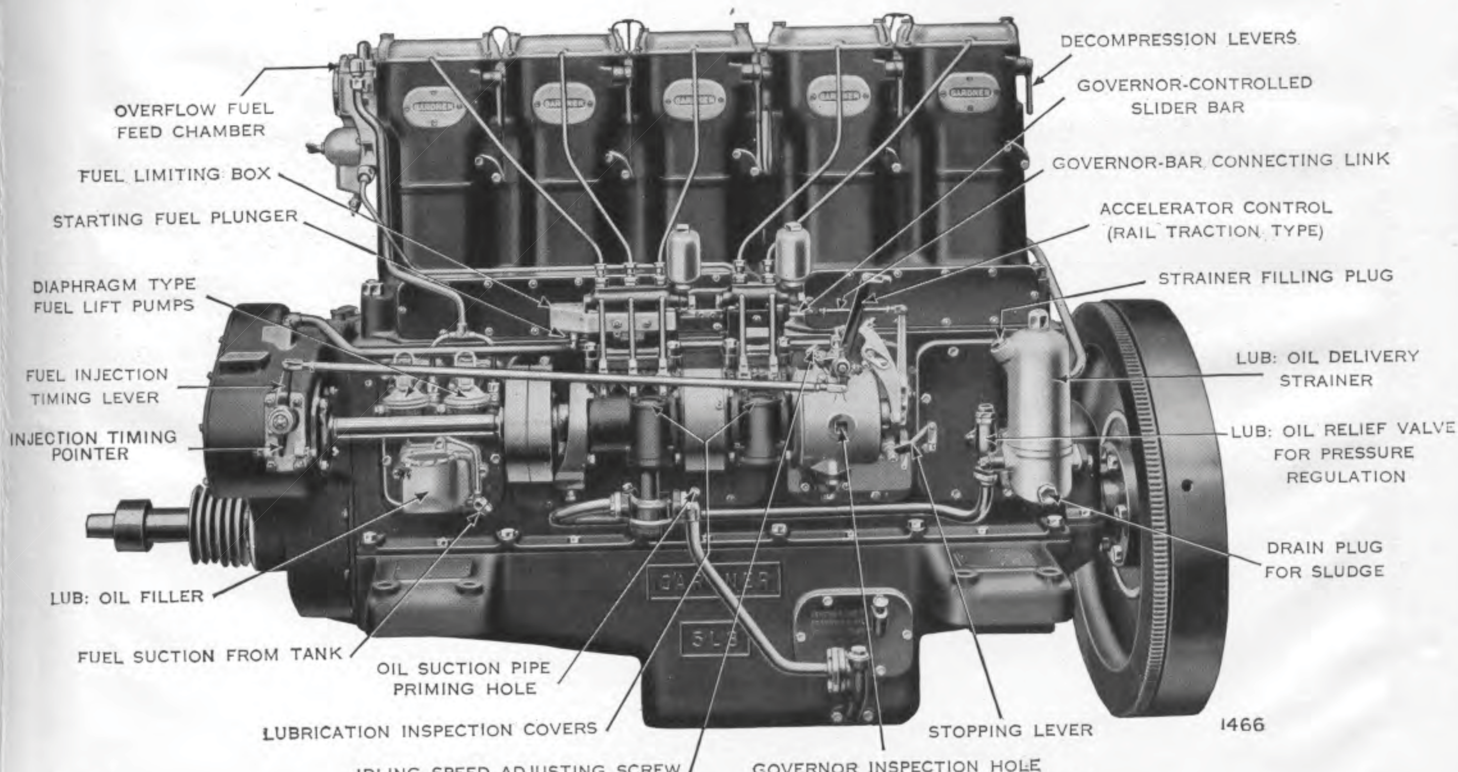


**Fig. 12** 5L3 RAIL TRACTION ENGINE with "AMAL" FUEL LIFT PUMP FITTED

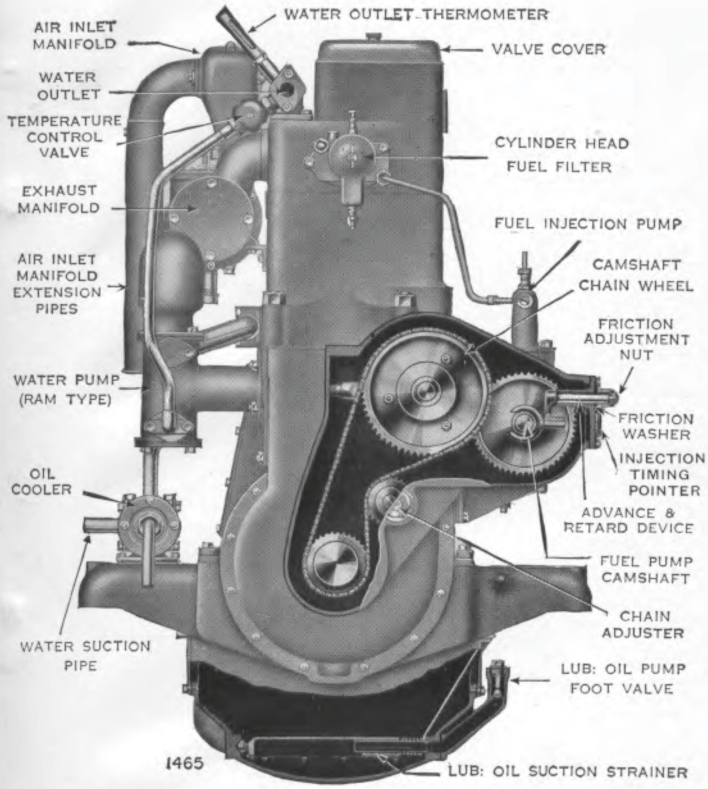


**Fig. 13** FORWARD END VIEW SHOWING CHAIN CASE ARRANGEMENT

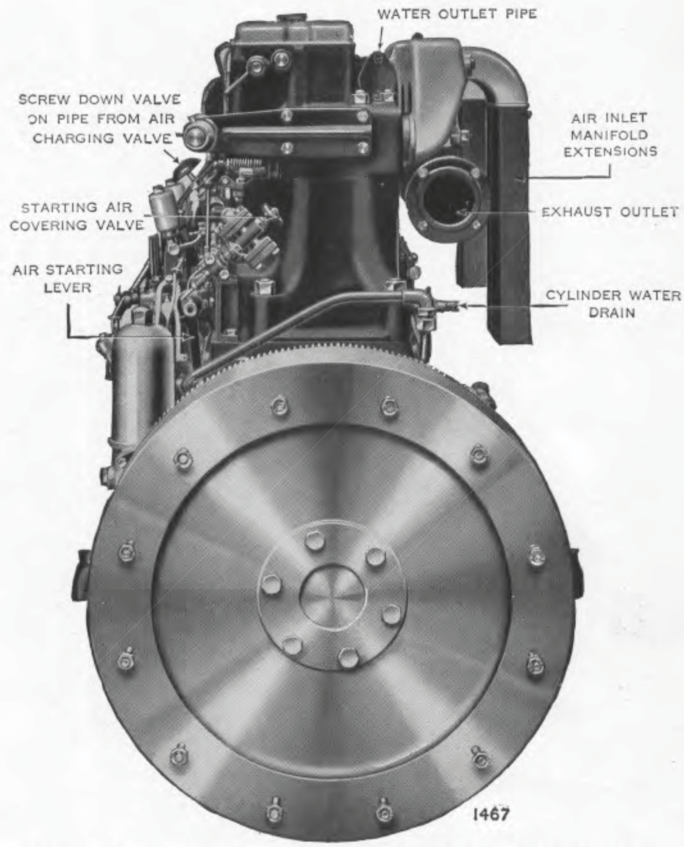


**Fig. 14** FLYWHEEL-END VIEW OF RAIL-TRACTION ENGINE

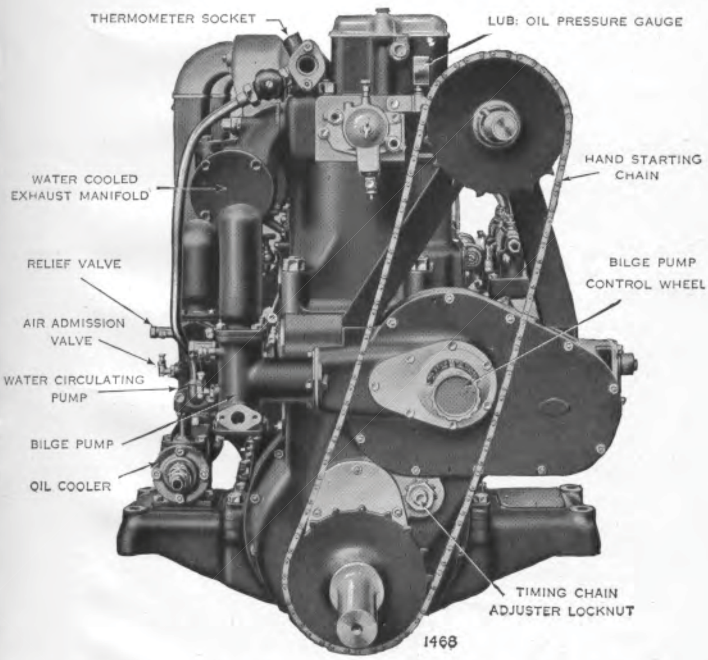


**Fig. 15** FORWARD END VIEW OF MARINE ENGINE

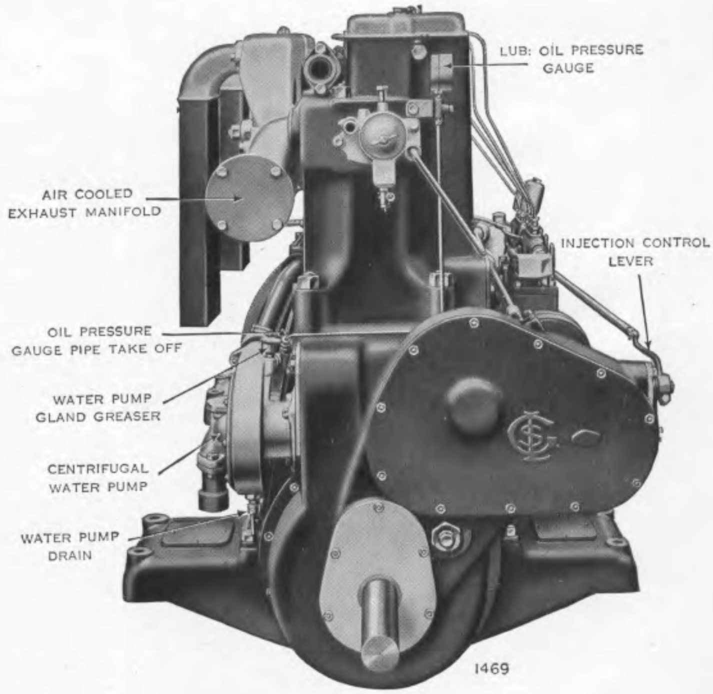


**Fig. 16** FORWARD END VIEW OF A RAIL TRACTION TYPE ENGINE