L2 TYPE
(Multi-Cylinder)

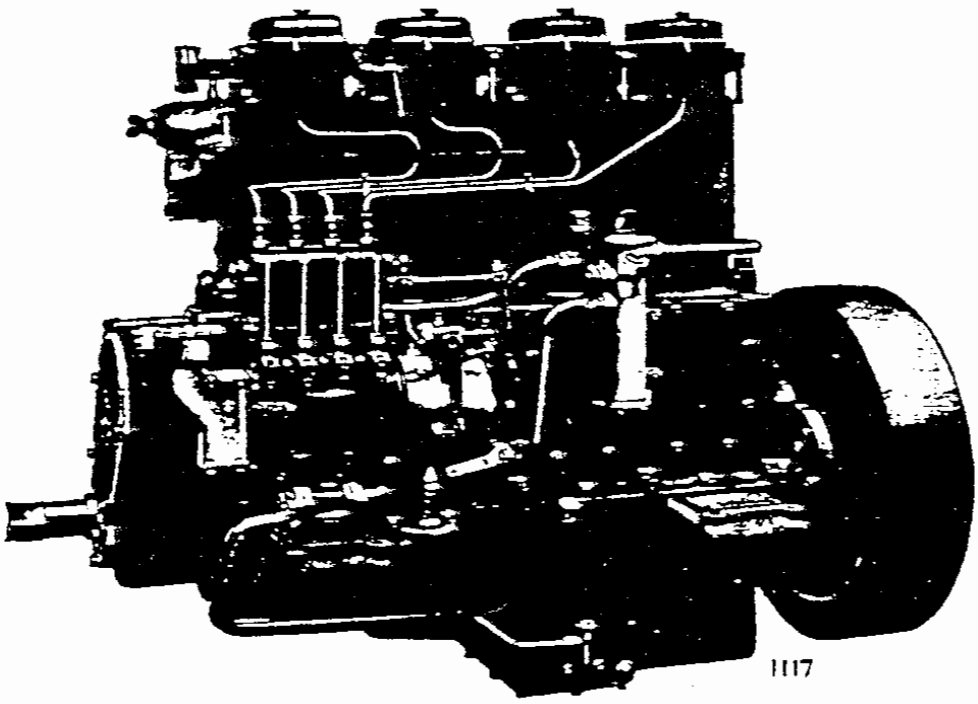
GENERAL DIRECTIONS

for the Management and Care of

GARDNER

OIL ENGINES

Verticle Four-Cycle Compression-Ignition
Airless Fuel Injection



1117

INDEX

(The numbers refer to the paragraphs)

Engine Performance at High Altitude and High Atmospheric Temperature

As is well known, the density of air is lower at both high altitude and high temperature and since a given amount of fuel requires a given amount of air for its combustion, it is necessary that the injected fuel supply to an engine operating under conditions of lower air density be restricted to a value satisfactory for combustion and operation with a smokeless exhaust.

Engine Catalogue powers are known as the 100% rating, and are those developed with a satisfactory fuel/air ratio under conditions of normal temperature and pressure. These conditions, namely, a barometric pressure of 30" Hg., and an atmospheric temperature of 55°F. normally obtain at the manufacturer's works at Patricroft, Lancashire.

Conditions of reduced air density encountered both as a result of high altitude and high atmospheric temperature, each separately have an effect on engine performance such that for every 1,000 ft. altitude and each 10°F. increase over sea level and 55°F. mean annual temperature respectively, it is appropriate to reduce the fuel supply 2%.

Example : Given that an engine has to operate at 2,000 ft. altitude with a mean annual atmospheric temperature of 75°F., from the graph on the left hand side of the opposite page, we read the following reductions :

For altitude	4%
For temperature	4%
Combined reduction	8% or 0·92 normal temperature and pressure rating fuel supply.

When it is intended that an engine shall operate permanently at 1,000 ft. altitude or 65°F. mean annual ambient temperature, or in excess of either of these figures, it is necessary that the length of the fuel pump output control trigger be increased in order to reduce the injected fuel supply appropriately according to altitude and temperature shown on the graph.

When site operating conditions are known, new engines are appropriately set during test at the maker's works, and the setting clearly stamped on the fuel pump rating plate. When, however, it is necessary to adjust spare or reconditioned fuel pumps the work can be accomplished only by use of the Gardner fuel pump calibrating machine and by observing precisely the provisions of Instruction Book 45·3. On page 9 of Book 45·3 will be found the average delivery from each plunger in cubic centimetres and the values quoted are to be reduced according to the graph.

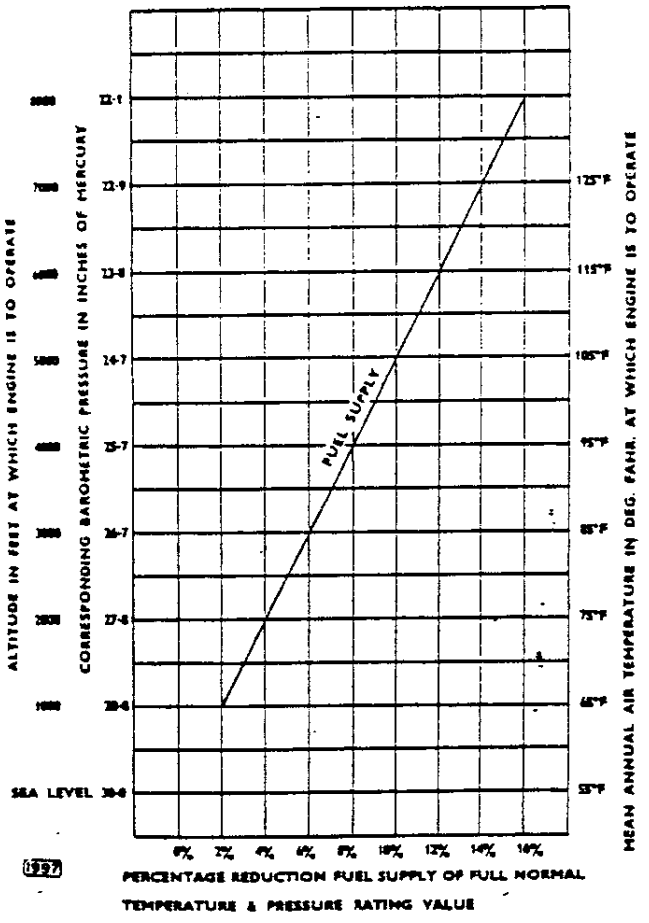
The graph on the right hand side of the opposite page shows the approximate reduction in B.H.P. when the fuel supply is reduced under altitude and temperature conditions.

Example : Combined reduction fuel supply 10%.
Reduction B.H.P. of full N.T.P. rating 12%.

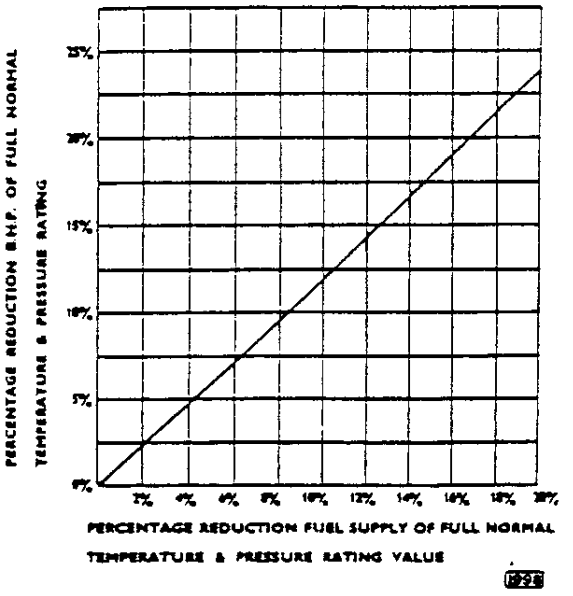
INDEX (continued)

(The numbers refer to the paragraphs)

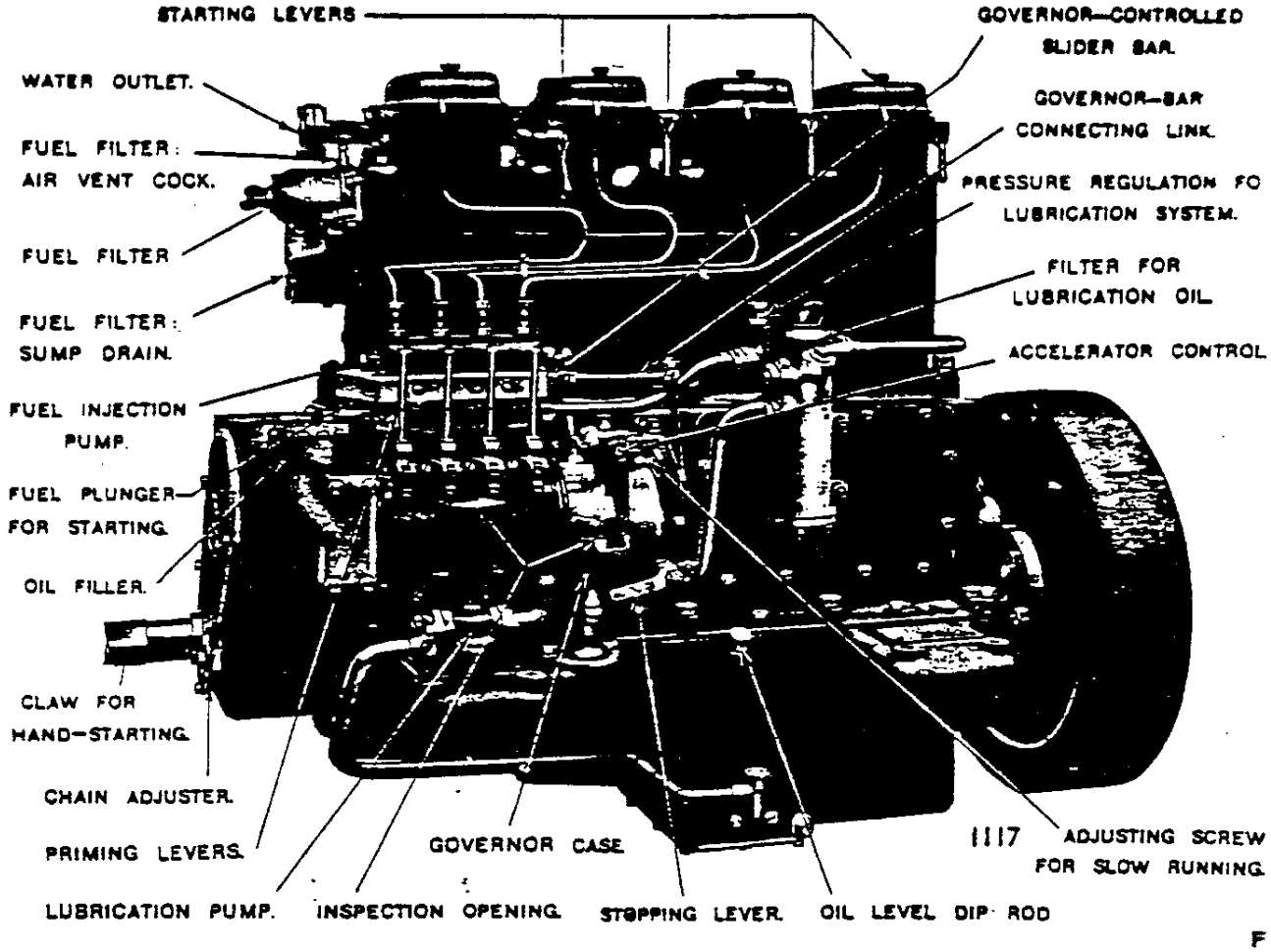
Altitude and Temperature Diagrams



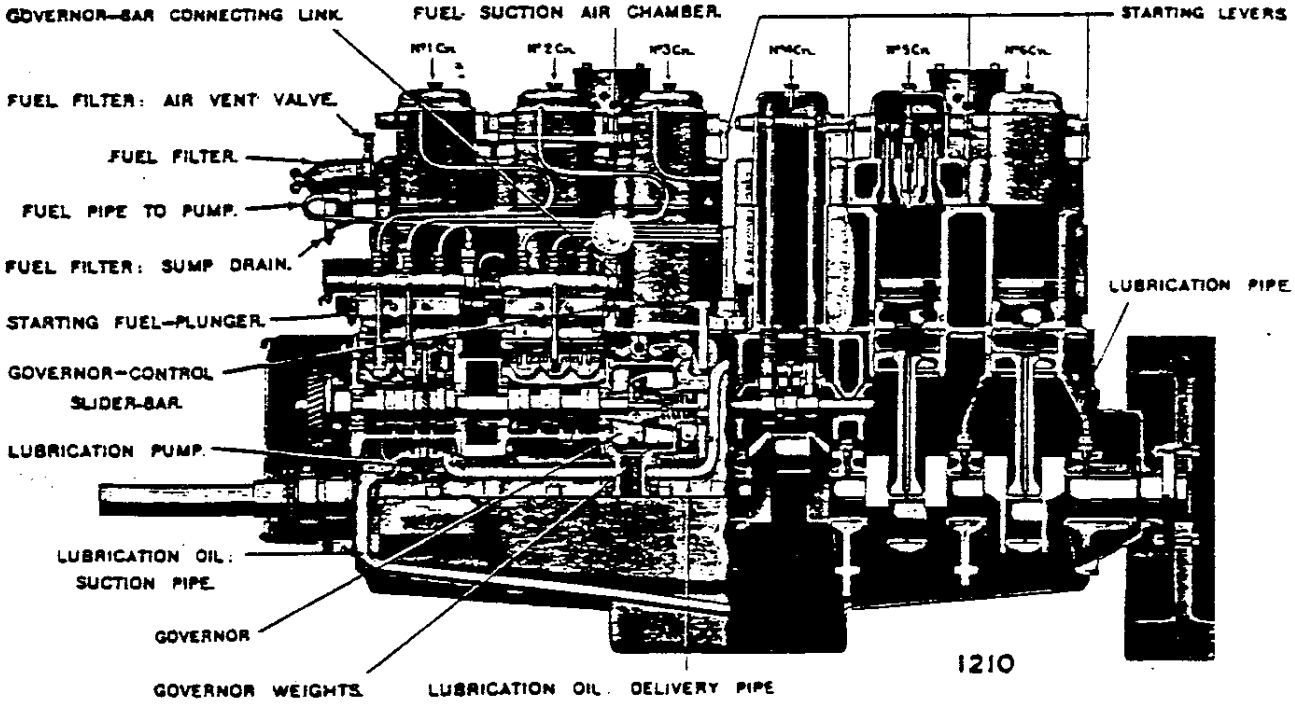
REDUCTION IN FUEL SUPPLY FOR ALTITUDE AND TEMPERATURE CONDITIONS.



REDUCTION IN B.H.P. WHEN FUEL SUPPLY REDUCED UNDER ALTITUDE AND TEMPERATURE CONDITIONS.


STARTING LEVERS
GOVERNOR—CONTROLLED SLIDER BAR.
WATER OUTLET.
GOVERNOR—BAR CONNECTING LINK.
FUEL FILTER: AIR VENT COCK.
PRESSURE REGULATION FO LUBRICATION SYSTEM.
FUEL FILTER
FILTER FOR LUBRICATION OIL.
FUEL FILTER: SUMP DRAIN.
ACCELERATOR CONTROL
FUEL INJECTION PUMP.
FUEL PLUNGER—FOR STARTING.
OIL FILLER.
CLAW FOR HAND—STARTING.
CHAIN ADJUSTER.
PRIMING LEVERS.
GOVERNOR CASE.
1117
ADJUSTING SCREW FOR SLOW RUNNING.
LUBRICATION PUMP.
INSPECTION OPENING.
STOPPING LEVER.
OIL LEVEL DIP ROD

F


GOVERNOR—BAR CONNECTING LINK.
FUEL SUCTION AIR CHAMBER.
STARTING LEVERS
FUEL FILTER: AIR VENT VALVE.
FUEL FILTER.
FUEL PIPE TO PUMP.
FUEL FILTER: SUMP DRAIN.
LUBRICATION PIPE
STARTING FUEL—PLUNGER.
GOVERNOR—CONTROL SLIDER-BAR.
LUBRICATION PUMP.
LUBRICATION OIL: SUCTION PIPE.
GOVERNOR
1210
GOVERNOR WEIGHTS.
LUBRICATION OIL DELIVERY PIPE

Fig

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 L2 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, while the 6-cylinder engine has two 3-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.

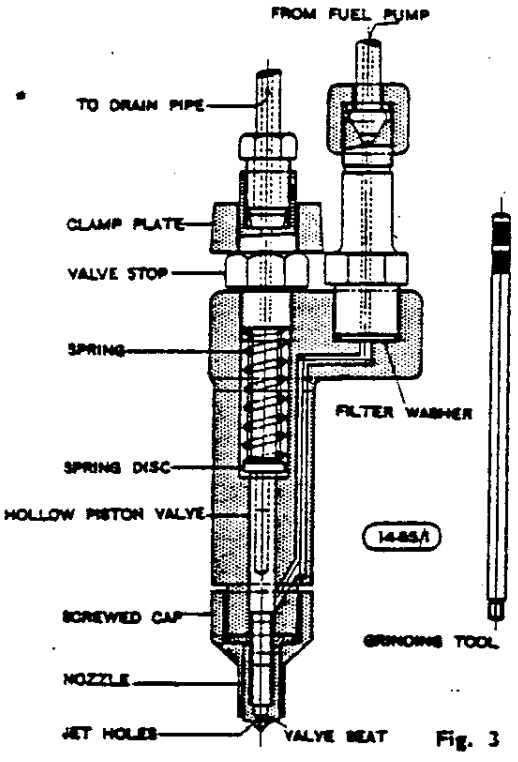
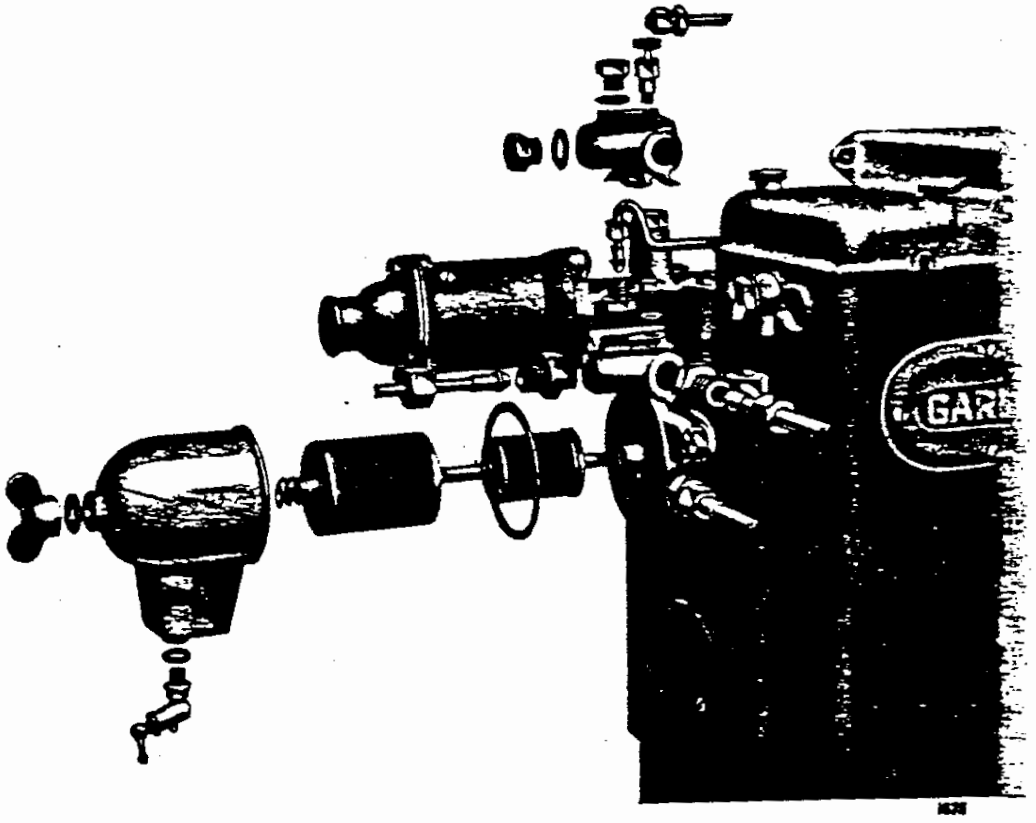


Fig. 3

GENERAL INTRODUCTORY NOTES—*continued.*

5. **Fuel Sprayers.** (See Fig. 3).—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

Fig.

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

GENERAL INTRODUCTORY NOTES—*continued.*

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 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. Each contains two gauze elements, an inner and an outer, which are removable for cleaning. Both filters are provided with a sump and a drain cock. For gravity Feed Systems the Second Filter is provided with a vent cock, but this is omitted with the Overflow Return System, which is automatically vented through the Fuel Return Pipe. See Para. 115.

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 cam shaft 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 one side of the delivery strainer will be found a connection which is to be coupled up to the pressure gauge on the instrument panel. On the forward side of the delivery strainer is a spring-loaded by-pass for regulating the oil pressure.

Lubrication.—Practically every organ of the engine is lubricated by a circulation-pressure system fed by a gear pump driven by the fuel 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 at the pressure of 30 lb./sq. in. through a second strainer fixed on the engine to a main service pipe from which it is distributed to the various parts of the engine—the main bearings, the crankpins, the gudgeon pins, the camshafts, 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, 51 and Fig. 14.

On the delivery side of the system is fixed a pressure gauge which when the engine is running at 1,000 r.p.m. should indicate 30 lb./sq. in. when the temperature of the oil is about 130°F.

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. When the circulation system is " open " as in marine engines, the pump is of the plunger type fitted with air vessel, drain tube, snifting valve and safety valve. When the circulation system is closed, as for example, when the water passes through a radiator, a gear-driven centrifugal pump is fitted. Normally the plunger types of pumps are of bronze and the centrifugal type is of aluminium.

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.

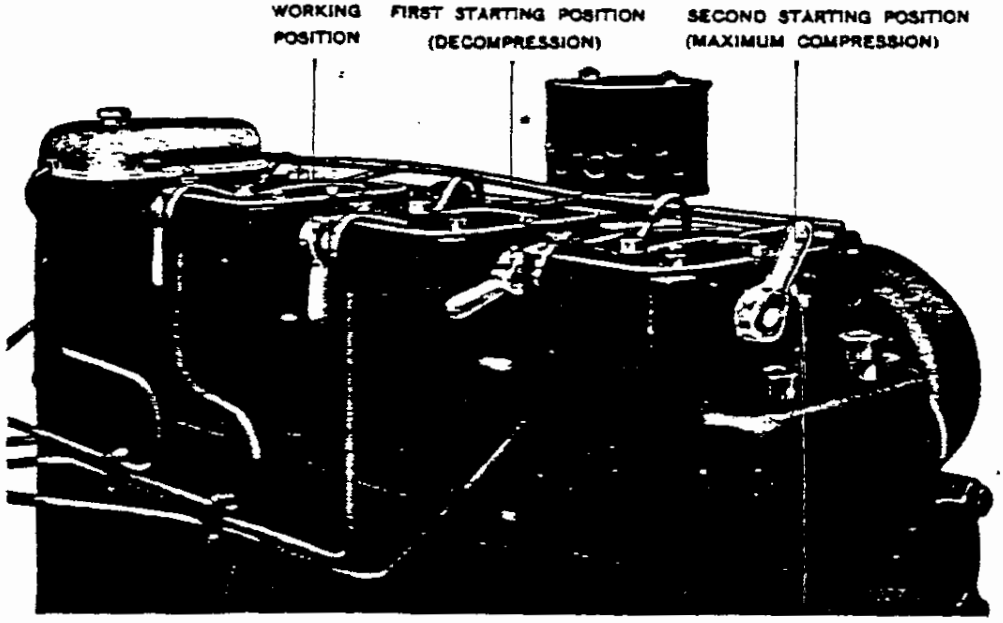
Engines are not supplied with bilge pumps unless expressly ordered : they are then the subject of an extra charge.

GENERAL INTRODUCTORY NOTES—*continued.*

STARTING AND VALVE GEAR

12. The essential feature of these engines is that the starting is effected by a hand cranking handle just the same as in the motor car engine. Hand starting is the standard form for all the L2 type engines but electric starters are supplied at an extra charge when so ordered. 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.



STARTING LEVERS. SHOWN IN THEIR THREE DIFFERENT POSITIONS — Fig. 5

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

GENERAL INTRODUCTORY NOTES—*continued.*

Starting and Valve Gear—*continued.*

of the air valve is altered so as to obtain 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. (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 all engines can be varied while the engine is running, from 400 r.p.m. to the maximum running speed including all intermediate speeds by merely turning a knurled knob or lever on the governor case. 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.

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 preventative 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 despatch. 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.

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

GENERAL INTRODUCTORY NOTES—*continued.*

when assembling on site. Take care that all oil holes are thoroughly cleaned out and fuel pipes, etc., are flushed through before assembly.

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 changing 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 Pipes.**—The exhaust system may be planned on lines similar to those customary in petrol-paraffin engines. Special care should be taken to avoid an unnecessary number of bends and great lengths of pipe which cause undue gas friction and impairs the working of the engine. The normal size of the exhaust pipe is 2 in. for 2, 3 and 4L2 engines and 2½ in. for 5 and 6L2 engines, increasing to 2½ in. for 4L2 engines at the exit from the expansion chamber or silencer.

Sometimes, in marine installations, circulation water is injected into the exhaust pipe for cooling : in such cases, the exhaust pipe should be increased all through to 3 in.

PREPARATION FOR STARTING AFTER INSTALLATION

22. **Lubrication System.**—To charge the sump in the lower crankcase, remove the cover of the oil filler box 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. 6, page 21.

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

24. Remove the screwed plug 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.

PREPARATIONS FOR STARTING—*continued.*

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.

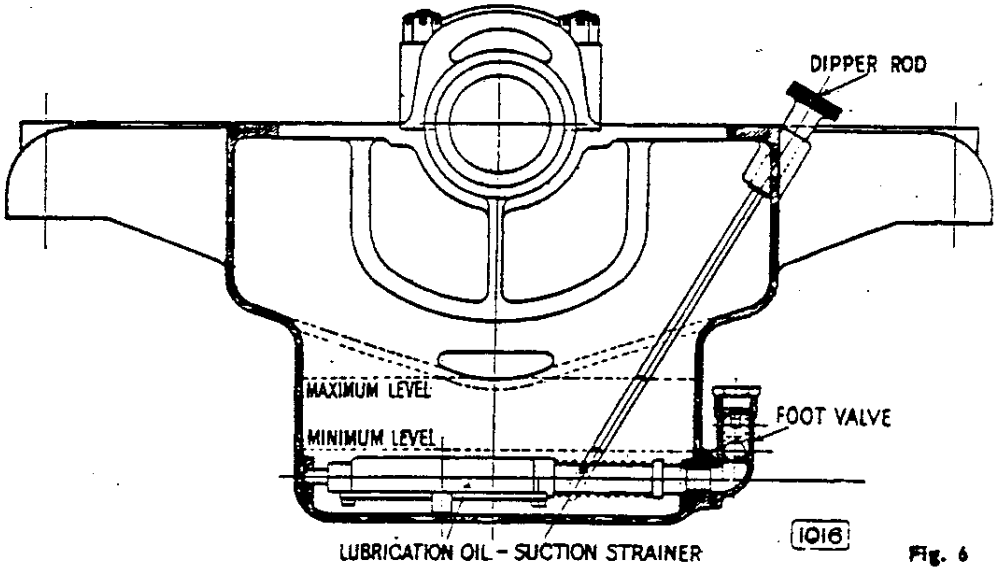


Fig. 6

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. **Suitable Lubrication Oil.**—This is supplied by any of the well-known makers, and must conform to the following viscosity specifications:

VISCOSITY REDWOOD No. 1

Specification BW For use in Winter or in Cold Climates		**Specification BS** For use in Summer or in Warm Climates	
Temp. °F.		Temp. °F.	
70 Not exceeding	1250 secs.	70 Not exceeding	1600 secs.
100 „ „	420 „	100 „ „	600 „
140 Not less than	120 „	140 Not less than	160 „
200 „ „ „	54 „	200 „ „ „	64 „
Cold Test Not higher than	5°F.		

PREPARATIONS FOR STARTING—*continued.*

29. **Lubrication Oil Pressure.**—The pressure gauge should read not less than 30 lb./sq. in. after starting from cold, while the engine is running at 1,000 r.p.m. If this pressure be not registered, stop the engine and investigate.

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 grease before starting (refer to para. 80) and give one turn to the cover of the cup.

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 @ 100°F.	not exceeding...	45 secs.
Sulphur :	„ „	·5%
Ash :	„ „	·01%
Water :	To be free from visible water	
Calorific Value : B.Th.U./lb.	... ...	19,400

32·1 **Ignition Quality.**—This is an extremely important factor. An excepted 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 approximate to this figure and should not in any case fall below 52.

Another figure in use is the Cetene Number. This is always several points higher than the Cetane Number for any given fuel. The above figures if quoted in Cetene Numbers are :—

Cetane 57—Cetene 65.
Cetane 52—Cetene 60.

PREPARATIONS FOR STARTING—*continued*

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.

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

(*a*) Autovac Vacuum Feed Tank, operated from the Vacuum Brake System. See Drawing No. 933H.

(*b*) S.U. Electric Petrolift Fuel Pump. See Drawing No. 933H.

(*c*) Gravity Feed Tank. See Drawing No. 714H.

(*d*) Amal Fuel Lift Pump and Gardner Overflow Return System. See Drawing No. 1592H.

(*e*) S.U. Electric Diaphragm Pump and Gardner Overflow Return System.

(*f*) Auto-Pulse Pump and Gardner Overflow Return System.

It is necessary 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 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.

PREPARATIONS FOR STARTING—*continued.*

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.

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 vestage 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.

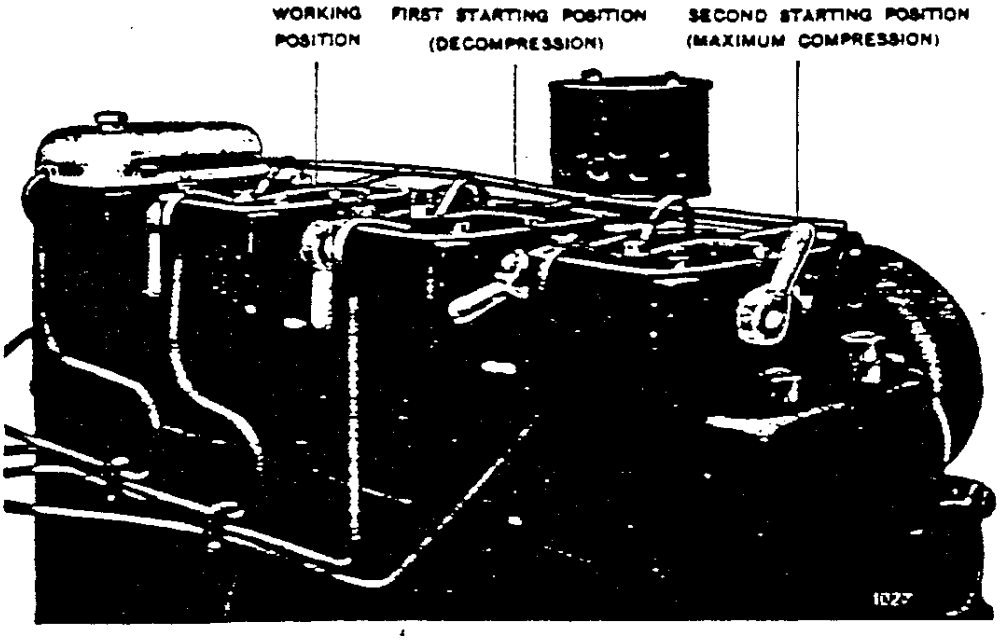
Caution.—Do not inject fuel into the cylinders by means of the priming levers.

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.

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.



STARTING LEVERS. SHOWN IN THEIR THREE DIFFERENT POSITIONS — Fig. 7

STARTING FROM "ALL COLD"

36. **Step No. 1.** Turn the stopping lever 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 governor-controlled bar and allow it to slide 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.

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.

Step No. 7. Turn all the starting levers vertically downwards 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"

STARTING A WARM ENGINE

36·1 Proceed as in para. 36 but omit Step No. 2 and do not use the maximum compression position of the starting levers.

TO START BY ELECTRIC STARTER MOTOR

37. **Step No. 1.** Make sure that all cylinders are on full compression (Fig. 5) or maximum compression (Fig. 5) if conditions are extremely cold.

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

Step No. 3. If the 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 30 lb./sq.in. at about 1,000 r.p.m., if not, shut down at once, and investigate : probably the suction 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. It is also advisable to follow this practice in order to permit the lubrication system to assume proper circulation.

39·1 **Idle Running.**—It is not good practice to run an engine idle for any length of time.

STOPPING THE ENGINE

40. **To Stop.**—Turn the stopping lever 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.

STOPPING THE ENGINE—*continued.*

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.

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.

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

GENERAL OPERATIONS AND MAINTENANCE

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.

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. Our agents have extensive lists of approved lubricating oils and can advise customers in this matter. In cases not covered by these lists we will be pleased to advise customers ourselves.

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 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 and pressure regulator. It now passes into the feed pipes of the main bearings and hence, 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 and 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.

GENERAL OPERATIONS AND MAINTENANCE—*continued.*

FILTER

48. **Delivery Filter.**—As will be seen, this unit is situated on the near side of the crankcase at the flywheel end. 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.

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 300 hours. To this end, remove the filter cover, take out the gauze element and wash it thoroughly in clean paraffin or fuel oil.

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 (Fig. 6), 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. 6.

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.

GENERAL OPERATIONS AND MAINTENANCE—*continued.*

51. **Pressure Regulation Valve.**—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 30 lb./sq. in. at about 1,000 r.p.m. with lubrication oil at a temperature of about 130°F. It is well to mention here that, until the engine attains maximum working temperature the oil in the sump may not attain so high a temperature as 130°F., consequently, the pressure recorded may be about 32 lb./sq. in. Therefore if this regulation valve be dismantled for any reason it should be re-set to give 32 lb./sq. in. when the engine is thoroughly warmed up at 1,000 r.p.m. 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 lock-nut. This, of course, should be done before dismantling. 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 20 lb./sq. in.

51·1 **Lubricating Oil Temperature.**—Just as in some installations the lubricating oil temperature may not rise above 130°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. 1) 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.

GENERAL OPERATIONS AND MAINTENANCE—*continued.*

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 allowing fuel to reach the crankcase.
    (5) The gauze filter in the sump is choked for want of attention.
    (6) Shortage of oil in the sump.
    (7) A pipe fracture somewhere in the system.
    (8) Worn bearings or bearing failure.

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 every 300 hours.
    (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.—When leading the small oil pipe from the pressure regulation valve to the pressure gauge on the instrument panel, it is important to secure the pipe from all vibration and consequent possible fracture.

54. **Crankcase Sump. Renewal of Lubrication Oil.**—It is recommended that the sump oil be completely drained off not less frequently than every 300 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.

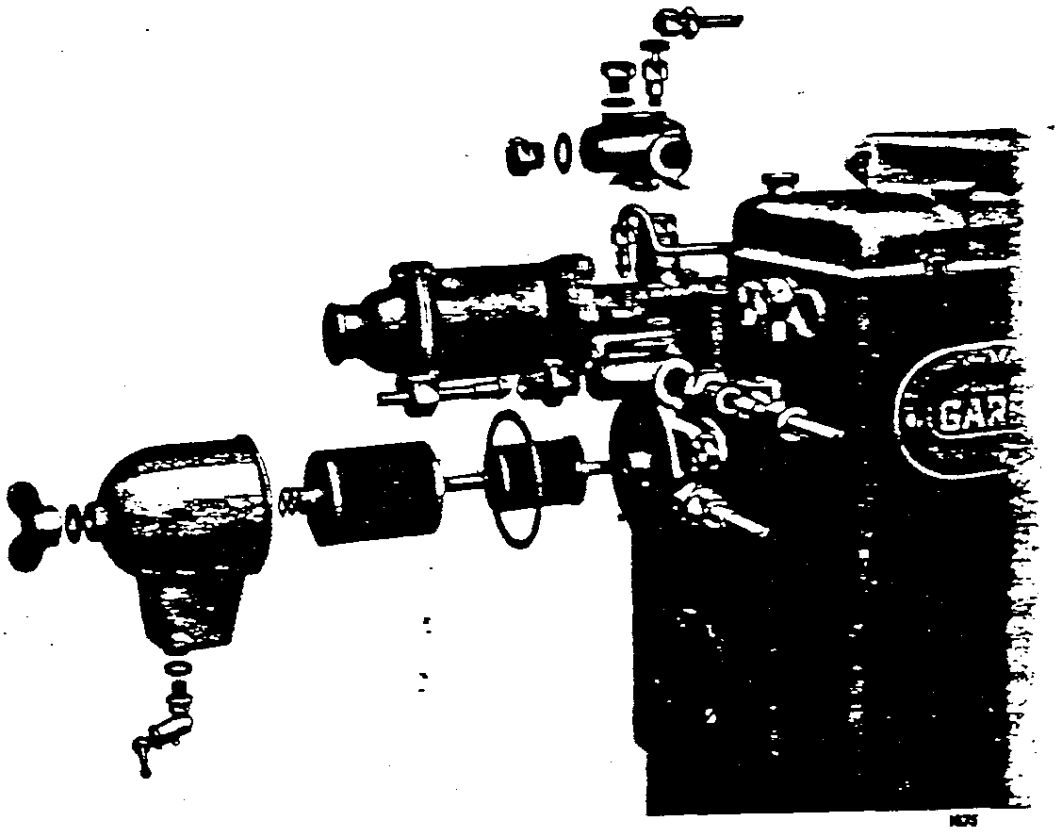
55. **Gauging the Sump Oil Level.**—This is described in para. 23.

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 as also the level which should be maintained.

57. **Oil Filler Box.**—This is mounted on the main gear or timing case at the forward end of the engine on the near side. The filler box opening to the timing case 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 timing case.

GENERAL OPERATIONS AND MAINTENANCE—*continued.*

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.



SECOND FUEL FILTER Fig. 9

59. **Fuel Filters.**—These are readily opened and contain an inner and an outer element, which are removable for cleaning. Both 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.**—If the filter elements are held up to a good light and the light cannot be seen through the gauze, it may be assumed that the filter is choked.
Another test is as follows : 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.

GENERAL OPERATIONS AND MAINTENANCE—*continued.*

60. **Cleaning of Fuel Filters.**—The frequency of this operation depends among other things on the type and quality of the fuel used. It is recommended that the outer element 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, 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.

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 600 hours.**

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

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

63. **Fuel Sprayer test every 300/600 hours.**—These should be tested without removal from the cylinder heads by operation of the hand priming levers fitted to the fuel injection pumps. This test can be carried out in a few minutes and if the sprayer valve is not heard or felt to vibrate when the lever is pulled quickly, the sprayer should be replaced by a service unit. This simple test will give a reliable indication of an imperfect sprayer valve seat or a friction bound valve.

Every 3,000 hours the sprayers should be withdrawn, inspected and serviced as indicated in the following paragraphs. It should be noted that GARDNER Factory-reconditioned Sprayers are available from the Works, Branch Offices, Service Depots and from our official Service Agents, at a modest cost in exchange for used sprayers.

GENERAL OPERATIONS AND MAINTENANCE—*continued.*

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. 11. The jets of fuel emitted from the jet-holes should all travel the same distance and should appear alike. If they do not, take the sprayer to pieces and prick and clear the jet-holes by means of the pricker 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.

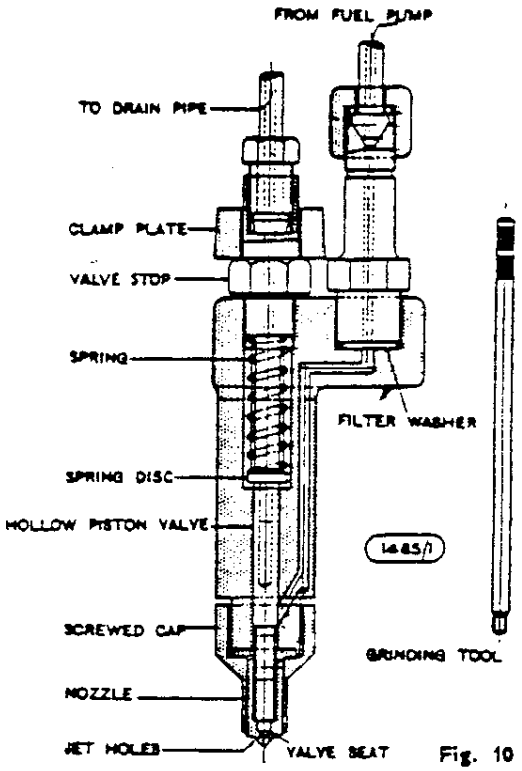
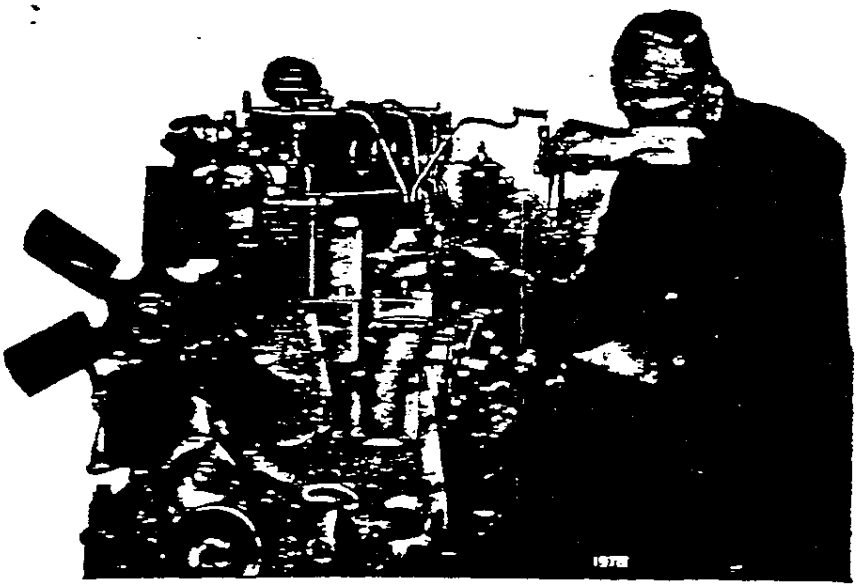


Fig. 10

65. **To Clean the Sprayer Nozzle.**—Having pricked the jet-holes (from the outside, of course), 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. 12.


TESTING A SPRAYER Fig. 11

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.

GENERAL OPERATIONS AND MAINTENANCE—*continued.*

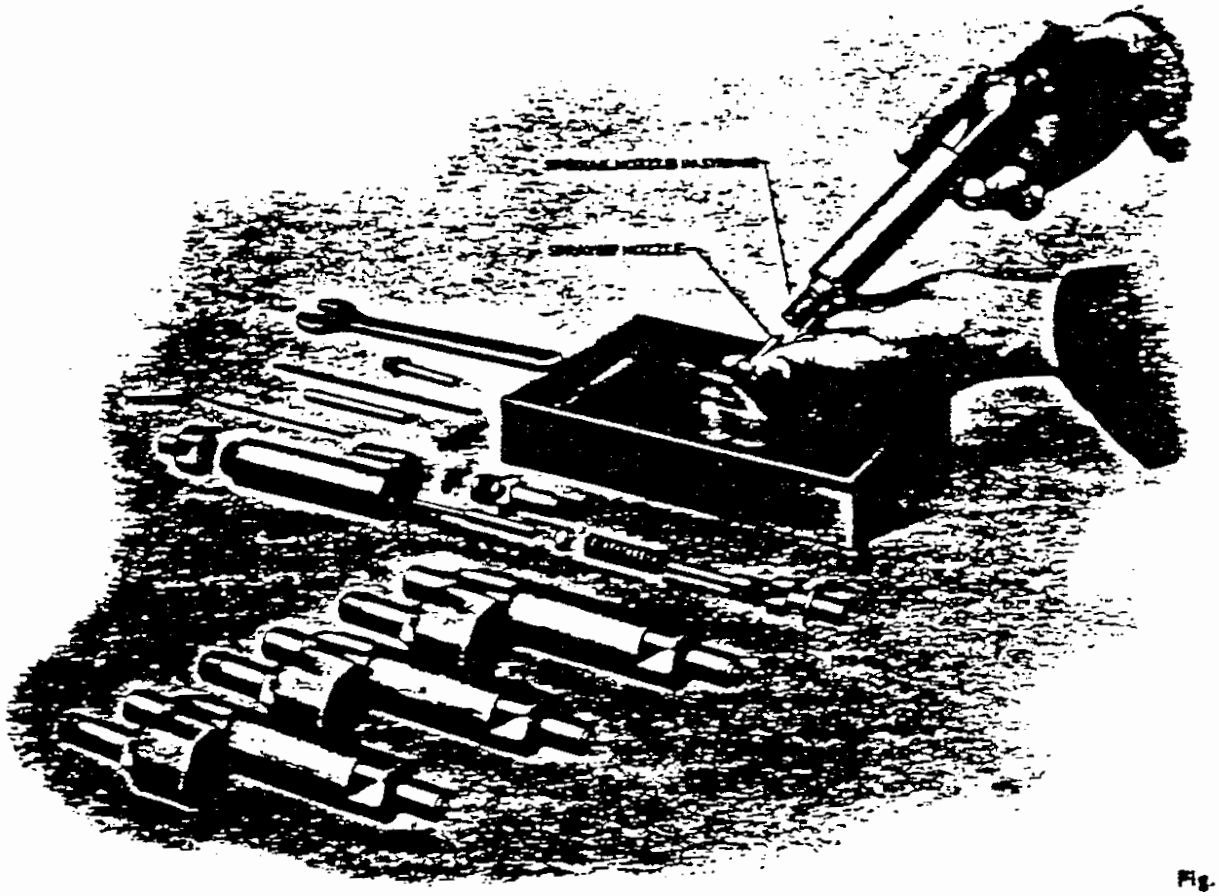


Fig. 12

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. 11).

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.*

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. 70. A leaking valve can often be traced to mis-setting of the nozzle to the body (alignment). 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.

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 valve stop and spring.

(3) The hollow piston valve with the small spring disc.

Remove the spring disc 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 70.

GENERAL OPERATIONS AND MAINTENANCE—*continued.*

70. **To Re-assemble the 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 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 disc.

(4) Spring and valve stop.

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 reconditioning which will be carried out at the least possible expense to the customer.

72. **Lift of Piston Valve.**—This dimension is 0·008 in., 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.

72·1 **Spring Load on Sprayer Valve.**—The opening and closing pressure of the sprayer valve is determined by the load required to compress the spring a given amount. This method of determining the opening and closing pressure is a more reliable means of setting than by using a pump and hydraulic gauge. The correct spring load (which should be rigidly adhered to) for sprayers stamped " E1 " is 55 lb., for this purpose the spring should exert this load (55 lb.) when compressed to its working length of 1·320 in. This load for sprayers stamped " E " was 50 lb. and when these sprayers are dismantled the spring load should be increased to the current figure 55 lb. at 1·320 in. by fitting shim washers between the upper end of the spring and the screwed stop. It will be convenient for future reference to stamp the Fig. " 1 " after the letter " E " on sprayers so modified.

The correct spring load for sprayers which are not stamped " E " or " E1 " is 60 lb. at a spring space of 1·320 in. These sprayers must not be modified. It is very desirable but not imperative that an engine delivered equipped with sprayers stamped " E1 " should be serviced with sprayers stamped " E.1"

GENERAL OPERATIONS AND MAINTENANCE—*continued.*

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 cuase 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 300 hours. This permits of systematic, leisurely cleaning and examintion without loss of running time. If they were returned to the makers they would be examined, cleaned and tested for a merely nominal charge.

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. Marine and Rail Traction Types.**—Marine engines are normally fitted with ram type pumps for this purpose. 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. 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 amout of air together 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.

Stationery or rail traction types of engines which have a " closed " circulation system, *e.g.*, a radiator or tank, are fitted with a centrifugal type of pump (see paras. 80, 81), gear driven, also from the valve camshaft.

GENERAL OPERATIONS AND MAINTENANCE—*continued.*

79·1. **Operating Temperatures.**—The desirable temperature of the water outlet for operation of marine, rail traction or stationary types is 140°F. (60°C.).

79·2. **Water Temperature Control.**—Marine engines and all engines which draw their cooling water from large or unlimited supplies of water at or about atmospheric temperature are fitted with a temperature control 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 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, 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 water at or about 140°F. (60°C.) (provided the radiator, pipes and ventilation are adequate).

79·3. **Operating Under Conditions of Extreme Cold—Closed Systems.**—Firstly, under these conditions it is necessary that an ' anti-freeze ' preparation is sufficient quantity to prevent freezing be added to the cooling water ; secondly, under conditions of light duty, the radiator may, with advantage, be partially blanked.

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. **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 a slight malalignment between the pump and its driving member.

The only attention which the pump requires is lubrication of the ball bearing. This should be carried out by using not more than one grease cup full per 3,000 hours. Use a lithium base grease to No. 2 or 3 N.L.G.I. rating system or a good quality calcium base grease, having a drop point of 100° C. nominal.

GENERAL OPERATIONS AND MAINTENANCE—*continued.*

81. **Water Pump. Drain. Frost.**—As the pump is exposed and is not automatically drained with the rest of the system, it is necessary to drain it separately. The drain cock will be found at the lowest point on the pump case. If, by any chance, water became frozen in the pump, it is obvious that serious consequences might follow any attempt to start and run the engine. In order to guard against this contingency, so far as is possible, the diameter of the impeller spindle of centrifugal pumps 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 damage to the driving gears which cost considerably more to replace than an impeller.

82. **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 is 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. **Circulation, again.**—Inspection should be made regularly in order to ascertain if circulation be taking place.

83·1. Circulation can be seen at the top of the radiator only when the temperature is above 135°F., when the engine is fitted with a thermostat.

83·2. On engines fitted with the Automatic Temperature Control Valve, 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 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.

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 3,000 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.

GARDNER
L2
TYPE

GENERAL OPERATIONS AND MAINTENANCE—*continued.*

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 3,000 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 18,000 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 inlet valves are replaced care must be taken to see that there is a minimum clearance of 0·002 in. (two-thousandths of an inch) between the stem and guides. Should the valve stems be a closer fit than this the guides must be reamed out until the 0·002 in. (two-thousandths of an inch) 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 0·003 in. (three-thousandths of an inch) between the stems and guides. Should the valves stems be a closer fit than this the guides must be reamed out until the 0·003 in. (three-thousandths of an inch) clearance is obtained.

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.

GENERAL OPERATIONS AND MAINTENANCE—*continued.*

89. **Replacing the Cylinder Head.**—The gas joint of head to cylinder is made by a soft copper plate. When replacing a head, it is therefore only necessary to see that the faces are absolutely clean and to apply a smear of seccotine or other fluid joint compound. Care should be taken to avoid scraping any metal off the surfaces and not to allow jointing compound to become hard before assembling. Screw up all the nuts equally.

When replacing a cylinder head, it is recommended, as in para. 84, to renew the small water joint rings.

90. **Tappet Clearance.**—After replacing a cylinder or after every 1,000 hours, adjust, if necessary, the clearance between the end of the tappet rod and the heel of the valve rocker. The correct clearance for inlet and exhaust valves is ·005 and ·010 inches respectively. 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 and when the engine is cold. 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 control of the governor the idling speed, which is set by the makers during test, remains sensibly the same whether the engine be hot or cold and does not vary with climatic conditions. Advantages of this stability should be taken by the user to set the idling speed to such as will give him the smoothest running for his particular installation. This adjustment is effected by a knurled screw and lock nut adjacent to the accelerator lever. During test at the works, the idling speed is set at 400 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 subject to regular inspection.

90·2. **Accelerator Control.**—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 is the screw which is sealed in the opposite arm to the idling screw, of this same lever.

90·3. **Position of Accelerator Lever** (Fig. 12).—In order that the remote control may be as light as possible, it is necessary to make the coupling rod, cable, etc., of such a length that the rod and the lever contain an angle of 90° when the control is in the position for maximum speed. This clearly gives the greatest leverage when the greatest effort is required. Otherwise stated, the length of coupling rod, cable, etc., should be such that it is square to the lever with the control in the maximum speed position, because then the leverage is greatest when it is most needed.

GARDNER
L2
TYPE

GENERAL OPERATIONS AND MAINTENANCE—*continued.*

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

91·1. It is of the utmost importance that the governor-bar connecting link be adjusted as above. Shoulc the link be adjusted to such a length as to leave no clearance in the above position there is 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 : 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 running on a stud eccentrically housed in the timing case. The method of adjustment is obvious.

The chain should be inspected for slack every 1,000 hours. To repeat, do not, on any account, run the chain with less slack than that indicated above.

92·1. **Timing Chain. Renewal and Refitting.**—After long use the timing chain will require renewal (see para. 107). 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 33$\frac{1}{4}$ 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.

93. **Decompression: Adjustment to Valve Lift.**—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. from its seat.

93·1 **Summary of attention in terms of running time.**—(Detailed instructions for the necessary routine attention are given in the respective paragraphs quoted).

DAILY

Lubrication System: Check level of oil in sump and replenish if necessary. See paras. 22 and 23.

Cooling System: Check level of coolant and replenish if necessary.

Ram Type Water Circulating Pump: Fill lubricating oil cup regularly with engine oil.

Lubricating Oil Pressure: Observe that the pressure gauge indicates the correct lubricating oil pressure within a few seconds of starting the engine. Refer to page 4 (1L2) and para. 51 (2L2 to 6L2).

EVERY 300 HOURS 1L2 → ? Revised G.T.O.: Office 30/6/71

Lubricating Oil Sump: (capacity six pints.) Drain and refill sump with fresh oil. See paras. 22 and 23.

NOTE: Where engines are operating under dusty conditions, it is desirable to change the engine oil more frequently. Under extreme conditions this may be necessary after periods of 100 hours or less regardless of fuel and lubricating oil qualities.

Lubricating Oil Delivery Filter (2L2 to 6L2 only): Examine and clean if necessary. See paras. 49 and 50.

Lubricating Oil Suction Filter: Examine and clean if necessary. See para. 50·1.

Fuel Filters: Examine and clean if necessary. See page 3 and paras. 58 to 62.

Sprayer: Operate fuel injection pump priming lever and observe by feel and sound that the sprayer is functioning correctly. This test can be made without removal of the sprayer from the cylinder head.

Air Induction Filter: Examine and service as required depending upon operating conditions.

EVERY 1,000 HOURS

Timing Chain (2L2 to 6L2 only): Inspect and adjust if necessary. See para. 92.

Radiator Fan (if fitted): Check driving belt and adjust if necessary. Grease spindle bearing.

Slow Running Adjustment: Inspect and adjust if necessary. See para. 90·1.

Valve Tappet Clearances: Check and adjust if necessary. See para. 90.

EVERY 3,000 HOURS

Decarbonise and Top Overhaul: See paras. 85 to 90 and 98.

Sprayer: Inspect and service if necessary. See paras. 63 to 71.

Fuel Injection Pump: Check maximum output and calibrate as directed in Fuel Pump Calibrating Machine Instruction Book No. 45·4.

Governor Control Slider Bar: Inspect and adjust if necessary. See paras. 91 and 91·1.

Centrifugal Water Circulating Pump: Inject not more than one grease-cupful of grease. Use a good quality calcium base grease having a drop point of 100°C. nominal or a lithium base grease to No. 2 or 3 N.L.G.I. rating system.

Pistons: Under particularly arduous operation and/or when fuel and lubricating oil conditions are very unfavourable it may also be necessary to remove and clean the pistons. See paras. 85·1 and 94.

EVERY 18,000 HOURS

Effect Major Overhaul of engine involving re-sizing of crankshaft and the fitting of new bearings if diametral wear exceeds ·005 in. (main bearings) or ·004 in. (big-end bearings).

NOTE: The preceding summary of recommended attention is based upon average conditions of operation including fuel, lubricants and duty, etc., and it is to be appreciated that heavy duty and adverse conditions compared with light duty and favourable conditions may respectively reduce, or considerably increase, the periods at which attention is advisable.
For example, it is not unusual that 25,000 hours be attained or exceeded before major overhaul is required. Cylinders, pistons and piston rings may have a useful life of 10,000 or 20,000 hours or more and without removal from the engine.

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.

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 $\frac{1}{32}$ 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 about 0·015 in. (fifteen-thousandths of an inch).

96. **Big-End Bearings. Main Bearings.**—Whenever new bearing shells have to be fitted to any of these bearings, the following points should be observed. The bearing shells must be a perfect fit in their housings. Both the big-end bearings 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 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. (two-thousandths of an inch) between the cap and the housing.

Bearing shells should be carefully hand-scraped so that, when bolted up, they are perfectly free on the pin or journal but yet have no play or slack. Do not make any attempt to " burn in " a bearing by running the engine, as this will bring no end of trouble. The big-end bearing endwise clearance between crank webs and bearing should be 0·003 in. Min., 0·010 in. Max.

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 wrong way round for these shells. Bearings are so fitted that the numbers lie on the governor side of the engine for the big end bearings and on the manifold side for the main bearings.

Pay particular attention to the joints of the feed pipe of the main bearings and use always new packings.

97. **Crankshaft.**—This is located endwise between the two main bearings nearest to the flywheel and should have an end-play of 0·005 in. (five-thousandths of an inch)

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 sign of abrasion : a scratch or a dinge can usually be detected by rotating the half of a bearing shell on the shaft.

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

98. **Valves.**—Exhaust valve stems should have a clearance of 0·003 in. in their guides while 0·002 in. will suffice for the inlet valve stems. When assembling the spring collars, do not screw them further down the valve stems than is necessary in order to thread in the cotter pin.

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 th 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.

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 and other organs 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 in the cam-tappet socket and not to push the upper end under the valve rocker 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. Top Dead Centre.**—Drawn across the periphery of the flywheel will be found a number of pairs of lines, one pair for each cylinder or crank, and a short line called the **zero line** will be found on the upper crankcase, in the case of engines fitted with normal (22 in.) flywheels and on No. 1 cylinder, in the case of engines fitted with extra heavy (26 in.) flywheels. Taking for example, the pair on the flywheel belonging to No. 1 cylinder, when the longer line marked

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

" No. 1 T.D.C." is opposite to the zero line, No. 1 crank is exactly on the top dead centre (T.D.C.), and when the line marked " No. 1 cylr. Injection " is opposite the zero line, the timing lines on the corresponding injection pump should coincide, as described in para. 105. Similar remarks apply to the other cylinders.

102·1. **Note.**—No. 1 cylinder is the one at the forward end of the engine, the injection pump end.

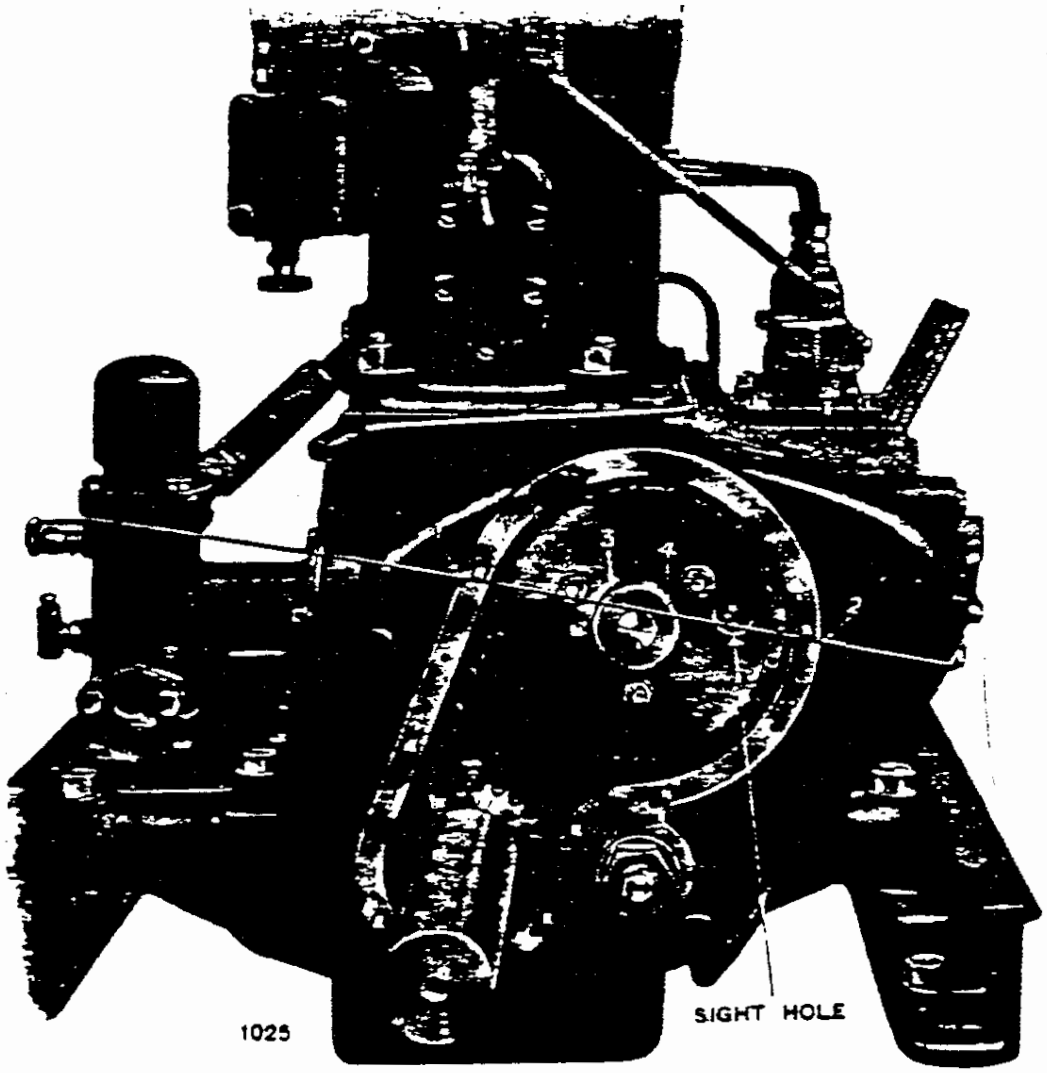


Fig. 13

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

103. **Timing of Fuel Injection.**—Each fuel pump is provided with a sight hole or window through which can be seen the plunger moving up and down. On the sides of the window is a horizontal line and also one on the plunger. When these two lines coincide, the corresponding injection line on the flywheel registers with the zero line as described in para. 102. When so checking the timing, be careful not to be misled by turning the flywheel in the wrong direction. On the fuel-pump tappet are locked screws which should never be disturbed (see para. 108).

104. **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. 13). 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. 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 :—

(1) The dots 1 and 2 on the gear case and the dots 3 and 4 on the periphery of the camshaft chain will all lie on a straight line as indicated by the stretched cord in Fig. 13.

(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.

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

105. **Timing of Inlet and Exhaust Valves.**—The cams are so fixed on the camshaft that they cannot be displaced. The only way therefore of deranging the timing is by disturbing the screws in the heel of the rocking levers. Should these be displaced they should be re-adjusted so as to give the correct clearance between the toes of the levers and the ends of the valves when the latter is closed (see para. 90).

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

106. **Correction for Stretch (Wear) of Timing Chain.**—In the course of time, the chain wears and consequently increases in length which causes the timing of the valves and fuel injection to become slightly retarded, therefore compensation should be made when required. To this end inspect the timing as indicated in paras. 102 and 103 after, say 1,000 hrs. working, and if it be found that the timing is retarded, proceed as follows : Turn the flywheel until one of the injection timing lines is in line with the zero line on the crankcase, then slacken the three hexagon nuts on the main chainwheel shown in Fig. 13 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. 103. Check the timing again after tightening the nuts.

107. **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).

108. **Fuel Pump Tappets.**—As mentioned in para. 103, 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 the tappet has lifted to its maximum, then turn the flywheel one more exact revolution, the 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 .103 ; 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 ·140 in. gauge is in position on any of the tappets. Very serious damage to the fuel pump will occur if this is not observed.

109. **Governor Bar Buffer.**—The purpose of this device is to prevent stalling of the engine in the event of a certain amount of friction being generated in the fuel pump, which can cause the slider bar to remain in the stop position. When correctly set the spring loaded buffer is in contact with, and exerting force upon, the slider bar only during that portion of the slider bar stroke from the idling position to the maximum stop position.

The adjustment of the buffer with respect to the slider bar must be checked only when the engine is thoroughly warm, after a considerable run under load. There should then be a clearance of approximately ·006 in. between the buffer and slider bar when the engine is idling at normal speed. This can be seen after the small hexagon headed sight hole plug has been removed. The clearances may be reset by slackening the locknut and adjusting the buffer, which is screwed into the control box, then retightening the locknut. Do not set the buffer actually in contact with the bar, as this will cause unstable idle running. Great pressure should not be exerted when re-tightening the locknut.

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

110. **Valve Lubrication.**—After a cylinder head has been dismantled and the engine is started up again, observation should be made to ascertain that the oil feed on each valve lever is operating and oil reaching the valve ends.

111. **Cylinder Liners.**—The cylinders are fitted with dry liners and full particulars for re-linering are available on application.

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. Cam Shaft 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. **Diaphragm Type Fuel Pumps and Gardner Overflow Return Feed System.**—These pumps, 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 at a pressure of about 1½ lb./sq. in. Out of the chamber, fuel and any air there may be, is allowed to overflow through a ·025 in. dia. hole back 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 levers 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.*

116. **Instructions for Fitting Spare Fuel Pumps on 5 and 6L2 Engines.**—In the event of this being necessary, due to 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. 108.

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 adjustments 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.

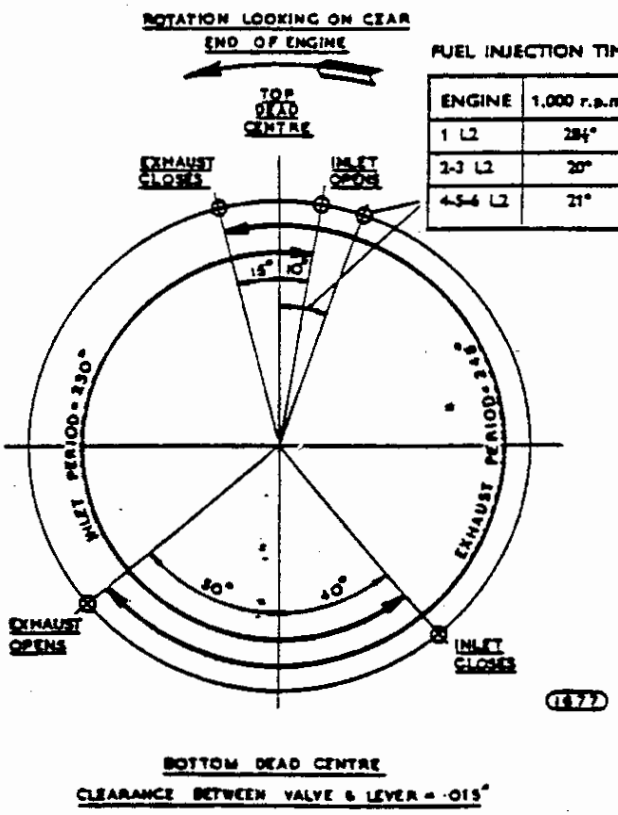
For fitting the spare pump to 2, 3 and 4L2 engines, proceed as above but omit items Nos. 2 and 3.

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.

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

117. **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.



FUEL INJECTION TIMING

ENGINE	1,000 r.p.m.	1,100 r.p.m.	1,300 r.p.m.
1 L2	28½°	29°	—
2-3 L2	20°	—	21°
4-5-6 L2	21°	—	22°

Service.—The following components are available from the Works as service/exchange units :—

Fuel Sprayers,
Fuel Injection Pump,
Cylinder Blocks,
Cylinder Heads,
Water pumps,
Governor body assemblies,
Lubricating oil pumps, etc.

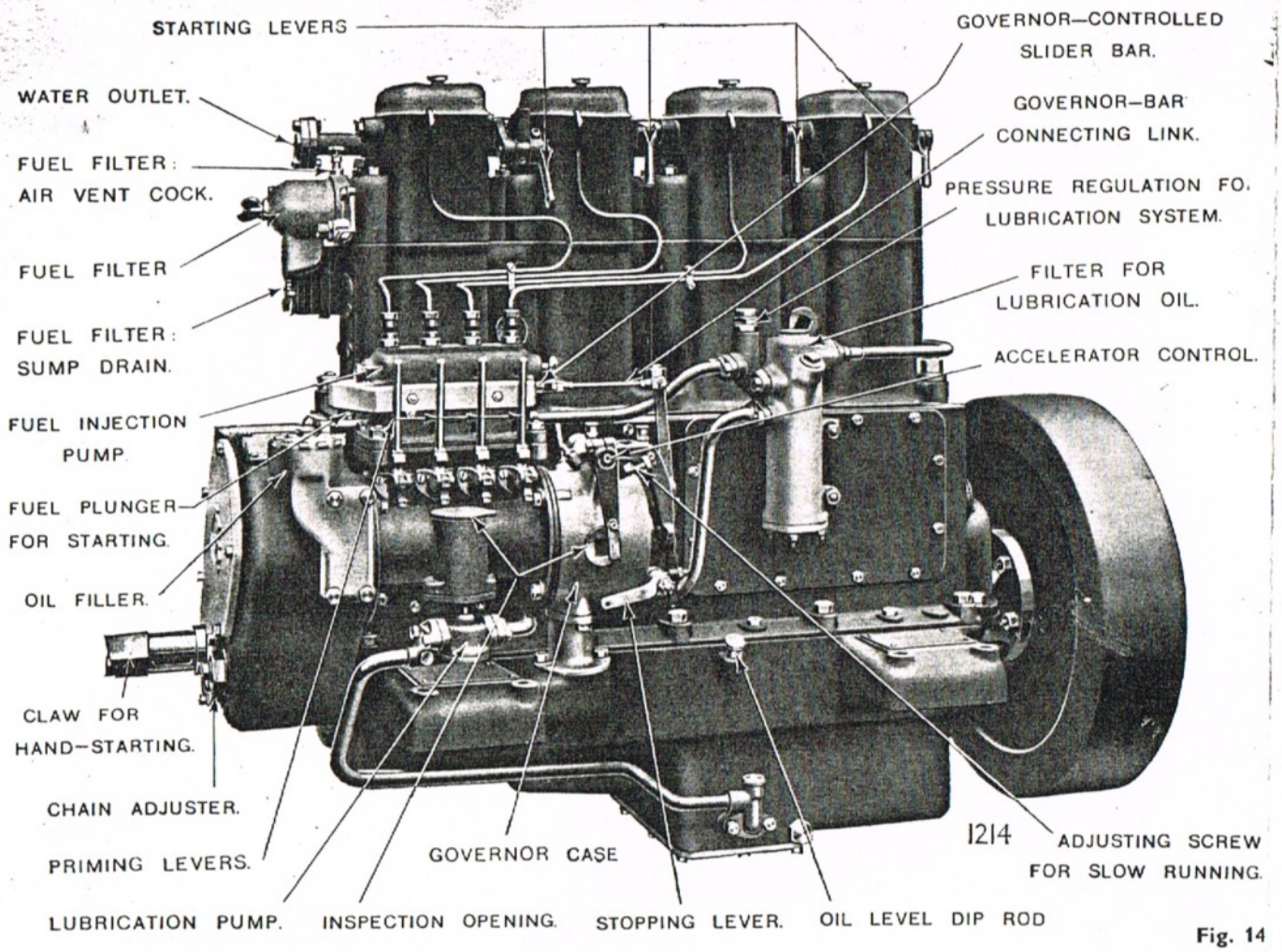

STARTING LEVERS
GOVERNOR—CONTROLLED SLIDER BAR.
WATER OUTLET.
GOVERNOR—BAR CONNECTING LINK.
FUEL FILTER: AIR VENT COCK.
PRESSURE REGULATION FO. LUBRICATION SYSTEM.
FUEL FILTER
FILTER FOR LUBRICATION OIL.
FUEL FILTER: SUMP DRAIN.
ACCELERATOR CONTROL.
FUEL INJECTION PUMP.
FUEL PLUNGER FOR STARTING.
OIL FILLER.
CLAW FOR HAND—STARTING.
CHAIN ADJUSTER.
PRIMING LEVERS.
GOVERNOR CASE
1214
ADJUSTING SCREW FOR SLOW RUNNING.
LUBRICATION PUMP.
INSPECTION OPENING.
STOPPING LEVER.
OIL LEVEL DIP ROD

Fig. 14

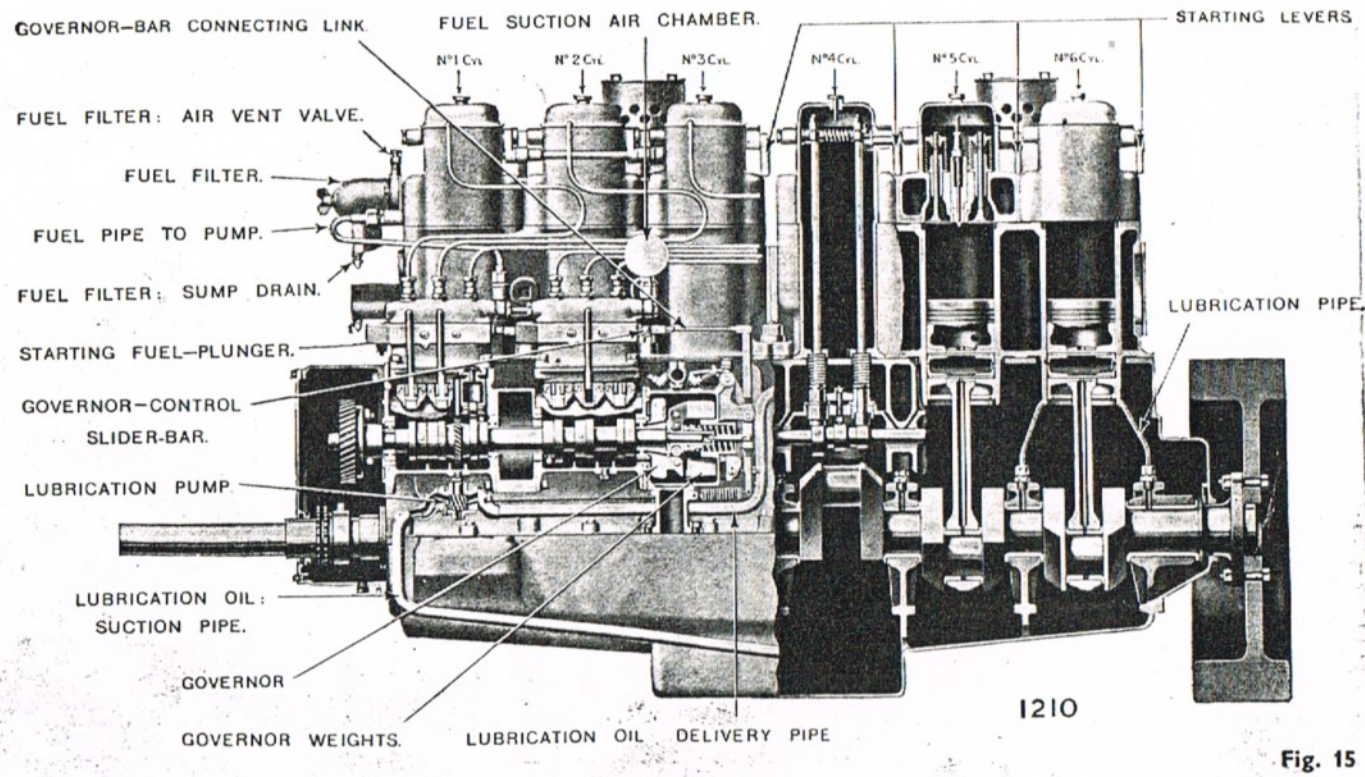

GOVERNOR—BAR CONNECTING LINK.
FUEL SUCTION AIR CHAMBER.
STARTING LEVERS
N°1 Cyl.
N°2 Cyl.
N°3 Cyl.
N°4 Cyl.
N°5 Cyl.
N°6 Cyl.
FUEL FILTER: AIR VENT VALVE.
FUEL FILTER.
FUEL PIPE TO PUMP.
FUEL FILTER: SUMP DRAIN.
LUBRICATION PIPE.
STARTING FUEL—PLUNGER.
GOVERNOR—CONTROL SLIDER-BAR.
LUBRICATION PUMP.
LUBRICATION OIL: SUCTION PIPE.
GOVERNOR
1210
GOVERNOR WEIGHTS.
LUBRICATION OIL DELIVERY PIPE

Fig. 15