INSTRUCTION BOOK No. 67

LW & HLW
LW20 & HLW20
DIESEL ENGINES

INSTRUCTION MANUAL

OPERATION

MAINTENANCE

OVERHAUL

INSTALLATION

GARDNER

AUTOMOTIVE • RAIL TRACTION • INDUSTRIAL

OPERATING and MAINTENANCE INSTRUCTIONS

for

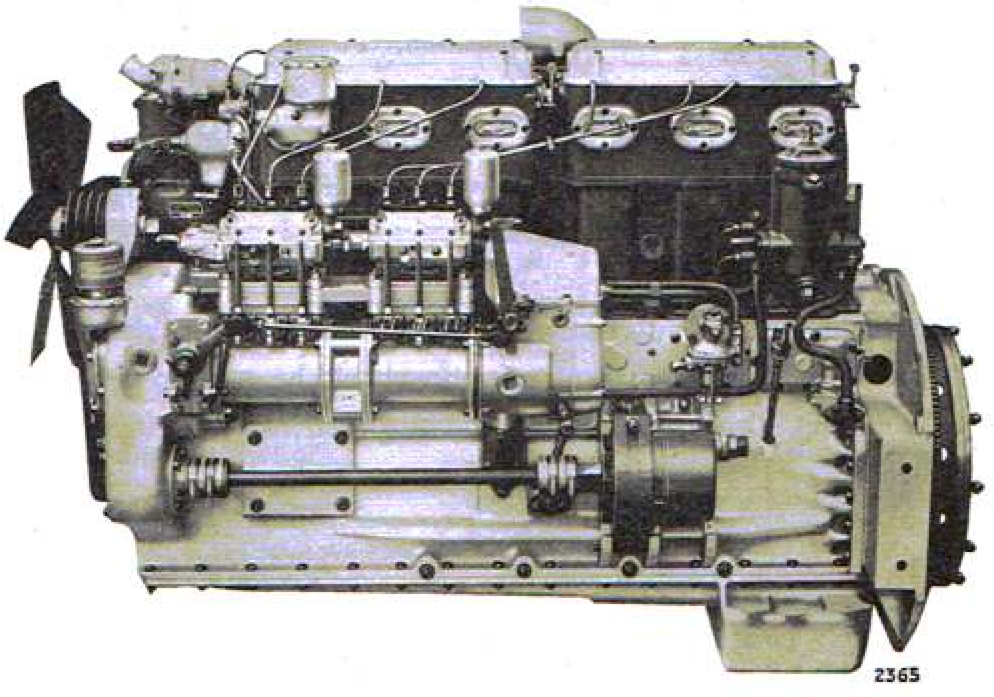
GARDNER

VERTICAL and HORIZONTAL

DIESEL ENGINES

TYPES

LW, HLW, LW20, HLW20



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HAWKER SIDDELEY

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FOREWORD

THE data contained in this Manual is based upon experience and has been compiled in an endeavour to facilitate efficient and durable operation of our engines in widely differing fields of application. To many who are familiar with our product much may be superfluous: to many the data may prove inadequate, and in this event on any occasion it is our wish that we be given the opportunity of offering our service and advice.

Should further information be desired in respect of component and engine overhaul, reference should be made to the Workshop Tools, Equipment and Instructional Drawings Book.

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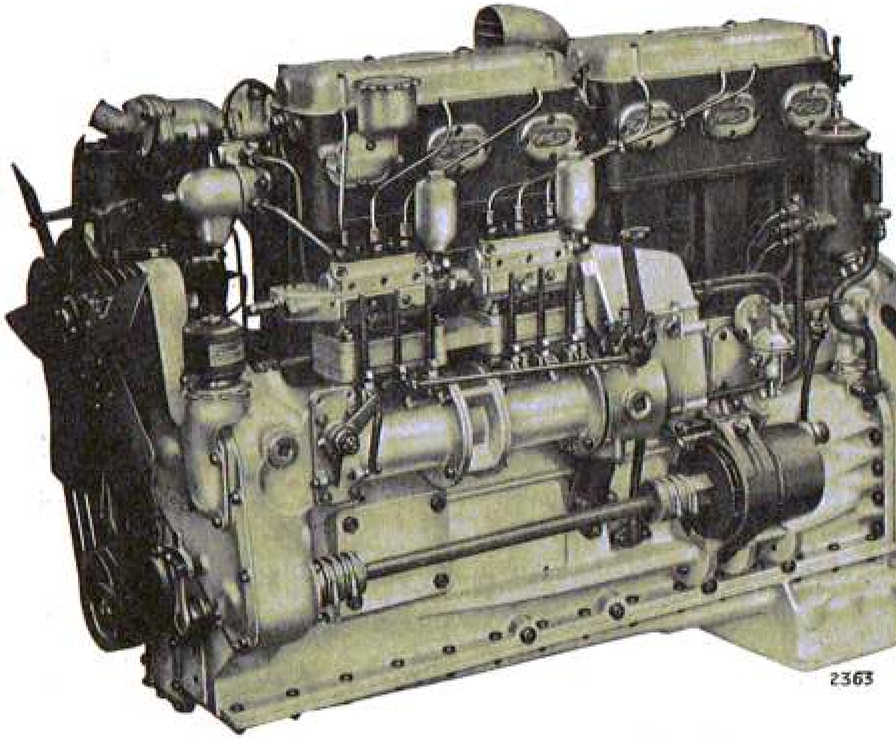
GARDNER



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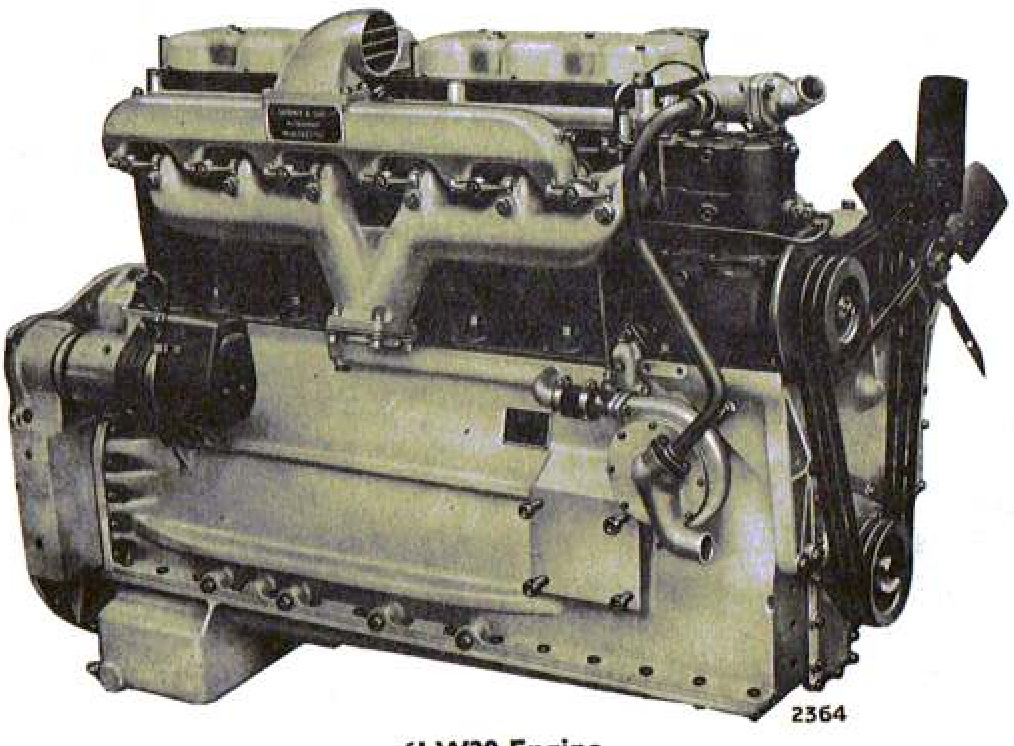

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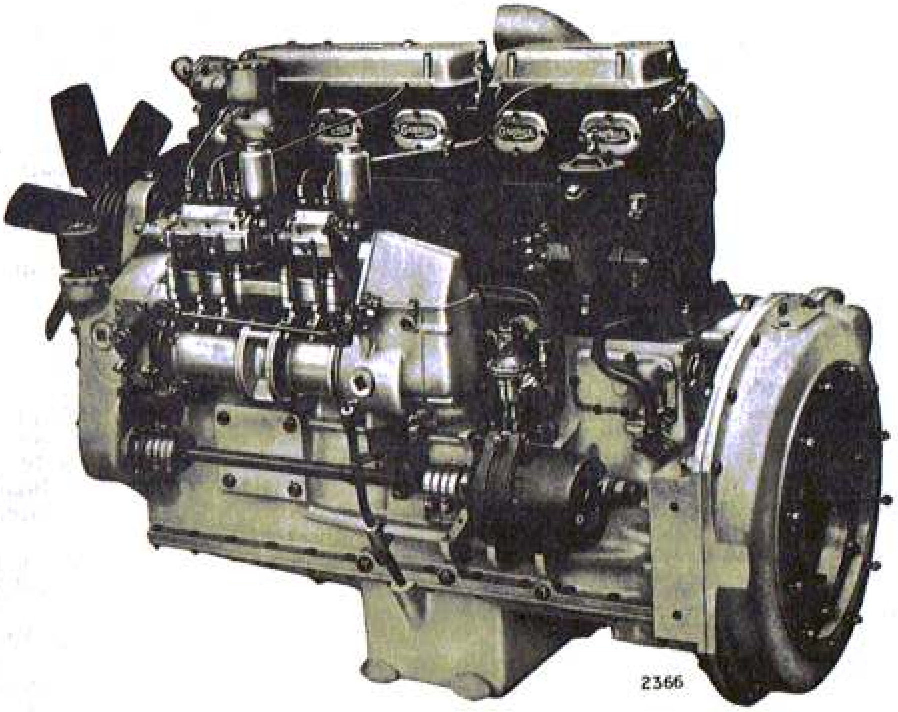
6LW20 Engine



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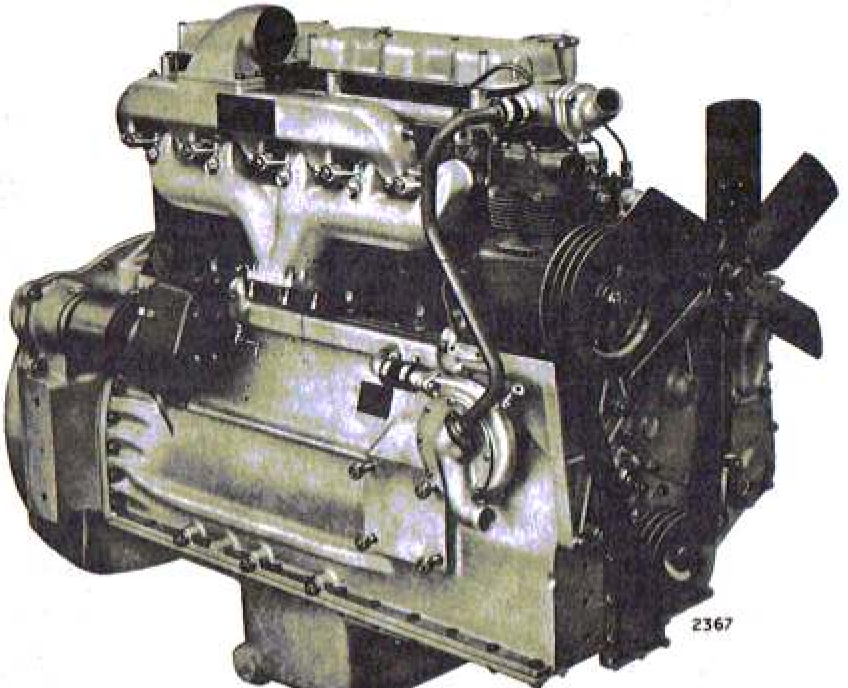

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5LW20 Engine

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GENERAL DATA AND POWER OUTPUT

The LW and LW20 Series Vertical and Horizontal engines have a common bore of 4¼ in. (107·95 mm.) and stroke of 6 in. (152·4 mm.). The numeral appearing before the type designation indicates the number of cylinders with which the engine is constructed and the letter "H" included in the type designation signifies the horizontal version, thus 6LW indicates the 6-cylinder engine of the Type LW, and 6HLW indicates the 6-cylinder version of the Horizontal Type LW.

AUTOMOTIVE RATINGS FOR ROAD VEHICLES

Engine	Swept Volume		B.H.P.	R.P.M.	Maximum Torque			Approximate Weight with Flywheel and Starter	
	cu. in.	litres			lb. ft.	kg. m.	r.p.m.	lb.	kg.
5LW20	426	6·974	100	1,700	317	43·8	1,350	1,295	587
6LW20	511	8·369	120	1,700	381	52·7	1,350	1,485	674
6HLW20	511	8·369	120	1,700	381	52·7	1,350	1,535	696

RAIL TRACTION RATINGS

Engine	Swept Volume		B.H.P.	R.P.M.	Maximum Torque			Approximate Weight with Flywheel & without Starter	
	cu. in.	litres			lb. ft.	kg. m.	r.p.m.	lb.	kg.
2LW	170	2·790	35·5	1,700	113	15·7	1,300	910	413
3LW	255	4·184	53·5	1,700	170	23·4	1,300	960	435
4LW	340	5·579	71	1,700	226	31·2	1,300	1,140	517
5LW20	426	6·974	100	1,700	317	43·8	1,350	1,295	587
6LW20	511	8·369	120	1,700	381	52·7	1,350	1,485	674

Note: The weights quoted are approximate only and will vary according to duty, size of flywheel and electrical equipment fitted. They are not necessarily the lightest specification which can be compiled.

The powers quoted are those developed at **normal atmospheric temperature and barometric pressure,** i.e. 60°F. and 30·0 in. Hg. respectively, without cooling fan, electric generator, compressor, hydraulic pump, exhauster and are to Specification B.S. AU141, 1967.

When an engine is to operate at high altitude or under adverse climatic conditions we observe the de-rating data detailed on pages 14 and 15.

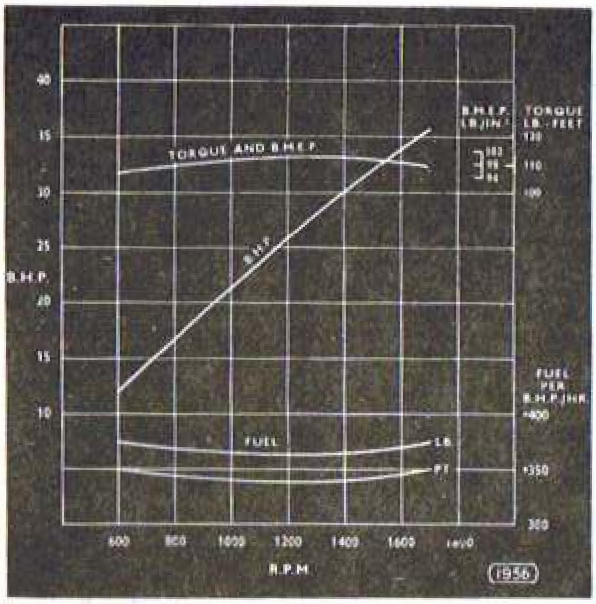
Conditions of duty may also necessitate some amendment to the powers quoted and further information in this respect will be provided by the Works upon receipt of the relevant details.

The governor controls the maximum engine speed to approximately 1,770 r.p.m. at no-load.

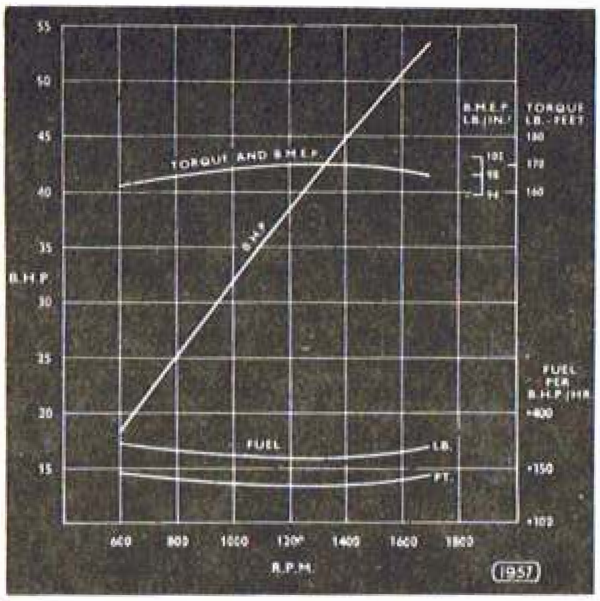
The radiator cooling fan on 2–6LW and 5LW20 engines absorbs approximately 0·75 b.h.p. and on 6LW20 engines approximately 1·5 b.h.p.

Performance Curves

FOR RAIL TRACTION DUTY ONLY

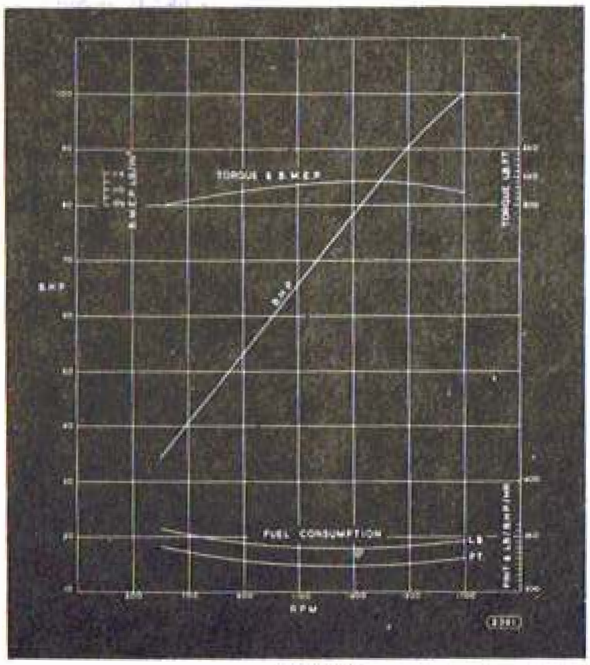


2LW

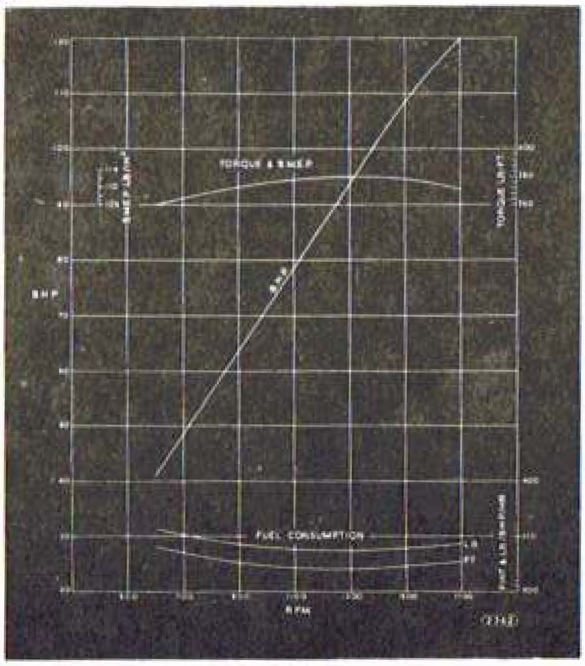


3LW

FOR ROAD VEHICLE AND RAIL TRACTION DUTIES



5LW20



6LW20

These curves are made from figures regularly observed during normal production tests of the engines. Large-scale prints of all performance curves are available on application.

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.

The powers quoted in the table on page 10 and shown on the graphs page 11, 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 1000 feet 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 2000 feet altitude with a mean annual atmospheric temperature of 75° F., from the graph, page 15, we read the following reductions:

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

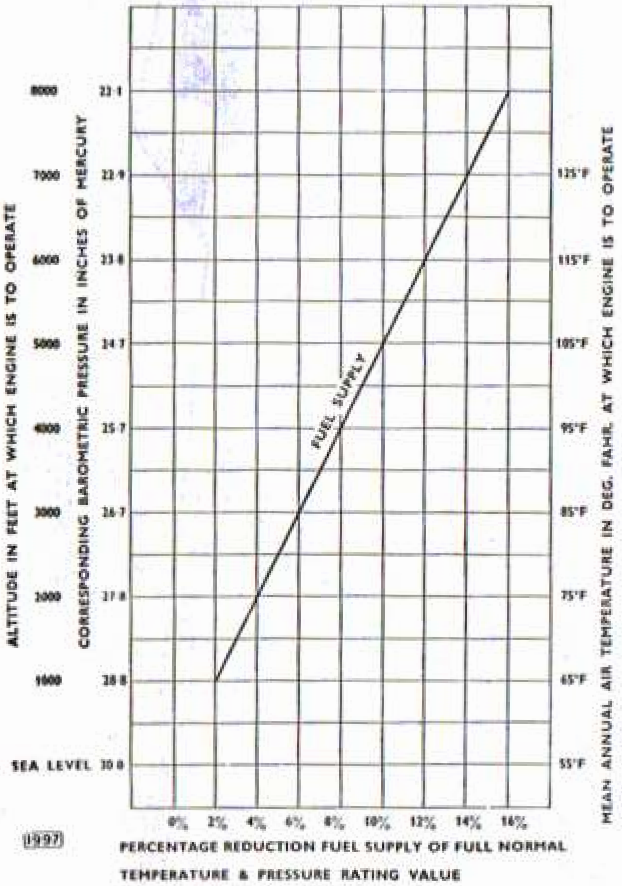
When it is intended that an engine shall operate permanently at 1000 feet altitude or 65° F. mean annual ambient temperature, or in excess of either of these figures, it is necessary that the length of the fuel pump output control trigger be increased in order to reduce the injected fuel supply appropriately according to altitude and temperature shown on the graph on page 15.

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 45·4. On page 9 of Book 45·4 will be found the average delivery from each plunger in cubic centimetres and the values quoted are to be reduced according to the graph on page 15.

On page 15 will also be found a graph showing 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%

Altitude and Temperature Diagrams



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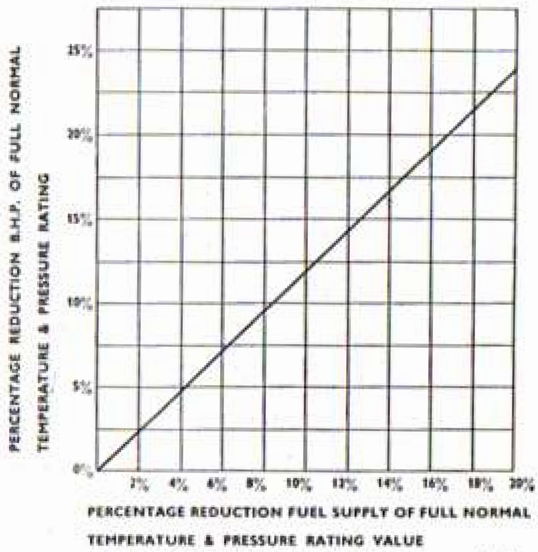
REDUCTION IN FUEL SUPPLY FOR ALTITUDE AND TEMPERATURE CONDITIONS



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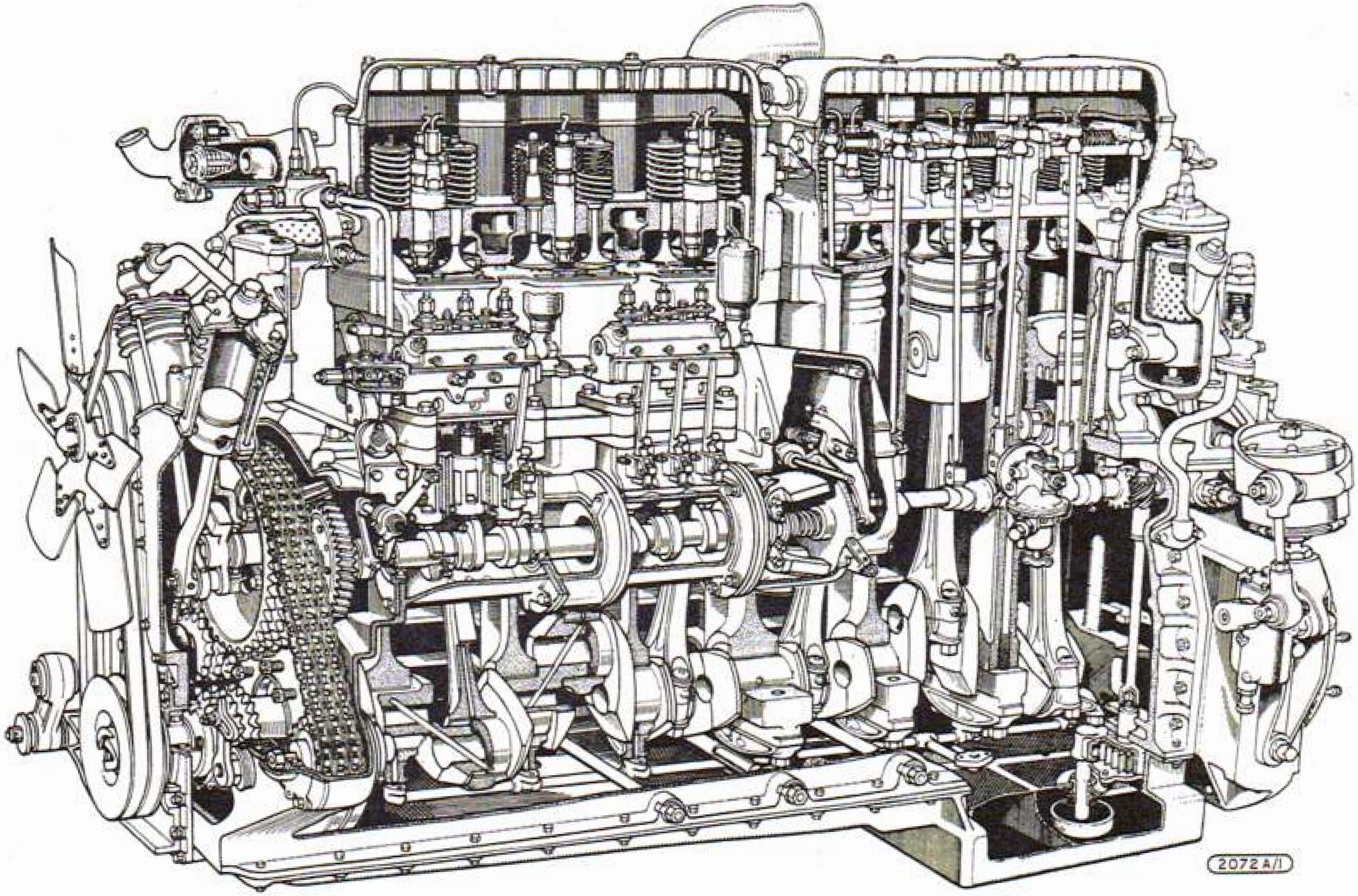
REDUCTION IN B.H.P. WHEN FUEL SUPPLY REDUCED UNDER ALTITUDE AND TEMPERATURE CONDITIONS



GARDNER
6LW20 AUTOMOTIVE ENGINE

GENERAL INTRODUCTORY NOTES

1. **General Principles of Operation.**—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.

   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 LW 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.

   The injection of the fuel into the combustion chamber is effected by an injection pump, one plunger 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.

2. **Preservation.**—Before dispatch, all external unpainted parts of an engine are coated with a special preservative to prevent corrosion. On engines destined for delivery in the United Kingdom a clear preservative is used, whilst on engines packed for export this same base preservative carries blue dye. This coating is readily soluble in fuel oil or paraffin.

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

   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 to retain the protective varnish until the last moment.

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

5. **Lifting the Engine.**—On LW and LW20 engines eye nuts are provided for screwing on to the cylinder head studs to form an attachment for lifting the complete engine. It will be observed that the appropriate cylinder head studs are extended beyond the normal nuts in order to receive the eye nuts. It is usual to remove the eye nuts after the engine is installed, and place them in the tool box. Protecting metal caps are provided to screw on the exposed portion of the stud on marine engines.

   On the horizontal engines the lifting arrangement consists of a lifting eye on the front and rear cylinder head and one at each end of the crankcase to provide a four-point lift. These lifting eyes are not to be removed after installation. When lifting, a spreader must be placed between each pair of sling hooks, i.e. between the two on the cylinder heads and between the two on the crankcase.

GENERAL INTRODUCTORY NOTES

LUBRICATING OIL SPECIFICATIONS

6. **LUBRICATING OIL.** The importance of using high quality lubricating oil and the draining and refilling of the engine oil sump at the recommended intervals cannot be over emphasized. These factors play a most important role in maintaining an engine in good and efficient condition and ensure a long engine life between overhauls.

Most oils available today are of the additive type; that is to say they all contain, to some degree, certain additives which ensure a minimum of deposits on internal parts of the engine and go a long way to combat the evils of sulphur present in varying amounts in almost all fuel oils. They also possess many other desirable properties.

These additive type lubricants are produced in compliance with various specification standards which are listed below in approximately descending order of additive level and, therefore, performance ability.

	MIL-L-2104C SERIES 3 + MIL-L-2104B MIL-L-45199B + MIL-L-2104B	A.P.I. Classification CD plus CC
• •		
	MIL-L-46152 MIL-L-2104B	A.P.I. Classification CC
•		
	MIL-L-2104A (SUPPLEMENT 1) DEF-2101D	A.P.I. Classification CB
•		

• These specifications are officially obsolete, but are still marketed throughout the world.

The higher the duty an engine is called upon to perform and/or the higher the sulphur content of the fuel oil the more desirable it becomes to use the best quality oil available.

Even when high quality oil is in use, we recommend that the sump is drained and refilled every 6,000 miles (400 hours for stationary and marine applications) and more frequently if the engine operates in dust laden atmospheres (some overseas regions, mines, quarries, etc.) and/or when using fuel of high sulphur content, say 0·5% and over.

6·1. **RECOMMENDED VISCOSITY.** As a general rule a lower viscosity lubricant should be used during cold weather, or in cold climates, than is used during hot weather or in hot climates.

The following tables show our recommendations for this purpose based on the mean ambient temperature prevailing during the operation of the engine.

GENERAL INTRODUCTORY NOTES

LUBRICATING OIL SPECIFICATIONS—*continued*

The table shows the SAE grades which we recommend for use at the varying ambient temperatures:—

Below —1°C	(30°F)	—	SAE 20W/20
—1°C to 13°C	(30°F to 55°F)	—	SAE 20 or SAE 20W/20
13°C to 32°C	(55°F to 90°F)	—	SAE 30
Over 32°C	(90°F)	—	SAE 40

There can be wide variations in the viscosity covered by SAE numbers and the above recommendations are based on the assumption that each grade has a viscosity index (V.I.) of not less than 95 in line with current high quality lubricants.

NOTE 1 — The Works will be pleased to advise in any case where operating conditions are particularly arduous or where temperature conditions are not covered by the above table, as for instance severe tropical and arctic conditions where oils heavier and lighter respectively than those quoted above should be used.

The use of ultra low viscosity lubricating oil is emphatically not recommended and indeed, we cannot accept responsibility for premature wear and failure of parts in an engine which has been operated on such oils. The only departure from the above tables which could be approved would be the use of oil to SAE 20W/20 in a public service vehicle engaged on a stage carriage service, provided the ambient temperature is not in excess of 70°F (21°C) **and provided that the vehicle does not have a transversely mounted engine at the rear without an oil cooler.**

NOTE 2 — In general there is little advantage to be derived from the use of multi-grade oils in the GARDNER engine operating under high duty conditions, but under certain other conditions, e.g., vehicles mainly involved in short haul, light, or mixed load work or when it is desired to use the same grade of oil throughout the year, a multi-grade oil can be used to advantage. Under these circumstances we would suggest the use of high quality oil of viscosity grade SAE 20W/40.

7. **FUEL OIL.** 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 if possible be the subject of an actual trial in an engine.

Any fuel for this purpose should be wholly distillate.

Specific Gravity at 60°F. (15·6°C.)	not exceeding	·845
Initial Boiling Point	.. not less than	356°F. (180°C.)
Distillation Test	.. not less than 90% at	675°F. (357°C.)
Flash point (Pensky-Martin)*	.. not less than	150°F. (65·6°C.)
Viscosity:		
Redwood No. 1 at 100°F. (37·8°C.)	not exceeding	40 secs.
Kinematic at 100°F. (37·8°C.)	not exceeding	5·5 cs.
Sulphur	.. not exceeding	0·4%
Cloud Point:		
Winter or say below 35°F. (1·7°C.)	not exceeding	14°F (–10·0°C.)
Summer	.. not exceeding	28°F. (-2·2°C.)
Ash	.. not exceeding	0·01%
Water	.. ..	To be free from visible water
Calorific Value Btu/lb.	.. ..	about 19,400 (10,800 kcal/kg)

*Local regulations may stipulate a higher Flash Point.

GENERAL INTRODUCTORY NOTES

FUEL OIL SPECIFICATIONS—*continued*

7·1. **IGNITION QUALITY.** A good quality fuel may have a Cetane value as high as 57, it is desirable that the Cetane value of the fuel approaches this figure and should not in any case fall below 52. Another unit in use is the Diesel Index Number which is usually several points higher than the Cetane number for any given fuel. The above figures quoted as Diesel Index numbers are:

Cetane 57	Diesel Index 62
Cetane 52	Diesel Index 56

7·2. **IGNITION QUALITY IMPROVER ADDITIVE.** Broadly speaking the best fuel is one having the minimum sulphur content and possessing the highest ignition quality. Fuels having a low sulphur content are usually of poor ignition quality.

It is established that the cylinder bore wear rate of engines with fuel containing less than 0·1% sulphur may be less than half that obtaining when the fuel contains 0·5% sulphur.

High ignition quality promotes quiet and smooth operation, durability and low maintenance, together with startability and smokeless cold running.

Fuel additive isopropyl nitrate marketed by Messrs. Imperial Chemical Industries Limited may be added to average fuels securing the following approximate Cetane Number Gain.

Addition	*Cetane Gain*
0·25% by volume	5–7 units
0·50% by volume	9–11 units
0·75% by volume	13–15 units
1·0% by volume	16–20 units

The gain in cetane number will vary with the source and quality of the fuel used but would be expected to fall within the above limits.

When using isopropyl nitrate observe manufacturer's recommended precautions with regard to storage, inflamability, handling, etc., of this product.

7·3. **LUBRICATING OIL ADDITIONS TO FUEL.** It is permissible that a small quantity of lubricating oil, up to a maximum of 1% be added to the fuel. If paraffin is used as a fuel, this addition of lubricating oil is desirable. Used sump oil may be employed, disposing of it usefully in this way. It must be allowed to stand for a few days so that carbon and solid matter may settle, the oil then being drawn from near the top of the container. Periodically the container must be drained, to remove the accumulating sediment. Alternatively, the used oil may be cleaned by filtering or centrifuging. Whichever method is employed, cleanliness is essential.

NOTE.—Special attention is called to the fact that in certain countries, including the United Kingdom, it is an offence to use as fuel, hydro-carbon oils that have been rebated. Such rebated oils include lubricating oil, spindle oil and paraffin. Where any such use is contemplated, payment of the full duty will be required and if in any doubt the Local Customs and Excise Officer should be contacted.

GENERAL INTRODUCTORY NOTES

ENGINE COOLING RECOMMENDATIONS

8. **Coolant Temperatures.**—It is recommended that the temperature of the outlet from the engine be not allowed to exceed 175°F. (80°C.) and that in most cases a satisfactory operating temperature is 140°F. to 160°F. (60°C. to 71°C.).

Engines used for Rail Traction duty and heavy duty vehicles should be operated at lower temperatures. Generally, the higher the duty which an engine is called upon to perform the lower should be the temperature to which the water is controlled and arrangements made to achieve this end.

Conversely, the water temperature of a short haul road vehicle or shunting locomotive, etc., should be maintained at a higher figure.

8·1. **Temperature Control.**—It is not normally necessary to fit shutters or blanking plates to the radiator under conditions of extreme cold providing an anti-freeze agent is added to the coolant in sufficient quantity, since the thermostatically controlled valve or valves, incorporated in the circulation system, will automatically govern the engine temperature to a suitable figure (provided the radiator pipes and bonnet ventilation, etc., are adequate), but under light duty and cold weather conditions, thermostatically controlled radiator shutters can be useful to enable the engine to attain optimum working temperature. Such shutters should be arranged to commence to open when the outlet water from the engine attains 140°F. (60°C.).

A suitable tapped boss is provided in the water outlet pipe to receive the bulb of the usual automotive type thermometer.

In general the application of these thermostat units according to engine duty and climatic conditions are as follows:—

Engine Duty or Application	Climatic Conditions	Thermostat Unit Code No.	
		Smith's (bellows type)	Western Thomson (wax type)
Passenger Carrying Road Vehicles, Locomotives, Earth Moving Equipment, Mobile Shovels, Cranes and Short Haul Road Vehicles.	Temperate	TH 2001/00/68	6B-1030-74 with S-3501-82-375
	Sub-tropical or tropical	TH 2001/00/59	6B-1030-60 with S-3501-82-375
Goods Carrying Road Vehicle, Rail Cars, Marine Propulsion and Auxiliary Units, Industrial and Electrical Generating Sets, Portable Welding and Compressor Sets.	All Climates	TH 2001/00/59	6B-1030-60 with S-3501-82-375

It is common practice on passenger vehicles to divert some of the engine cooling water through heaters in the saloon(s), but this is not always satisfactory, principally on account of the overall relatively low waste heat passed to the water from a Diesel engine and also the relatively low temperature of the coolant. Furthermore, it is always possible for the heaters to run almost cold whilst the engine is running slowly. As soon as the engine is accelerated to high speed all this cold water from the heating system is forced into the cylinder jackets. This "quenching" effect can be a source of danger to a hot engine. Furthermore the volume of water contained in such heater systems can delay the engine "warming up" process. All these difficulties can be overcome by the various proprietary makes of heating units which do not rely upon the engine for their source of heat or circulation.

GARDNER

GENERAL INTRODUCTORY NOTES

ENGINE COOLING RECOMMENDATIONS—*continued*

8·2. **Operating Under Conditions of Extreme Cold.**—It is necessary that a reputable anti-freeze solution, containing a corrosion inhibitor, is added to the cooling water to prevent freezing and reduce internal corrosion. Radiators and water pipes can become frozen with consequent serious damage even when the engine is driving a vehicle on the road under very low temperature conditions.

Use only Ethanediol Anti-freeze conforming to one of the following British Standard Specifications:—

BS.3150—1959, BS.3151—1959 or BS.3152—1959.

To be safe down to + 15°F. (– 9°C.) add 20% (by volume) Anti-freeze.
,, ,, ,, ,, ,, – 3°F. (– 19°C.) ,, 33% ,, ,, ,, ,,
,, ,, ,, ,, ,, – 14°F. (– 26°C.) ,, 40% ,, ,, ,, ,,

To maintain the desired degree of frost and corrosion protection it is necessary to use the appropriate strength of solution (not plain water) for "topping-up" purposes.

If anti-freeze is used throughout the year it is desirable to drain and flush the system every six months and refill with the correct solution. In this way the internal corrosion will be largely prevented.

Do not mix one anti-free formulation with another. See paragraph 8.4.

8·3. **Operating Under Conditions of Extreme Cold When an Anti-Freeze Agent is Not Available.**—Under these conditions the risk of freezing the radiator, whilst the engine is running, may be greatly minimized by causing all the water circulation to pass through the radiator by removing the thermostat unit from its housing, and plugging with cork bung or blank packing the by-pass pipe between the housing and the water pump suction. In addition, and in order to further reduce the risk of freezing, and to enable the engine to attain a suitable operating temperature, blank off from the bottom upwards 50% or more of the radiator frontal area, until a temperature of 140°F. to 160°F. is attained in service. When a vehicle has to stand idle for any period sufficiently long for the radiator tubes to approach freezing point, drain away the water from the system as soon as possible after stopping the engine and leave all cocks open until the system is to be refilled (see para. 81). Hang suitable label on the radiator or take other precautions to ensure that the vehicle is not inadvertently put in service with a dry system. When filling the system preparatory to service, use hot water, since the combination of cold water and engine and radiator parts below freezing point may generate ice before the heat generated by running the engine is sufficient to prevent this.

8·4. **Cooling System Corrosion Inhibitor.**—If anti-freeze as mentioned above is not used, it is very desirable to introduce one of the many effective corrosion inhibitors into the cooling water. By this means internal corrosion of engine water jackets, heat exchangers, radiators or marine keel coolers is greatly reduced.
Certain corrosion inhibitors are available in crystal form for the charging of dispensers, through which sea cooling water can be drawn, and so reduce the corrosion usually associated with "open" sea water cooling systems.

When "topping-up" a radiator or other "closed" system it is desirable to use the appropriate strength of solution (not plain water). Every six months cooling systems should be drained, flushed out with clean water and refilled with a new solution of water and corrosion inhibitor. This is desirable because after long use the corrosion inhibitor ceases to be effective. **Corrosion inhibitors of differing formulation should not be mixed.**

Many Oil Companies and Chemical Manufacturers market suitable inhibitors.

OPERATING THE ENGINE

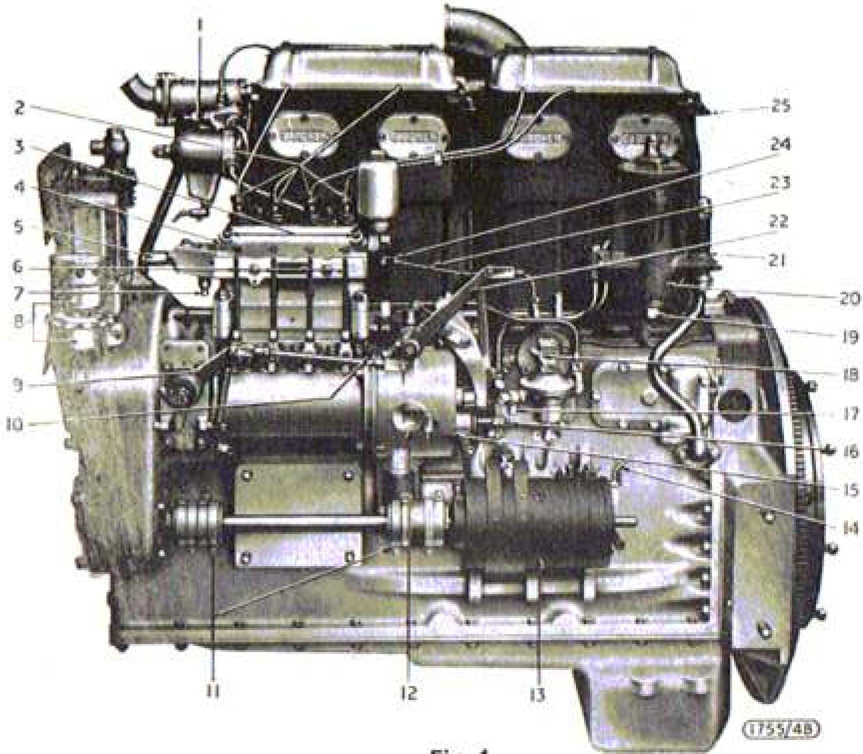


Fig. 1

Near Side Elevation

1 Fuel Overflow Return to Tank
2 Sprayer Pipe Unions
3 Injection Pump Vent Screws
4 Fuel Injection Pump
5 Governor Control Bar Buffer
6 Charging Levers
7 Starting Fuel Plunger
8 Oil Filler and Breather
9 Fuel Injection Timing Lever
10 Accelerator Lever Idler Stop
11 Dynamo Flexible Drive Couplings
12 Governor Inspection Opening
13 Dynamo
14 Oil Level Dip Rod
15 Stopping Lever
16 Idle Speed Adjuster
17 Fuel Lift Pump Inlet
18 Fuel Lift Pump Hand Priming Lever
19 Oil Filter Drain Plug
20 Lubricating Oil Delivery Filter
21 Oil Pressure Regulating Valve
22 Accelerator Control Lever
23 Connecting Link—Governor to Slider Bar
24 Governor Controlled Slider Bar
25 Decompression Lever

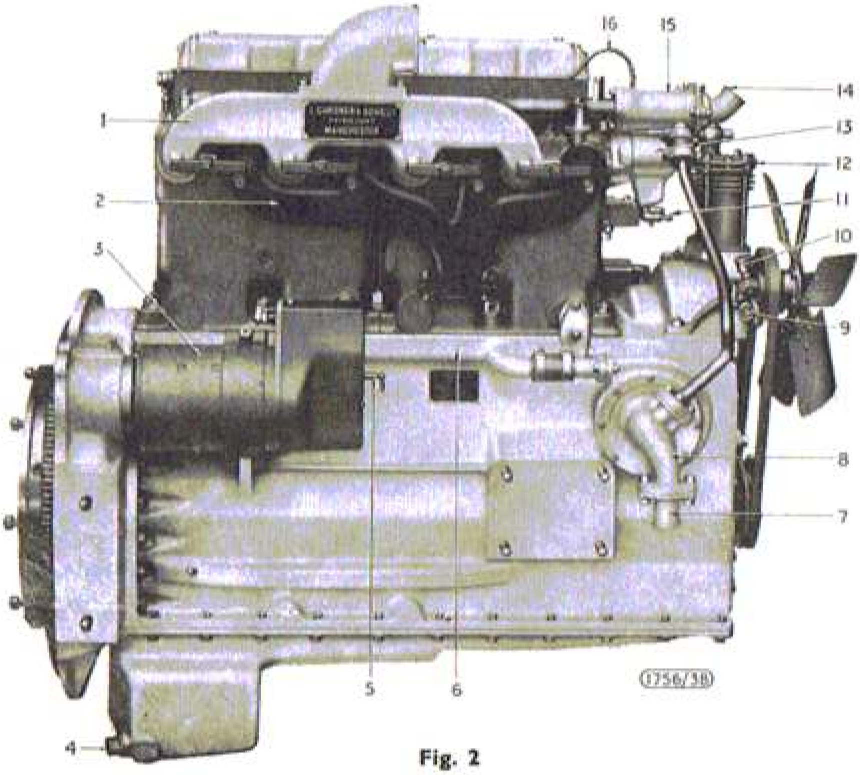


Fig. 2

Off side Elevation

1 Air Inlet Manifold
2 Exhaust Manifold
3 Electric Starter
4 Oil Sump Drain Plug
5 Cylinder Water Drain Cock
6 Cylinder Water Inlet Pipe
7 Water Inlet
8 Water Circulating Pump
9 Fan Belt Adjustment Cotter
10 Fan Bearing Greaser
11 Fuel Filter Sump Drain
12 Exhauster for Vacuum Servo Brakes
13 Second Fuel Filter
14 Water Outlet
15 Automatic Temperature Control (Thermostat)
16 Sprayer Leak Pipe

OPERATING THE ENGINE

PREPARATIONS FOR STARTING

9· **Filling the Sump and Checking Oil Level.**—The oil sump should be charged through the filler marked "OIL" situated at the front end of the crankcase, or in certain installations, on the cylinder head on the "Near Side" of the engine. Before filling the sump, reference should be made to the lubricating oil specifications given in paras. 6 and 6·1 for correct type and grade of oil.

The level of oil in the sump is measured by the dip-stick which will be found on the rear of the "Near Side" passing through a hole in the main crankcase and into the base chamber below. The sump should be charged until the level rises to the maximum mark on the dip-stick and this is the level at which it should be maintained. The quantity of oil required varies according to the design and shape of the sump fitted and, for this reason, only the dip-stick which is supplied with the engine must be used to check the sump contents.

The following are the capacities of the standard oil sump Type 11 as illustrated on Page 4.

Engine Type	*U.K. Galls.*	*Litres*
2 & 3LW	3	13·6
4LW, 5LW & 5LW20	4	18·2
6LW & 6LW20	5	22·7
4, 5 & 6HLW	4	18·2

To test the level, withdraw the dip-stick and wipe perfectly dry, then re-insert and withdraw again to obtain the correct reading.

When filling or replenishing the sump with oil, a few minutes must be allowed to elapse before the level can be checked on the dip-stick as time is required for the added oil to gravitate to the reservoir portion of the sump. Similarly, when checking the oil level shortly after the engine is stopped, allowance must be made for the circulated oil to drain back into the sump from all internal working parts of the engine, in fact the level of oil in the sump will continue to rise for some four or five hours after an engine is stopped. For this reason, when possible, it is preferable to allow an engine to stand overnight before measuring the oil level. The vehicle or machine must always be standing on level ground when the oil sump content is measured.

10. **Filling the Cooling System.**—Before filling the cooling system, reference should be made to Engine Cooling Recommendations in paras. 8·2 and 8·4 for information concerning anti-freeze solutions in conditions of extreme cold and the addition of special corrosion inhibitors. Ensure that the radiator and cooling system are filled to maximum capacity, preferably with rainwater. This is particularly important in "hard water" districts in order to avoid deposits which will impair cooling efficiency. Care must be taken during initial filling to ensure that all trapped air has been expelled from the cooling system and it is very desirable to inspect the coolant level after the engine has run for a short time and add coolant if necessary to replenish that which has entered the cab or saloon heaters.

When topping-up the system always use the correct mixture of anti-freeze or corrosion inhibitor **never** plain water as this will weaken the solution and increase the risk of freezing and/or corrosion.

If the radiator is overfilled when cold, expansion of the coolant when hot will cause loss through the overflow pipe. Always use warm coolant to replenish the cooling system of a warm engine.

11. **Priming the Fuel System.**—It is here assumed that arrangements have been made to supply fuel to the injection pumps of the engine by one of the following means.

(*a*) Amal Fuel Lift Pump and Gardner Overflow Return System.

(*b*) Gravity Feed Tank.

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.

OPERATING THE ENGINE

PREPARATIONS FOR STARTING—*continued*

(a) **With the Amal Fuel Lift Pump and Gardner Overflow Return,** delivery of fuel for priming purposes is obtained by hand operation of the Lift Pump Priming Lever, Fig. 1 Item 18.

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 Diaphragm.

Step No. 1. Slacken the forward vent screw at the top of each block of injection pumps, Fig. 1, Item 3, and operate the Fuel Lift Pump priming lever until a flush of fuel emerges, then firmly retighten the screws. Continue operating the priming lever and after one or two strokes a very much reduced resistance will be felt. This will indicate that the system is fully primed up to the elements of the Fuel Injection Pumps.

Note.—After starting a newly installed engine for the first time it may be necessary to again slacken the vent screws while the engine is running to liberate any further air remaining in the system.

Step No. 2. Work each charging lever, Fig. 1 Item 6, on the Fuel Injection Pumps 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. 2 is to clear out the air from the sprayer pipes. Each stroke of the charging lever forces some of the imprisoned air through the sprayer into the cylinder. When the last vestige of air has been forced out, the "feel" of the lever suddenly becomes "solid". It is important to cease working the levers as soon as the "solid feeling" is attained, otherwise, one is liable to inject a harmful amount of fuel into the cylinders.

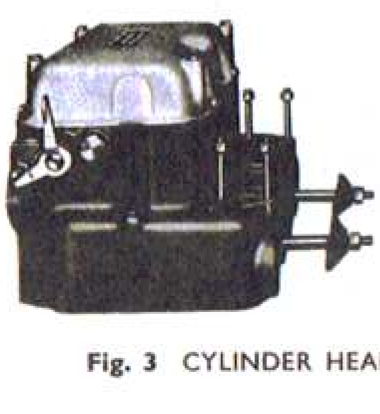
Caution.—Do not inject more fuel into the cylinders by means of the priming levers than is necessary for sprayer testing purposes, or for the purpose of "easing" a stiff cold engine.

(b) **With a Gravity Feed System,** a vent valve is provided at the top of the engine mounted fuel filter, see Fig. 9. To prime the system, release the vent valve until all air is expelled from the filter chamber and when fuel emerges close the vent valve. Next slacken the vent screws on each block of pumps to liberate any further air still remaining in the system and when a flush of fuel emerges, firmly retighten the screws. The system will now be fully primed up to the elements of the fuel injection pumps and to complete the priming, operate each charging lever as described in Step No. 2 above.

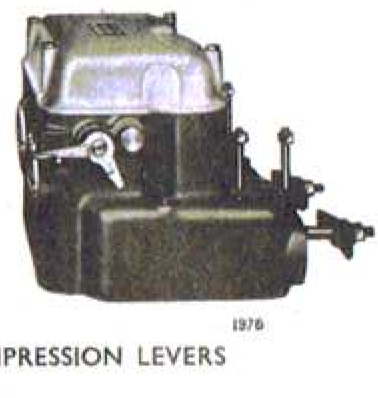
12. **Sprayer Pipe Connections.**—After the preceding priming operations are complete, ensure that the union nuts of the sprayer pipes are tight, particularly at the sprayer end, since any leakage from these unions will fall into the crankcase and contaminate the lubrication oil. This applies equally to the unions on the drain pipes of the sprayers. Inspection for leakage is readily made by removing the valve covers whilst the engine is running.

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

Position No. 1
(Decompression)



Position No. 2
(Running)



1970

Fig. 3 CYLINDER HEADS SHOWING DECOMPRESSION LEVERS

OPERATING THE ENGINE

STARTING THE ENGINE

13. **Decompression Gear.**—The essential feature of these engines is that starting may be effected by a hand cranking handle when equipped with suitable flywheel. Hand starting may be utilised for all the LW engines, electric starters are supplied when so ordered. As already explained 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, 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 is quite an achievement and is greatly facilitated by the decompressing device fitted to each inlet valve and operated by a small lever at the rear end of each cylinder head (Fig. 3). The relief of compression on all cylinders enabling the engine to be freely rotated is also a great help when carrying out routine service checks and adjustments.

14. **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 (Fig. 1 Item 7) which, on being pressed up as far as it will go releases the slider bar of the pumps and allows it to move towards the flywheel, in which position the pumps deliver an increased charge of fuel for starting from cold. If the slider bar be sluggish in operation, it may be assisted by finger pressure on the governor lever, or (if the mechanism is enclosed), by assisting the action of the return spring behind the fuel pumps. As soon as the engine is started, the slider bar automatically retakes its normal working position in which the pumps cannot give an excessive charge of fuel.

Important.—This plunger is to be used only when starting from cold: **it must on no account be used when the engine is running, in order to increase 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. The excess fuel device (Para 14·1) fitted to certain engines obviates this possibility.

14·1. **Excess Fuel Device.**—Regulations under the United Kingdom Road Traffic Act make it necessary that any device which will facilitate the starting of a motor vehicle compression ignition engine by causing it to be supplied with excess fuel must be so arranged that the device cannot be readily operated while the vehicle is in motion on the road. We have accordingly produced a tool-operated excess fuel device which is shown under operation in Fig. 4. The device consists of an extension to the aluminium housing of the fuel control box fitted on the fuel injection pump. The housing extension contains a compression spring and plunger which carries two 90° screw-driver slots at its outer end and an eccentrically disposed peg at the inner end.

The device is operated by lifting the dust flap and engaging a screwdriver in the plunger slot. The plunger is then pushed inwards and rotated approximately half a revolution. This engages the eccentric peg with an arm on the fuel limiting trigger and lifts it upwards thus allowing the fuel pump slider bar to move to the excess fuel, or cold starting position. When the screwdriver is removed, the internal compression spring moves the plunger outwards and disengages the eccentric peg. The only maintenance required is lubrication with a few drops of oil on the plunger and spring.

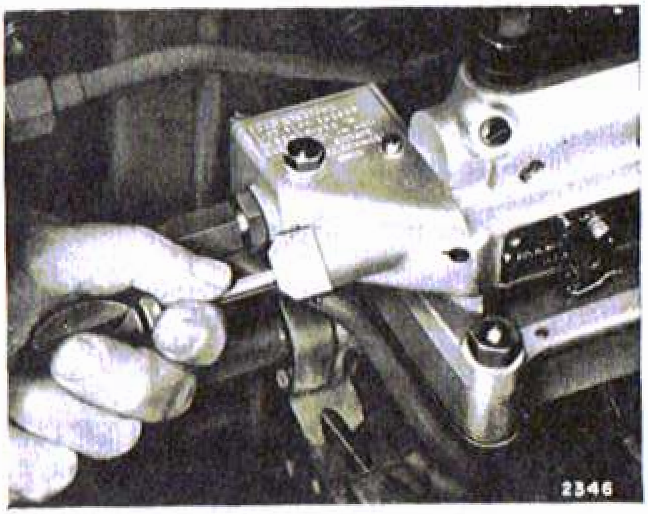


Fig. 4. TOOL OPERATED EXCESS FUEL DEVICE

OPERATING THE ENGINE

STARTING THE ENGINE—(*continued*)

15. **Accelerator.**—The speed of the engine is controlled by means of the usual pedal which is coupled to the lever provided on the governor case. The engine is under complete control of the governor at all speeds ranging from the lowest, idling speed, to the maximum.

When driving a passenger or goods vehicle, etc., and when accelerating from rest, do not, unless maximum acceleration is required, run engine up to maximum speed in the indirect gear ratios. More fuel is used, more noise is generated, more wear is occasioned.

HAND STARTING

16. **Hand Starting (Cold Engine) under Normal Temperature Conditions.**

(This operation may require assistance for the driver.)

1. Set the engine stopping lever to the running position.
2. Open very slightly hand speed control if fitted.
3. Press up the starting fuel plunger as far as it will go. See paras 14 and 14·1.
4. Set the decompression lever in position No.1 (Decompression). Fig. 3.
5. Turn smartly at the starting handle, and when maximum speed is attained turn the decompression lever to the engine running position No. 2, Fig. 3. The store of energy in the flywheel will overcome the compression and the engine will commence to work on all cylinders.
6. Allow engine to run at a fast idle speed for some minutes to warm up before applying load.

16·1. **Hand Starting (Cold Engine) under Cold Conditions.**

(This operation may require assistance for the driver.)

1. Set the decompression lever in position No. 1. (Decompression.) Fig. 3.
2. Test if engine is stiff to turn.
3. If engine is stiff to turn, but not unless, operate each hand priming lever five times after having set the engine stopping lever to the running position.
4. Set the engine stopping lever to the engine "stop" position, so as to avoid injecting fuel and turn engine until it is free.
5. Set the engine stopping lever to the running position.
6. Open very slightly hand speed control if fitted.
7. Press up the starting fuel plunger as far as it will go. See paras. 14 and 14·1.
8. Set the decompression lever in position No. 1. (Decompression.) Fig. 3.
9. Turn smartly at the starting handle and when maximum speed is attained turn the decompression lever to the engine running position No. 2, Fig. 3. The store of energy in the flywheel will overcome the compression and the engine will commence to work on all cylinders.
10. Allow engine to run at a fast idle speed for some minutes to warm up before applying load.

Note.—If the driver and assistant cannot impart sufficient energy to the flywheel to overcome compression, a loop of rope may be put around the starting handle and by this means the two men can pull the engine over one full compression, i.e., without using the decompression lever. In this way the engine will start.

16·2 **Hand Starting (Warm Engine) under all Temperature Conditions.**
When the engine is warm it is unnecessary to operate the starting fuel plunger as the engine will start very readily with the fuel pump slider bar in position to which it is limited by the full load stop trigger.

ELECTRIC STARTING

17. **Electric Starting (Cold Engine) under Extremely Cold Conditions.**

(This operation may require assistance for the driver.)

Under extremely cold conditions before attempting to start follow the procedure as set out in para. 16·1 in order to "free" the engine.

OPERATING THE ENGINE

ELECTRIC STARTING—(*continued*)

Note 1.—In the event of the engine still being stiff to turn after the above steps have been taken, or if the battery is in a discharged state, give assistance to the electric starter by turning the crank handle at the same time as the starter is engaged.

With all electric starters it is vital that the batteries and cables are as recommended in paras. 158 and 159, it is also of vital importance that all connections are clean and making perfect contact. The importance of adequate "earthing" of the engine and one pole of the battery is frequently overlooked and indeed, difficulty experienced in electric starting has many times been found to be due to faulty or inadequate earth connections.

Note 2.—Where engines are operated under arctic conditions, it may be necessary to introduce special starting fluids into the intake manifold at the time of cold starting; the works will be pleased to advise on this subject.

Starting under these conditions can of course always be facilitated by heat applied to the air intake in the form of a flame from a blow lamp or from a burning rag or waste previously soaked in fuel oil. Under arctic conditions engines and batteries should always be protected as far as practicable from the cold so that they may retain as much heat as possible from the previous running period.

17·1 **Electric Starting (Warm Engine) under all Temperature Conditions.**

1. Set the engine stopping lever to the running position.
2. Set the decompression lever in position No. 2 (Normal Running).
3. Depress the electric starter button when the engine will instantly work on all cylinders after the first or second compression stroke. See para. 17·2.

17·2. **Starter Button.**—Do not keep the starter button depressed for long periods if the engine fails to start readily or depress the button when the engine is running.

AFTER STARTING

18. After starting the engine see that the water circulating pump and lubricating oil pump are operating and that the oil pressure gauge registers the correct pressure in accordance with the figures stated in para. 27. If not, shut down at once and investigate.

With a newly installed, or an overhauled engine, it will probably be necessary to wait 10/15 seconds before the gauge registers oil pressure.

When an engine is cold, slightly higher pressures will be noticed due to the higher viscosity of the oil. When started, 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. It is also advisable to follow this practice in order to permit the lubrication system to assume complete circulation.

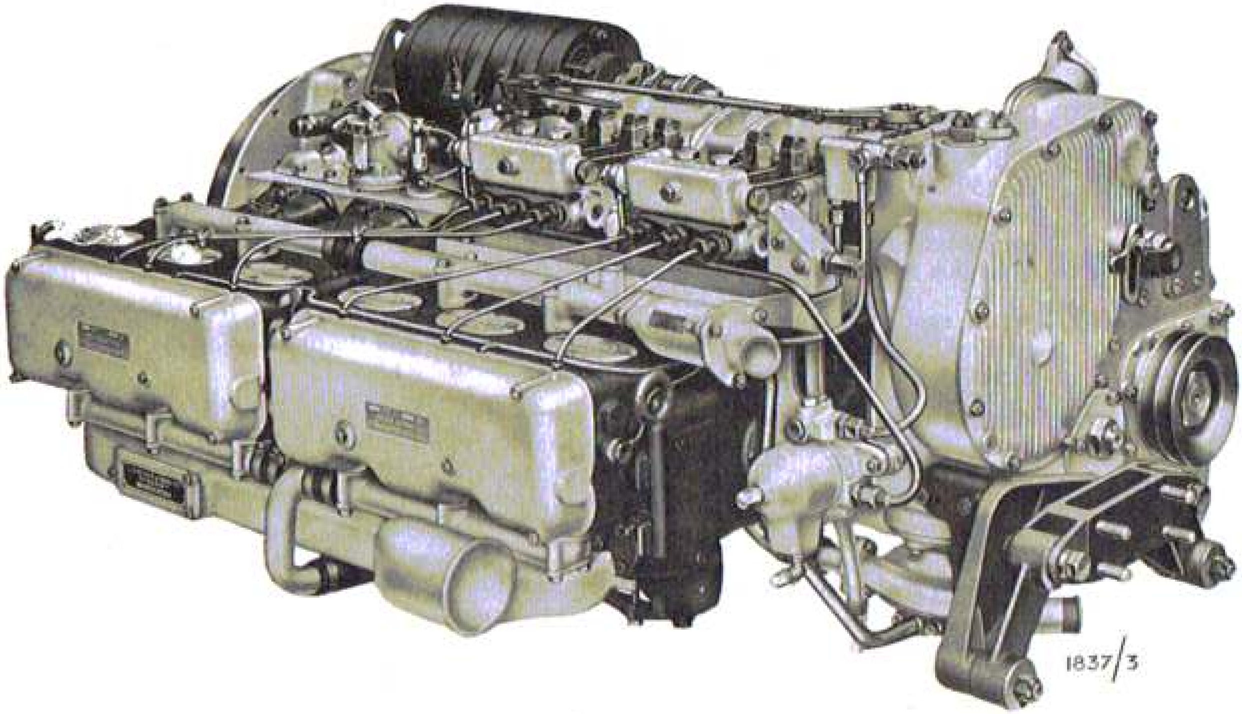
19. **Idle Running.**—It is not good practice to run an engine idle for long periods, especially when cold.

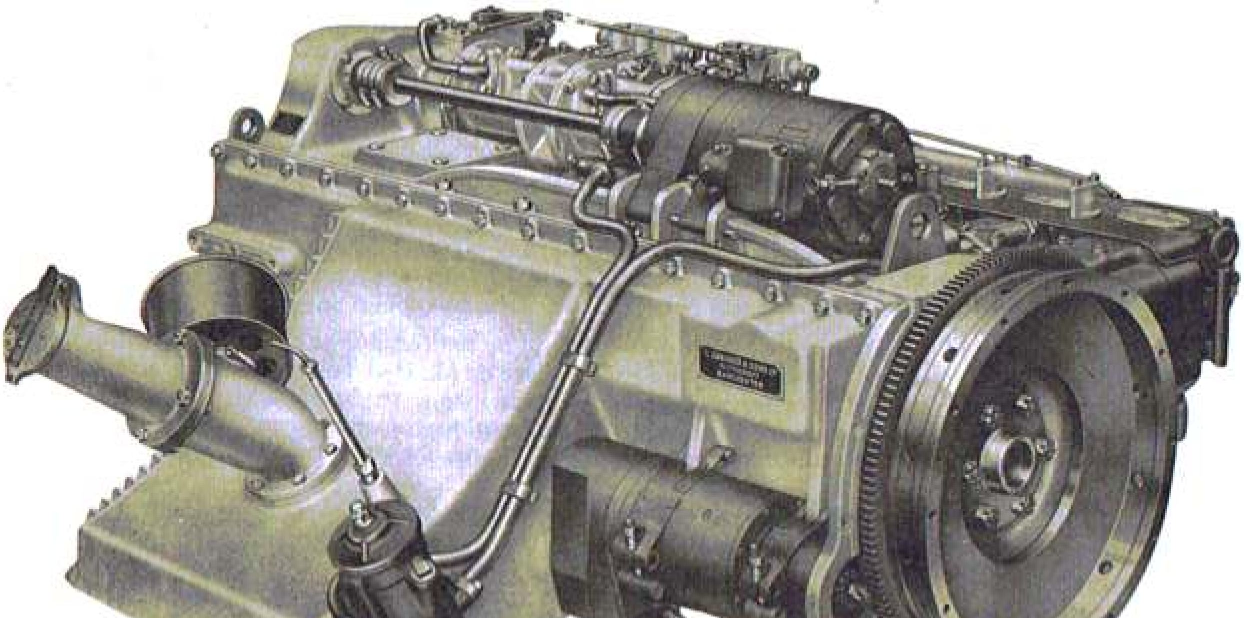
STOPPING THE ENGINE

20. **To Stop the Engine.**—Turn the stopping lever in a clockwise direction so moving the governor control bar forwards as far as it will go. In this position the fuel injection pumps immediately cease to deliver fuel.

On no account should the engine be stopped by turning off the fuel supply, since this would empty the fuel pipes and 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.





6HLW Engine

SERVICING AND MAINTENANCE

SERVICING AND MAINTENANCE

LUBRICATION

21. **Lubrication.**—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 recommendations and instructions set forth hereunder.

The grades of oil recommended for various duties and climatic conditions are detailed in paras. 6 and 6·1. Our Agents have extensive lists of approved lubricating oils and can advise customers in this matter. In cases not covered by these lists application should be made to the Works.

22. **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 crankcase immediately over the oil sump. The pump is driven by a vertical shaft from the camshaft. The oil sump is formed in the base-chamber which is readily removable for inspection. The sump is protected by a primary gauze filter of extremely large area which requires cleaning only after long intervals. The oil is delivered from the pump through a passage formed in the crankcase and thence by an external pipe to the delivery filter and pressure regulator. It passes into the feed pipes of the main bearings and thence, by drilled passages, to the crank pins and gudgeon pins. From the same pressure system, oil is fed under pressure to the valve gear in the cylinder heads. The surplus oil rejected by the pressure regulator is separately circulated through the governor unit, the fuel injection pump cams, the tappet mechanism, and finally through the main timing drive of the valve camshaft. This surplus oil pipe is located externally on the fuel pump side of 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 at every light overhaul period, say every 48,000 miles.

In the HLW range of engines the lubrication system is basically the same as that described above. The principal difference is in the oil pump, oil sump and the method of forming the joint between the valve covers and the cylinder heads.

In the HLW engine a scavenge pump is combined with the main pressure pump. This scavenge pump transfers oil which has passed the rear end main and big end bearings via a coarse mesh gauze screen from a pocket formed in the rear end of the sump and returns it into the main body of the sump proper. This is, of course, necessary as in the average chassis the engine is installed at an angle to the horizontal with the flywheel end low so that under these conditions, or when hill climbing, the oil from the rear end of the engine cannot return by gravity to the sump.

It will be appreciated that on the HLW engines an oil-tight joint is necessary between the valve covers and the cylinder heads. This is obtained by means of a small groove which is cut in the joint face of the covers into which is lightly pressed a length of synthetic rubber cord. The diameter of the rubber cord and the depth of groove in the covers are such that the rubber when fitted in the groove projects slightly beyond the cover face, in this way the tightening of the cover screws pulls the covers down on to the heads making a metal to metal joint at the same time compressing the rubber cord to produce a durable oil-tight seal. All sprayer pipes enter the covers on their upper edges and their points of entry are sealed with special rubber grummets.

23. **Oil Cooler System.**—In many applications of the engine it is necessary to circulate the lubricating oil through some form of oil cooler from which the heat is extracted by a flow of water or air. Generally speaking, in automotive or industrial engines the oil is pumped through a number of finned tubes which are cooled by an air stream, whilst in marine engines the oil is pumped through an indented pipe encased in gunmetal jacket through which the cooling water passes before entering the cylinder block.

On 4-, 5- and 6-cylinder engines a separate pump is employed to circulate the oil through the oil cooler. This pump is mounted on the cambox and driven by helical gears from the fuel pump camshaft. The oil is drawn from a foot valve in the main engine sump, circulated through the cooler and returned to the sump.

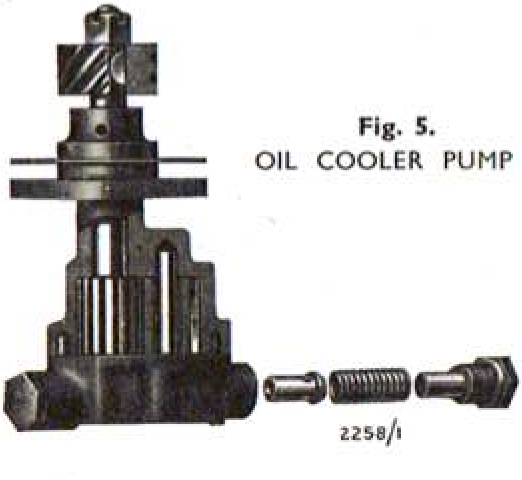


Fig. 5.
OIL COOLER PUMP

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SERVICING AND MAINTENANCE

LUBRICATION—*continued*

If the cooler is of the air cooled type, the oil is returned to the sump via a thimble type filter located in the sump at the junction of the oil return pipe. This filter should be inspected and cleaned when the oil sump is removed at overhaul periods, i.e. every 48,000 miles and the oil cooler flushed through with clean fuel oil or paraffin.

Under very cold conditions the oil cooler can offer considerable resistance to the oil and so create dangerously high pressures. To counter this possibility the covers of the oil cooler pumps have been fitted with two relief valves. When the resistance of a cooler creates a pressure of 75 lb./sq. in. (5·3 Kg./sq. cm.) or more, the relief valve on the delivery side of the pump lifts from its seat and permits the oil to by-pass from the delivery side to the suction side of the pump, until oil becomes warm and its viscosity thereby reduced sufficiently to lower the resistance of the cooler to something less than 75 lb./sq. in. (5·3 Kg./sq. cm.) when of course all the oil will pass through the cooler. On engines prior to serial No. 105023, an external oil relief valve was fitted to the oil cooler pump to serve the same purpose, the oil from the relief valve was in this case piped back to the suction pipe of the pump. The second valve in the oil cooler pump cover provides protection against dangerous pressures which could be generated in the suction pipe if an engine is rotated in a reverse direction. These spring loaded, thimble type relief valves are contained in the pump cover by hexagon-headed plugs on which are stamped the pressures at which the valves are set to operate. Normally these relief valves should not require any maintenance.

Covers fitted to earlier pumps contained ball type valves set to operate at 45 lb./sq. in. (3·2 Kg./sq. cm.). These covers are no longer available and in the event of replacement, the new type cover complete with thimble type valves and springs will be supplied. On 2LW and 3LW engines a second oil pump is not fitted for oil cooling. With these engines the oil which is by-passed from the main pressure regulating valve is lead through the cooler before returning to lubricate the auxiliaries, as described in para. 22.

For more severe duties and climatic conditions, or when a radiator type oil cooler is employed, these engines are fitted with an external relief valve to protect against high oil cooler resistance when cold. This relief valve is mounted on the side of the crankcase and is set to operate at 65 lb./sq. in. (4·6 Kg/sq. cm.) at which pressure the oil is allowed to by-pass the cooler and is fed directly to the main pressure regulating valve on the base of the delivery filter.

24. **Delivery Filter.**—As will be seen, this unit is situated on the near side of the engine. It is of simple yet special construction, comprising a vertical cylinder in which is a special paper element instantly detachable by removing the filter cover which is secured by a single nut. In the base of this unit is a sludge sump provided with a plug for drawing away any foreign matter extracted by the filter element. The unit embodies a relief valve which operates and maintains lubrication in the event of filter chokage. See para. 25. The whole of the lubrication oil passes through this filter, so that it is of the greatest importance that the filter be kept clean as in the next paragraph.

25. **Cleaning of Delivery Filter Element.**—Under normal working conditions the filter element should have a useful life of about 20,000 miles (2,000 hours).

A drop of 3 to 4 lb./sq. in. (·211 to ·281 Kg/sq. cm.) or more in the oil pressure will indicate that the element has become choked and in this event must be replaced by a new element. If a new element is not available it is permissible to wash the existing element with clean paraffin or fuel oil. When washing, a reverse flow of paraffin or fuel oil (from inside to outside) will assist in removing the sediment formation and make the element fit for further use.

Nevertheless, since there is a risk of foreign matter remaining inside the element which, if present, may reach the bearings, it is imperative that at the first opportunity, a new element Part No. LW/6/252 be fitted. These elements are inexpensive and quickly replaceable and are readily obtainable from the Works, Branch Office Depots and Official Spare Part Stockists.

LW and HLW engines prior to serial No. 118684 were fitted with metal gauze covered elements. It is recommended that these elements be exchanged for the current paper element filters at the first opportunity.

Special Caution: After decarbonising or otherwise disturbing the engine, an increased collection may be formed on the element. Anticipate this by early inspection. Also when using a detergent oil for the first time in an engine which has been in service, it is advisable to inspect the filter element after a short period and pay due regard to engine oil pressure, since oils of this type will free deposited carbon and if the filter does not receive attention it may suddenly, in the case of a dirty engine, become choked.

GARDNER

SERVICING AND MAINTENANCE

LUBRICATION—*continued*

26. **Delivery Filter: Reassembling**—Use a new joint ring and rotate the cover of the filter in order to minimise the chance of any foreign matter causing a leak. It is recommended that the filter be replenished with clean oil through the orifice closed by the square-headed plug.

27. **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. 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. 22.

The following are the pressures at which the valve is set to operate:—

(*a*) On engines fitted with white metal lined main bearing shells the pressure regulation valve is set to operate at 45 lb./in.^{2} (3·2 Kg./cm.^{2}) at 1,000 r.p.m. and with lubricating oil temperature at 130°F. (54°C.). With oil temperature at 110°F. (43°C.) the pressure will read approximately 47 lb./in.^{2} (3·3 Kg./cm.^{2}).

(*b*) On engines equipped with pre-finished thin wall main bearings the pressure regulation valve is set to operate at 35 lb./in^2. (2·46 Kg./cm.^{2}) at the same r.p.m. and oil temperature readings given above, and at 110°F. (43°C.) the pressure will read approximately 36 lb./in.^{2} (2·5 Kg./cm.^{2}).

The pressure at which the valve is set to operate is stamped on the cap nut of the adjusting screw and engines fitted with thin wall main bearings can be identified by the letter "S" stamped on the top face of the crankcase at the flywheel end, fuel pump side; (Engine Serial No. 147676 and all subsequent engines).

If the regulation valve is dismantled for any reason, it must be re-set to give the appropriate pressure given in (*a*) or (*b*) and in accordance with the oil temperature obtaining. A useful guide to the setting of the adjusting screw is to count and record before dismantling the number of screw threads that are exposed above the hexagon lock nut. If correctly counted this should prove a useful aid when reassembling.

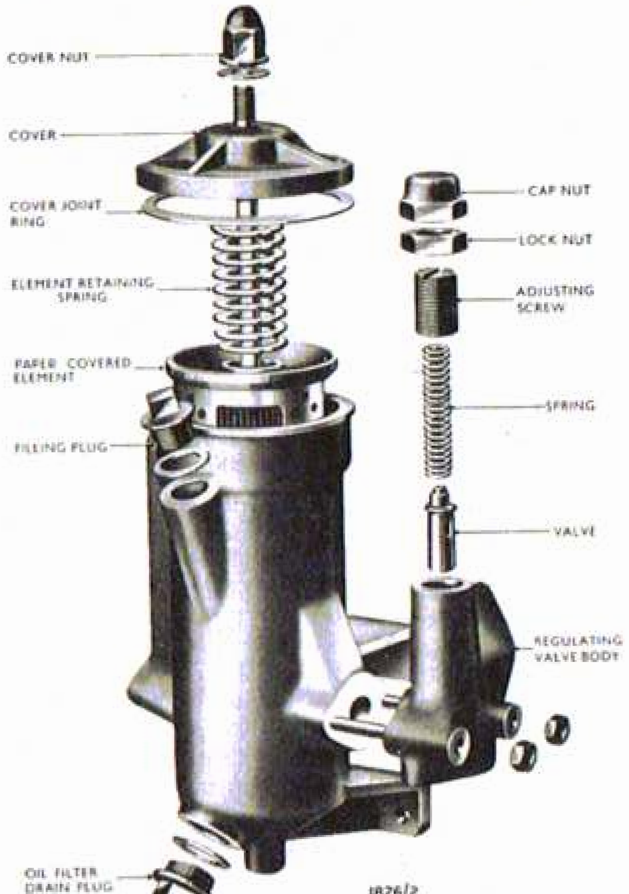


Fig. 6
LUBRICATING OIL DELIVERY FILTER

SERVICING AND MAINTENANCE—*continued*

LUBRICATION—*continued*

28. **Low Oil Pressure. Causes and Remedies.**

Oil Pressure too Low.

(1) Delivery filter requires cleaning.
(2) Foreign matter under the seat of the pressure regulation valve.
(3) Fracture of the spring of the regulation valve.
(4) Sprayer pipe unions slack or pipe broken, allowing fuel to reach the crankcase.
(5) The gauze filter over the sump is choked by sludge deposit.
(6) Shortage of oil in the sump.
(7) A pipe fracture somewhere in the system.
(8) Worn bearings or bearing failure.
(9) Excessive temperature or incorrect lubricant viscosity.

To Remedy the above Defects.

(1) Dismantle, clean and reassemble as described in paras. 25 and 26.
(2) If foreign matter prevents the proper seating of the regulation valve, this may be 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. 27.
(3) Replace with spare spring.
(4) Drain the base-chamber sump and replenish with new oil of the correct grade. In any case, this operation should be carried out after every 4,000 miles.
(5) Remove and clean the base-chamber. (See paras. 35 to 38.)
(6) The oil level in the sump should not be allowed to fall below the minimum mark on the dip-stick. Replenish with fresh oil until the level reaches maximum mark on dip-stick. (See para. 9.)
(7) Renew defective pipe and see that it is properly secured against vibration and possible chafing. (See para. 29.)

29. **Security of Pipework.**—It is important to ensure that all pipework is effectively insulated against chafing and properly secured against vibration and consequent fracture. A length of flexible pipe is supplied for this purpose for the remote reading oil pressure gauge which insulates from the engine the small bore solid pipe leading to the instrument panel. The solid pipe should be firmly secured throughout its length. Similarly, the fuel and oil pipes passing behind the fuel pumps must be securely clamped one to the other by the anti-vibration clips provided, in order to avoid possible chafing and fracture.

30. **Draining and Replenishing the Oil Sump.**—It is recommended that the sump oil be completely drained off not less frequently than every 4,000 miles. This should be effected after a long run while the oil is warm and fluid. See also para. 9. The use of a "flushing" oil or washing out the sump with paraffin is not recommended since there is a liability of disturbing particles which might re-enter the lubrication system.

31. **Oil Filler Box and Crankcase Breather Filter—Vertical Engines.**—The oil filler box is mounted on the timing case or on the cylinder head on the near side of the engine. A crankcase breather filter incorporating a renewable impregnated paper element is fitted to the oil filler cap. When, to suit certain chassis requirements, the filler box is mounted on the cylinder head the breather filter is fitted to the filler box casting on the timing case cover.
The filter element should be washed thoroughly in either petrol, paraffin, fuel oil or water containing a detergent every 4,000 miles and should be renewed after 24,000 miles. Replacement elements are readily obtainable from our Works, Branch Office Depots and Official Stockists.

Note: Wire Mesh Type Filter Elements. Earlier LW series engines were fitted with a wire mesh type breather filter. This should be removed and washed thoroughly in fuel oil or paraffin every 4,000 miles and the gauze re-oiled with engine oil before being refitted. It is recommended that the wire mesh type breather filter be exchanged for the more efficient paper element type unit when the opportunity arises.

GARDNER

SERVICING AND MAINTENANCE

LUBRICATION—*continued*

32. **Oil Filler and Crankcase Breather Filter—HLW Engines.**—The horizontal engine is fitted with a combined oil filler and crankcase vent and is mounted on the upper face of the sump. The oil-filler cover or lid is held in the closed and open positions by means of a simple leaf spring. Contained in the oil filler is a gauze screen of large area and on the forward side of the filler is mounted a breather filter to prevent the entry of dust and other foreign matter into the sump.
This filter is of the paper element type and should be removed and washed as indicated in para. 31.
Note: Wire Mesh Type Filter Elements. These filters, which have now been superseded by the inexpensive paper element type filter, should be removed periodically and washed as indicated in the Note in para. 31. The frequency of this operation must depend largely on the service conditions under which the engine is operating.

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

34. **Gauging the Sump Oil Level.**—The oil level indicated on the dip rod will vary according to the elapsed time, often up to approximately four hours after stopping a hot engine the level indicated will increase. The corresponding figure for cold engines may reach 12 hours. When making accurate measurement of oil level in a road vehicle engine it is essential that due regard be paid to gradient and camber.

35. **Removal and Cleaning of Base-Chamber, Sump and Primary Oil Filter—LW Engines.**—It is recommended that this be effected not less frequently than every 48,000 miles. Remove the primary gauze filter which is secured by a number of cheese-head screws, and also the thimble type oil cooler filter, if fitted. Wash the gauzes and surfaces of the base-chamber with clean fuel oil or paraffin. Allow the washed parts to drain in preference to wiping with a cloth which is liable to leave behind swarf.

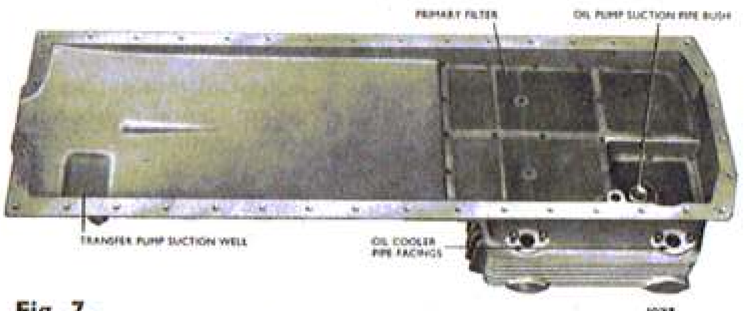


Fig. 7.
BASE CHAMBER—LW ENGINE

36. **Removal and Cleaning of Sump Filter—HLW Engines.**—This filter should be withdrawn and cleaned every 48,000 miles. It will be seen that the filter is circular in shape and held up to the under-side of the sump by eight hexagon nuts. The scavenge pump mentioned in para. 22 draws oil from a small gauze-covered pocket in the sump. The duty, mesh and gauge of this gauze are such that cleaning is unlikely to become necessary between sump removals.

37. **Reassembling Primary Filter in Base-Chamber.**—Make sure that the securing screws are perfectly tightened home and that the making-up collar around the connection to the lubrication pump is correctly positioned.

38. **Reassembling Base-Chamber on Crankcase.**—The joint between the base-chamber and the crankcase is designed to be made by gold size or other suitable jointing compound. Clean the joint surfaces with meticulous care and apply the liquid with a brush. Do not use paper or other packing.

39. **Lubrication of Fuel Pumps.**—Every 12,000 miles a small quantity (about 30 c.c.) of engine lubricating oil should be injected through the 2 B.A. screw hole located in the front face of the fuel control box on all engines and also through a similar screw hole in the cast aluminium cover plate fitted to the rear set of fuel pumps on 5- and 6-cylinder engines.
This oil will assist in lubrication of the slider bars, quadrants and regulating sleeves inside the fuel pump housings.

40. **Lubrication of Fan Spindle Bearings.**—Every 12,000 miles (1,200 hours) inject a small quantity of grease into the grease nipple provided on the hub of the fan spindle.

SERVICING AND MAINTENANCE

FUEL FEED SYSTEM

41. **Fuel Lift Pump and Gardner Overflow Return Feed System.**—Engines may be supplied with fuel by means of gravity or by a diaphragm type fuel pump system. With the latter arrangement the pump, of which the "Amal" is a typical example, is mounted on the crankcase and driven by the valve camshaft on 4-, 5- and 6-cylinder engines. On 2- and 3-cylinder engines the pump is mounted on the cambox/governor unit and driven by the fuel pump camshaft. A small hand-operated lever is provided on the pump for priming the fuel system up to the fuel injection pumps. (See para. 11.)

The fuel lift pump operates at a pressure of about $1\frac{1}{2}$ lb./in.^{2} (·105 Kg./cm.^{2}) and is capable of delivering approximately 60% more fuel than the engine demands on maximum load, thus it is never called upon to operate at full capacity.

The pump lifts the fuel from the tank through a paper element filter and delivers to the fuel injection pumps through a second filter mounted on the engine. (See para. 42.)

At the highest point in the body of the second filter is a ·018 in. (·457 mm.) dia. hole through which a small quantity of fuel and any air that is in the system is allowed to escape and be piped back to the tank (along with the leak fuel from the sprayers). By this method any air which finds its way into the fuel on the suction side of the fuel lift pump at joints, taps, etc., is separated from the fuel which is fed to the injection pumps on the engine.

It is of the greatest importance to prevent air leaks at any point in the suction pipe line between the fuel lift pump and the tank and to ensure that the suction filter does not become choked since this will induce an increased load on the flexible diaphragm which may precipitate failure of this component.

42. **Fuel Filters.**—In circuit with the fuel system are two filters of special design. One filter is always mounted on the chassis, bulkhead or machine frame and is referred to as the "First" filter Part No. GFF3/10 as fuel passes through this filter before the "Second" filter Part No. GFF2A/2 which is always mounted on No. 1 cylinder head on the vertical engine and on No. 1 cylinder block on the horizontal engine. Both filters contain special paper filtering elements which have to be replaced when they have become choked. These elements are inexpensive and readily obtainable from the Works, Branch Office Service Depots and Official Spare Parts Stockists. The "First" filter element, Part No. GFF3/10 is supplied complete with inner sealing ring, Part No. GFF3/11. The element in the "First" filter has a greater area than that fitted to the "Second" filter, thus the two elements are not interchangeable.

Both filter chambers are provided with a collecting sump and the engine mounted "Second" filter carries a drain cock to enable the filter sump to be readily drained prior to dismantling. A plug is provided at the lowest point of the "First" filter for this purpose. On gravity feed systems, a vent valve is fitted to the body of the "Second" filter for releasing air from the system during priming operations. With the "Amal" fuel lift pump and Gardner overflow return system, air is automatically separated from the fuel feed and the vent valve, therefore, is replaced by a plug.

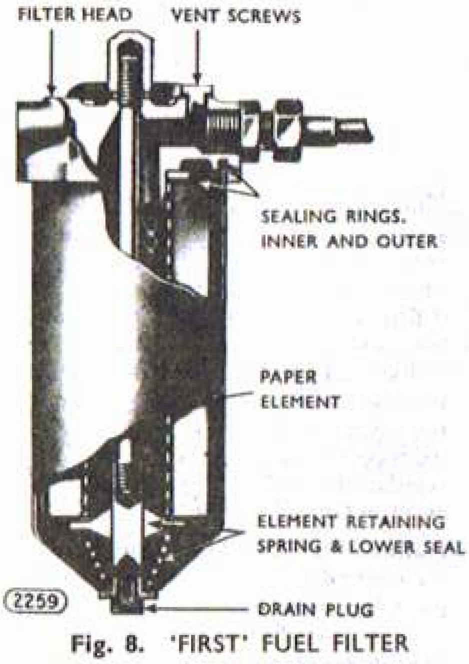


Fig. 8. 'FIRST' FUEL FILTER

42·1. **Choked Fuel Filters.**—Certain fuels have shown a tendency to form a deposit on the filter elements and so choke the filtering media. This occurrence necessitates the replacement of the affected elements. The deposit is more liable to occur during cold weather and therefore the first filter which is usually in an exposed position, is more likely to be affected before the second filter. When convenient this first filter should be mounted low down on the bulkhead under the bonnet where it may derive some heat from the engine.

GARDNER

SERVICING AND MAINTENANCE

FUEL FEED SYSTEM—*continued*

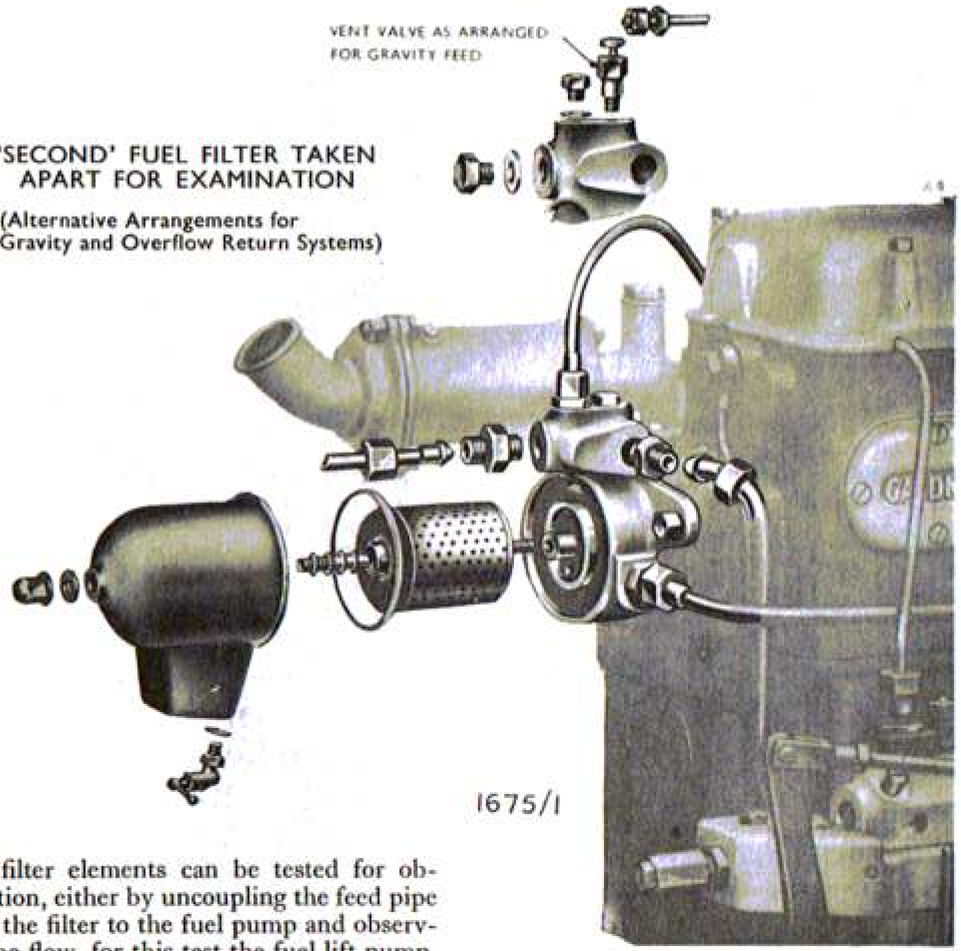


Fig. 9. 'SECOND' FUEL FILTER TAKEN APART FOR EXAMINATION

(Alternative Arrangements for Gravity and Overflow Return Systems)

The filter elements can be tested for obstruction, either by uncoupling the feed pipe from the filter to the fuel pump and observing the flow, for this test the fuel lift pump, if fitted, will have to be hand operated. Alternatively, the filter elements may be removed from the assembly and held in a vertical position, closing the hole at the lower end and pouring fuel into the upper open end. If fuel collects and does not run through the filter paper almost as quickly as it is poured in, the filter is probably choked sufficiently to cause erratic running of the engine and should be replaced. Our experience indicates that a large percentage of service calls are due to choked or partially choked fuel supply. Therefore we recommend the user to make quite sure that a copious flow of fuel is obtainable beyond both filters at regular intervals and that there are no air leaks at any point in the suction pipe between the fuel lift pump and the tank.

43. **Renewal of Fuel Filter Elements.**—Apart from stoppage due to the causes outlined in paragraph 42·1, they are of course more usually liable to stoppage by foreign matter from the fuel in the form of solid particles; particularly does this apply to engines operated under dusty conditions and where good fuel storage and filling cannot be arranged.
Whilst the duty, location, cleanliness of fuel supply and system, can all have a profound influence on the "clean" life of the filter elements, they should, under average conditions, not require replacement before they have been in use for at least 48,000 miles or 4,800 hours. Generally speaking the second filter element should have a "clean" life longer than that of the first filter element.

44. **Reassembling Fuel 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 excessive pressure when tightening the nut on the cover. Use a new standard specification joint ring to ensure absence of leakage.

SERVICING AND MAINTENANCE

FUEL SPRAYERS

45. **Fuel Sprayers.** (See Fig. 10)—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 being taken to pieces for cleaning or examination (as distinct from overhauling), it requires no adjustment of any kind. The sprayer may be said to be one of the most important components 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 in para. 42.

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

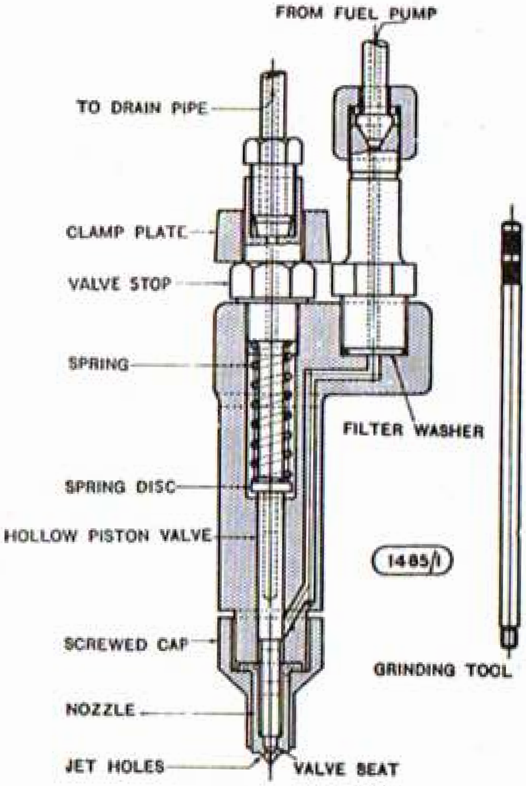


Fig. 10. FUEL SPRAYER

47. **Fuel Sprayer Test every 8,000 miles (800 hours).**—These should be tested, without removing from the cylinder heads, by operation of the hand priming levers fitted to the fuel pumps on all Gardner engines. 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. Continued use of a defective sprayer can have very undesirable results such as fuel dilution of lubricating oil, impaired fuel consumption, loss of power, burning of exhaust valves and even cracking of cylinder heads, etc., etc.

Fig. 11 illustrates the hand operation of the fuel pumps but shows the sprayer removed from the engine as would be the case when a corrected sprayer was being re-tested without the facility of bench testing equipment.

Every 48,000 miles (4,800 hours).—Fit Gardner Factory-reconditioned or other suitably inspected and serviced set of sprayers. Return removed set to Works or Depots for reconditioning, or inspect and workshop service as directed in paras. 52 to 62.

48. **Reconditioning of Sprayers.**—Large scale manufacture and reconditioning of sprayers facilitated by specialised machines, equipment and knowledge, is continuously in progress at our Works and it is recommended that sprayers be sent to the Works for this purpose since, by adopting this procedure, the user will be assured of the most efficient and durable sprayer operation being obtained at the most economical cost. A system of exchange is operated and stocks are held at Depots for immediate use.

SERVICING AND MAINTENANCE

FUEL SPRAYERS—*continued*

49. **Routine Change of Sprayers.**—In cases of large annual mileage, it is an excellent practice to stock a complete set of spare sprayers which may be changed every 48,000 miles (4,800 hours). This permits of systematic cleaning and examination without loss of mileage. In many duties it is commonly found that this period can be at least doubled.

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

51. **Removing the Sprayer from the Cylinder Head.**—Should the sprayer prove difficult to remove from the cylinder head, there is supplied with each engine special drawing tackle, consisting of a flat bar, passing through which is a screwed rod with 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, to draw out the sprayer.

52. **Fuel Sprayer Inspection.**—Make the following inspections and tests, etc.:
    (1) Test for stoppage of jets and shape of issued jets of fuel.
    (2) Test for leak of sprayer valve-nozzle seat.
    (3) Test for satisfactory vibration of sprayer valve.
    (4) Test for leakage of fuel past large diameter of valve.
    (5) Test spring load on sprayer valve and/or hydraulic opening pressure.
    (6) Observe sprayer cap nut for effective gas seal with cylinder head.
    (7) Renew filter washers.

53. **Test for Stoppage of Jet Holes and Shape of Issued Fuel Jets.**—Mount the sprayers on a fuel pipe connected to the engine fuel pump, see Fig. 11, or to a bench-mounted test pump in such a manner that the fuel jets are visible when the hand lever is operated. The jets of fuel emitted from the nozzle holes should all travel through the same distance and possess the same shape. If defective, prick out the holes with the standard pricker supplied with the engine, and at the same time clean out the central bore of the nozzle. The size of the holes is of great importance, therefore use only prickers of the correct diameter.

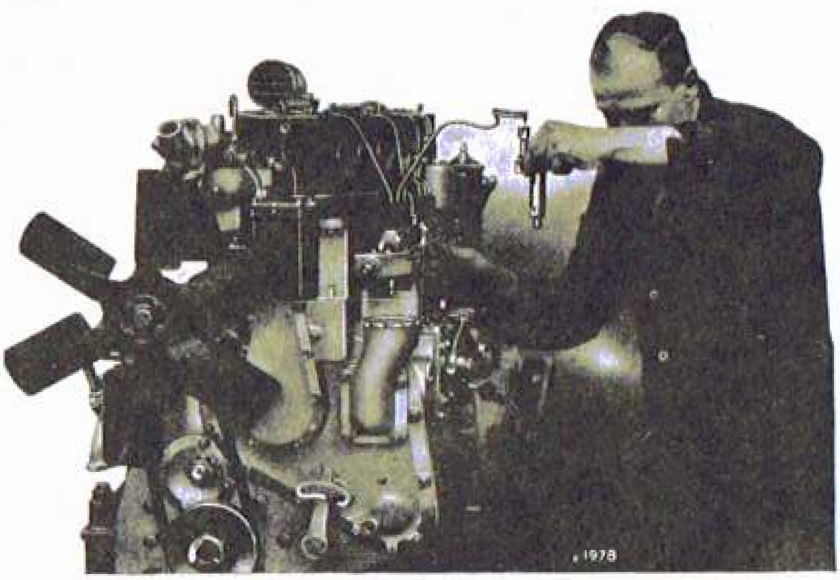


Fig. 11. TESTING SPRAYER REMOVED FROM ENGINE

54. **To Clean Sprayer Nozzle.**—Cut a piece of wood or cane to approximately the same shape as the sprayer valve tip and rotate same in bore on seat of nozzle, using metal polish or 600 grit Carborundum powder. Prick out the jet holes and finally wash out by forcing paraffin from outside to inside of nozzle. Supplied with the engine is a syringe complete with special fitting made to receive the nozzle, which enables paraffin to be forced through the jet holes in a direction opposite to that obtaining when the engine is in operation. See Fig. 12.

SERVICING AND MAINTENANCE

FUEL SPRAYERS—*continued*

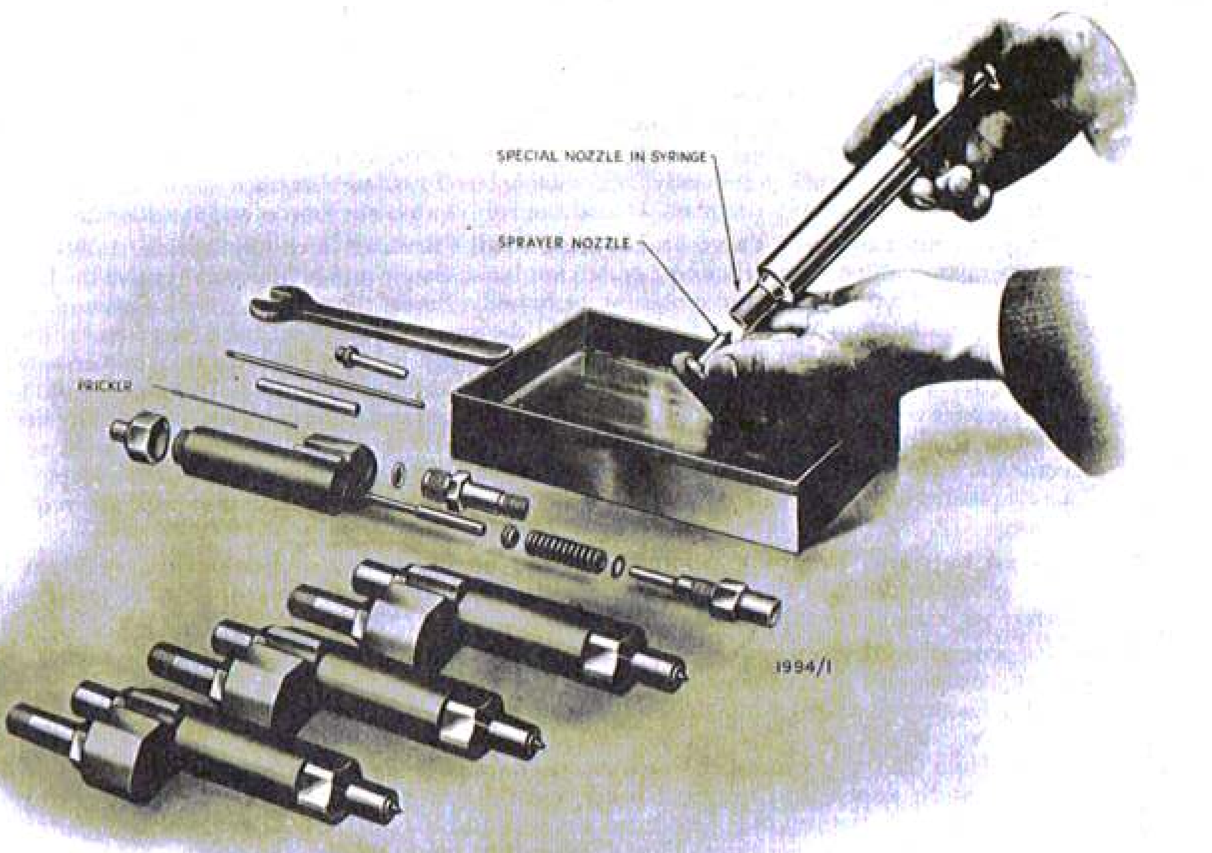


Fig. 12. CLEANING SPRAYER NOZZLE

55. **To Test for Leak of Sprayer Valve Seat, Vibration of Sprayer Valve and Leak Past Large Diameter of Valve.**—Mount the sprayer on a fuel pipe connected to the engine fuel pump, or to a bench-mounted test pump having *same diameter plunger as engine pump.*

Operate hand priming lever and expel all air from system; apply a force to the lever just short of that required to lift sprayer valve from its seat. If the seat be unsound fuel will run down the nozzle. A valve seat may be accepted as satisfactory if when approximately half the force necessary to lift the valve from its seat is applied to the lever, not more than two drops per minute fall from the nozzle.

Operate the priming lever rapidly and observe that the sprayer valve vibrates satisfactorily. This is indicated by feel and noise generated by the rapid opening and closing of the valve. The noise can be described as a squeak and sprayers may vary in this characteristic; those which make most noise are not of necessity operating more satisfactorily than those which make only a moderate noise. When making this test for valve vibration it is essential that any pressure recording means, which may be mounted between pump and sprayer, be omitted. A leaking valve seat, a worn and consequently wide valve seat, malalignment of valve and nozzle causing friction, and in rare instances a leak past the large diameter of the valve may prevent satisfactory vibration.

Operate the priming lever in manner described for testing valve seat. If a "solid feel" is not obtained observe whether fuel be leaking past large diameter of valve into leak pipe union bore. A slight leak is

SERVICING AND MAINTENANCE

FUEL SPRAYERS—*continued*

desirable and a considerable leak is permissible since on engine operation it has little effect. If a reasonably "solid feel" is not obtained return sprayer to Works for the fitting of a new valve.

Note.—A leaking fuel pump plunger may also prevent the attainment of a "solid feel."

56. **To Correct a Leaking Valve.**—Dismantle the sprayer and examine minutely the seat on both the nozzle and the valve for dirt or anything which may prevent the correct seating of these 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. 59. A leaking valve may be traced to mis-setting of the nozzle to the body (alignment). If, on further trial, the seats be still defective, they may require lapping together, but this should be effected only as a last resource, and as seldom as possible.

57. **To Lap Together Sprayer Valve and Nozzle Seat.**—Remove valve stop, spring, screw cap and nozzle, mount sprayer body in vice with nozzle end to left hand. Screw into hollow end of valve the knurled lapping tool supplied with the engine and replace valve in body. Smear the valve seat with a minute quantity of 600 grit Carborundum powder mixed with oil. Hold the sprayer nozzle with the finger and thumb of the left hand up against the end of the sprayer body. Apply very light end-load to the sprayer valve and rotate slowly both valve and nozzle in opposite directions. The absolute minimum of lapping should be performed as an excessive amount will seriously damage both valve and seat. The best seat is formed by little more than line contact and the more a valve is lapped into its nozzle the wider becomes its seat. A seat which has become too wide is prone to leak and can be rectified only by re-grinding the valve and re-lapping the nozzle. These operations are normally effected by the Works since specialised machines are required for this purpose.

58. **Screwed Cap and Nozzle.**—Before assembling after grinding or examination, see that the outside surface of the nozzle and the bore of the cap are perfectly clear of carbon or other matter which might interfere with the alignment mentioned in para. 59.

59. **To Re-assemble the Sprayer.**—Wash every part scrupulously clean with clean paraffin, and **without wiping,** re-assemble in the following order:—

    (1) Piston valve with grinding spindle attached.

    (2) Nozzle and cap.

    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.

60. **Lift of Sprayer Valve.**—The maximum lift of this component is determined by an extension of the valve stop reaching inside the spring. The correct lift is ·008 in. (·203 mm.) which may be measured by means of a depth recording micrometer inserted in the sprayer body, resting on the valve stop face and measuring depth to spring disc and similarly measuring the length of the valve stop.

61. **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.

"K" Type Sprayers — LW and HLW Engines.—The correct spring load (which should be rigidly adhered to) for sprayers stamped "K" is 61·5 lb. (27·9 Kg.); for this purpose the spring should exert this load (61·5 lb. or 27·9 Kg.) when compressed to its working length of 1·320 in. (33·5 mm.). The correct spring load for sprayers which are stamped "E" or "E1" is 55 lb. (24·9 Kg.) at a spring space of 1·320 in. (33·5 mm.). These sprayers are now superseded.

This load must **not** be modified. It is very desirable but not imperative that an engine delivered equipped with sprayers stamped "K" should be serviced with sprayers stamped "K" or "E1K".

When Type "E1" Sprayers are returned to the Works for reconditioning they are modified as far as possible and stamped with letter "K" on the top face of the body; such sprayers are known as Type "E1K" and have the same spring load and opening pressure as the Type "K".

SERVICING AND MAINTENANCE

FUEL SPRAYERS—*continued*

When fitting a replacement spring it may be necessary—if the correct loading does not register—to fit shim washers between the upper end of the spring and the screwed stop, in order to obtain correct spring loading. These are available in thicknesses of ·003 in. (·0762 mm.) and ·007 in. (·1778 mm.).

LW20 Sprayer.—The correct spring load for the LW20 sprayer is 68 lb. (30·8 Kg.) when compressed to its working length of 1·008 in. (25·6 mm.). These sprayers are marked LW20 and are not interchangeable with the "K" Type sprayers. They must be used only on LW20 Type engines.

62. **Sprayer Valve Hydraulic Opening Pressures.**—The following hydraulic opening pressures are quoted as a guide when using a hand test pump. The pump must be operated slowly and have a plunger diameter approximately equal to that of the engine injection pump.

(*a*) With sprayer valve seats in new condition the spring load will correspond to the following hydraulic opening pressures:—

Spring Load		Hydraulic Opening Pressure
61·5 lb. ("K" Type Sprayers)	—	138 Kg./cm² or 1960 lb./in.²
68 lb. (LW20 Sprayers)	—	136 Kg./cm.² or 1935 lb. in.²

A tolerance of plus or minus $1\frac{1}{2}$% is regarded as permissible.

(*b*) When sprayer valves and seats have had long use, the seat width is increased and the effective seat diameter becomes smaller, in which event the corresponding hydraulic opening pressures will be as follows:—

Spring Load		Hydraulic Opening Pressure
61·5 lb. ("K" Type Sprayers)	—	136 Kg./cm.² or 1936 lb./in.²
68 lb. (LW20 Sprayers)	—	134 Kg./cm.² or 1905 lb./in.²

Providing the needle valve *vibrates satisfactorily* and *does not leak* when these pressures are recorded it is unnecessary to increase the spring load to attain the opening pressures given in (*a*).

63. **Replacing a Sprayer in the Cylinder Head.**—The nose of the sprayer is slightly tapered, 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. 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 readily removed by the aid of the fluted reamer supplied with all engines, which should also be used to clean the seat.

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 different from that of bolting two surfaces together, and thus is liable to deceive the engineer into screwing down harder 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. If excessive pressure is used the sprayer body may be distorted and its functioning impaired, in addition the cylinder head may suffer distortion and possible cracking.

64. **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 para. 12. In course of time the conical pipe ends may become reduced in bore by the action of the conical seat. This restriction of the fuel passage is detrimental to engine operation and may cause excessive fuel injection pump pressures. Therefore make inspection at overhaul that the minimum bore available at the unions is ·0625 in. (1·588 mm.) over a length of $\frac{1}{2}$ in. (12·7 mm.) from the end of the pipe.

65. **Checking for Leakage at the Sprayer Seating in the Cylinder Head.**—When sprayers have been refitted to the cylinder head, run the engine with the valve covers removed and make careful inspection to ensure that there are no fuel leaks at the sprayer pipe unions (as mentioned in para. 64 above) and check that the sprayers make a gas-tight seal in the cylinder head by applying oil from an oil-can to the recess around the sprayer whilst the engine is running. In this way any leakage will be detected by the formation of bubbles.

SERVICING AND MAINTENANCE

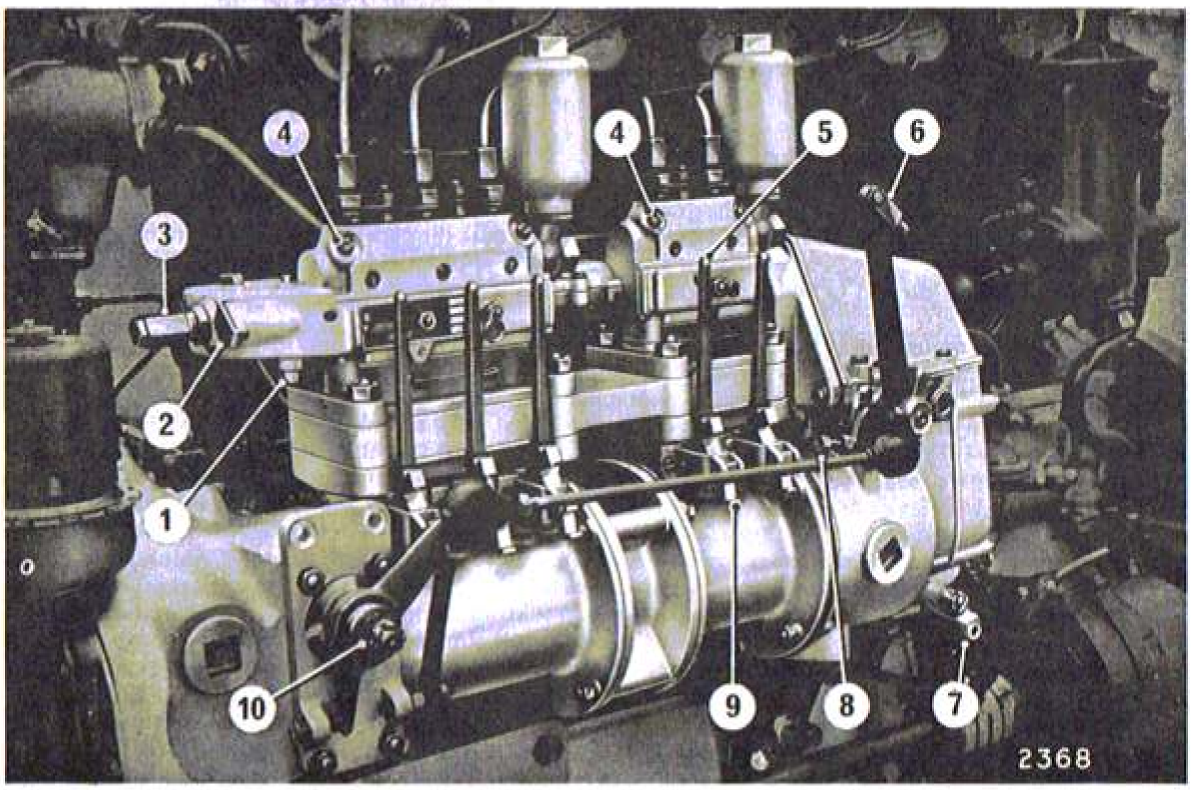
FUEL INJECTION PUMPS AND GOVERNOR UNIT

66. **Fuel Injection Pumps.**—These are built in units each containing as many pumping elements (plungers and barrels) 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 plunger is operated by its own cam on the camshaft and in addition, is furnished with a hand lever and latch enabling the plunger to be worked by hand for priming the injection system. The latches enable any plunger to be put into or out of action.

67. **Accelerator Control.**—This should be inspected every 48,000 miles to ensure that the pedal-operating mechanism is working the control throughout the whole of its range, that is, from idling to maximum speed. An inspection of the accelerator mechanism will reveal two stops to limit the angular travel of the accelerator lever in either direction; the setting of these two stops should not be deranged. When the accelerator lever is in its maximum speed position the two $\frac{5}{16}$ in. (7·937 mm.) dia. pegs at the lower end of the forked governor spring lever should be just touching the rear face of the governor case. Do not under any circumstances alter or interfere with these pegs, or otherwise increase the maximum governed speed of the engine which is 1,700 r.p.m. crankshaft at full load and approximately 1,770 r.p.m. at no load. See para. 69.

68. **Position of Accelerator Lever.**—In order that the foot control be "light" it is necessary to arrange the geometry of the accelerator linkage so that the rods and levers are mutually at an angle of 90° when the accelerator lever is in a position 40° from the idling speed position. This provides the greatest leverage when the greatest effort is required and avoids heavy pedal pressure.

69. **Advance and Retard of Injection.** Adjustment.—Since the accelerator lever is essentially a speed control and not primarily a torque control, it is coupled by a connecting rod to the lever of the advance and retard



1 Fuel Plunger (Not on Road Vehicle Engines)
2 Excess Fuel Device
3 Governor Bar Buffer
4 Vent Screws
5 Charging Levers
6 Accelerator Lever
7 Stopping Lever
8 Slow Running Adjusting Screw
9 Charging Lever Latches
10 Injection Advance and Retard Lever

Fig. 13.

SERVICING AND MAINTENANCE

FUEL INJECTION PUMPS AND GOVERNOR UNIT—(*continued*)

mechanism, and thus the timing of the moment of injection is varied automatically according to the speed of the engine. The mechanism consists of a small lever adjacent to the accelerator lever which is coupled by a horizontal, forked-end connecting rod to the lever of the advance and retard mechanism located on the chain case at the forward end of the engine. Should the mechanism become deranged it is a simple matter to re-adjust it since the maximum advance mark on the index plate corresponds to the maximum speed position of the accelerator lever. Occasional inspection should be made to see that this position is maintained. When driving the engine depress accelerator pedal progressively according to speed. This procedure will be found to provide the best acceleration and the quietest engine operation. Unlike throttle controlled or other engines, it is unnecessary to depress fully the pedal to obtain maximum torque unless maximum speed is attained whereupon it is necessary to fully depress the pedal. Slight acquaintance with the engine will automatically establish the facility of the preceding recommendations.

70. **Advance and Retard Friction Device.**—The advance and retard mechanism controls the axial position of a helical gear capable of sliding along the helically splined camshaft of the injection pumps, consequently, there is a slight reaction from the cams on the mechanism. To provide against this movement being transmitted to the accelerator lever and so wearing the connecting links, etc., an adjustable friction device is fitted consisting of a cork disc clamped between the case and the advance pointer lever and loaded by a castle nut and a spring washer. See Figs. 13 Item 10.

To set the spring washer to the correct load the nut should be tightened until the spring washer is fully compressed, the nut should then be undone one hexagon flat and the split pin fitted.

This friction device should be inspected and adjusted if necessary as indicated at 48,000 mile intervals. The castle nut should not be made tighter than stated otherwise the accelerator lever will be made stiff in action and be prevented from returning to the slow-running position. The amount of friction applied by this means may be judged by operating the accelerator lever, but if this is done whilst the engine is stopped the fuel pump levers must be latched back to relieve the fuel pump tappet spring load from the fuel camshaft.

The friction disc should be renewed at major overhaul.

On horizontal engines the recess around the castle nut should periodically be packed with stiff grease to prevent possible entry of water at this point.

71. **Governor Control Slider Bar and Governor Weight Pins.**—This slider bar is operated by the centrifugal governor and its function is to vary the amount of fuel injected into the cylinders and thus vary the delivered power of the engine. It is connected to the governor lever by the governor bar connecting link. The effect of moving the slider bar towards the flywheel is to increase the amount of fuel injected into the engine and *vice versa*. If the bar is moved to the full extent towards the timing case, there is no injection. The correct setting of the slider bar with relation to the governor 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 governor bar connecting link is so adjusted as to give the slider bar a position approximately $\frac{1}{32}$ in. (·794 mm.) from its maximum stroke towards the timing case. Inspect that this dimension obtains every 48,000 miles (4,800 hours) in order that the governor may exercise complete control of engine speed. Inspect also governor weight pin securing split pins.

It is of the utmost importance that the governor bar connecting link be adjusted as above. Since, if the link be adjusted to such a length as to leave no clearance in the above position, there is a grave risk of the small centre ball races sustaining damage with serious consequences. The governor weights are provided with a substantial abutment at their fulcrum to determine their maximum extended position, and thus relieve the connecting link and small ball race of this duty. If $\frac{1}{32}$ in. (·794 mm.) clearance be not allowed, the full power of the governor weights may be transmitted through the small bearings, which normally carry only the load applied by the outside governor bar return spring.

In an engine which has operated for long periods with a very slack or badly worn timing chain and/or severely worn splines on the fuel pump camshaft, the consequent very uneven drive to the governor can create serious wear on all parts of this mechanism, and particularly on the double split pins which retain the $\frac{1}{4}$ in. (6·35 mm.) and $\frac{3}{8}$ in. (9·525 mm.) dia. steel pins in the superseded design of governor weights. Worn split pins should be replaced immediately with pins of the correct size, opened before fitting, to ensure that when fitted they are not free to move in their holes. The faults in the timing drive must not, of course, be allowed to persist.

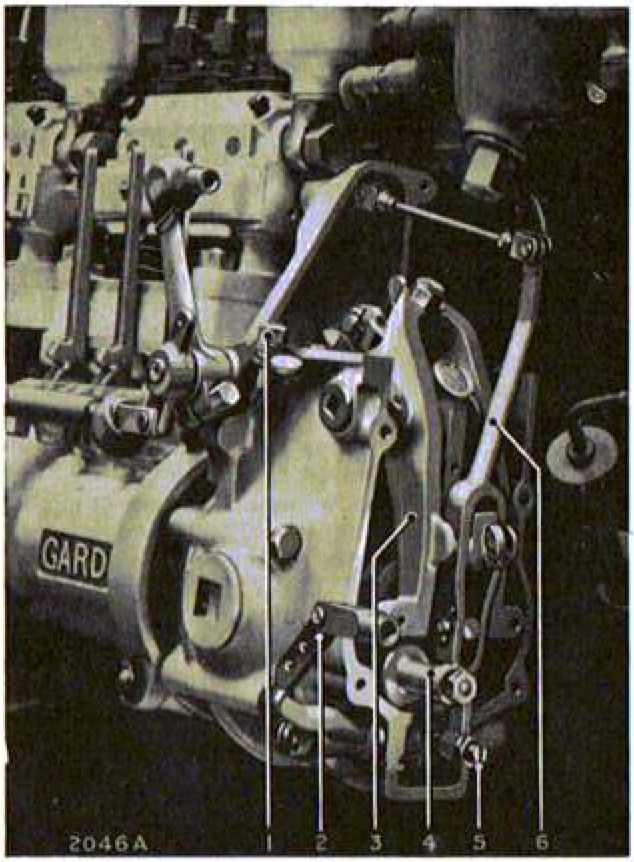
SERVICING AND MAINTENANCE

FUEL INJECTION PUMPS AND GOVERNOR UNIT—(*continued*)

72. **Slow Running Adjustment.**—The engine is set to idle at approximately 420 r.p.m. during test and this speed should be adjusted accordingly every 12,000 miles or when necessary, since slight wear of parts may reduce speed and lead to unsteady idling.

After starting a cold engine and before adjusting the slow-running, make use of the hand speed control (if fitted) until the engine attains normal operating temperature. If hand control is not fitted ensure by pedal control that engine speed is suitably maintained. Preliminary setting of the idling speed is effected by the adjustable hexagon headed screw and locknut located on the remote control cam stop mounted on the accelerator cam spindle Fig. 13 Item 8—on marine engines this screw is located on the friction-disc lever control plate mounted on the reverse gear casing—and final setting is regulated by the flanged sleeve-nut and locknut situated at the rear of the governor casing (see Fig. 14 Item 4). If mechanism is enclosed, access to the sleeve-nut is obtained by removing the rear cover.

To set the slow-running adjust the hexagon headed screw to maintain an idling speed of approximately 415 r.p.m. and lock with the locknut. Screw the flanged sleeve-nut gradually inwards until it bears on the governor spring guide and thereby increase the slow-running to a steady no-load idling speed of 420 r.p.m. Lock in position with the locknut. When correctly adjusted the roller on the fork lever should be just clear of the cam, allowing the slightest rock to be felt at the lower end of the fork lever whilst the engine is idling.



1 Maximum Speed Limiting Screw
2 Stopping Lever
3 Governor Spring Lever (cam operated)
4 Idle Speed Adjustment Nut
5 Stopping Lever Cam Tappet Screw
6 Governor Lever

Fig. 14. GOVERNOR CONTROL

73. **Adjustment of Fuel Pump Slider Bar Buffer.**—At the forward end of the fuel control box is located the governor bar buffer Fig. 13 Item 3, the purpose of which is to prevent stalling of the engine in the event of friction being generated in the fuel pumps. The governor bar buffer should be adjusted according to the following procedure when the engine has reached normal operating temperature. Adjust idling speed to 420 r.p.m. by means of the flanged nut on the governor case, as previously described, and screw the buffer gradually towards the bar until slight speed increase is experienced. Finally, withdraw by unscrewing the buffer ten hexagon flats and lock in position. If the buffer is set with insufficient clearance from the bar unstable idling will result. Use only light pressure to lock the buffer in the fuel control box.

74. **Fuel Injection Pump Output.**—Every 48,000 miles (4,800 hours) remove pump or pair of pumps complete with mounting plate and fit to **"Gardner"** calibrating machine. Make test of maximum fuel delivery with slider bar in contact with control trigger and idling position balance as described in Book No. 45·4. In course of time maximum fuel delivery may tend to increase and the pump should be re-set to the standard output. Do not, for any purpose, increase the standard setting or operate the engine with excess fuel delivery from the injection pump. Wear of fuel pump delivery valve seat assembly adversely affects timing and hydraulic characteristics and it is recommended that these parts be renewed at major engine overhaul.

SERVICING AND MAINTENANCE

COOLING SYSTEM

75. **Cooling System.**—Always ensure that the radiator or cooling system is filled to maximum capacity, preferably with rainwater. This is particularly important in hard water districts in order to avoid deposits which will impair cooling efficiency. The addition of a corrosion inhibitor to all engine cooling systems will be found beneficial. Refer to Engine Cooling Recommendations para. 8·4.

76. **Water Circulation.**—This is effected by a centrifugal type pump mounted on the manifold side of the engine and driven by helical gears from the valve camshaft. Temperature is automatically controlled by a thermostat unit situated at the forward end of the engine and mounted on the water outlet pipe from the cylinder heads. Inspection should be made regularly in order to ascertain if circulation is taking place, especially if there has been any possibility of damage to the water pump impeller due to frost. Above 160°F. or 71°C. it should always be possible to observe this circulation through the radiator header tank fillercap.

77. **Automatic Temperature Control.**—Until a pre-determined temperature is exceeded all the circulating water is diverted through a by-pass port in the thermostat and returned to the intake side of the pump. Thus there is no circulation through the radiator, or in the case of marine units, the heat exchanger or keel cooler so enabling "warming-up" time to be reduced to a minimum and normal running temperature to be achieved in the shortest possible time.
As the temperature increases, the temperature sensitive elements in the thermostat unit expand, gradually opening the control valve whilst at the same time closing the by-pass port. This permits a progressively increasing volume of water to flow through to the radiator or heat exchanger, etc., where it is cooled before being returned to the pump. When a certain temperature is reached, dependent on the type of thermostat fitted, the by-pass port is finally closed and all the circulating water is pumped through the radiator or cooling device. This temperature, for the various duty thermostats mentioned in para. 8·1, is as follows:—

Smith's Bellows Type Thermostat
TH 2001/00/68 — 188°F. (87°C.)
TH 2001/00/59 — 172°F. (78°C.)

Western-Thomson Wax Type Primary Thermostat
6B-1030-74 — 189°F. (87°C.)
6B-1030-60 — 163°F. (73°C.)

78. **Thermostat Unit.**—The Thermostat Unit incorporates a jiggle pin automatic vent valve which operates in an air release hole drilled in the main delivery valve.
This arrangement permits venting during filling or replenishment of the system whilst the engine is stationary. Immediately the engine commences running however, the coolant, circulated by the action of the centrifugal pump, forces the jiggle pin against the vent hole, closing the aperture and thereby shutting off any flow of coolant to the radiator, heat exchanger or keel cooler. This reduces to a minimum the "warming-up" period on initial starting from cold.
Earlier engines were fitted with thermostats having a ·052 in. (1·321 mm.) diameter air release hole drilled in the annulus that forms the seating for the main delivery valve, to prevent air locks forming in the system during filling and replenishing. This hole was of necessity small in diameter, in order that optimum temperature could be more readily attained in low duty engine applications.
It is recommended that these thermostats be exchanged for the later type at the first opportunity. Alternatively, on Marine Propulsion Engines, *if due regard is paid to coolant level when filling the system,* the ·052 in. (1·321 mm.) diameter hole may, with advantage, be reduced to ·040 in. (1·016 mm.) diameter and in this way further reduce the "warming-up" period.
When inspecting the Thermostat Unit ensure that the jiggle pin (if fitted) is free in the hole and seats properly against the aperture. Operation of the temperature sensitive element and delivery valve can be readily observed by removing the unit from its housing and raising its temperature when immersed in water.
With the bellows type thermostat, in the event of the bellows becoming damaged the valve will assume a full open position and therefore dangerously high temperatures do not occur. In fact, severe bore wear will possibly develop due to prolonged "warming-up" periods and low temperature, except when on full load.

SERVICING AND MAINTENANCE

COOLING SYSTEM—*continued*

With the dual wax type thermostats (Fig. 15) the reverse is the case and in the event of failure of the primary element the main valve will remain shut resulting in a rise in coolant temperature. The subsequent increase in temperature will cause the secondary element to expand and open the secondary valve, which then passes the coolant through to the radiator, heat exchanger or keel cooler, thus preventing the engine attaining a dangerously high temperature.

The secondary valve cracks open at 180°F. (80°C.) and is fully open at 200°F. (93°C.).

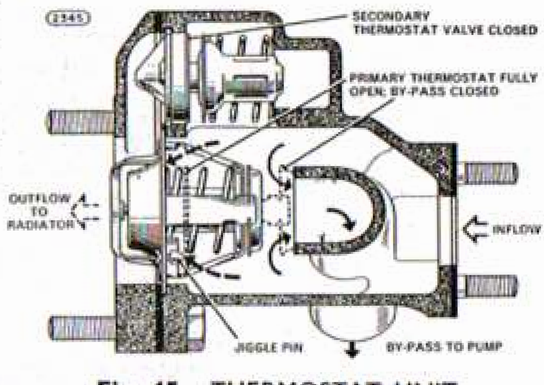


Fig. 15. THERMOSTAT UNIT

79. **Water Pump.**—This is of special 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. If water became frozen in the pump it is obvious that serious consequences would follow any attempt to start and run the engine. In order to guard against this contingency, so far as it is possible, the diameter of the impeller spindle is reduced for a short length near the driving square so that any undue load will fracture the reduced spindle by twisting and thus prevent more serious consequences in the form of damage to the driving gears. In this event the driving square can be withdrawn from the driving member after the water pump has been removed, by inserting a stud extractor or other implement, into the hole provided for this purpose in the centre of the square. A piece of wire or wood screw may also be used for this purpose. Spare parts for the water pump and complete service pumps may be obtained from our Service Depots and from the Works.

80. **Lubrication of Water Pump.**—The only attention which the pump requires is the lubrication of the ball bearing. This should be carried out by using not more than one grease cup full per 48,000 miles or 4,800 hours. Use a lithium base grease to No. 2 or 3 NLGI rating system or a good quality calcium base grease having a drop point of 100°C. nominal. **Do not fit grease nipple in order to use a grease gun. Grease is detrimental to carbon glands.**

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

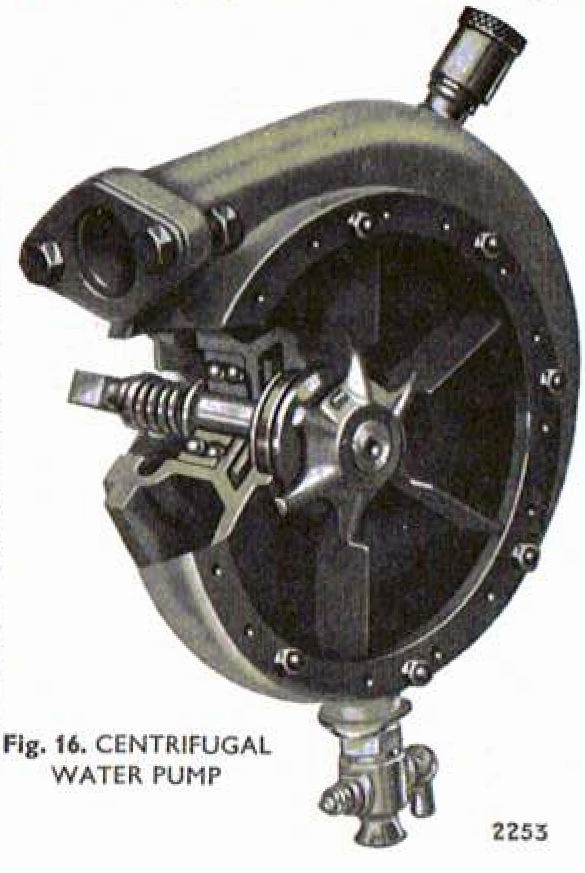


Fig. 16. CENTRIFUGAL WATER PUMP

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SERVICING AND MAINTENANCE

COOLING SYSTEM—*continued*

When the pump is dismantled this small drain hole will be found crossing the joint face of the cover to the body and care should be taken to avoid blanking this hole with any packing or jointing used. If the engine installation is such that the engine is inclined rearwards, the water manifold from the water pump to the base of the cylinders will require separate draining by means of the cock or plug provided at the rear end.

AIR INDUCTION FILTERS

82. **Air Induction Filters: Gardner Universal Oil Bath Type.**—The filter body is attached to the mounting head by means of side bolts and incorporates inner and outer cavities both of which are made "air tight" by the use of sealing rings. The inner ring seals the cavity to the air cleaner element and the outer seals the cavity to the air cleaner body. Dust laden air is drawn into the cavity "B" of the mounting head, and passes down the annulus "C". This annulus is reduced in area at the base, which results in an increased velocity where the dusty air impinges on the oil. The air flow is reversed upwards through the element into the inner cavity "D" thence through outlet "E" to the engine. See Fig. 17. At the reversal of the air at oil level "A", dust particles are precipitated into the oil, and a small quantity of oil is picked up by the air stream and carried into the filter element. The oil wets the element and retains any dust remaining in the air. This dust is continually washed into the oil container as the oil drains back from the element. The dust eventually settles in the base of the oil container in the form of sludge, and the displaced oil enters the compensator chamber through a series of holes at "F" and finally through the centre hole "G".

83. **Air Induction Filters: Gardner Twin Oil Bath Type.**—With this type of filter, see Fig. 18, air enters through the aperture between the filter cover and body and is drawn downwards through the annular space between the filter body and filter element where it comes into contact with the oil. Dust particles are precipitated into the oil and the air flow is reversed upwards through the element carrying with it a small quantity of the oil which wets the element so extracting further dust from the air. The dust is washed back into the oil container as the oil drains from the element, and eventually settles in the base of the oil container in the form of sludge. The filters are easily and quickly removed as complete units by releasing the two wing nuts on top of the covers.

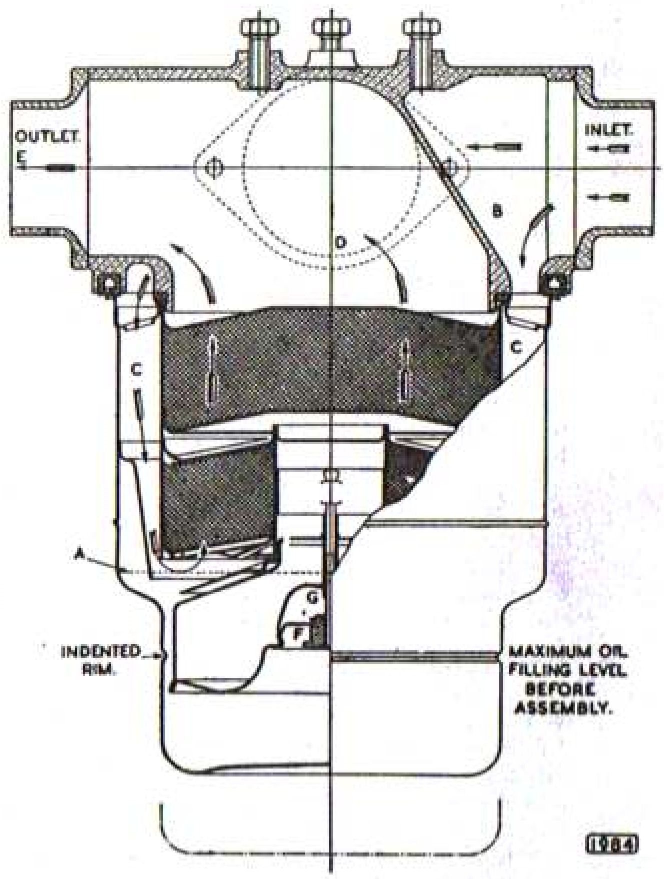


Fig. 17. GARDNER UNIVERSAL AIR FILTER

SERVICING AND MAINTENANCE

AIR INDUCTION FILTERS—*continued*

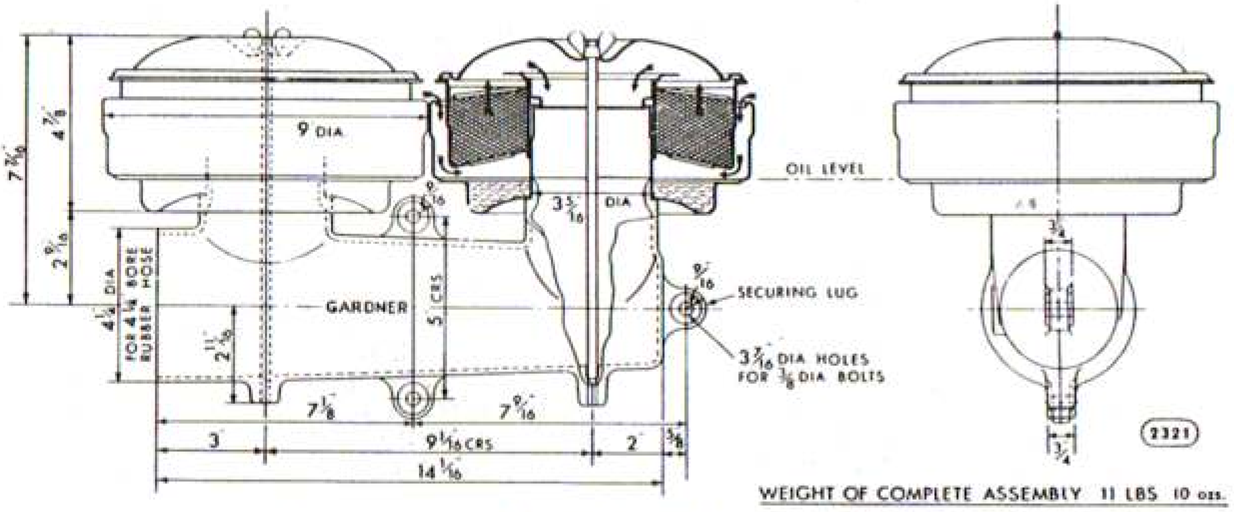


Fig. 18. GARDNER TWIN OIL BATH TYPE FILTER

84. **Cleaning and Replenishing Containers.**—It is recommended that the elements of oil bath type filters be removed and washed in fuel oil and the container cleaned and replenished with fresh oil every 400 hours or 4,000 miles or alternatively at more or less frequent intervals depending upon the conditions under which the engine is operating. When this type of filter is used on an engine which never exceeds say 1,200 r.p.m., the air velocity through the filter may be insufficient to cause adequate oil washing of the element. Under such conditions the element must be removed at more frequent intervals and washed in a hot water detergent solution, after which it must be blown through and thoroughly dried with a compressed air jet before re-assembling. The grade of oil used for replenishing containers must be of suitable viscosity according to the prevailing climatic conditions. The following grades of oil are recommended:—

Mean Annual Temperature	*Grade of Oil*
40°F. (4½°C.) to 70°F. (21° C.)	S.A.E. 30
Over 70°F. (21°C.)	S.A.E. 50

To remove the filter unit on the Universal Type Cleaner unscrew the two elongated brass nuts and withdraw the container downwards and away from the filter head. The filter unit may then be dismantled for cleaning by removing the filter element from the container and disconnecting the compensator chamber by unscrewing the thumb nut located in the recess underneath. After cleaning the containers of both Universal and Twin Oil Bath Type filters containers should be filled to the level indicated with clean fresh oil and care taken to ensure that the oil does not rise above this level otherwise serious damage to the engine may result. After washing the elements in fuel oil they must be allowed to drain before being replaced in the containers. With routine attention of this nature, the filters may be expected to give trouble free service throughout the life of the engine.

85. **Dry Type Induction Air Filters.**—The elements of dry type induction air filters are constructed with specially processed paper and they may, in service, be subject to rapid accumulation of filtered media which they have successfully prevented from passing to the engine.
CAUTION.—When such accumulation occurs, there is created an increased resistance to the passage of air to the engine. This condition is highly undesirable since it will cause smoke, high fuel consumption, loss of power overheating, together with other attendant ills and high maintenance. *The importance, therefore, of regular and frequent cleaning of this type of filter cannot be over emphasised.* Engine induction air should always be drawn from the coolest place and paper elements or filter units should be so positioned that they do not receive water, oil or oil vapour. If an element is to be mounted under the bonnet or engine casing it should be forward of the engine so that the air stream will carry engine fumes away from the filter.

86. **Measuring Resistance to Air Flow.**—Resistance to air flow develops during varied periods of time or mileage, according to the duty and operating conditions, etc. Field experience indicates that a regular and

SERVICING AND MAINTENANCE

AIR INDUCTION FILTERS—*continued*

frequent measurement of the resistance should be made in order to secure efficient and durable engine operation. A user will, from experience, readily determine the "check" periods necessary for his own service. The resistance of the filter may be assessed by measuring the depression in inches of water with a simple water manometer coupled to the end of the engine induction manifold, when the engine is running at maximum speed. The latest engines are permanently fitted with a $\frac{1}{8}$ in. BSP connection for this purpose and existing engines can be readily so equipped. A simple manometer can be readily constructed comprising a parallel transparent P.V.C. plastic tube, approximately $\frac{5}{32}$ in. (4 mm.) bore, $\frac{13}{32}$ in. (10 mm.) outside diameter and a total length of 15 in. (381 mm.). Manometers of this type, Part No. MA 536 are available from the Works, and if desired, can be carried in the driving compartment for use at any time. Alternatively, it may be considered convenient to mount two tubes in a suitable position on a vertical or near vertical surface of the driving compartment so that it can be permanently connected to the air intake manifold to record manifold depression. The lowest depression obtainable is desirable and with a well-designed layout less than 4 in. (102 mm.) of water is measurable. Some filter assemblies incorporate a warning whistle, but it is advisable to make the above manometer test.

87. **Cleaning and Renewal of Paper Filter Elements.**—As mentioned earlier, it is of vital importance that the element receives regular and frequent attention and if, during use, chokage of the element occurs sufficiently to create a depression of 7 in. (178 mm.) of water, immediately replace or clean the filter element. It is good practice to carry a new or clean element in the vehicle. Elements may be successfully cleaned (*a*) by tapping gently on the sealing faces and blowing out from inside to out with a compressed air jet directed up and down each pleat, and (*b*) by washing in a hot water detergent solution and blowing out with an air jet as above. After washing it is advisable to dry the element in an oven or by other means in order to secure the lowest resistance. The temperature should not exceed 250°F. (121°C.). In some cases process (*a*) satisfactorily cleans the element; in others perhaps associated with an oily atmosphere, (*b*) produces better results. Under certain circumstances it is sometimes found that after a paper element has been cleaned a few times, either by washing or compressed air, its satisfactory clean life becomes rapidly shorter. When this condition arises the old element should be discarded and replaced by a new one.

TIMING CHAIN

88. **Timing Chain Adjustment.**—After the first 12,000 miles (1,200 hours) and every 48,000 miles (4,800 hours) inspect and adjust if necessary by means of the manual chain lever adjuster shown in Fig. 19. 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. (6·35 mm.) on either side of the mean position. Do not run engine with excessive chain slackness or without slackness. Chain slack may be estimated by rotating the dynamo drive by hand in either direction after having turned the engine backwards a portion of a turn in order that its tension be relieved.

Adjacent to the injection timing pointer will be found a larger diameter plug; access to the timing chain may be gained by removal of this plug, so providing a further means of judging chain tension.

A piece of $\frac{1}{8}$ in. (3·175 mm.) steel wire, with a short length at one end bent to form a right angle and inserted through this hole, will be found to form a convenient means of assessing the slack.

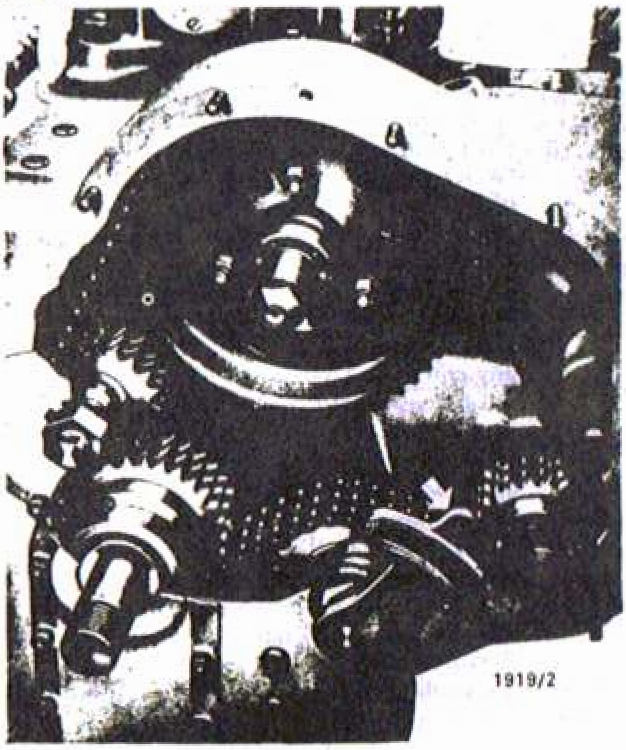


Fig. 19. TIMING CHAIN ADJUSTER

GARDNER

SERVICING AND MAINTENANCE

TIMING CHAIN—*continued*

89. **Correction for 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 injection to become slightly retarded, with consequent appreciable reduction in engine efficiency. Tightening of the chain by movement in a clockwise direction of the chain adjuster lever automatically restores correct timing, but on earlier engines fitted with the adjuster at the offside or water pump side of the chain case and also later engines that have been arranged for opposite rotation (clockwise viewed from flywheel end) it will be necessary to correct the timing as well as the chain tension since adjustment of the tension will further retard the timing of the valves and fuel injection.

To correct the timing proceed by first removing the chain case cover to gain access to the three nuts securing the valve camshaft chain wheel to the camshaft hub. Tighten the chain and lock the adjuster by means of the large hexagon nut. Set the injection control pointer in the full speed position and turn the flywheel so that the injection timing mark coincides with the line on the crankcase end-plate or flywheel housing. Slacken the three nuts on the chain wheel (see Fig. 19) and rotate the camshaft slightly anti-clockwise (which also slightly rotates the fuel pump camshaft) until the timing lines on the fuel pump plunger guides coincide with the lines on the sides of the fuel pump body windows. The three nuts on the chain wheel should then be firmly retightened.

Every 48,000 miles (4,800 hours) the timing should be checked as indicated in paras. 132-133. Wear of chain is accelerated by lack of adjustment and undue slackness may promote noise and unsteady governing. It is important to avoid over-tightening a chain as, of course, this also will create an abnormal rate of wear.

90. **Replacement of Timing Chain Detachable Link.**—A chain has a useful life of 180,000 miles or more providing our engine lubrication recommendations are followed and reasonable attention is paid to adjustment, but it is advisable to renew the detachable link assembly (if fitted) at about half this distance.

To replace the link proceed as follows:—

(1) Remove chain case cover and slack off chain adjuster.

(2) Decompress engine, remove push rods. Latch back fuel pump hand priming levers.

(3) Rotate engine until detachable link assembly is opposite recess cast in crankcase immediately below fuel camshaft gear. Remove spring clip and push link back into recess. Reverse operation when fitting new link. When fitting spring clip it is advisable to fit one leg of the clip into the grooved pin before pushing the second leg into position. If the clip is pushed in endways both legs are opened simultaneously, so raising possibility of straining clip.

On earlier engines the crankcases were not recessed but were fitted with a large brass plug above the generator drive. The above procedure can be followed by pushing the detachable link through this plug hole.

On still earlier engines which had neither recess nor plug in crankcase it is necessary on 6LW engines (which are fitted with crankshaft dampers) to remove the sump and insert the link at a point between side of crankcase and outside diameter of damper.

In 2, 3, 4 and 5LW engines of similar age, it will be found convenient to replace the link when the sump is removed and the crankshaft turned until the spring link is located at about 10 o'clock on the camshaft chain wheel. Reach up behind the chain wheel with the right hand (this is possible as there is no damper on these crankshafts), and with a spare link in the left hand push the old link out into the right hand. Insert new link from the back, pushing out spare link in the process, and turn engine so that link occupies any convenient position for the fitting of the new side plates and clip.

To fit new chain turn engine until No. 1 piston is at T.D.C. Thread the new chain over the camshaft chain wheel, inside the adjuster and idler sprockets and around the crankshaft sprocket. Jump the chain over the teeth of the camshaft chain wheel so rotating the chain wheel until the dots are in a straight line as shown in Fig. 32, Page 80.

90·1 **Removal of Endless Chains and Fitting and Riveting Joint Links.**—The use of the detachable link (para. 90) on all engines after 6LW/112100 and 5HLW/112152 has been abandoned in favour of a riveted link. Thus the operation of replacing the detachable link at some interim period before complete engine overhaul will no longer be necessary.

Factory tools have been developed to press the chain side plate on to the studs and to rivet the ends of the studs. See Fig. 35, also Para. 138, Page 82.

SERVICING AND MAINTENANCE

VALVE TAPPETS

91. **Valve Tappet Clearances.**—After every 12,000 miles (1,200 hours) adjust, if necessary, the clearance between the end of the valve and the toe of the valve lever. The correct clearance for inlet valves is ·005 in. (·127 mm.) and for exhaust valves ·011 in. (·279 mm.). 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 which will show by its unloaded action that the pump tappet is in the lifted position.

RADIATOR FAN

92. **Radiator Fan Belt Adjustment.**—The belt drive should be inspected and the adjustment checked every 12,000 miles (1,200 hours). If properly maintained, its useful life can be as much as 100,000 miles or more. It is important that periodic inspection is maintained, since after prolonged use, stretch and wear will occur causing slackness. If this is allowed to become excessive it will result in rapid deterioration and eventual failure of the belt.
The fan mounting bracket incorporates an adjusting screw for tensioning the belt drive. Adjustment is effected by slackening the large nut at the rear of the fan spindle and turning the adjusting screw until the tension is such that a side movement of approximately 1 in. (25·4 mm.) is obtained on the longest run of the belt. After re-tightening the spindle nut, a final check should be made that correct adjustment has been maintained, since the act of tightening this nut may tend to increase the tension. Over-tensioning is to be avoided. It will be just as harmful as slackness and will overload the bearings of the fan spindle and also the compressor crankshaft, if a compressor is fitted.

AUXILIARY UNITS

93. **Alternator Drive Flexible Coupling Assembly.**—When fitting an alternator or dynamo which is driven by a flexible hose type coupling, the clips on the shaft couplings must be tightened up **before** the clamp straps are tightened. If the latter are tightened before the coupling clips, the expansion of the flexible rubber couplings will impose a heavy end-load on the armature and alternator bearings.

94. **Electric Starter Ring on Flywheel.**—A standard toothed ring is retained in position on the flywheel by shrinking in place and is not retained by dowels or bolts. It may be removed by progressive light driving around the upstanding edge. A new ring may be fitted by heating until it assumes the first straw colour and then applying it to the flywheel.

95. **Exhauster.**—(See also para. 140). These Exhausters are of the simple reciprocating type, the piston being driven by a connecting rod from a crank fitted to the forward end of the valve camshaft.
Lubrication is effected by splash from oil which is collected via a trough in the timing case cover. No external lubrication attention is, therefore, required.

95·1 **Exhauster Suction Filter.**—Clean periodically the filter located inside the suction union or the cylinder head and if, in so doing, a quantity of matter is disturbed remove the cylinder head and clean thoroughly to avoid fouling the system. This filter is capable of preventing entry of large particles only and is incapable of arresting fine dust or scale, etc. It is essential, therefore, to ensure that the complete vacuum tank and pipe system is thoroughly cleaned with compressed air, steam or other means during overhaul.

96. **Exhauster Breather Filters (Dust-proofed Engines only).**—These contain inexpensive replaceable paper elements which can be washed as directed in para. 31, but should be renewed after 24,000 miles' use (2,400 hours). They are readily obtainable from the Works, Service Depot and Stockists.

SERVICING AND MAINTENANCE

VALVE TAPPETS

91. **Valve Tappet Clearances.**—After every 12,000 miles (1,200 hours) adjust, if necessary, the clearance between the end of the valve and the toe of the valve lever. The correct clearance for inlet valves is ·005 in. (·127 mm.) and for exhaust valves ·011 in. (·279 mm.). 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 which will show by its unloaded action that the pump tappet is in the lifted position.

RADIATOR FAN

92. **Radiator Fan Belt Adjustment.**—The belt drive should be inspected and the adjustment checked every 12,000 miles (1,200 hours). If properly maintained, its useful life can be as much as 100,000 miles or more. It is important that periodic inspection is maintained, since after prolonged use, stretch and wear will occur causing slackness. If this is allowed to become excessive it will result in rapid deterioration and eventual failure of the belt.

The fan mounting bracket incorporates an adjusting screw for tensioning the belt drive. Adjustment is effected by slackening the large nut at the rear of the fan spindle and turning the adjusting screw until the tension is such that a side movement of approximately 1 in. (25·4 mm.) is obtained on the longest run of the belt. After re-tightening the spindle nut, a final check should be made that correct adjustment has been maintained, since the act of tightening this nut may tend to increase the tension. Over-tensioning is to be avoided. It will be just as harmful as slackness and will overload the bearings of the fan spindle and also the compressor crankshaft, if a compressor is fitted.

AUXILIARY UNITS

93. **Alternator Drive Flexible Coupling Assembly.**—When fitting an alternator or dynamo which is driven by a flexible hose type coupling, the clips on the shaft couplings must be tightened up **before** the clamp straps are tightened. If the latter are tightened before the coupling clips, the expansion of the flexible rubber couplings will impose a heavy end-load on the armature and alternator bearings.

94. **Electric Starter Ring on Flywheel.**—A standard toothed ring is retained in position on the flywheel by shrinking in place and is not retained by dowels or bolts. It may be removed by progressive light driving around the upstanding edge. A new ring may be fitted by heating until it assumes the first straw colour and then applying it to the flywheel.

95. **Exhauster.**—(See also para. 140). These Exhausters are of the simple reciprocating type, the piston being driven by a connecting rod from a crank fitted to the forward end of the valve camshaft.

Lubrication is effected by splash from oil which is collected via a trough in the timing case cover. No external lubrication attention is, therefore, required.

95·1 **Exhauster Suction Filter.**—Clean periodically the filter located inside the suction union or the cylinder head and if, in so doing, a quantity of matter is disturbed remove the cylinder head and clean thoroughly to avoid fouling the system. This filter is capable of preventing entry of large particles only and is incapable of arresting fine dust or scale, etc. It is essential, therefore, to ensure that the complete vacuum tank and pipe system is thoroughly cleaned with compressed air, steam or other means during overhaul.

96. **Exhauster Breather Filters (Dust-proofed Engines only).**—These contain inexpensive replaceable paper elements which can be washed as directed in para. 31, but should be renewed after 24,000 miles' use (2,400 hours). They are readily obtainable from the Works, Service Depot and Stockists.

SERVICING AND MAINTENANCE

97. **Summary of Attention by Mileage and Running Time.**—The following Recommended Maintenance Schedule is based upon average conditions of service including the use of good quality fuel and lubricating oils, etc. It will be appreciated that heavy duty and adverse operating conditions compared with light duty and favourable conditions, may respectively reduce or considerably increase, the periods at which attention is required. It is intended therefore, that this schedule provides a basis only, upon which operators may formulate a schedule of inspection and maintenance to cover their own special requirements and conditions of service. The benefits to be obtained from the use of good quality "Supplement 1" type lubricating oil, low sulphur content fuel oil and frequent draining and refilling of engine oil sump, cannot be over emphasised —in fact, it can safely be said that the more frequently the sump oil is renewed the lower will be the rate of engine wear. The inspections laid down are based on intervals of approximately 4,000 miles (400 hours) running time and are cumulative. Thus, when completing the inspections given at 12,000 mile periods, they must include the items given at 8,000 and 4,000 mile periods.

Operators are advised to add to this schedule any items of equipment which may have been introduced for special installations.

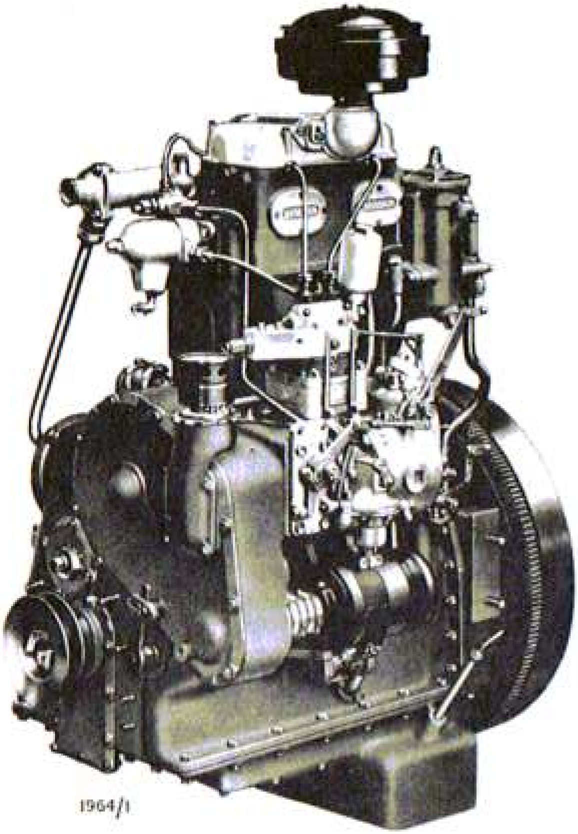
The final columns provide a cross-reference to detailed instructions—contained within this manual—covering the appropriate maintenance procedure.

Top overhaul and major overhaul periods are frequently more than doubled and will be determined largely by operating duty and service conditions. For example an engine in a highly loaded tractor unit will require overhaul at a lower mileage than an engine in a passenger vehicle. Cylinder liners, piston rings and pistons may have a useful life varying from 100,000 miles (160,000 Km.) to 200,000 miles (320,000 Km.) and without removal from the engine.

PERIOD		OPERATING CONDITIONS	ITEM	PROCEDURE	Para.	Page
Miles	Hours					
DAILY		All Conditions	Lubrication System	Check oil level: Replenish if necessary	9	25
			Cooling System	Check Coolant level: Replenish if necessary	10	25
EVERY 1,000 (or less)	100	Extreme Dusty Conditions	Lubricating oil sump	Drain and refill sump	30 & 33	36
			Air Induction Filter (Dry Type)	Check for chokage with manometer and clean if necessary	86 & 87	50
EVERY 4,000	400	Average conditions	Lubricating oil sump	Drain and refill sump	30 & 33	36
			Lub. oil delivery filter	Examine and clean if necessary Replenish with fresh oil	25 & 26	33
			Fuel Filters	Examine and clean if necessary	42 to 44	37
			Air Induction Filters (Oil Bath Type)	Clean filter element/s: Clean and re-charge element container/s	84	50
			Air Induction Filter (Dry Type)	Clean the element or renew if manometer reading exceeds 7 in. of water	86 & 87	50
			Crankcase Breather Filter	Examine and clean if necessary	31 & 32	35
EVERY 8,000	800	Average conditions	Sprayers	Test by feel and sound that sprayers are functioning correctly by operating hand charging levers on engine	47	39

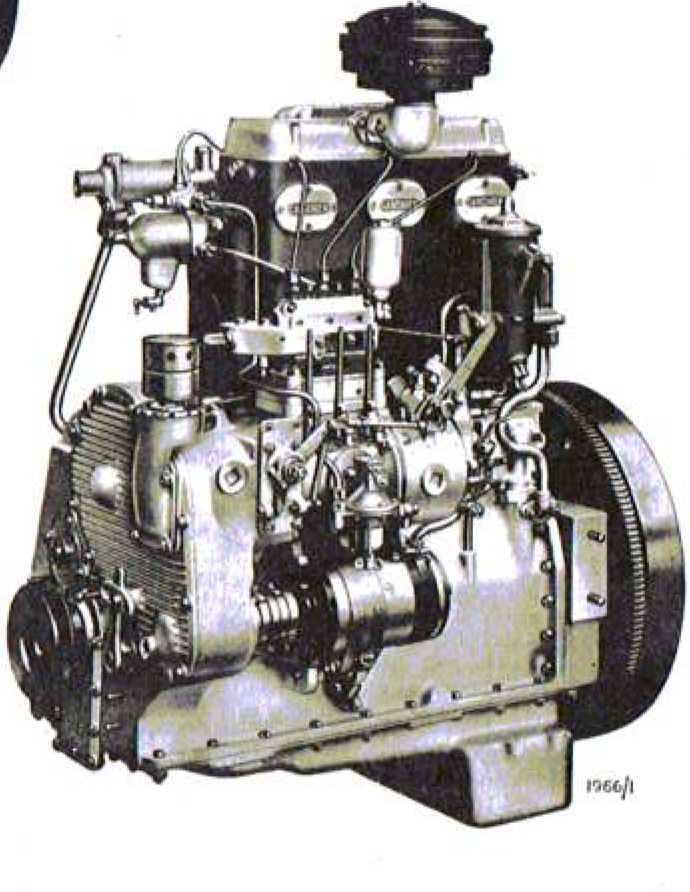
SERVICING AND MAINTENANCE

PERIOD Miles	PERIOD Hours	OPERATING CONDITIONS	ITEM	PROCEDURE	Para.	Page
EVERY 12,000	1,200	After *first* 12,000 miles	Main Timing Chain	Check tension and adjust if necessary	88	51
		Every 12,000 miles Average conditions	Radiator Fan	Lubricate fan spindle bearing with grease gun	40	36
				Check driving belt tension and adjust if necessary	92	53
			Slow Running	Check and adjust if necessary	72	46
			Fuel Injection Pumps	Lubricate slider bar and quadrants	39	36
			Exhauster Breather Filter	Examine and clean if necessary	96	53
			Valve Tappets	Check clearances and adjust if necessary	91	53
EVERY 20,000	2,000	Average conditions	Lub. Oil Delivery Filter	Renew Paper Element	25 & 26	33
EVERY 24,000	2,400	Average conditions	Crankcase Breather Filter	Renew Filter Unit or paper element if removable	31 & 32	35
			Exhauster Breather Filter	Renew filter unit	96	53
			Exhauster Suction Union	Remove and clean	95·1	53
EVERY •48,000	4,800	Average conditions	Top Overhaul	Decarbonise	116	72
			Lubricating oil sump	Remove and clean	35 to 38	36
			Air Cooled Oil Cooler	Flush through with clean fuel oil or paraffin	23	33
			Fuel Filters	Renew filter elements	43	38
			Fuel Injection Pumps	Check maximum output and balance on calibrating machine. Refer to Calibrating Machine Instruction Book No. 45.4	74	46
			Sprayer	Test by fast pull on hand charging levers. If sprayer valves do not vibrate fit service units	52 & 53	40
			Main Timing Chain	Check and adjust tension if necessary	88 & 89	51
			Governor Control Slider Bar	Check $\frac{1}{32}$ in. (·794 mm.) dimension and adjust if necessary	71	45
			Advance and Retard Friction Device	Check range of movement and adjust if necessary	69 & 70	44
			Accelerator Control	Check range of movement in relation to pedal mechanism	67	44
			Water Pump	Lubricate spindle bearing with one grease cup full of grease	80	48
EVERY •200,000	20,000	Or when a ·006 in. (·152 mm. diametral clearance has developed in any one crankshaft main	Effect Major Overhaul	Resize crankshaft and fit new bearing shells, etc. etc.	101	60
				White metal bearings	105	61
				Pre-finished thin wall bearings	107	63



1964/1

2LW Rail Traction Engine



3LW Rail Traction Engine

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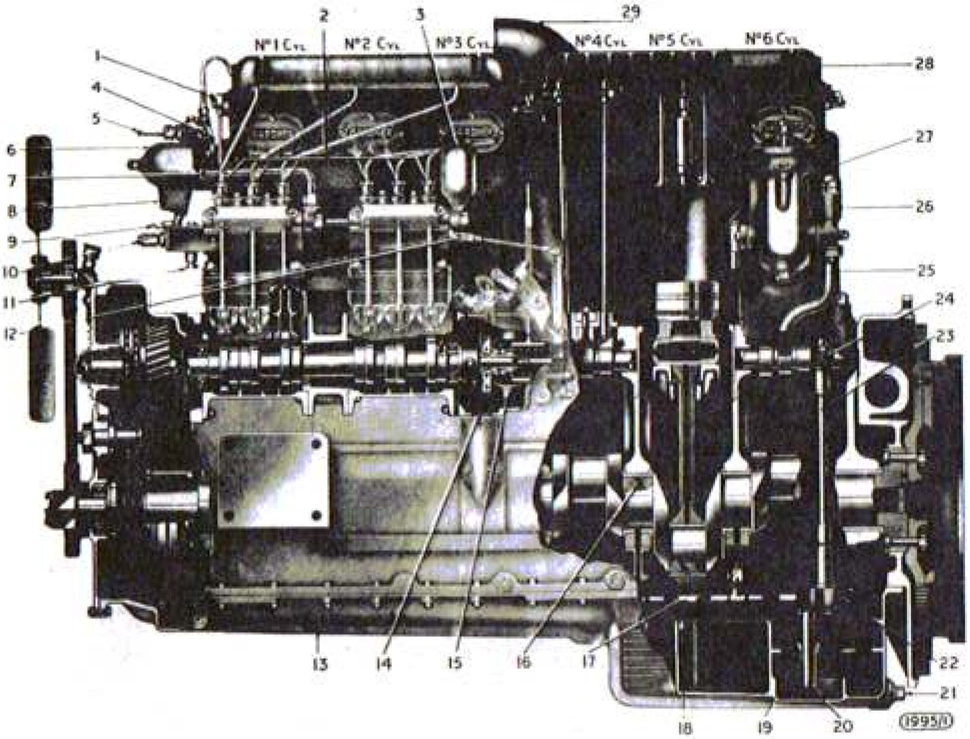
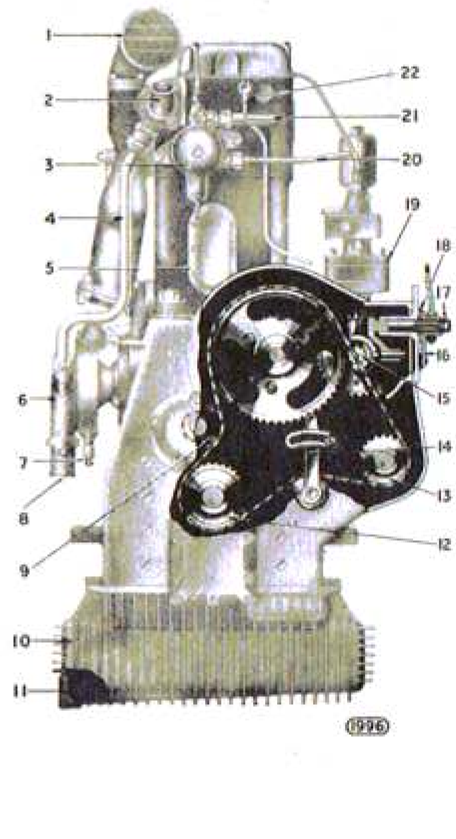
OVERHAUL AND ASSEMBLY

GARDNER



Longitudinal Section

1. Valve Gear Oil Feed
2. Sprayer Pipe Unions
3. Fuel Suction Air Chamber
4. Fuel Inlet to Filter
5. Fuel Overflow Return to Tank
6. Second Fuel Filter
7. Fuel Outlet to Pump
8. Filter Sump
9. Filter Sump Drain
10. Governor Control Bar Buffer
11. Starting Fuel Plunger
12. Governor Controlled Slider Bar
13. Oil Sump
14. Oil Return Passage
15. Governor Weights
16. Oil Feed Tube to Crankpin
17. Main Bearing Feed Pipe
18. Primary Filter
19. Oil Pump Suction Pipe Bush
20. Oil Pump Suction Pipe
21. Oil Sump Drain Plug
22. Oil Pump
23. Oil Pump Driving Shaft
24. Oil Pump Driving Gear
25. Oil Delivery Pipe to Relief Valve
26. Oil Pressure Regulating Valve
27. Lubricating Oil Delivery Filter
28. Valve and Cylinder Head Cover
29. Air Intake Elbow

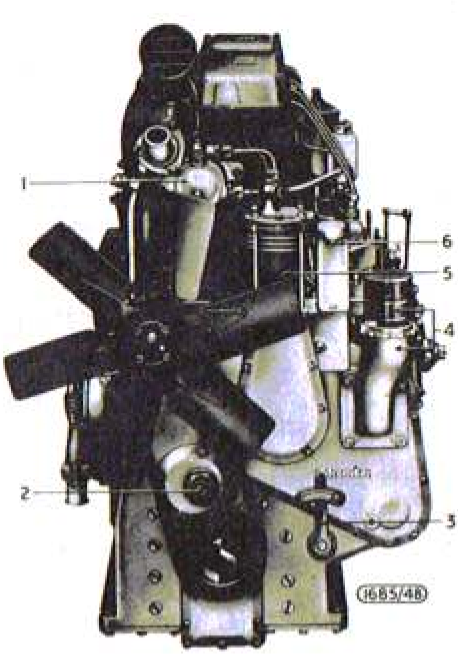


Chaincase Section

1. Air Intake Elbow
2. Water Outlet
3. Second Fuel Filter
4. Temperature Control Bye-pass Pipe
5. Cylinder Water Door
6. Water Circulating Pump
7. Water System Drain Cock
8. Water Inlet
9. Timing Chain Idler (Fixed)
10. Oil Sump
11. Oil Sump Drain Plug
12. Crankshaft Sprocket
13. Dynamo Drive Sprocket
14. Timing Chain Adjuster Lever
15. Fuel Pump Camshaft
16. Injection Timing Pointer
17. Friction Device Nut
18. Friction Washer
19. Fuel Injection Pump
20. Fuel Outlet to Pump
21. Fuel Feed to Filter
22. Valve Gear Oil Feed

Forward End Elevation

1. Second Fuel Filter
2. Timing Chain Idler (Fixed)
3. Timing Chain Adjuster Lever
4. Oil Filler
5. Exhauster for Vacuum Servo Brakes
6. Combined Oil Separator and Breather



SPECIAL TOOLS, INSTRUCTIONAL DRAWINGS AND DATA, Etc.

98. The following paragraphs should be read in conjunction with Workshop Tools Book No. 48·2 which contains an illustrated list of special tools to facilitate major servicing of the engines; it also contains drawings with brief operational instructions, etc., and is available at a small charge upon application to the Works.

SPARE PARTS

99. **Requisition of Spare Parts.**—Spare Parts are readily available from the Works, also from our officially appointed Service Agents or Recommended Repairers in the United Kingdom. In addition, stocks of Spare Parts are carried by our Overseas Representatives in all parts of the World and lists of all such Agents, etc., will be found on pages 6 to 9. At the Depots in the United Kingdom and also overseas are Practical Engineers from whom users of Gardner Engines can obtain assistance and advice regarding their engines.

Enquiries or orders for spare parts should include the type and serial number of the engine. The serial number is stamped on the upper surface of the crankcase adjacent to No. 1 cylinder on the fuel pump side of the engine and on the Fuel Control Box on the forward pump unit.

Enquiries concerning fuel pumps should also include full particulars given on the data plate attached to the Fuel Control Box.

Spare Part Fitting Instructions.—In all cases where it is necessary, Assembly Instructions for the fitting of spare parts accompany each consignment of spares. These instructions should always be carefully followed since all modifications to the engine receive the most careful consideration to ensure interchangeability and it is, therefore, necessary to closely follow the Assembly Instructions when fitting new parts. By this means it is also possible to ensure that the latest modification or additions to an engine can be incorporated in the oldest engines. Full instructions for the correct ordering of Spare Parts are contained in the appropriate Spare Parts Catalogue.

SERVICE EXCHANGE SCHEME

100. **Service Exchange Scheme.**—It is recommended that Home operators should avail themselves of the Service Exchange facilities which are offered. Special machines, equipment and knowledge are used in the reconditioning of service units and the operator will be assured of the highest standard of workmanship at the lowest economical cost.

The following re-conditioned components and assemblies are held in stock at the Works and Depots for immediate exchange, providing that the exchange unit is not worn or damaged beyond satisfactory repair limits.

Cylinder Blocks. (Fresh water cooled only.)
Cylinder Heads (Bare) Type 2A and later. (Fresh water cooled only).
Cylinder Head Assemblies Type 2A and later. (Fresh water cooled only).
Lubricating Oil Pumps.
Lubricating Oil Relief Valve Assemblies.
Fuel Lift Pumps.
Fuel Injection Pumps.
Fuel Sprayer Assemblies.
Governor Unit Assemblies.
Water Pump (Centrifugal Type only).
Exhauster Connecting Rods.
Crankshafts.

GARDNER

OVERHAUL AND ASSEMBLY

CRANKSHAFT AND MAIN BEARINGS

101. **Crankshaft Re-sizing.**—When re-sizing a crankshaft it is essential that the work be effected with the greatest accuracy. The shaft must run truly about its axis and the bearing surfaces must be parallel and perfectly round. The axis of the crankpins must be parallel with the journal bearings in both planes and the radii where journals and crankpins join the webs must be accurately formed with high finish, free from lines or marks and be not smaller than the original dimension. If the above provisions are not observed failure of crankshaft and bearings may ensue. See Workshop Tools Book No. 48·2, pages 56 and 57 for sizes and clearances. Before assembly, clean thoroughly all passages and examine surfaces for abrasion; a scratch or indentation may be detected by rotating a half shell on the shaft. Any blemishes of this nature should be carefully removed by using an Arkansas marble or similar stone.

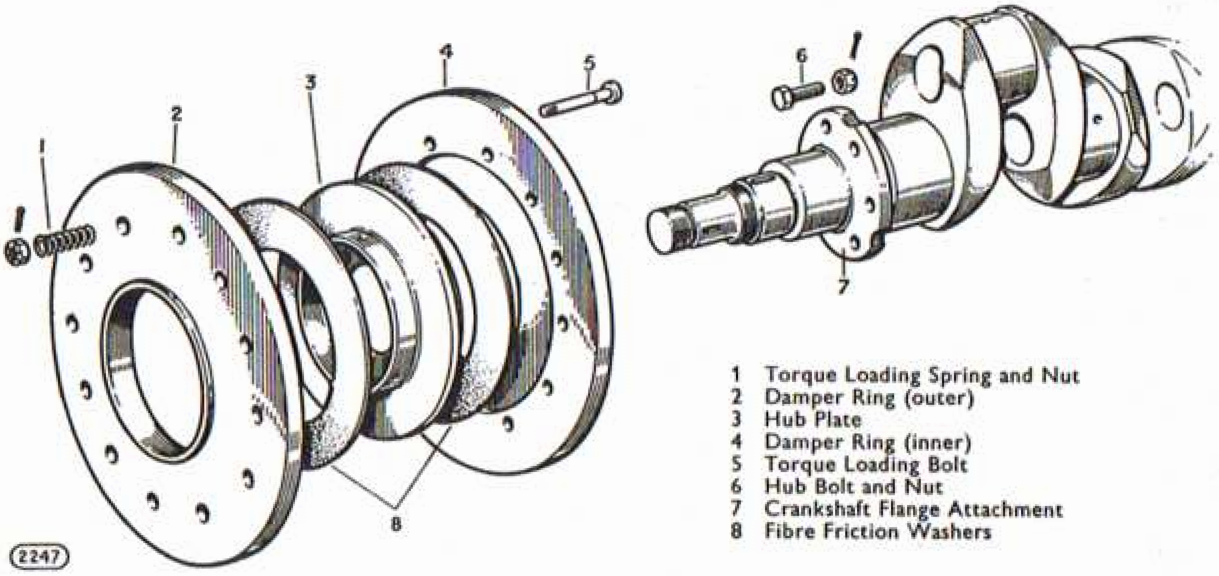
Fig. 20. 6LW CRANKSHAFT

102. **Flatting of Crankshaft Oil Holes.**—When a shaft is reground, sharp corners will be reproduced where the transverse oil holes emerge on the crankpins and journals. These sharp corners must be removed after grinding and also the original flatted portion around the circumference of the holes at each end must be restored. The flatted portion takes the form of a $\frac{1}{16}$ in. (1·59 mm.) wide band around the circumference of the holes on pins and journals and can be formed by use of a small oil stone.

103. **Crankshaft Damper.**—The crankshaft damper which is fitted to the 6-cylinder engine only should be inspected at major overhaul of engine. The friction surfaces are composed of hard red fibre. If renewal of these discs is necessary, **use only genuine "Gardner" replacements.** Do not use any other friction medium since the coefficient of friction may be entirely unsuitable. The original internal-spring type damper was taper mounted on the crankshaft and when assembling this type damper do not over-tighten the nut securing the sprocket and damper on the crankshaft — see Workshop Tools Book No. 48·2, pages 12, 13, 14 and 69. When the damper is assembled, each spring should exert a load of 105 lb. (47·5 Kg.). The slip torque of the dampers at first "break" from rest when newly assembled is approximately 65 lb. ft. (8 Kg./m.). This type damper has now been superseded by the Type 3, and subsequently the Type 4 damper on the latest 6LW and 6HLW crankshafts. The 6LW20 engine is fitted with the Type 4 damper. These damper assemblies are bolted to an integral flange situated on the crankshaft forward of the front main bearing. The Types 3 and 4 damper each comprise two cast iron rings loaded externally by 12 bolts and springs. The cast iron rings bear on a flanged steel hub plate through the intermediary of two hard red fibre friction discs. The Type 4 damper which superseded Type 3 is identified by peripheral grooves machined on the outer flange of the hub plate and on the periphery of the front and rear cast iron rings. The component parts of these two dampers are not interchangeable and it is essential that the plain (Type 3) and grooved (Type 4) components are not mixed in any one assembly. When the new type dampers are assembled, the springs should each exert a load of 110 lb. (50 Kg.) when compressed to 1·11 in. (28·2 mm.). Since the springs are recessed in the cast iron ring, the loading can more readily be determined by measuring the distance from the top of the spring to the surface of the cast iron ring. If the nut is tightened until a distance of ·704 in. (17·88 mm.) plus or minus ·003 in. (·076 mm.) is obtained, the correct spring load will be achieved. Ensure, when re-assembling on the crankshaft, that the mating faces of the damper hub and crankshaft flange are perfectly clean and that no burrs are present which could impair the seating of the two faces. The correct tightening torque for nuts securing the damper hub to the crankshaft is 650 lb./in. (7·5 Kg./m,).

OVERHAUL AND ASSEMBLY

CRANKSHAFT AND MAIN BEARINGS—*continued*



1 Torque Loading Spring and Nut
2 Damper Ring (outer)
3 Hub Plate
4 Damper Ring (inner)
5 Torque Loading Bolt
6 Hub Bolt and Nut
7 Crankshaft Flange Attachment
8 Fibre Friction Washers

Fig. 21. CRANKSHAFT DAMPER ASSEMBLY—TYPE 4

104.—**Interchangeability of Crankshafts and Crankcases.**—Crankshafts manufactured on and after 1st March, 1964, have been machined to suit both the Type 2 crankcase (with flywheel-end endwise location of crankshaft) fitted with white metal lined bearing shells and the Type 3 crankcase (with centre endwise location of crankshaft) fitted with pre-finished thin wall copper lead lined bearing shells. These crankshafts can be identified by the manufacturing date stamped on the side of No. 1 web. Crankshafts manufactured prior to this date—having flywheel-end location—can only be fitted to Type 2 crankcases.

The Type 3 crankcases, which are identified by the letter 'S' stamped on the top face at the flywheel end (fuel pump side), are not interchangeable with the Type 2 crankcases used on earlier engines, unless the latter has subsequently been fitted with the latest type crankshaft, *which has been machined for both centre and flywheel-end location*, in which case the Type 3 crankcase will be supplied as a replacement complete with pre-finished thin wall bearings and thrust washers. All current production flywheel-end bearing caps of both aluminium and cast iron crankcases are drilled to accommodate the two additional ½ in. (12·7 mm.) B.S.F. studs. Replacement caps, so drilled, can be fitted to the earlier Type 2 aluminium crankcases but the ½ in. (12·7 mm.) stud holes will not be used.

105. **Crankshaft Main Bearings (WHITE METAL LINED SHELLS).**—When fitting new bearing shells of this type the following points should be observed:—

(*a*) The bearing shells must be a perfect fit in their housing.

(*b*) The half-bearings are so designed that when bolted up, the faces of the shells butt against each other metal to metal, as also does the cap of the bearing and its housing, and when finally bolted up the crankshaft journals must be perfectly free in the bearings.

(*c*) In order to ensure that the bearing shells are tightly held in their housings the main bearing caps must be adjusted by careful filing or other method, so that when the nuts are only slightly more than finger-tight (just before final tightening) there remains a gap of ·002 in. to ·003 in. (·051 mm. to ·076 mm.) at each side between the cap and its housing.

(*d*) When assembling the bearing caps, it is desirable to tighten the cap nuts in the order and manner shown in the outline sketch and table on page 65.

OVERHAUL AND ASSEMBLY

CRANKSHAFT AND MAIN BEARINGS—*continued*

(*e*) The correct tightening torque for the ⅝ in. B.S.F. main bearing cap nuts is 2,100 lb./in. (24·15 Kg./m.) and for the ½ in. B.S.F. nuts on the rear main bearing 700 lb./in. (8·05 Kg./m.).

(*f*) Split pins are not used on the main bearing cap nuts in current engines and providing the cap nuts (whether castellated or current plain type) are tightened to the correct torque, no additional locking is necessary.

105·1 **Fitting WHITE METAL LINED Main Bearings.**—When main bearings are line bored the size of the bore so produced should be such as to give ·0015 in. (·038 mm. to ·051 mm.) clearance between the crankshaft journal and bearing for engines with aluminium crankcases. For engines with cast iron crankcases, the bearings must be bored slightly larger, i.e. to give ·003 in. (·076 mm. to ·095 mm.) clearance. After boring and before final assembly of the crankshaft the flywheel-end lower half bearing on the vertical engines must be removed and the white metal relieved by a 45° chamfer extending the full length of the bearing at the abutment side *which lies towards the manifold side of the engine on standard rotation engines*, i.e. anti-clockwise rotation viewed on flywheel-end, and *on the fuel pump side of the engine on opposite rotation engines.* The chamfer should be filed to a width of $\frac{1}{16}$ in. (1·59 mm.) plus or minus ·006 in. (·152 mm.) and continued around the corners at each end to the full width of the flange abutment face. After completing this operation, fit the crankshaft and, with all nuts finally tightened, check for zones of hard or tight contact between journal and bearing, particularly adjacent to the radii. If present, remove these by careful use of the hand-scraper until there remains no local high places and the shaft can be turned freely by hand-pressure only when applied to the coupling flange and with all nuts fully tightened. On no account must any attempt be made to "burn in" the bearing by running an engine in which any bearings have been fitted with inadequate clearance, since this will cause certain failure.

105·2 **Crankshaft Endwise Clearance.**—On engines fitted with white metal lined main bearing shells, endwise location of the crankshaft is maintained by the "Babbitted" ends of the flywheel-end bearing. With the crankshaft assembled, all bearings in position and cap nuts fully tightened, the crankshaft endwise clearance measured at the flywheel-end bearing should be ·004 in. (·102 mm.) min. to ·006 in. (·152 mm.) max. The procedure for checking end clearances on all remaining bearings is set out in Workshop Tools and Instruction Drawings Book No. 48·2, page 56.

106. **Crankshaft Main Bearing Oil Distribution Pipe.**
Brazed Copper Pipe Assembly.—During major overhaul it is desirable to anneal the main oil distribution copper pipe before re-assembly on the main bearing bridge pieces. Always use new "O" rings at the flange connections when assembling.

When fitting the pipe, tighten each pair of securing nuts and/or setscrews fully and evenly on to the locking plates (Part No. 126LP) at each connection and afterwards slightly ease-off each pair by one half hexagon flat before finally locking with the locking plates. Note when locking, that the tabs must be bent over the correct and opposite side at each end of the flange so that they lock against the projecting pipe union or "T" connection.

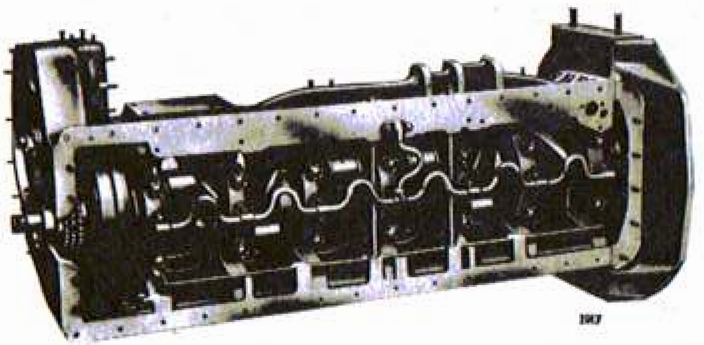


Fig. 22. MAIN BEARING OIL DISTRIBUTION PIPE—COPPER

OVERHAUL AND ASSEMBLY

CRANKSHAFT AND MAIN BEARINGS—*continued*

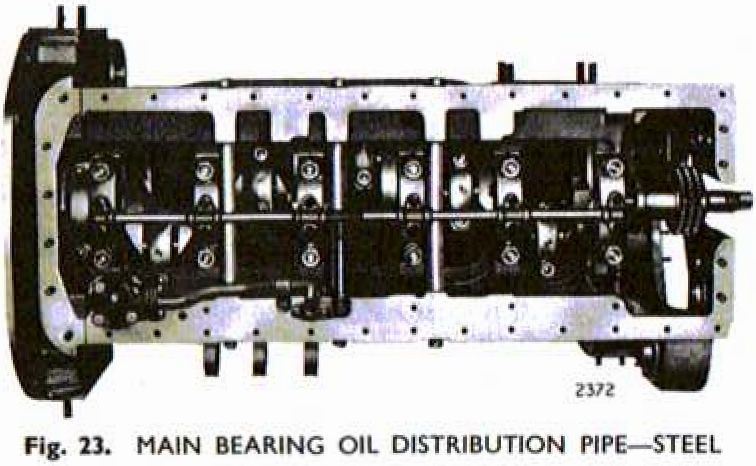


Fig. 23. MAIN BEARING OIL DISTRIBUTION PIPE—STEEL

Steel Main Bearing Pipe Assembly.—In all LW20 engines and later LW engines oil is distributed to the main bearings by an arrangement of separate inter-connecting steel pipes, the ends of which enter the main bearing flanged "ties" and are sealed by "O" rings. "O" rings also form the joints between the flanged "ties" and the bearing cap bridge pieces. Always use new "O" rings when re-assembling. When the assembled pipework is correctly fitted to the bearing cap bridge pieces it should be possible to rotate each pipe by hand and also to obtain a minimum end-float of $\frac{1}{16}$ in. (1·588 mm.), i.e. $\frac{1}{32}$ in. (·794 mm.) each side of the mean position. This movement does not apply to the branch pipe between "T" connection and crankcase wall as this pipe is positively located in the crankcase connection. The correct tightening torque for the oil distribution pipe nuts is 400 lb./in. (4·6 Kg./m.). *The new steel pipe arrangement and the copper pipe assembly are not directly interchangeable.*

Note.—It is good practice always to pressure test the pipework (whether copper or steel pipe arrangement) after completing the assembly to ensure absence of leakage.

107. **Crankshaft Main Bearings: PRE-FINISHED THIN WALL STEEL SHELLS.**—Current LW and HLW series and all LW20 engines are fitted with pre-finished thin wall bearings lined with copper lead, overlay plated. LW and LW20 engines so fitted are identified by the letter "S" stamped on the top surface of the crankcase at the flywheel-end, fuel pump side. HLW engines so fitted are similarly identified at the chaincase end of the crankcase. These bearings cannot be re-bored and must be replaced if damaged in any way, or if the overlay plating be worn to such an extent that the copper lead so exposed amounts to 20% of the bearing area. **Under no circumstances must a hand-scraper be used to bed the bearings to the crankshaft journal**; this would cause irreparable damage to the surface finish and render the bearing unfit for use. Pre-finished main bearings are available in a range of undersizes to suit reconditioned crankshafts as follows:—

From — ·005 in. (— ·127 mm.) to — ·020 in. (— ·508 mm.) undersize in steps of ·005 in. (·127 mm.) and thereafter in steps of ·010 in. (·254 mm.) down to — ·060 in. (— 1·524 mm.) undersize. These bearings will give the correct running clearance when fitted to crankshaft journals that have been reduced in diameter by precisely these amounts below the original nominal size of 3·250 in. (82·55 mm.) + ·0000 in. — ·0005 in. (+ ·000 mm. — ·0127 mm.).

107·1. **Assembling PRE-FINISHED THIN WALL Main Bearing Shells.**—The two halves of the bearing are not interchangeable and a locating tongue on each half-bearing ensures correct assembly in the centre of the housing and bearing cap. Each half-bearing is identified by one or more lines scribed on the edge of the steel shell; these lines correspond in number with the figure stamped on the bearing housing and cap to which they are fitted. When assembled the identification lines must face towards the **chaincase** end of the crankcase.

Before assembling the bearing shells see that all parts are scrupulously clean and that the bearing surfaces are free from abrasions, scratches or indentations, etc., any blemishes of this kind should be rolled out or

OVERHAUL AND ASSEMBLY

CRANKSHAFT AND MAIN BEARINGS—*continued*

"ironed" smooth by means of a high finish hardened steel burnishing bar, for example a piston pin.

After thoroughly cleaning the bearing shells and housing bore, apply a thin film of engine oil to the housing and cap. Assemble the shells so that their butt faces are aligned with the abutment faces of both housing and cap at each side and check coincidence of the oil holes in the lower half bearing shell and cap.

107·2. **Checking for "nip" on Thin Wall Bearing Shells.**—The two halves of the bearing should be firmly gripped in their housing when the cap nuts are tightened to full torque on final assembly. To ascertain that the correct amount of "nip" is present proceed as follows:—

(1) Assemble the bearing cap and steel bridge and tighten the two nuts down evenly to the correct torque load of 2,100 lb./in. (24·15 Kg./m.).

(2) Slacken the nuts alternately from each side until fully released.

(3) Run down the nuts with fingers until they contact the bridge pieces, then with the special box key provided, slightly nip each nut to take up remaining slack, i.e. just less than "one eighth" of a turn.

(4) Check the gap clearance between the abutment faces of cap and housing by inserting feeler gauges at each of the four corners adjacent to the bearing shell.

With aluminium crankcases the average of these four gap dimensions should be ·006 in. (·152 mm.) min. to ·0075 in. (·191 mm.) max. and with cast iron crankcases ·0035 in. (·089 mm.) min. to ·0055 in. (·140 mm.) max. This means that when the bearing cap nuts are tightened to full torque the bearing shells have a circumferential nip of ·012 in. to ·015 in. (·305 mm. to ·381 mm.) with alloy crankcases or ·007 in. to ·011 in. (·178 mm. to ·279 mm.) with cast iron crankcases.

107·3. **Crankshaft Endwise Location.**—Crankshaft endwise location is achieved by specially designed thrust washers positioned at the front and rear of the locating bearing. These thrust washers, each comprising of an upper and lower half, are matched and sized in pairs and are not interchangeable. The front pair of washers are each identified by a single line filed on the edge near the abutment of the upper and lower halves, and the rear pair are marked with two lines in a similar manner. The upper half of each pair of washers is assembled against the machined surface on the crankcase and abuts with its matching lower half fitted in the main bearing cap. The lower half washer carries a locating tongue engaging with a recess in the bearing cap which prevents rotation of both halves when the bearing cap nuts are tightened down.

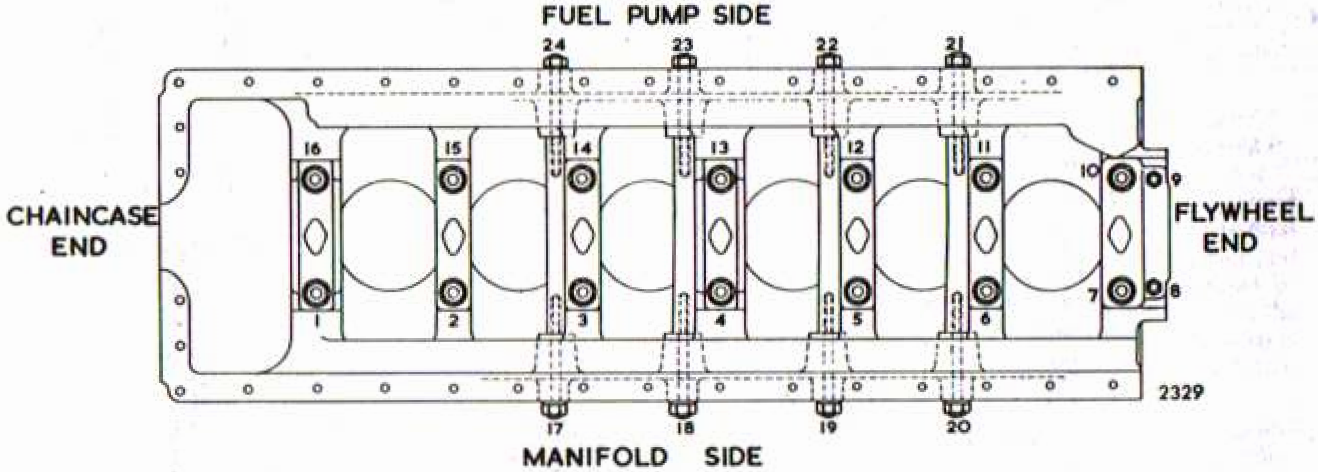
In the event of replacement washers being necessary, they must be obtained from the Works. Exact thickness of all thrust washers is recorded during initial assembly and correct thickness washers can be supplied from stock to suit the original crankshaft/crankcase assembly, providing the crankshaft thrust faces are not worn beyond permissible limits. Any alteration to the original assembly may necessitate the fitting of non-standard washers to obtain correct endwise clearance.

107·4. **Checking Crankshaft Endwise Clearance.**—Having assembled the thrust washers and all main bearings, lightly nip down the cap nuts of the locating bearing and fully tighten all the remaining cap nuts to correct torque, set the crankshaft so that the centre line of the crankwebs adjacent to the locating bearing are in line with the split between the housing and cap. Tap the crankshaft endwise—first from the flange end and then from the chaincase end—to butt the crankweb thrust faces against the washers. This will ensure that the bearing cap and the two half thrust washers are aligned with the crankcase bearing housing and that the thrust faces of each half bearing are also in alignment one with the other. The true end clearance can then be recorded by setting a dial indicator on the end of the crankshaft. Correct end clearance is ·004 in. (·102 mm.) min. to ·007 in. (·178 mm.) max.

107·5. **Tightening Sequence for Main Bearing Cap Nuts.**—The size and roundness of the shell bore are dependent on the tightening procedure and it is essential that these nuts are re-tightened in exactly the same order and to the same degree of tightness every time the bearing caps and cross struts are assembled. The outline sketch and table below show the order and manner of tightening respectively.

OVERHAUL AND ASSEMBLY

CRANKSHAFT AND MAIN BEARINGS—*continued*



Sequence of Operation	Method of Tightening	Main bearing cap nut torques Aluminium and cast iron crankcases	
		Nut Nos. 1–7 and 10–16 ¾ in. B.S.F. (19 mm.)	Nut Nos. 8 and 9 ½ in. B.S.F. (12·7 mm.)
1st stage	Using fingers only	Fingertight	Fingertight
2nd stage	Nip with ratchet spanner	Approx. 25 lb.in. (0·3 Kg.m.)	Approx. 50 lb.in. (0·6 Kg.m.)
3rd stage	1st nip with "T" spanner	Approx. 175 lb.in. (2·0 Kg.m.)	Approx. 150 lb.in. (1·7 Kg.m.)
4th stage	2nd nip with "T" spanner	Approx. 500 lb.in. (5·8 Kg.m.)	Approx. 250 lb.in. (2·9 Kg.m.)
5th stage	Half tight with torque spanner	1050 lb.in. (12·08 Kg.m.)	350 lb.in. (4·03 Kg.m.)
6th stage	Full tight with torque spanner	2100 lb.in. (24·15 Kg.m.)	700 lb.in. (8·05 Kg.m.)
		Cross-strut nut torques Nut Nos. 17–24	
		Aluminium Crankcase — in. B.S.F. (11·1 mm.)	Cast iron Crankcase ½ in. B.S.F. (12·7 mm.)
7th stage	Nip with "T" spanner	Approx. 75 lb.in. (0·9 Kg.m.)	Approx. 75 lb.in. (0·9 Kg.m.)
8th stage	Half tight with torque spanner	275 lb.in. (3·2 Kg.m.)	200 lb.in. (2·3 Kg.m.)
9th stage	Full tight with torque spanner	550 lb.in. (5·8 Kg.m.)	400 lb.in. (4·6 Kg.m.)

In the case of the 2-, 3-, 4- and 5-cylinder engines the order and method of tightening are to follow the same pattern as the 6-cylinder engine, described above.

Cross struts are only fitted to 4-, 5- and 6-cylinder aluminium engines and the 6-cylinder cast iron engine.

Tightening torques

¾ in. B.S.F. main bearing cap nuts 2,100 lb.in. (24·15 Kg.m.) (Cast iron and aluminium crankcase).
½ in. B.S.F. main bearing cap nuts 700 lb.in. (8·05 Kg.m.) (Cast iron and aluminium crankcase).
½ in. B.S.F. cross strut nuts 400 lb.in. (4·6 Kg.m.) (Cast iron crankcase).
7/16 in. B.S.F. cross strut nuts 550 lb.in. (5·8 Kg.m.) (Aluminium crankcase).

GARDNER

OVERHAUL AND ASSEMBLY

CONNECTING RODS AND BIG-END BEARINGS

108. **Connecting Rods. Before fitting the connecting rods the following points should be observed.**—

(*a*) Rods should be thoroughly cleaned and tested for cracks by any of the well-known methods during major overhaul.

(*b*) Big-end bolts must be examined for stretch and renewed if necessary. Stretch can be gauged by measuring the diameter of the $\frac{5}{8}$ in. bolt shank. Maximum permissible stretch is $\frac{5}{8}$ in. — ·003 in. (15·875 mm. — ·0762 mm.) measured at a distance of 1 in. (25·4 mm.) from the bolt-head.

(*c*) Small-end bushes which have ·003 in. (·0762 mm.) or more clearance with a new pin should be pressed out and new ones fitted. The running clearance between a new bush and a new pin is ·00125 in. to ·00175 in. (·0318 mm. to ·0445 mm.). Should scraping be necessary this must be confined to the upper and more lightly loaded half of the bore so that the more accurate machined surface remains untouched on the heavily loaded bottom portion.

(*d*) Before finally assembling the rod, the oil duct through the centre should be thoroughly flushed out with paraffin or fuel oil.

(*e*) When the rod is assembled on its crankpin, the piston pin in the small-end bush should be parallel to the crankcase top surface to within ·001 in. (·025 mm.) in the length of the pin.

(*f*) The connecting rods and caps are stamped with a number to correspond with the number on the respective cylinders as also are the half bearings.

(*g*) When assembling, it is important that numbers face towards the tappet-side of the engine and lie to the flywheel-end. When ordering a replacement rod complete with bearing shells it is important to specify the direction of rotation of the engine. This will ensure that the rod and bearings will be assembled correctly when fitted in accordance with the above numbering system. Rods for opposite rotation engines, i.e. clockwise rotation viewed on the flywheel-end, are stamped with a letter "C" after the cylinder number.

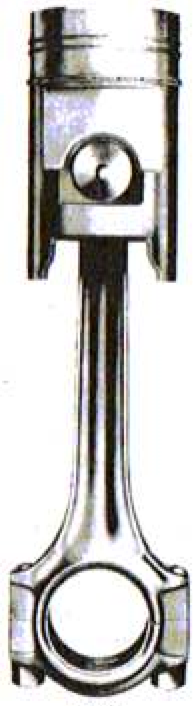


Fig. 24.

108·1. **Non-Interchangeability of Connecting Rods.**—Earlier engines were equipped with Type "B" connecting rods having white metal lined big-end bearing shells. On later engines these were superseded by Type "B1" connecting rods equipped with pre-finished thin wall bearings lined with copper lead, overlay plated. It is not possible, due to the weight factor, to mix Type "B" and Type "B1" rods in any one engine. Engine sets of rods must consist of **all** Type "B" connecting rods or **all** Type "B1" connecting rods.

108·2. **Conversion of Type "B" Connecting Rods to receive Pre-finished Thin Wall Shell Bearings.**—A Service Exchange Scheme is available from the Works whereby LW connecting rods with white metal lined big-end bearings (Type "B") may be exchanged at a modest charge for connecting rods which have been converted to carry pre-finished thin wall type bearing shells. Details of this Service Exchange Scheme are available on application and are described in our Assembly Instructions Leaflet No. 12D.

109. **Assembling WHITE METAL LINED Big-End Bearings—Type "B" Rods.**—These big-end bearings should be bored or hand-scraped to give ·00175 in. to ·002 in. (·045 mm. to ·051 mm.) clearance on the crankpins. When this clearance has to be produced by hand the scraping should be confined as far as possible to the cap-half bearing, since this is relatively lightly loaded under working conditions and does not, therefore, require to have such accurate bedding as does the top or rod-half bearing. By this procedure the surface of the top-half bearing will remain as originally bored and consequently will have a more accurate shape and, therefore, more complete contact with the crankpin than can be produced by hand scraping. As in the case

CONNECTING RODS AND BIG-END BEARINGS—*continued*

of the white metal main bearings, it is essential to check that the big-end bearing is freed from tight places adjacent to the radii. If these do exist they must, of course, be relieved by light hand scraping. The big-end bearing endwise clearance between crankwebs and bearings should be ·005 in. (·127 mm.) min. to ·012 in. (·305 mm.) max. This clearance should be checked around the full extent of the flange faces of both rod-half and cap-half bearings and measured against the crankweb by rotating the crankshaft to a suitably convenient position.

When replacement bearings are supplied unbored it is necessary, after boring, to reproduce all chamfers, etc., in accordance with the labels attached. Having obtained the correct clearance of ·00175 in. to ·002 in. (·045 mm. to ·051 mm.) the finished big-end bearing should be slightly relieved at the sides by hand-scraping right through the bore of each half of the bearing adjacent to the split. This relief should extend into each half bearing for a chordal distance of ⅜ in. (9·5 mm.) from the butt face or split, thus in the final assembly there will be two fully relieved portions extending from one end of the bearing to the other and having a total width of approximately ¾ in. (19 mm.). The white metal of the cap-half bearing must be further relieved on the oil groove side by a 45° chamfer 1/16 in. (1·6 mm.) wide extending the full width of the abutment face and around the flange faces at each end. These diametral clearances, together with correct end clearances and correct positioning of grooves and chamfers on the big-end bearings are fully illustrated by diagrams in Workshop Tools Book No. 48·2 on pages 56, 57 and 60.

When replacement bearings are supplied by the Works bored to standard size, these relieved portions and chamfers are already embodied and the bearing halves are stamped with the figure "O" for guidance when assembling. Before assembly it is recommended that the "O" be removed by filing or light peening and the bearing re-stamped with the cylinder number on the rod to which it is being fitted. The bearing should, of course, be fitted to the rod so that this number and the rod and cap numbers lie together. When correctly fitted in this way the offset hole in the rod-half bearing will be towards the numbered side of the rod and the chamfer and groove in the cap-half bearing will be diametrically opposite and towards the unnumbered side of the cap. With opposite rotation engines (clockwise viewed on the flywheel-end) the shells are reversed so that the offset hole in the rod-half bearing will be towards the unnumbered side of the rod, and the chamfer and groove in the cap-half bearing will be towards the numbered side of the rod, i.e. the tappet side of engine.

The correct tightening torque for the connecting rod big-end nuts is 1,250 lb./in. (14·38 Kg./m.). It should be noted that the use of split pins for castellated nuts is now discontinued and providing the big-end nuts, whether castellated or current plain type, are tightened to the correct torque no other means of locking is necessary.

109·1. **Checking for "Nip" on WHITE METAL Big-end Bearing Shells.**—The two halves of the bearing should be firmly gripped in the rod and cap when finally assembled. The correct degree of clamping is ascertained by first tightening the big-end nuts to the correct torque of 1,250 lb./in. (14·38 Kg./m.) and afterwards releasing the nut on one side only when there should be a gap clearance of ·005 in. (·127 mm.) min. to ·007 in. (·178 mm.) max. between the abutment face of the rod and shim or cap and shim measured at the innermost end of the split adjacent to the shell bearing. Adjust to obtain this "nip" by filing the shims or the abutment faces of the cap-half bearing (depending upon whether the gap clearance is smaller or greater respectively than the required amount). **Do not file the connecting rod or cap.** Make quite sure when filing that the metal is removed equally. This may be conveniently checked in the case of the shims by a micrometer and in the case of the bearing half by checking with a feeler and bedding black on a small service plate.

110. **Assembling PRE-FINISHED THIN WALL Big-end Bearings—Type "B1" Rods.**—Engine serial No. 144,978 and all subsequent engines, including the LW20 engines, have been fitted with Type "B1" connecting rods equipped with pre-finished thin wall big-end bearing shells lined with copper lead, overlay plated. These bearings cannot, of course, be re-bored and are, therefore, made available in a range of undersizes to suit reconditioned crankpins as follows:—

From — ·005 in. (·127 mm.) to — ·020 in. (·508 mm.) undersize in steps of ·005 in. (·127 mm.) and thereafter in steps of ·010 in. (·254 mm.) down to — ·090 in. (2·286 mm.) undersize. These bearings will give the correct running clearance when fitted to re-sized crankpins that have been reduced in diameter by precisely these amounts below the original nominal size of 2·875 in. (73·025 mm.).

OVERHAUL AND ASSEMBLY

CONNECTING RODS AND BIG-END BEARINGS—*continued*

Replacement thin wall shells are supplied only in pairs comprising upper and lower half. **Under no circumstances must these bearings be touched with a hand-scraper,** as this will cause irreparable damage to the surface finish. If damaged in any way, or if the overlay plating be worn to such an extent that the copper lead so exposed amounts to 20% of the bearing area, they must be replaced.

The two half-bearings are not interchangeable and a locating tongue on each half-bearing ensures correct location in the centre of the rod and cap. It should be noted, with this type bearing that no shims are fitted between the rod and cap.

Before assembling the bearing shells see that all parts are scrupulously clean and that the bearing surfaces are free from abrasions, scratches or indentations, etc., any blemishes of this kind should be rolled out or "ironed" smooth by means of a high-finish hardened-steel burnishing bar, for example a new piston pin. Connecting rods and caps are stamped with a number to agree with the number on the respective cylinder and each half-bearing is identified by a corresponding number of lines filed on the edge of the steel shell near the abutment face. When assembling, it is essential that the numbers on the rod and cap and the corresponding identification lines on the bearing shells all lie towards the tappet side (near side) of the engine. Rods and caps must NOT be interchanged, keep each cap to its respective rod and the half-bearings number to number.

110·1. **Checking for "nip" on PRE-FINISHED Big-end Bearing Shells.**—The bearings must be firmly gripped in the big-end when finally assembled. To ascertain the correct "nip" on the bearing shells, screw each big-end nut down in stages until both nuts are tightened to the full torque of 1,250 lb. in. (14·38 Kg.m.) and afterwards release the nut on one side only. There should then be a gap clearance of ·006 in. to ·007 in. (·152 mm. to ·178 mm.) between the abutment of the rod and cap at the innermost end of the split adjacent to the bearing shell. The nominal running clearance in a correctly assembled big-end bearing on Type "B1" rods is ·0018 in. to ·0032 in. (·046 mm. to ·081 mm.). The side location of the big-end of the rod is obtained directly by the side facing of the rod itself and endwise clearance between the rod and crankwebs is ·005 in. (·127 mm.) min. to ·012 in. (·305 mm.) max. When assembling the connecting rod on the crankpin, the greatest care must be taken to prevent the projecting ends of the big-end bolts from bruising the polished surface of the crankpin, as any bruises or indentations thus caused will, in turn, seriously damage the bearing surfaces of the big-end shells.

PISTONS

111. **Pistons.**—The pistons and connecting rods of 4, 5 and 6-cylinder engines may be withdrawn in two ways: (1) by lifting the cylinder blocks, or (2) by withdrawing from underneath after removing the base chamber. The pistons of the 2 and 3-cylinder engine may only be withdrawn by method (1). The useful life of a piston is determined almost wholly by: (*a*) wear of the upper two ring grooves, and (*b*) by diametral wear. According to fuels, lubricants, engine duty, etc., pistons will run for 100,000 to 200,000 miles or more without dismantling and, of course, without the need to re-machine the upper two grooves to receive available standard oversize width rings. Owing to the peculiar shape assumed due to wear, the faces of the grooves will not make a satisfactory gas seal with new rings. Therefore, it is essential that when new rings are to be fitted, the grooves must be re-sized. Before fitting new rings the worn bores should be treated as described in para. 113. Diametral wear mainly affects piston noise, and pistons which have been re-grooved may be used for a total of 300,000 miles or more. The above recommendations are based upon the use of genuine "Gardner" pistons of "Gardner" manufacture with "Gardner" specification equipment and only by their use may optimum engine performance and durability be obtained.

Unless operating conditions are known to produce unclean running, do not remove pistons until cylinders require re-sleeving (see para. 113). The pistons are equipped with two pressure rings (the top ring being plated on its side faces and periphery and the second ring plated on its periphery only) and a single scraper ring. The first and second pressure rings are not interchangeable. The second ring is identified by a phosphating etch on its side faces which takes the form of a dark stain extending about 1 in. (25·4 mm.) each side of the ring gap. The piston pin is free to move in the piston and in the connecting rod bush, and endwise location in the cylinder bore is maintained by aluminium end pads fitted in the ends of the pin. The nominal clearance between the pin and bush is ·0015 in. (·043 mm.).

OVERHAUL AND ASSEMBLY

PISTONS—*continued*

111·1. **Pistons—Offset Pin Hole Type.**—The latest engines are fitted with pistons where the piston pin is offset from the axis of the piston and these are identified by the word "GARDNER" cast in the side panels. Since the effect of this construction is greatly to reduce the noise generated at inner dead centre when the piston transfers from one cylinder wall to the other, it is desirable, but not essential, that all cylinders of an engine be equipped with either this design of piston or the previous one. The piston pin endwise location pads have for all pistons been modified to suit the offset piston pin. Previous type pin pads may, however, be used in current LW and HLW piston pins.

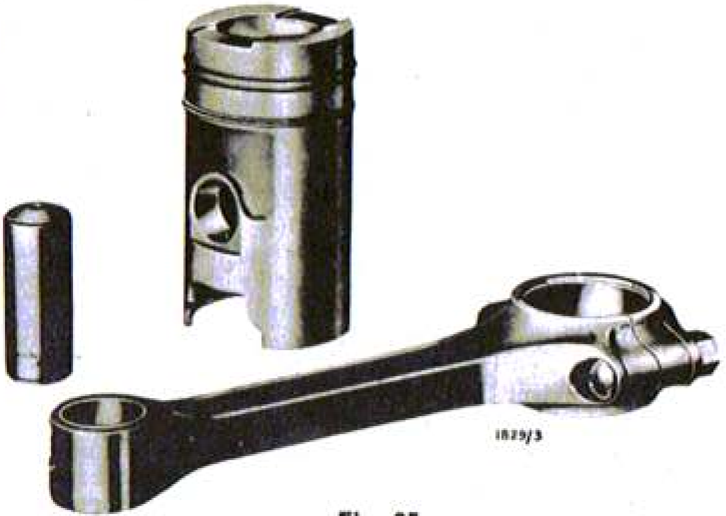


Fig. 25.

112. **Clearance between Valve Heads and Piston.**—It will be seen that shallow recesses are formed on the top of the pistons to provide clearance for the valve heads and to allow of an overlap timing diagram. The diameter of the inlet valves and their recesses differ from those of the exhaust valves. When fitting the piston to the connecting rod ensure that the recesses are placed under the corresponding valves. The correct position for the piston is clearly indicated by the lettering "TAPPET SIDE" on the top of the piston and by the arrow which must correspond with the direction of rotation of the crankshaft.

112·1. **Piston to Cylinder Head Clearance.**—When the piston is at T.D.C. the piston to cylinder head clearance should be within the limits given in the following table.

Engine	Nominal in. (mm.)	Maximum in. (mm.)	Minimum in. (mm.)
LW & HLW	·0444 (1·118)	·0514 (1·295)	·0384 (·965)
LW20	·030 (·762)	037 (·940)	·023 (·584)

The clearances must be obtained with the cylinder foot and head packings fitted and with all nuts tightened to full torque.

Standard packing thicknesses are:—

Cylinder foot — ·004 in. (·102 mm.)
Cylinder head — ·013 in. (·330 mm.)

Piston to cylinder head clearance can be readily determined before the cylinder heads are fitted by measuring with a feeler gauge the gap between the top of the piston and a straight edge placed across the joint face of the cylinder block. To the clearance thus recorded must be added ·013 in. (·330 mm.) for the thickness of the cylinder head packing. If clearance is less than the minimum stated, shims must be inserted between the cylinder block and crankcase to obtain the desired clearance. Shims for this purpose are supplied in thicknesses of ·010 in. (·254 mm.) and ·020 in. (·508 mm.) and are readily available from our Works, Service Depots and official Stockists.

OVERHAUL AND ASSEMBLY

CYLINDER BLOCKS

113. **Cylinder Blocks.**—At major overhaul when re-sleeving the cylinder blocks, or when required by operating conditions, clean out thoroughly the water spaces by removal of the doors and plugs. Re-make all joints with paint. When diametral cylinder bore wear exceeds ·012 in. (·305 mm.) the cylinder block should be re-sleeved. In many instances this figure is exceeded, but power and startability may then be adversely affected. Full instructions for the fitting of new cylinder liners are contained in Workshop Tools Book No. 48·2 and where facilities are not available for the re-sleeving of cylinder blocks, the customer's block can be exchanged under the Service Exchange Scheme for a replacement block which has been re-sleeved at our Works.

Whenever new piston rings are to be used in worn cylinder liners it is very desirable that the surface of such liner bores is lightly lapped with a fine carborundum using an old piston and ring, or honed to create a matt surface. If new rings are fitted in a worn and therefore polished bore, the "bedding-in" process will be protracted with consequent probable high oil consumption and "blow-by". When honing new liner bores a surface-finish of 25 to 30 micro inches is desirable. When assembling the blocks use a standard paper joint between blocks and crankcase and when tightening the foot nuts commence from the centre of the block and tighten each nut evenly and in sequence each side, working towards the ends of the block in such a way that the pressure is distributed uniformly across the joint face.

The correct tightening torque for the cylinder holding-down nuts is 1,300 lb. in. (14·95 Kg. m.). Do not exceed this value.

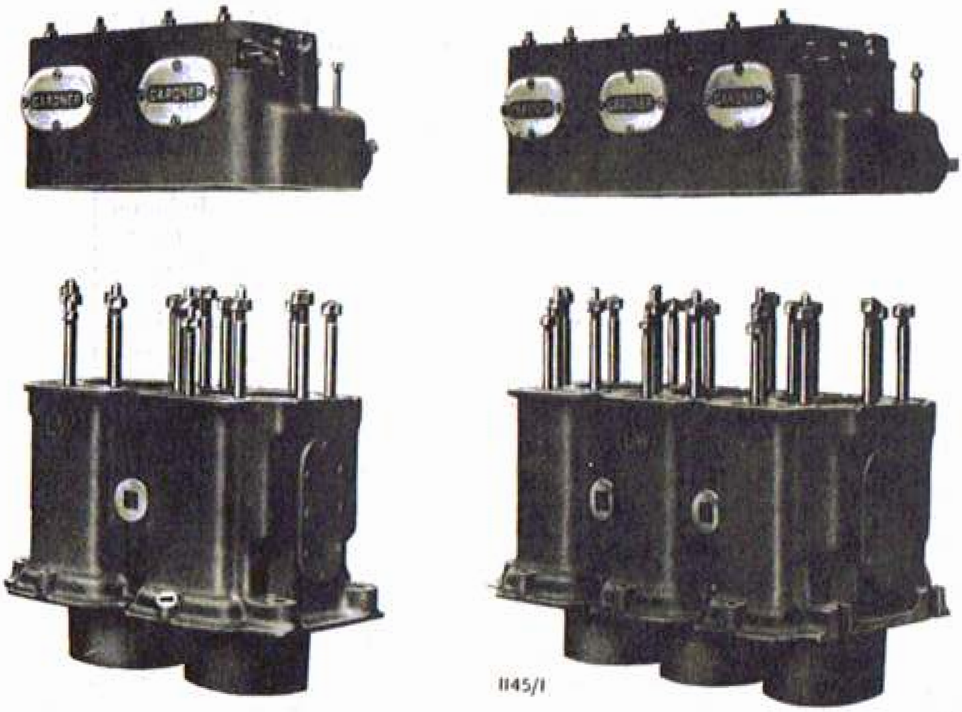


Fig. 26. A TWO AND THREE-CYLINDER BLOCK WITH MATCHING HEADS

OVERHAUL AND ASSEMBLY

CAMSHAFT

114. **Camshaft Assembly.**—When assembling this component ensure that the cams are assembled under the correct tappet, e.g. that the exhaust cam is under the exhaust tappet and not under the inlet tappet or vice versa. The exhaust cam has less rise than the inlet cam, but gives a longer opening period and is stamped with an "EX" on the side face. Assemble the cams with this side facing the chain case. Ensure that the locking screws engage in the countersinks in the shaft and are thoroughly tightened home. A special square box key is supplied with the engine for this purpose.

After prolonged service the tappets and possibly the cams may become slightly scored. This scoring can be removed by the use of an oil stone, taking great care to reproduce the original radii. Should, however, the hardened case be worn through it will be necessary to fit new parts.

Exchange cams are readily available from our Works and Service Depots. The valve camshaft and bushes should not require renewal (unless they have been subject to accidental damage) until a unit receives its second major overhaul. When new, the clearance between shaft and bush bearings is ·001 in. (·250 mm.). Bushes are a light drive fit in the crankcase and are located by means of cheese-head screws inserted from the outside of the crankcase wall.

114·1. **Camshaft Endwise Location.**—Endwise location of the camshaft is effected by a locating collar of suitable thickness interposed between the bearing bush at the chain case end of the crankcase and the exhaust cam of No. 1 cylinder.

Camshaft end-float should be ·004 in. (·102 mm.) min. to ·006 in. (·152 mm.) max. and may be ascertained by inserting a feeler gauge between the locating collar and No. 1 exhaust cam. If the clearance be greater than ·006 in. (·152 mm.) the locating collar must be replaced. Oversize collars of ·886 in. (22·504 mm.) thickness are readily obtainable from our Service Agents and Spares Stockists and these must be carefully faced off to give the desired clearance of ·004 in. (·102 mm.). It is advisable to rotate the collar through one or more complete turns when checking this clearance.

CAMSHAFT TAPPETS AND GUIDES

115. **Camshaft Tappets and Guides.**—Before fitting the tappet guides in the crankcase, check that each tappet moves freely in its guide over the full length of its stroke, and examine carefully the outside diameter and edges of the guide slots for any burrs or abrasions which might impair its free entry and seating in the crankcase.

When fitting the guide ensure that there is adequate clearance between its locating lug and the shank of the clamp stud; excessive tightness at this point may prevent the guide seating squarely on the face of the crankcase when clamped in position.

Do not use excessive pressure when tightening the tappet guide clamp nut. It is good practice to again check the freedom of each tappet in its guide **after** the clamp has been tightened down.

CYLINDER HEADS

116. **Cylinder Heads; Removal, Decarbonising and Servicing.**—In order to obtain the best results from the engine and to maintain it in its most efficient and economical condition, it is recommended that the heads be lifted off and the valves and other parts cleaned and serviced not less frequently than every 48,000 miles. These mileages are commonly doubled and trebled, but this can be accompanied by reduced combustion efficiency and impaired internal cleanliness, and under these conditions the rate of engine wear is increased. Wear and erosion of valves and seats, and carbon deposits in the valve ports are mainly responsible for loss of efficiency. Valves should be accurately ground in the usual special purpose machine to 45°, remove as little metal as possible. The valve seats are of hardened material and should be ground to 45° by special purpose machines, preferably of the "generating" type. Remove the minimum of metal. Lap valve and seat together with fine abrasive, say 400 grit Carborundum powder. When after long use

OVERHAUL AND ASSEMBLY

CYLINDER HEAD—*continued*

valve heads become thin, and valve seats become enlarged, renew parts in order to maintain engine efficiency. Renew valves if any of the following conditions obtain:—

(1) Valve head thickness, after re-surfacing, is less than ·037 in. (·940 mm.) Exhaust.
·045 in. (1·143 mm.) Inlet.

(2) Valve stem measures less than ·370 in. (9·398 mm.) Exhaust.
·371 in. (9·423 mm.) Inlet.

(3) Flat face on head shows any distortion when tested on lapping plate.

(4) Surface of stem, neck and flat face exhibit imperfection of surface-finish i.e. scaling, pitting, corrosion.

(5) Magnetic-flux flaw detection reveals any defects.

Note.—Always fit new valve guides when fitting new valves.

Use only genuine "Gardner" replacement parts to ensure durability and freedom from failure which might seriously damage the engine.

The Workshop Tools Equipment & Instructional Drawings Book No. 48·2 contains much useful information with regard to the servicing of valves, valve seats and valve seat inserts.

117. **To avoid Damage to the Sprayer Nozzles.**—The sprayer nozzles project from the flat surface of the cylinder head and it is essential that they be withdrawn before removing the heads otherwise they may suffer severe damage. See para. 51.

118. **Replacing Inlet Valves and Guides.**—These valves are formed with patent deflectors and are prevented from turning round by the specially formed valve collars and split pins or cotters. It is **essential** that the valves be replaced in their correct position, that is, with the deflectors towards the manifold side of the engine, the precise position being determined by the split pin in the valve collar. To ensure this, the slot for the pin in the collar and also the pin hole in the valve stem do not pass through the centre line of the valve stem. With this construction it is impossible for one to screw the valve into the collar and to thread in the split pin or cotter with the valve in wrong position. When the inlet valves and guides are replaced care must be taken to ensure that there is a suitable clearance between the stem and guides. The correct clearance for a new assembly is 0·00125 in. (·0318 mm.) and should the valve stems be a closer fit than this the guides must be reamed out until the 0·00125 in. (·0318 mm.) clearance is obtained. Inlet valve guides for HLW engines are provided with an oil drain groove and hole at their outer ends. These guides must be pressed into the heads so that when the heads are fitted to the engine the drain holes are downward, i.e. towards the manifold side of engine.

119. **Replacing Exhaust Valves and Guides.**—When the exhaust valves are re-fitted care should be taken to see that the carbon is removed from the bore of the guides. When the exhaust valves and guides are replaced ensure that there is suitable clearance between the stems and guides. The correct clearance for a new assembly is 0·00275 in. (·0699 mm.) and should the valve stems be a closer fit than this, the guides must be reamed out until the 0·00275 in. (·0699 mm.) clearance is obtained. When replacing exhaust valve guides in HLW horizontal engines it should be noted that these guides are provided with an oil hole and groove at their outer end, the guides must be pressed in the head so that when the heads are fitted to the engine the hole and grooves in the guides are upwards, i.e. towards push rod side of heads.

120. **Refitting Inlet and Exhaust Valve Spring Collars.**—Particular care should be taken to ensure that the spring collars are not screwed farther down the valve stems than is necessary to thread in the split pin, otherwise the valves may not have sufficient lift and the opening mechanism may suffer damage. Always use a new split pin of correct size and having equal legs which should be sprung open before fitting to prevent movement in service. To lock in position the legs should be opened to form an included angle of approximately 90°.

121. **Decompression Shaft Oil Seal.**—These shafts are grooved at each end and fitted with synthetic rubber sealing rings, which prevent oil leakage at these points on the cylinder heads. Where desired it is a simple matter to convert shafts from earlier engines which were not originally grooved to receive sealing rings.

OVERHAUL AND ASSEMBLY

CYLINDER HEADS—*continued*

Fig. 27. TWO BLOCK CYLINDER HEAD

121·1. **Decompression Adjustment of Valve Lift.**—When the decompression levers are moved upwards the decompression shaft is rotated and cams, which are formed in the shaft below each inlet valve, engage with an adjustable screw located in the heel of each inlet valve lever. See Fig. 27. In this way t' e valves are lifted from their seats thus relieving all compression in the cylinders. The correct lift for this purpose is ·040 in. (1·016 mm.). After grinding and lapping of valve seats it will be necessary to re-set to this lift by means of the adjusting screw and locknut. See Book No. 48·2.

122. **Cylinder Head Water Joints.**—These are made by a series of small, synthetic rubber rings. It is good practice to renew these whenever the cylinder heads are removed. **Use standard "Gardner" spares which are made of special material.**

123. **Replacing the Cylinder Heads.**—The gas joint between head and cylinder is made with a thin metallic/asbestos packing which should be renewed whenever the cylinder head is removed. Do not use any jointing compound whatever. **Use only genuine "Gardner" packings.**

When fitting these packings take all precautions to avoid foreign matter becoming entrapped between the joint faces of head and block. Foreign matter entrapped can result in serious damage to these joint surfaces necessitating re-surfacing.

Entrapped matter can cause leakage and surface erosion in service.

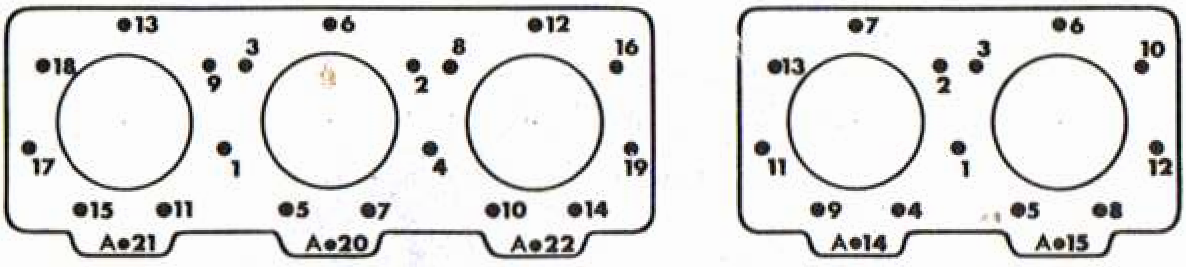
Ensure that parts are scraped scrupulously clean without damaging the surfaces and finally clean away all loose particles with a compressed air jet, particular attention being paid to stud holes in the cylinder head. If surfaces have become damaged it may be necessary to return the parts to the Works for precision regrinding. Alternatively, minimum damage and inspection of surface accuracy may be effected by lapping together with fuel oil and 400 grit abrasive, a cylinder head to a cylinder head or a cylinder head to a cylinder block, after withdrawing cylinder block studs. Ensure complete removal of abrasive from the threaded stud holes in the block and all other parts after lapping is completed.

Before lowering the cylinder head the last few inches on to the block, make thorough inspection to ensure that all the water joint sealing rings are in position and that the surface of the packing is clean and free from any loose particles.

GARDNER

OVERHAUL AND ASSEMBLY

CYLINDER HEADS—*continued*



3-Cylinder Block 2-Cylinder Block 2371

Fig. 28. CYLINDER HEAD TIGHTENING SEQUENCE

The correct tightening torque for ½ in. (12·7 mm.) B.S.F. cylinder head nuts is 1,000 lb. in. (11·5 Kg./m.) and for the ⅜ in. (9·525 mm.) B.S.F. nuts is 350 lb. in (4·0 Kg./m.). With the cylinder head nuts lightly nipped down, check the alignment of the two cylinder heads on 4, 5 and 6-cylinder engines by placing a straight edge along the manifold ports. Adjust by tapping the heads in the direction required. The final tightening of the cylinder head nuts must be carried out in three stages, i.e. 3° of tightness as follows:—

1st stage: screw up lightly in order shown in Fig. 28.

2nd stage: screw up medium tight in order shown.

3rd stage: screw up to final tightness in order shown.

Do not exceed the respective torque loadings given above.

VALVE TIMING

124. **Timing of Valves.**—When re-assembling an engine after overhaul, it is of the utmost importance to pay special attention to the timing of the valves with relation to the crankshaft, since if the timing be not in accordance with the timing marks on the flywheel and the timing gears (See Paras. 131 and 133) the valves will foul the pistons and *serious consequences will result*. For this reason it is desirable, on assembling, to place the lower end of the tappet rod in the cam-tappet socket without 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. When correctly set, the motion should be such that when the piston is towards the top of the exhaust stroke, 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. With the tappet clearances adjusted to the following settings and the timing chain tight, the valve timing should be as follows:—

LW and HLW Engines. Tappets set to ·010 in. (·254 mm.) clearance.
Inlet valve opens 12° before T.D.C.
Exhaust valve closes 19° after T.D.C.

LW 20 Engines. Tappets set to ·020 in. (·508 mm.) clearance.
Inlet valve opens 13° before T.D.C.
Exhaust valve closes 13° after T.D.C.

Note.—After timing has been completed see that timing chain is re-adjusted to the correct running tension, refer to para. 88, and the tappets re-adjusted to the correct running clearances given in para. 91.

125. **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 that oil is reaching the valve ends via the specially constructed flat upper surface of the valve levers. The width of this surface is regulated to provide the desired flow to the valve ends.

OVERHAUL AND ASSEMBLY

FUEL INJECTION PUMPS AND GOVERNOR UNIT

126. **Fuel Pump Tappets.**—Adjustment of these fuel pump tappets should not be de-ranged. They are adjusted during engine test and will not require any further attention. Should this adjustment be inadvertently upset or a new part have to be fitted, due to accident or wear, reset as follows:—

Turn the flywheel until the tappet has lifted to its maximum, then turn the flywheel one more revolution so that the tappet will now be resting on the base of the cam.

Place on top of the tappet screw the appropriate setting disc or gauge. The thickness of these discs is as follows:—

LW and HLW	"K" Type Sprayers.	·150 in. (3·810 mm.).
LW20	LW20 Type Sprayers.	·108 in. (2·743 mm.).

Refit the fuel pump and tighten the holding down nuts. The lines in the windows of the fuel pump should now coincide, if the lines do not coincide adjust the tappet screw either up or down until this condition obtains. Remove the disc or measuring gauge, firmly lock the screw and refit the pump. This operation must be carried out on each tappet in turn, the remaining tappets being latched out of action whilst adjustment is being carried out.

IMPORTANT NOTE: Under no circumstances must the engine be revolved whilst the disc or measure gauge is in position on any of the tappets. Very serious damage to the fuel pump will occur if this is not observed.

127. **Fitting New Tappet Rollers and Pins.**—The pin hole in the tappet is slightly smaller at one side than at the other, thus the plain unstepped pin is a shrink fit in one side only of the tappet.

To Remove Pins.—Heat the tappet by holding in boiling water for a moment when the pin may be tapped out using a light hammer and brass drift.

To fit New Pins.—By using the new pin as a "go" and "not go" gauge determine which is the larger of the two holes in the tappet; this should be marked by pencil. Heat tappet in boiling water, enter pin through the larger of the two holes and through the roller, re-heat tappet assembly and push pin into tappet until the pin projects an equal amount on either side.

Whilst tappet is still hot turn pin until flats on ends of pin are square with bottom face of tappet.

Note.—Grooved pins must be fitted with groove towards top of tappet. Later pins are ungrooved and such pins when worn may have a second life by rotating through 180°. The unworn side of pin will then carry the load.

128. **Fitting Spare Fuel Pumps**:—

5 and 6 Cylinder Engines.—In the event of this being necessary, due to a failure in either block of pumps, it is essential that **both** pumps are replaced by the spare pair, i.e. one pump of the spare pair will **not** replace one of the original pair. This is necessary because the pumps are calibrated when in pairs.

To replace, proceed as follows:—

Stage 1. Fit the pumps after having checked and corrected where necessary the tappet setting on each pump line as directed in para. 126.

Stage 2. 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. (·794 mm.) from its maximum stroke towards the timing case. Should it be necessary to make adjustment to this rod, great care should be exercised to see that the holes for the joint pins are parallel when the nuts are locked and that the control bar moves freely.

Stage 3. When the stopping lever is in the "stop" position the control bar should have a movement of $\frac{1}{32}$ in. (·794 mm.) before reaching the maximum "in" position (as in Stage 2). To obtain this, adjust the screw in the lower end of the governor lever.

OVERHAUL AND ASSEMBLY

FUEL INJECTION PUMPS AND GOVERNOR UNIT—*continued*

Stage 4. Fit the pipe-work and the slider bar return spring behind the "forward" pump.

2, 3 and 4LW Engines.—Proceed as for 5 and 6 cylinder engines. Pumps are in one block.

Important Note.—The fuel limiting box fitted to the pump must only be used on the pump to which it was fitted when delivered (unless the pump has been subject to full calibration procedure). 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.

129. **Governor Weight Toe Bearing.**—The toes of the governor weights are fitted with rectangular bronze trunnion blocks which, except in the case of 6LW and 6HLW engines, are loaded endwise by small springs. Engines used for generating sets are fitted with steel rollers as standard in place of trunnion blocks. The number and location of springs used in each pair of trunnion blocks are shown in the table and sketch below (Fig. 29).

Engine	No. of springs per toe	Spring location in holes	Total springs per engine
2, 3 and 4LW 4HLW, 5LW20	3	**a**, **b** and **d**	6
5LW, 5HLW	2	**a** and **c**	4
6LW20	1	**a**	2
6LW, 6HLW	None	—	None

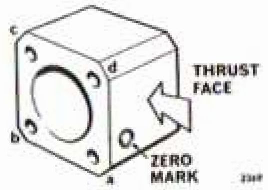


Fig. 29. GOVERNOR WEIGHT TRUNNION BLOCK

For the governor weights to operate smoothly it is necessary that the various pins, bushes and trunnion blocks have a cumulative total of not more than about ·004 in. (·102 mm.) diametral slack. Where exceeded it will be necessary to fit new blocks and pins in the toes of the weights and new pins and bushes in the weights and body. As it is quite essential that the weights do equal work it will be understood that if one pin requires renewal all the pins and bearings will require restoration to their new state.

To facilitate re-assembly, the hinge ends of the governor body are stamped 1 and 2, as also are the corresponding governor weights and each pair of trunnion blocks. These parts should always be re-assembled number to number. Replacement trunnion blocks are not numbered and are stamped with a zero on their thrust faces. When assembling new trunnion blocks it is desirable that the zero marks on each pair of trunnion blocks are coincident and positioned in the angle formed by the flange so that the thrust faces bear on the loaded flange of the governor sleeve, i.e. the rearmost of the two flanges. The springs between each pair of blocks must be positioned as indicated in the diagram; hole (*a*) being adjacent to the zero mark. Always use new split pins of the correct size and length when re-assembling. Before fitting the split pins, bend slightly about half way along the length of the pin to ensure they fit tightly in their holes. After fitting, open the legs and bend them so that they are firmly bedded around the radius of the governor weight toe. See Fig. 30.

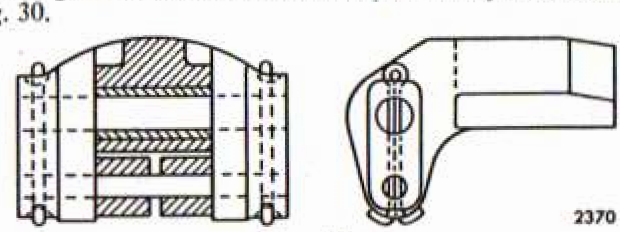
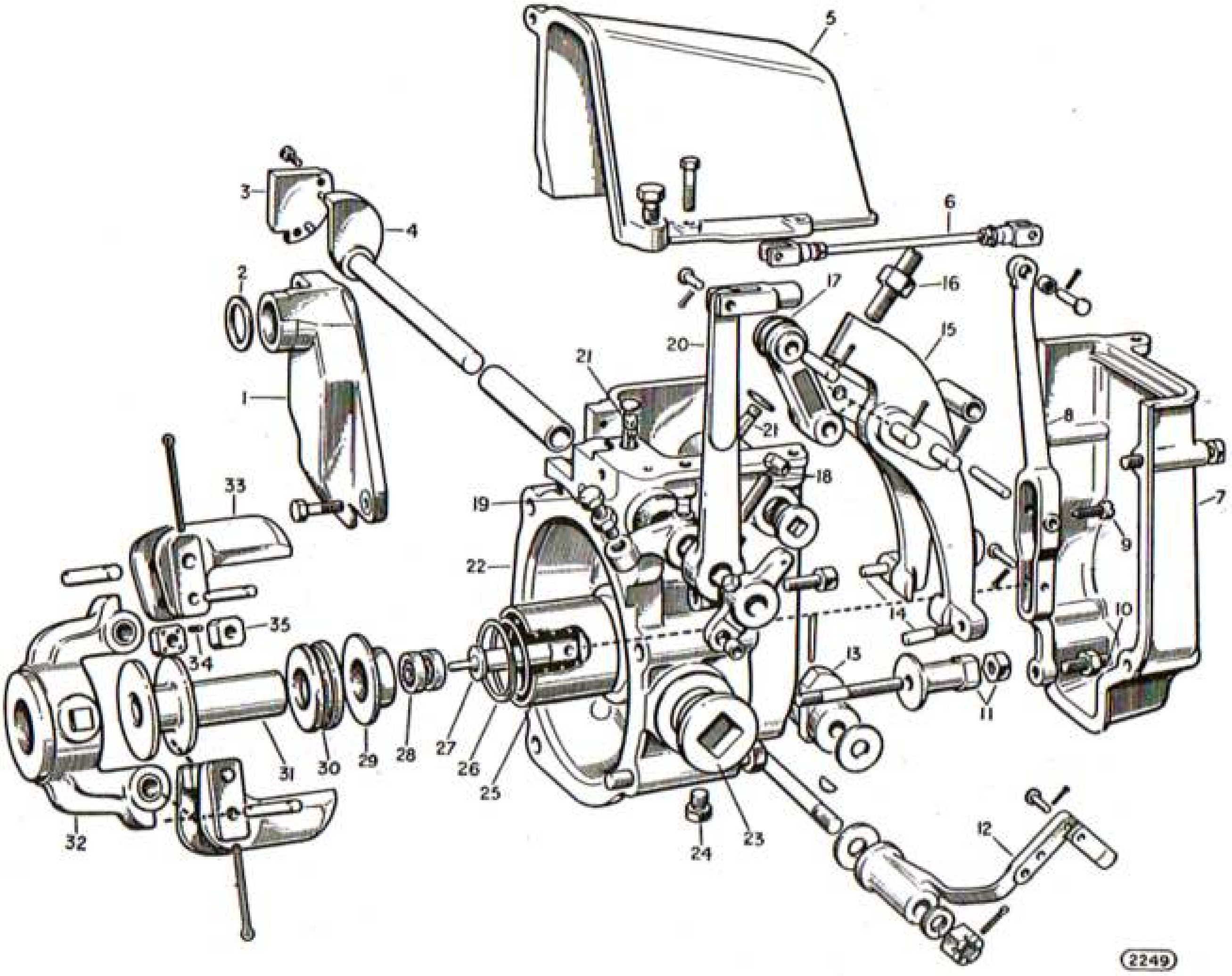


Fig. 30

129·1. **Governor Body, Withdrawal Tool.**—A special tool is available for removing the governor body from the fuel pump camshaft and details are given in Workshop Tools Book No. 48·2.

FUEL INJECTION PUMPS AND GOVERNOR UNIT—*continued*



1 Governor Casing Front Cover
2 Slider Bar Sealing Ring
3 Governor Casing Side Cover
4 Accelerator Cam
5 Governor Casing Upper Cover
6 Slider Bar Connecting Link
7 Governor Casing Rear Cover
8 Governor Lever
9 Fulcrum Pin Locking Screw
10 Stopping Cam Tappet Screw
11 Idle Speed Flanged Adjusting Nut and Locknut
12 Stopping Lever
13 Stopping Cam
14 Governor Spring Lever Stop Pegs
15 Governor Spring Lever (cam operated)
16 Spring Lever Adjusting Screw
17 Accelerator Cam Roller and Lever
18 Maximum Speed Limiting Screw
19 Slow Running Adjustment Screw
20 Accelerator Lever
21 Wick Lubricators
22 Governor Casing
23 Access Plug
24 Drain Plug
25 Governor Spring Guide
26 Governor Spring
27 Governor Push Rod
28 Ball Bearing
29 Governor Spring Collar
30 Thrust Bearing
31 Governor Sleeve
32 Governor Body
33 Governor Weight
34 Trunnion Block Compression Spring
35 Trunnion Blocks

GOVERNOR ASSEMBLY

OVERHAUL AND ASSEMBLY

FUEL INJECTION PUMPS AND GOVERNOR UNIT—*continued*

130. **Governor Readjustment.**—After overhaul or when a new governor spring is fitted or the setting is otherwise disturbed, the governor and fuel pump slider bar connecting link must be readjusted in the manner described below.

The operation is normally carried out during the dynamometer tests of the engine after assembly but, if the following instructions are observed, adjustment may be effected before fitting the cambox assembly to the engine.

(1) With the governor weights parted to their full extent, adjust the length of the governor bar connecting link to give the slider bar a position approximately $\frac{1}{32}$ in. (·794 mm.) from its maximum stroke towards the timing case, as described in para. 128.

(2) By adjustment of the maximum speed limiting setscrew in the rocking lever on the accelerator cam spindle (see Fig. 31) set the straight flank of the accelerator cam at the appropriate angle, given in the following table, for the required maximum speed.

CAM ANGLE AND SPRING MEASURING LOAD
LW, HLW and LW20 Engines

Maximum r.p.m.		Spring Load		Cam Angle
Full Torque	No Load	lb.	kg.	
1,700	1,770	111	50·35	+ 27°
1,500	—	76	34·47	+ 7·5°
1,300	—	50	22·68	— 4·5°
1,200	—	36	16·33	— 9°
1,100	—	25	11·34	— 13°
1,000	—	16	7·26	— 17°

Note.—A "plus" sign before the angle given indicates that the straight flank is leaning towards the flywheel whilst a "minus" sign indicates that the straight flank is leaning towards the forward end of the engine.

(3) Determine the length of the actual spring to be used, when loaded to the figure given in the table for the particular maximum speed concerned. Initial assembly is then made with a tubular distance piece in place of the spring. The length of this distance piece **must** be made precisely the same as that of the spring when compressed to the working load given in the table above.

(4) With the governor weights fully closed, the distance piece in position and the cam set as above, adjust the governor spring lever screw (Fig. 31) until the rounded toes at the lower end of the lever touch the end face of the spring guide. Fit the stop pegs in the lever arms and file each peg to give ·002 in. (·051 mm.) clearance from the face of the governor case.

(5) Fit the spring in place of the distance piece.

(6) Readjust the governor spring lever screw to restore the ·002 in. (·051mm.) clearance between the stop pegs and governor case.

For automotive engines, which can be run in neutral gear at maximum speed and no load, the following alternative procedure may be adopted to readjust the governor control.

(*a*) Remove the governor bar buffer from the fuel pump control box.

(*b*) Proceed as described in sub-paragraphs 1 and 2 above and start the engine.

(*c*) After the engine has attained normal working temperature, set the accelerator cam to the maximum r.p.m. position at 27° then adjust the governor spring lever screw to obtain the maximum no-load speed of 1,770 r.p.m.

(*d*) Reduce the engine speed to idling, replace the buffer in the control box and adjust the slow running and slider bar buffer as described in paras. 72 and 73 respectively.

Note.—As indicated this method applies only to automotive type engines used in road vehicles, rail cars and locomotives. This method must **NOT** be applied to engines arranged for other duties where original maximum r.p.m. differs from those quoted above.

OVERHAUL AND ASSEMBLY

FUEL INJECTION PUMPS AND GOVERNOR UNIT—*continued*

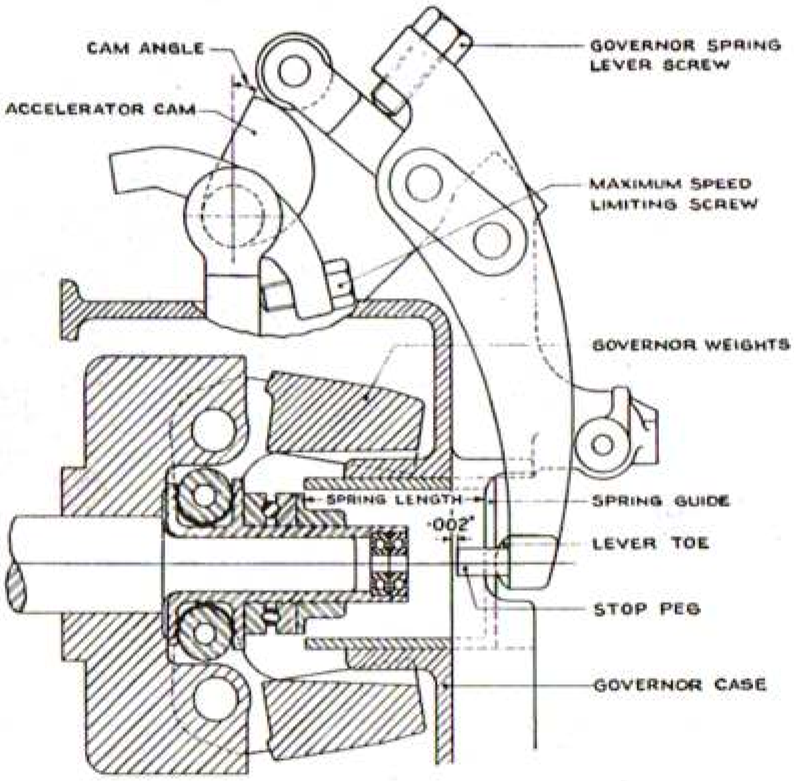


Fig. 31. GOVERNOR RE-ADJUSTMENT

INJECTION TIMING

131. **Timing Marks of Fuel Injection. Top Dead Centre.**—Drawn across the periphery of the flywheel will be found timing lines for each cylinder. A short line will also be observed on top of the crankcase at the base of the cylinders, called the **zero line.** Taking, for example, the lines on the flywheel for No. 1 cylinder, when the line marked "No. 1 T.D.C." registers with the zero line, crank No. 1 is exactly at top dead centre (T.D.C.) and when the line marked "No. 1 injection 28°" registers with the zero line on the compression stroke, the timing lines on the fuel injection pump should coincide, as described in para. 132. The line marks the position of maximum advance and the number denotes the number of degrees before T.D.C. In certain LW installations the upper portion of the flywheel and clutch housing is obscured; in such cases the timing marks will be observed through an oval aperture in the front face of the crankcase flanged end plate on the fuel pump side of the engine.

It is to be understood that, whilst checking the timing in this way, the pointer of the advance and retard device must be turned to point to position of maximum advance; this of course, can be obtained by movement of the accelerator lever to maximum speed position.

Note.—No. 1 cylinder is that situated at the forward end of the engine.

OVERHAUL AND ASSEMBLY

INJECTION TIMING—*continued*

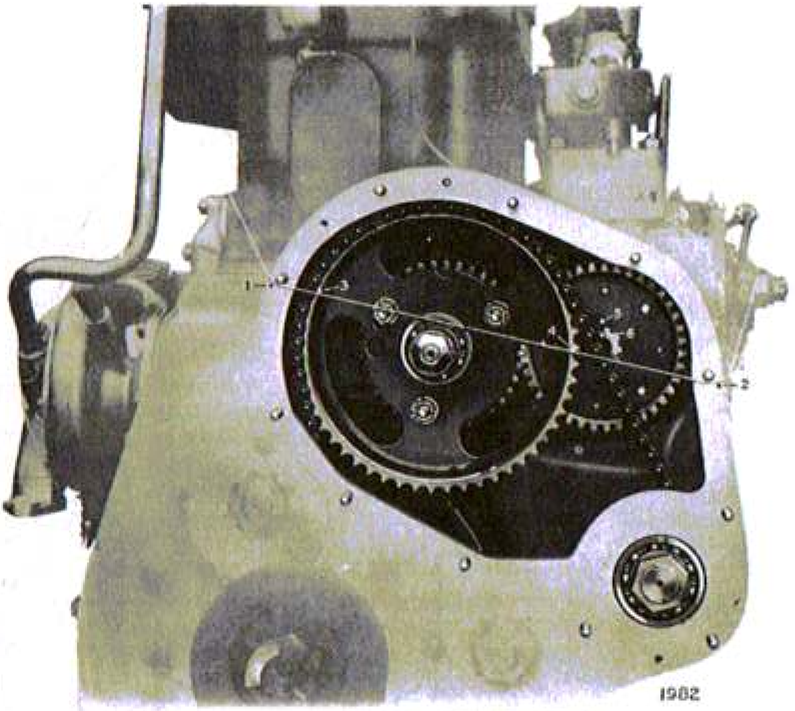


Fig. 32. TIMING MARKS FOR VALVES AND INJECTION

132. **Timing of Fuel Injection.**—Each fuel pump is provided with a sight hole or window through which can be seen the plunger guide moving up and down when the crankshaft is rotated. On the sides of the window is a horizontal line and also one on the plunger guide. When these two lines coincide, the corresponding injection line on the flywheel should register with the zero line, as described in para. 131. When so checking the timing, the engine must of course be rotated in its running direction and the plunger guide under observation must be ascending. On the fuel pump tappet are adjusting screws which should never be disturbed. See para. 126.

133. **Timing of Valve and Injection Pump Camshafts.**—The large chain gear and the hub and gear of the valve camshaft are bolted together face to face by three studs. The stud holes in the chain gear are elongated to permit a certain small amount of rotation relative to the camshaft hub for the purpose of accurate timing. When the timing is correct, the relative position of the two gears is marked by tracing on the periphery of the camshaft hub the contour of the sight hole in the chain wheel, the resulting mark forming a lune or arc of a circle. When the cover of the chain case is removed and the flywheel set to bring No. 1 crank to T.D.C at end of compression stroke, as directed in para. 131, and if chain, gears and spline have been correctly meshed the following conditions will obtain:-

(1) The dots 1 and 2 on the gearcase and the dots 3 and 4 on the periphery of the camshaft gear will all lie on a straight line as indicated by the stretched cord in Fig. 32.

(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 on the valve camshaft lies between the dotted teeth of the gear on the fuel pump camshaft.

(3) Through the same sight hole it will be seen that the lune on the edge of the hub of the valve camshaft (described above) is in its correct position. Should the gears be incorrectly bolted together, the lune will exhibit the defect conspicuously.

(4) The dotted spline on the camshaft of the fuel pump will register with the dot on the splined hub (see dots 5 and 6 in Fig. 32).

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

OVERHAUL AND ASSEMBLY

CHAIN DRIVE

134. **Chain Drive Arrangement.**—Engines from serial Nos. LW 86977 to 139163 and all HLW engines up to No. 139170 were fitted with a Type 1 adjusting idler having a $\frac{1}{2}$ in. (12·7 mm.) throw on its eccentric. With these engines, the run of the timing chain inside or outside the fixed idler sprocket depended upon the length of chain and size of generator sprocket fitted. See Fig. 33.
Engines from serial Nos. LW 139164 and HLW 199171 onwards were fitted with a Type 2 adjusting idler having a $\frac{7}{8}$ in. (22·225 mm.) throw and with these engines the timing chain is arranged to run round the outside of the fixed idler irrespective of the size of generator sprocket fitted.
Lengths of chain in relation to sprocket size, etc., are detailed in the table below.

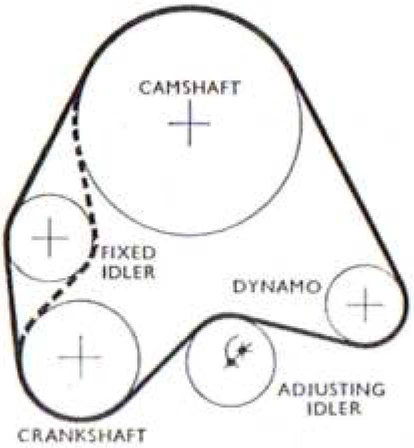


Fig. 33. CHAIN DRIVE ARRANGEMENT

	Type of Adjusting Idler	No. of Teeth on Generator Sprocket	No. of Pitches in chain	Run of Chain round fixed idler
All LW engines up to No. 86976 (Single Idler) (Adjustable)	Type 1	20 18	96 96	* Inside (Chain Adjuster) * Inside (Chain Adjuster)
All LW engines from 86977 to 139163 and All HLW engines up to 139170 (Double Idler)	Type 1	20 18 15 †12	98 98 96 96	Inside Inside Outside Inside
All LW engines from 139164 onwards and HLW engines from 139171 onwards (Double Idler)	Type 2	20 18 15	98 98 96	Outside Outside Outside

*Early engines had a single idler only (adjustable) located at the current fixed idler position.

†12-tooth generator sprockets (used only on a few special engines) are now discontinued.

135. **Assembling the Adjusting Idler.**—When fitting the adjusting idler check that the sprocket is in alignment with the crankshaft driving sprocket by placing a straight-edge across the face of both sprockets. Any slight malalignment can be remedied by tapping the idler sprocket in the required direction on the outer race of the idler sprocket bearing. When assembled, the adjuster eccentric must be so positioned that when the adjuster is rotated *clockwise* the chain tension is *increased*. In this way the idler sprocket will be positioned mid-way between the crankshaft and generator drive sprocket.

136. **Alignment of Alternator Drive Sprocket.**—Alignment of the alternator sprocket is obtained by the use of shims interposed between the sprocket and the inner races of the front and rear ball-bearings, as indicated at "X" and "Y" in Fig. 34.

These shims are available in the following thicknesses:—

·004 in. (·102 mm.), ·012 in. (·305 mm.), ·019 in. (·483 mm.).

Normally the total thickness of shimming required amounts to ·040 in. (1·016 mm.) divided between points "X" and "Y" to give the required end clearance at "E" of ·010 in. (·254 mm.) to ·015 in. (·381 mm.).

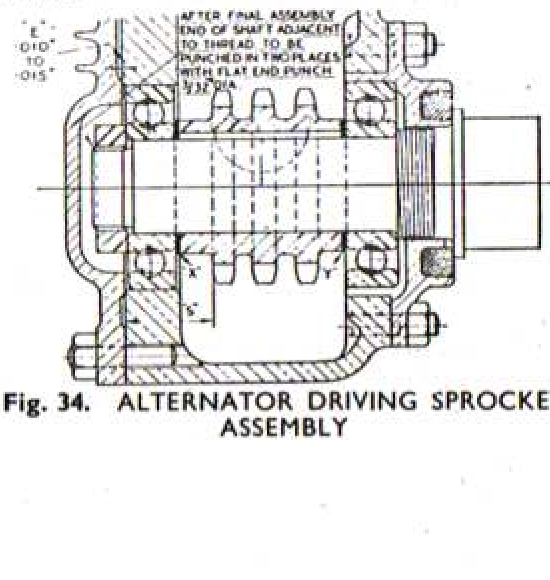


Fig. 34. ALTERNATOR DRIVING SPROCKET ASSEMBLY

OVERHAUL AND ASSEMBLY

CHAIN DRIVE—*continued*

Before commencing assembly of the alternator sprocket measure the distance from the front face of the chain case to the front face of the sprocket at "S". The difference between this reading and the one taken on the crankshaft sprocket will determine the thickness of shims required at point "Y" to align the two sprockets.

As already mentioned the total amount of shimming required at points "X" and "Y" is ·040 in. (1·016 mm.) therefore having assessed the thickness of shims required at "Y", it is a simple matter, by subtraction, to determine the thickness of shims required at point "X" to provide the desired end clearance of ·010 in. (·254 mm.) to ·015 in. (·381 mm.) at point "E".

After final assembly with all shims in position, a final check should be made at point "E" to ensure that this clearance has been maintained.

Lock the retaining nut by punching the end of the shaft adjacent to the thread in two places with a small flat-ended punch.

137. **Renewal of Sprockets and Chainwheels.**—These are unlikely to require renewal except after extremely long service and only if the teeth have become "hooked" to such an extent that they are liable to interfere with the smooth driving of the chain.

This can be checked by wrapping a **new** chain around the chainwheel and if slight impact can be felt at the engagement of each tooth, a replacement is indicated.

When renewing the camshaft chainwheel, ensure on assembly that it is in alignment with the crankshaft sprocket. Check by first recording the depth from the front face of the timing case to the crankshaft sprocket and then similarly measuring the depth of the camshaft chainwheel. Any difference recorded will indicate the thickness of shims required between the chainwheel and the camshaft hub. These shims are available in thicknesses of ·010 in. (·25 mm.) and ·020 in. (·50 mm.). A tolerance of — ·000 in. to + ·010 in. (+ ·25 mm.) on the final dimension is permissible.

138. **Removal and Replacement of Timing Chain.** (See also Paras. 90 and 90·1.)—The endless timing chain has a riveted joint link which can be recognised by the small indents in the stud ends and it is desirable that this link be removed to break the chain. The well-known standard Renold Stud Extractor may be used for this purpose after removal of the chain case cover. Alternatively, if the sump and splash door have been removed, the engine may be turned until the joint link is engaging with the crankshaft sprocket, when the studs may be driven through the link plate, using a pin punch and hammer. **Under no circumstances should any of the other sprockets be used as an anvil for this operation.**

Special workshop tools are available for pressing on the outer plate and for indenting the studs when re-assembling. See Fig. 35 and also Workshop Tools Book No. 48·2. These tools greatly facilitate assembly but the work can also be done using a hollow punch obtainable from the Works. A light hammer can be used to rivet the stud ends whilst holding a small anvil block against the opposite ends of the studs.

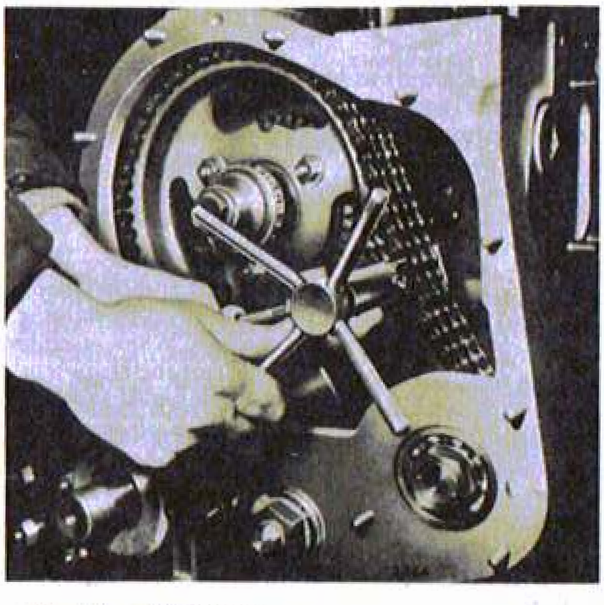


Fig. 35. CHAIN RIVETER AND EXTRACTOR TOOL

139. **Fitting a Replacement Chain Case Cover.**—The camshaft roller bearing is located in the chain case cover and forms the support for the end of the camshaft. It is necessary, therefore, to avoid any excessive chain tension whilst the cover is removed, otherwise undue deflection of the camshaft will occur.

OVERHAUL AND ASSEMBLY

CHAIN DRIVE—*continued*

For this reason, *chain adjustment must only be carried out when the chain case cover is bolted in position.* If a replacement cover is to be fitted it is essential to ensure perfect alignment of the cover with the camshaft roller race. To do this, first fit the outer race of the roller bearing into its housing in the chain case cover followed by the retaining circlip, bedding the latter firmly into its groove.

Fit the cover over the chain case studs and make sure that the outer race slides easily over the roller bearing on the camshaft. If any tightness is experienced when pressing the cover into position, the camshaft may be forced out of alignment. To remedy this, the stud holes which are binding must be eased until sufficient clearance is obtained to permit the cover to be rocked slightly on the studs using the bearing as a fulcrum. Having verified that all is correct, position the cover midway between the limits of the stud hole clearances and holding it in this position tighten all nuts. Finally drill and peg the cover to the chain case, using oversize pegs.

EXHAUSTER

140. **Exhauster Suction and Delivery Valves.**—The suction valve is of the "flap" type and is fitted to the upper cylinder head plate. If this valve is replaced, care should be taken to avoid bending and to see that when clamped under its stop it is in contact with the head plate over the whole of its area. The metal of the valve stop plate should be lightly punched into the screw slots to provide a means of locking the countersunk screw heads. The delivery valve is formed by the piston ring which has approximately ·013 in. (·350 mm.) vertical slack in its groove. On the upward stroke of the piston, air in the cylinder is forced past the top face of the ring and through small holes behind the piston ring into the exhauster crankcase. From there it passes to atmosphere through the combined oil separator and breather. (Exhausters on horizontal engines are not fitted with external oil separators as air discharged from the exhauster passes to atmosphere via the engine crankcase vent.) On the downward stroke, the piston ring makes contact with the top face of the groove and automatically seals the discharge holes in the ring groove. Any air which is in the vacuum tank and pipes is, therefore, drawn into the exhauster cylinders through the suction valve.

It will be observed that one face of the piston ring is bevelled. The ring must always be assembled so that the bevel is facing downwards. These rings should not require any attention until major overhaul when a new piston assembly may be desirable.

140·1. **Removal of Exhauster Crank.**—A special tool is available for withdrawing the exhauster crank from the valve camshaft and this is illustrated and described in Workshop Tools Book No. 48·2.

140·2. **Re-assembling the Chain Case Cover: Twin Exhauster.**—If the chain case cover has been removed, see that the locating pegs are in position before re-assembly. The locating pegs ensure true alignment of the exhauster crankcase bearing with the end of the camshaft, and it is important that this alignment is maintained otherwise difficulty may be experienced when fitting the exhauster crank. The slightest malalignment or eccentricity may result in damage to the casing or roller race when driving the crank into position on the camshaft.

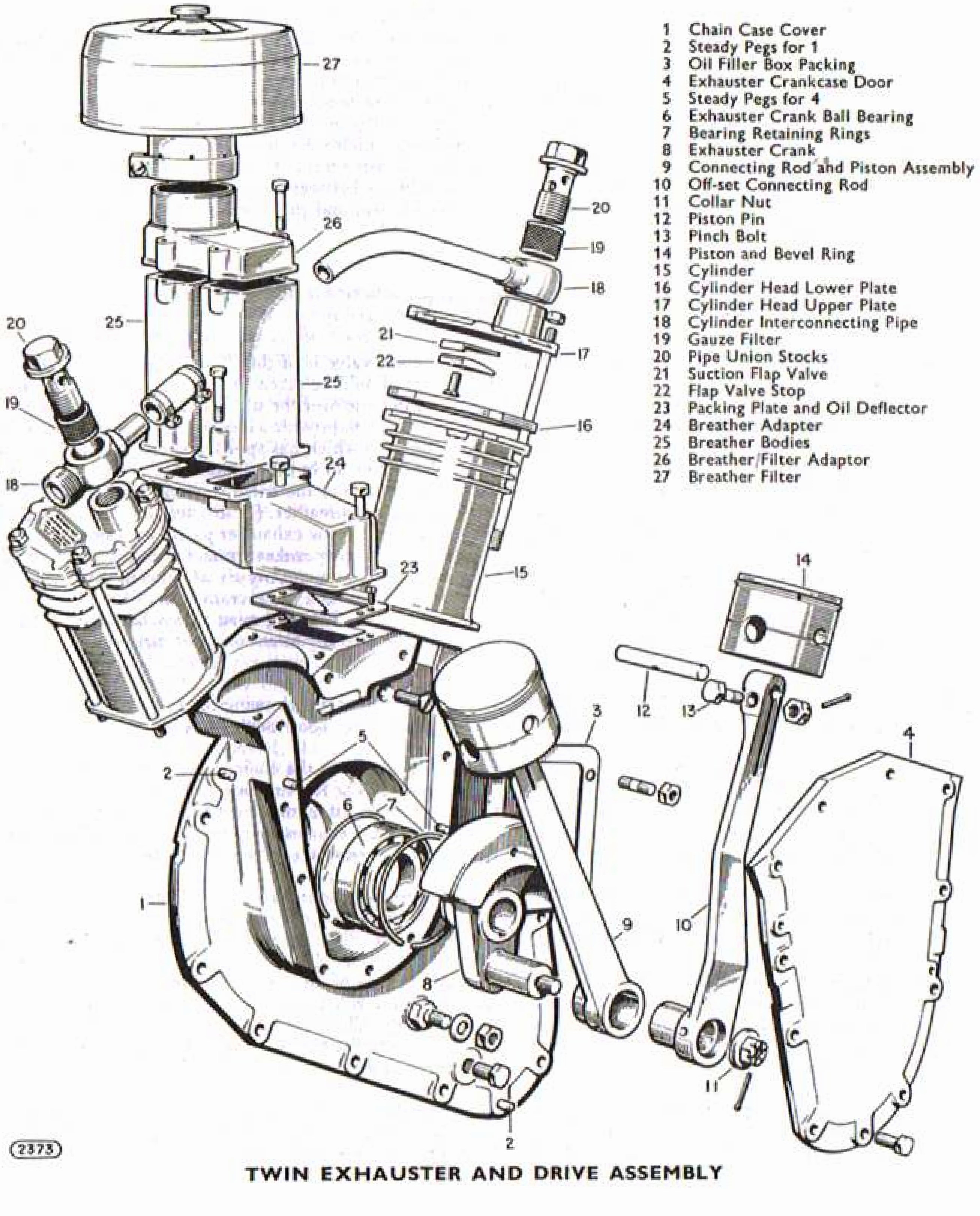
If a new chain case cover is to be fitted, proceed by first fitting the outer race of the roller bearing in its housing in the exhauster crankcase followed by the retaining circlip, pressing the latter firmly into its groove. Place the cover in position over the studs on the chain case. Place the roller bearings with inner race over the camshaft, so that it just enters its outer race in the cover. Next slide the exhauster crank on to the camshaft, aligning the Key-way and key and entering the boss of the crank in the inner race of the bearing. Then with a suitable hollow drift drive the crank with the roller race on to the camshaft until it is hard against the collar on the boss of the chainwheel assembly. Check that the bearing is free by rocking the cover to the limit of the stud hole clearances. Finally, centralise the studs in their holes in the cover plate then drill and peg the cover to the chain case, using oversize pegs.

140·3. **Re-assembling Exhauster Pistons and Connecting Rods.**—The piston pin is located and locked in the connecting rod by a pinch bolt and the ends rotate freely in the piston bosses. Assembly of the piston on its connecting rod is facilitated if carried out before fitting the rods to the engine.

OVERHAUL AND ASSEMBLY

EXHAUSTER—*continued*

1 Chain Case Cover
2 Steady Pegs for 1
3 Oil Filler Box Packing
4 Exhauster Crankcase Door
5 Steady Pegs for 4
6 Exhauster Crank Ball Bearing
7 Bearing Retaining Rings
8 Exhauster Crank
9 Connecting Rod and Piston Assembly
10 Off-set Connecting Rod
11 Collar Nut
12 Piston Pin
13 Pinch Bolt
14 Piston and Bevel Ring
15 Cylinder
16 Cylinder Head Lower Plate
17 Cylinder Head Upper Plate
18 Cylinder Interconnecting Pipe
19 Gauze Filter
20 Pipe Union Stocks
21 Suction Flap Valve
22 Flap Valve Stop
23 Packing Plate and Oil Deflector
24 Breather Adapter
25 Breather Bodies
26 Breather/Filter Adaptor
27 Breather Filter



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TWIN EXHAUSTER AND DRIVE ASSEMBLY

OVERHAUL AND ASSEMBLY

EXHAUSTER—*continued*

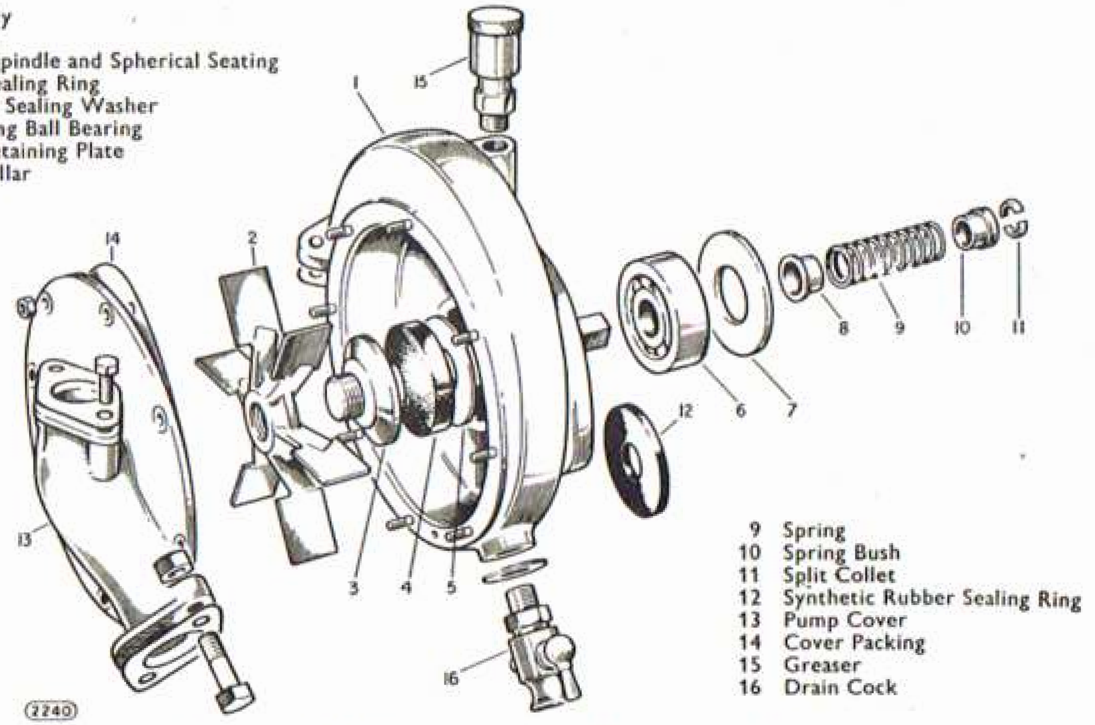
It will be observed that the outer periphery of the piston ring is bevelled and the ring must always be fitted with this bevel facing downwards. A note to this effect is stamped on top of each piston and both pistons must be assembled on their rods so that this stamping may be read from the front of the engine. It should be noted that the connecting rods are assembled, one to the other, with the extended big end bosses inwards towards the crank and the off-set connecting rod positioned to operate in the near side or right-hand cylinder (looking on the front of the engine).

140·4. **Checking Exhauster Cylinder Head to Piston Clearance.**—With the connecting rod and piston assemblies correctly positioned as described in para. 140·3, fit the exhauster cylinders and check the cylinder head to piston clearance with a dial indicator or with a straight edge and feeler gauges.
The nominal clearance is ·0156 in. (·396 mm.) + ·011 in. (279 mm.) — ·004 in. (·102 mm.) see also Workshop Tools Book No. 48·2. This clearance, measured in line with the axis of the piston pin must be uniform from front to rear of the piston crown.
Having checked the cylinder head to piston clearance, fit the cylinder cover plates with the suction valves positioned over the forward half of each cylinder.
Note.—The breather cases are embossed with the words "NEAR SIDE" and must always be assembled accordingly, that is, with the embossed side facing the fuel pump side of the engine.

WATER PUMP

141. **Inspection and Overhaul of Centrifugal Water Pump.**—Spare parts for the water pump and complete service pumps may be obtained from our Service Depots and from the Works. Special tools are used for the fitting of impellers to the spindles, which are balanced as an assembly, and for this reason impellers and spindles cannot be supplied separately.
If, the carbon ring has worn so that the blades of the impeller are less than $\frac{1}{32}$ in. (·794 mm.) clear of the internal face of the pump body it should be renewed. At the same time any score marks in the mating face of the impeller spindle should be removed by skimming in a lathe.

1 Pump Body
2 Impeller
3 Impeller Spindle and Spherical Seating
4 Carbon Sealing Ring
5 Polythene Sealing Washer
6 Self-aligning Ball Bearing
7 Grease Retaining Plate
8 Spring Collar



9 Spring
10 Spring Bush
11 Split Collet
12 Synthetic Rubber Sealing Ring
13 Pump Cover
14 Cover Packing
15 Greaser
16 Drain Cock

(2240)

Fig. 37. CENTRIFUGAL WATER PUMP ASSEMBLY

OVERHAUL AND ASSEMBLY

WATER PUMP—*continued*

If, after pressing the impeller against the carbon and rotating by hand, an unbroken line of contact is not obtained, the spindle may with advantage, be lightly lapped against the carbon ring using a little fine pumice powder and water which of course must be carefully removed prior to final assembly.

Do not on any account use "Carborundum" or equivalent abrasive and do not lap the parts if satisfactory seating is indicated by rubbing the parts together.

The self-aligning ball-bearing which supports the spindle has a long life and is not likely to require renewal until the second major overhaul.

Should it be necessary to replace the carbon gland, it is desirable that the pump be returned to the Works since a special tool is necessary for this purpose. Under certain circumstances this procedure may be impracticable, in which case the Works will be pleased to supply the necessary tool and instructions to enable the operator to carry out this work. Further details in this respect will also be found in Workshop Tools Book No. 48·2 which contains drawings and instructions depicting the use of the carbon gland fitting and extracting tool.

The spherical seat on the spindle is accurately formed and it is essential to avoid accidental damage in handling and storage of this component.

Before assembling, wash parts in petrol.

Do not allow grease to contact carbon gland; grease is detrimental.

After initial packing of the ball race with suitable grease it is unnecessary and indeed inadvisable to apply more than one occasional grease cap full of grease as directed in para. 80.

When re-assembling the pump, care must be taken to refit the synthetic rubber washer on the impeller spindle; this washer (item 12, Fig. 37) is located in the water and grease drain slot.

Note.—With the vertical engines, when re-assembling the pump, make sure that the small drain hole which crosses the joint between the pump cover and the pump body is clear from obstruction and properly registered and avoid blanking this hole with any packing or jointing used.

On the horizontal engines the pump lies horizontally and will drain completely via the pump inlet connection. It is, therefore, unnecessary for these holes to be in alignment.

INSTALLATION
INSTRUCTIONS AND RECOMMENDATIONS

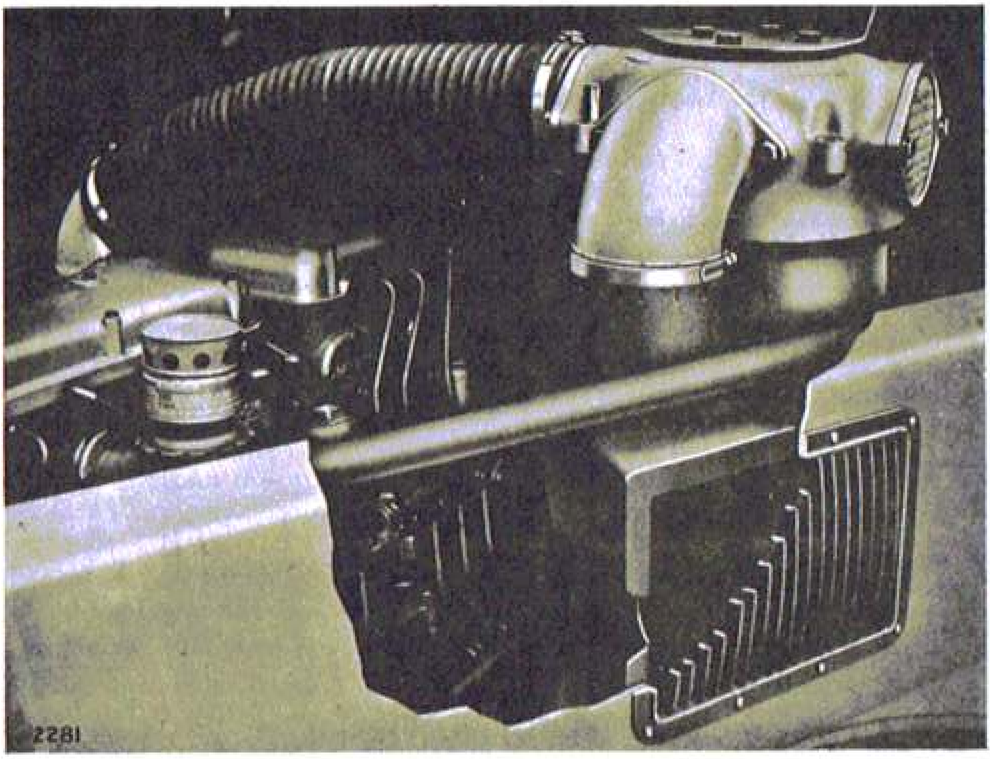


Fig. 38. UNDER-BONNET INSTALLATION OF UNIVERSAL OIL BATH TYPE AIR FILTER ON A SEMI-FORWARD CAB VEHICLE

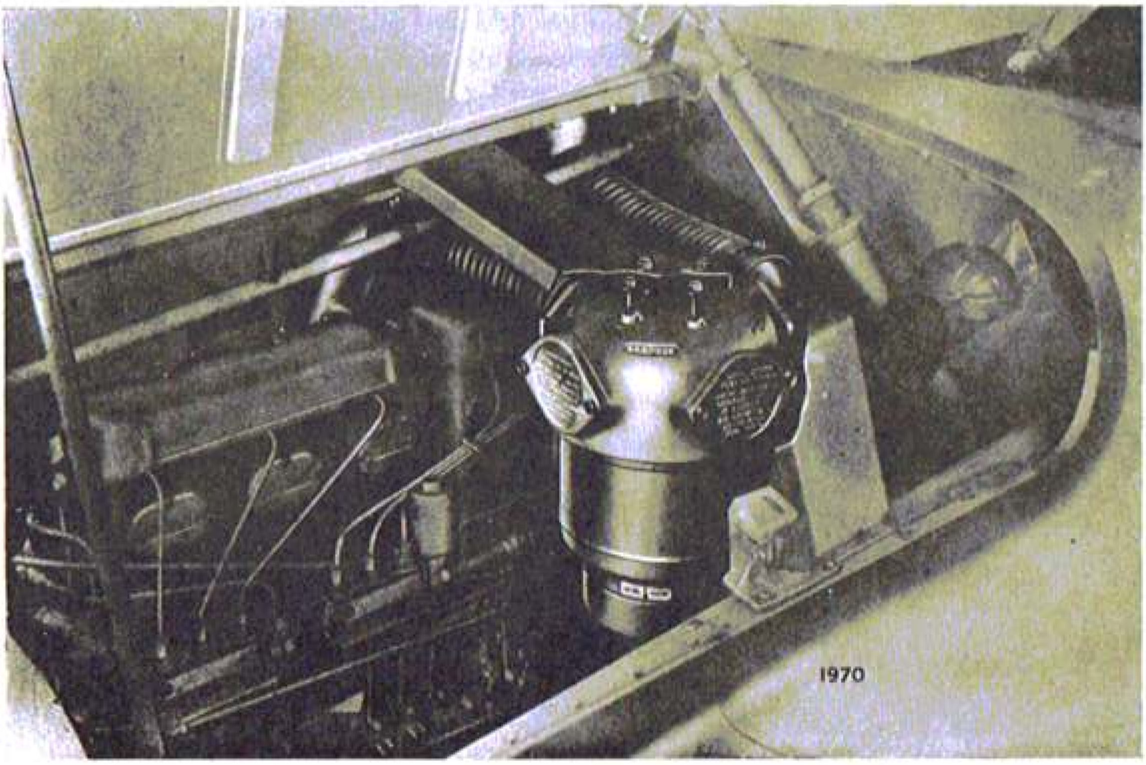


Fig. 39. UNDER-BONNET INSTALLATION OF UNIVERSAL OIL BATH TYPE AIR FILTER ON A DOUBLE-DECK PASSENGER VEHICLE

INSTALLATION INSTRUCTIONS AND RECOMMENDATIONS

AIR INDUCTION SYSTEM

142. **To Avoid Induction of Heated Air.**—It is **very important** that provision be made for the induction of the coolest available air into the engine. Fittings can be supplied to couple the air inlet manifold by means of a flexible suction hose to a point at which cool air may be drawn directly from the atmosphere through a remotely mounted air filter. It is necessary that means be provided to eliminate any possibility of the entry of hose or flood water into the induction system, and the system must be designed to operate at a manifold depression of not more than 5 in. (127 mm.) water gauge at full speed of the engine. Maximum power, economy and durability will not be available if the engine is permitted to induct heated under-bonnet air.

143. **Use of Oil-washed Air Filters.**—There is ample evidence to show that even when operating under conditions which are regarded as dust-free, the employment of oil-washed air filters can have a very beneficial effect in reducing the wear rate of many engine components, particularly cylinder bores, pistons, rings and grooves. For this purpose there is available the Gardner Universal Air Filter which can be mounted close to or remote from the engine, and the Twin Oil Bath Type Air Filter for under-bonnet installation. Instructions and recommendations concerning the installation of these filters are contained in the following paragraphs.

In some parts of the world air filters are necessary on marine engines. Similarly, air filters are also a necessity in some industrial engine applications.

144. **Installation of Gardner Universal Oil Bath Filters.**—This air filter is a totally enclosed weatherproof unit combining fully efficient filtration at low resistance with ease of installation and the provision of "cold air" induction. Automatic control of the oil level in the container compensates for accumulation of foreign matter in the filter sump, and uniform filtering conditions are maintained.

The cast aluminium alloy mounting head receives the A.C. Delco filter body and incorporates three alternative inlet ports and one outlet port. The latter is fitted with a connection or elbow of suitable size and is coupled by means of flexible hose directly to the engine air inlet manifold. The inlet ports are fitted with suitable size straight type or elbow connections to suit the installation. The head is provided with four setscrews for attachment to the supporting member on the chassis; one of the setscrews is offset to prevent incorrect assembly.

The filter is so designed that it may be mounted in any convenient position between engine and point of air entry (preferably adjacent to the engine). The inlet then being coupled by flexible hose to a point from which the **cleanest cold air** is available, due regard being paid to the location of the entry end of the intake on vehicles which may encounter flood water and the embodiment of a rigid flared metallic sleeve in order to avoid deformation of the conduit and facilitate entry of the air.

The unit may be mounted externally on the forward facing bulkhead outside the engine bonnet on certain passenger vehicles or rear of, or in, the driver's cab on commercial vehicles; the downward pointing elbow may then provide protection against the entry of rain or foreign matter. A variety of elbow and straight connections can be fitted to the filter head, to satisfy installation requirements. For under floor mounting, the inlet connection to the filter is conveniently ducted to a point below the vehicle floor, as high as is practicable and forward of the front axle.

Since the filter is totally enclosed, it may be mounted in the driver's cab without the introduction of objectionable noise created by open filters. The filter inlet may then be ducted to a hollow bulkhead or through the floor, whereby the cleanest cold air is obtained without the introduction of draughts and noise into the cab. (When coupled to a hollow bulkhead ensure that panels are not vibrated by the air pulsation and that the panels do not have direct communication with road wheel arches.)

Finally, when mounting the filter unit, ensure that there is a clear space of at least 3½ in. (88·9 mm.) below the container to permit removal for cleaning and inspection.

Fig. 39 illustrates the air filter mounted under the bonnet of a double-deck passenger vehicle, the inlet connection in the installation being ducted to a clean cold air position with suitable water excluding means on the top of the bonnet. The inlet connection may alternatively be ducted to the forward panel at the side of the engine compartment or other suitable position from which cold air may be inducted, as shown in Fig. 38. In this installation the cold air is inducted through a protecting grille in the bonnet side panel at a position below the intake head of the filter unit thus safeguarding against the ingress of foreign matter and water.

INSTALLATION INSTRUCTIONS AND RECOMMENDATIONS

AIR INDUCTION SYSTEM—*continued*

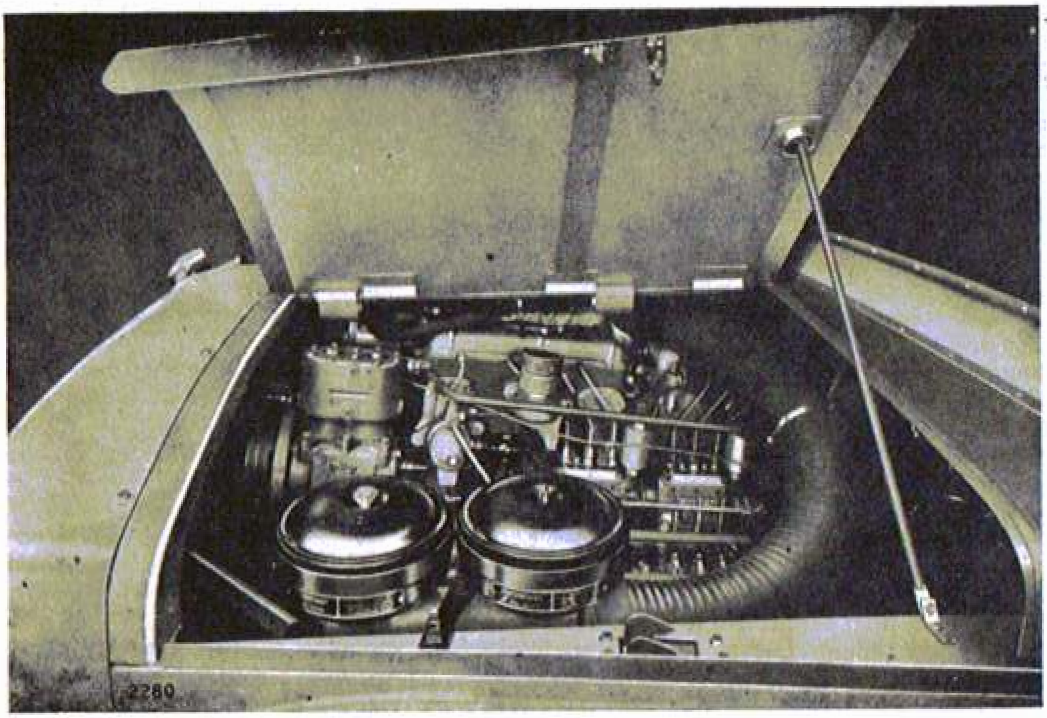


Fig. 40. UNDER-BONNET INSTALLATION OF TWIN OIL BATH AIR FILTERS ON A PASSENGER CARRYING VEHICLE

145. **Installation of Twin Oil Bath Type Filter.**—The twin oil bath type air cleaner is designed for under-bonnet installation on passenger vehicles where space is limited but where suitable protection from weather is available, for example in forward engine double-deck passenger vehicles, see Fig. 40. The unit is easily and quickly adaptable to any under-bonnet arrangement and combines fully efficient filtration with simplicity and ease of maintenance. Installation dimensions are shown in Fig. 18, Page 50.
The manifold must be mounted horizontally with the inlet ports uppermost and attached by suitably rigid brackets to any convenient point on a side panel or bulkhead (preferably remote from the exhaust manifold and where the cleanest and coolest air is available). It is so designed that it may be reverse mounted, thus enabling the suction hose to lead off in whichever direction is the more convenient.
The mounting brackets must be so arranged that when installed, the filter units containing the oil are maintained upright on a level plane.
Details of the suction hose are given in para. 147.

146. **Use of Pre-cleaners for Extreme Dust Concentrations.**—Overseas experience dictates that a satisfactory installation for operation in a heavily dust-laden atmosphere is one in which the air is additionally drawn through pre-cleaners from inside the driver's cab or passenger accommodation. These remove a large proportion of the heavier dust particles and are recommended for use in a heavily dust-laden atmosphere in order to lengthen the intervals between which cleaning of the main filter becomes necessary. Dust-laden air entering the pre-cleaner is caused to rotate within the body and in so doing dust particles are ejected at the peripheral slots.

147. **Suction Hoses.**—The suction hose used on both the inlet side and between the filter and engine manifold is of light canvas type with internal wire reinforcement. A total system length of up to 12 ft. (3,658 mm.) is permissible. The bore diameter must not be less than 3¾ in. (95·25 mm.).

INSTALLATION INSTRUCTIONS AND RECOMMENDATIONS

AUXILIARY UNITS AND DRIVES

148. **Auxiliary Drives.**—The standard fan drive arrangement on all vertical engines consists of a belt and single "V" groove driving pulley mounted on the forward end of the crankshaft. Alternatively, if specified, the engine can be supplied with a plain parallel forward extension of the crankshaft on which a multi-groove pulley may be fitted to provide an additional drive for auxiliaries. All horizontal engines are arranged for the mounting of a pulley or flexible coupling at the forward end of the crankshaft.
It is essential that each non-standard arrangement on the forward end be submitted to the Works Technical Staff for consideration of its effect upon crankshaft torsional characteristics.
Under no circumstances must a heavy mass be rigidly attached to the forward end of the crankshaft.

149. **Air Compressor.**—These are fitted to engines for the operation of compressed air braking systems and other auxiliaries and are always of proprietary make. They are driven from a three groove pulley on the front end of the crankshaft by means of triple belts which also drive the fan. Lubrication of the compressor is maintained automatically by the engine lubrication system and for further maintenance instructions reference should be made to the maker's handbook.

150. **Exhauster.**—When so ordered a vacuum pump (exhauster) may be fitted to automotive engines for operating a vacuum Servo Brake System. Available in single or twin cylinder arrangements they are mounted on the timing case and are crank-driven from the valve camshaft. A diagrammatic arrangement of the vacuum Servo Brake pipes is shown on Drawing No. 3387H in Workshops Tools Book No. 48·2 and the sizes of pipes are as follows—

Between Exhauster and Check Valve or Vacuum Tank—Single Cylinder	—⅝ in. (15·9 mm.) o.d.—18G
,, ,, ,, ,, ,, ,, ,, ,, —Twin Cylinder	—¾ in. (19·1 mm.) o.d.—18G
Between Vacuum Tank and Servo Unit	1 in. (25·4 mm.) o.d.—16G

COOLING SYSTEMS

151. **Cooling System.**—To enable the engine to satisfactorily and reliably maintain full power for long periods it is essential that the cooling system be designed to control suitably the maximum water temperature under all conditions. See also para. 153. Cooling of Lubricating Oil.
The advice and co-operation of our Technical Staff will be offered willingly upon application to the Works.
Essential features are as follows:—

(*a*) The engine shall be equipped with an efficient fan, which will be supplied if specified on the order. The fan, which is usually driven from the forward end of the crankshaft, shall be fully cowled with provision for best adjustment.

(*b*) The radiator shall have a heat dissipating capacity capable of limiting the water temperature at the engine outlet to 80F. above atmospheric temperature, under temperate climatic conditions, when the engine is developing full power in still air. Special consideration is required for service in climatic conditions less than favourable than those obtaining in the British Isles.

Low-load Operation and Precautions against Frost.—The engine is fitted with a thermostat which controls the water temperature under conditions of light load. See paras. 8, 77 and 78. For operation under conditions of extreme cold and for precautions against frost see paras. 8·2, 8·3 and 79.

152. **Constructional Details of Fan and Radiator.**—The following constructional details must be observed since the deficiency of any one will impair the efficiency of the system.

(1) **Radiator Fan.**—The distance from the tubes or element to the fan blades must not be less than 1¾ in. (44·5 mm.) and the fan blades **must** be enclosed by a cowl, the diameter of which is not greater than the fan blades plus 1½ in. (38·1 mm.).

(2) **Water Inlet and Outlet Connections.**—The minimum permissible bore of any portion of the connections between radiator, thermostat outlet and water pump inlet is 1¼ in. (31·8 mm.) and the minimum bore size for hoses is 1½ in. (38·1 mm.).
If any smaller connections are used the water circulation rate will be reduced and the system will lose efficiency.

INSTALLATION INSTRUCTIONS AND RECOMMENDATIONS

COOLING SYSTEMS—*continued*

RADIATORS
For Temperate, Sub-Tropical, and Tropical Conditions
Wire-Wound Tubes

Engine	Fan Particulars (Gardner Std.)		Radiator Particulars and Dimensions															
			Temperate Conditions Mean Annual Temp. 40 F. to 60 F.					Sub-Tropical Conditions Mean Annual Temp. 60 F. to 70 F.					Tropical Conditions Mean Annual Temp. 70 F. to 80 F.					
			Tubes		Effective Area	Typical Dimensions		Tubes		Effective Area	Typical Dimensions		Tubes		Effective Area	Typical Dimensions		
	Dia. in.	Blades	No.	Rows	$in.^2$	Width in.	Height in.	No.	Rows	$in.^2$	Width in.	Height in.	No.	Rows	$in.^2$	Width in.	Height in.	
2LW	18	4	25	2	380	19¼	20	27	2	430	20¾	21	38	3	370	19¼	20	
3LW	18	4	41	3	420	20¼	20	41	3	480	20¾	23	47	3	560	23¾	24	
4LW	18	6	47	3	570	23¾	24	50	3	650	25¼	26	53	3	760	26¾	29	
5LW 5LW20	18	6	53	3	720	26¾	27	56	3	820	28¼	29	62	3	960	31¼	31	
6LW 6LW20	18 20	6	59	3	880	29¾	29	62	3	1000	31¼	32	68	3	1170	34¼	34	

(3) **Free Entry of Air to Radiator.**—Any ornamental grille or guard fitted in front of the radiator must offer the minimum resistance to air flow.

(4) **Free Exit of Air from Engine Bonnet.**—Any restriction offered to the escape of the heated air from under the bonnet will reduce the volume of cool air induced through the radiator, therefore, an adequate bonnet must be provided with large area exit.
Note.—The Works will be pleased to advise and co-operate in the design and development of the somewhat special cooling equipment generally required for the horizontal engines.

(5) **Tubes.**—Brass tube ⅜ in. (9·5 mm.) o.d. — 22 G., wire wound type 1 3/16 in. (30·2 mm.) o.d. (approx.).

(6) **Tube Layout.**—Pitch of tubes 1½ in. (38·1 mm.) in rows spaced 1 5/32 in. (29.4 mm.), alternate rows staggered.

(7) **Alternative Tubes.**—The above dimensions of radiators and tube layout are based on the performance of wire-wound tubes. Other types of tube are in regular use, for which modified layout is required or permitted. In general these have lower heat dissipating capacity and radiator dimensions must be increased proportionately, but the Withnell tube, manufactured by Messrs. Norman Isherwood & Co. Ltd., Bolton, to quote one particular example, is highly efficient and permits the use of radiators having approximately 20 per cent. less frontal area than given in the table.

153. **Cooling of Lubricating Oil in Automotive Installations.**—The primary functions of an engine lubricant are twofold (*a*) to avoid so far as be possible actual metallic contact of the sliding surfaces within the engine and (*b*) to carry away the heat generated by such sliding motion. One means of avoiding metallic contact is to ensure that the lubricant has sufficient viscosity (thickness) and since lubricant viscosity falls rapidly with increasing temperature, it is essential to prevent it reaching undesirable values by limiting its temperature. The advent of increased output engines places emphasis on the provision of additional means for cooling of the lubricant. In addition the load carrying capacity and, therefore, durability of the engine components is increased by limiting their maximum temperature. **If it be known therefore, that any vehicle is to spend a large part of its life at high speeds on motorways, use of oil cooling equipment is desirable and beneficial.**

In order to meet such conditions Gardner oil cooling equipment has been designed and perfected for LW and LW20 automotive type engines.

The equipment, which is described and illustrated in our Publication No. 762 comprises an oil to air heat exchange unit (oil cooler) of either 10- or 14-tube construction (according to climatic conditions) for mounting forward of the engine jacket coolant radiator on conventional forward engined vehicles and an

INSTALLATION INSTRUCTIONS AND RECOMMENDATIONS

COOLING SYSTEMS—*continued*

additional engine driven high pressure pump for circulating oil through the cooler and returning it to the engine. The correct application of these oil coolers for freight vehicles according to climatic conditions and duty are as follows:—

(*a*) Special Heavy Load Duty in temperate conditions	10-tube oil cooler
(*b*) For temperatures in excess of temperate	14-tube oil cooler

DUST PROOFING

154. In overseas territories where engines are required to operate in dust-laden atmospheres all apertures on the engine must be sealed against the entry of dust which otherwise would create abnormal wear in engine components.
During installation provision should be made to ensure that inducted air is properly and effectively filtered, as described in paras. 143 to 147.

ELECTRICAL EQUIPMENT

155. **Voltage.**—24 volt (min.) equipment is recommended for all vertical and horizontal LW Type engines.

156. **Alternator.**—A cradle is provided on the fuel pump side of the engine to accommodate the alternator which is positively driven from a sprocket incorporated in the timing drive. Cast integrally with the crankcase the cradle ribs are bored to receive the following sizes of alternator:—

2LW and 3LW	Up to 6½ in.	(165·1 mm.)	diameter
4LW, 5LW and 5LW20	,, ,, 7 in.	(177·8 mm.)	,,
6LW and 6LW20	,, ,, 8 in.	(203·2 mm.)	,,

The cradles are readily adapted to accommodate smaller diameter alternators by the provision of specially machined packing pieces, together with appropriate straps to ensure positive and accurate alignment for the drive shaft arrangement. The type of drive used depends upon the size of alternator fitted. In general, alternators below 7 in. (177·8 mm.) diameter are driven by the well-proven Gardner flexible hose type couplings and a hollow steel shaft, whilst with alternators of 7 in. (177·8 mm.) diameter or larger, the drive shaft embodies two disc type couplings one at each end of the shaft.
When a Hoburn Eaton hydraulic pump is incorporated in the drive arrangement, disc type couplings are interposed between driving sprocket and pump and between pump and alternator, but with the Plessey hydraulic pump the coupling arrangement between the driving sprocket and pump consists of two abutting sprockets linked together by a duplex chain.
All alternators, irrespective of size, are driven by a 15-tooth sprocket at 1·8 times crankshaft speed.

157. **Starter.**—Provision is made on the manifold side of the engine to accommodate a starter motor in a similar manner to the alternator. The standard mounting parts are designed to accommodate the following motors:—

C.A.V. U624A/15M	6 in. (152·4 mm.)	diameter
C.A.V. SL524/17M	5 in. (127 mm.)	,,

The above starter motors are suitable for use in a radio interference suppressed circuit.

158. **Battery.**—The size of battery will usually be determined by lamp load, but for engine starting only the recommended capacity is 100 ampere-hours at 10-hour rate.

159. **Cable Sizes.**—The minimum sizes of cable should be not less than the following:—

Battery to Starter	61/·044 in.	10 ft. (3,048 mm.) max.
Alternator to Control Board	226/·012 in.	15 ft. (4,572 mm.) max.
Field	1/·044 in.	,, ,, ,,
Switch to Starter	14/·012 in.	,, ,, ,,
Control Board to Battery	19/·044 in. or 266/·012 in.	,, ,, ,,
Warning Light	14/·012 in.	,, ,, ,,

INSTALLATION INSTRUCTIONS AND RECOMMENDATIONS

ENGINE CONTROLS

160. **Engine Speed Control.**—In order that the foot control be "light" it is necessary to arrange the geometry of the accelerator linkage so that the rods and levers are mutually at an angle of 90° when the accelerator lever is in a position 40° from the idling speed position. This provides the greatest leverage when the greatest effort is required and avoids heavy pedal pressure.
A foot control providing a pedal travel, at the point of application of the toe, of 4½ in. (114 mm.) is optimum.

ENGINE MOUNTINGS

161. **Gardner Flexible Engine Mounting Arrangement.**—In order to avoid the transmission of sound and vibration from the engine to the chassis it is most desirable that the engine be supported by some approved flexible means permitting a sufficient degree of engine movement about its natural axis. Such a scheme also relieves the engine unit of dangerous strains which can be imposed by chassis deformation.
The Gardner flexible mounting is the result of many year's experience and development of this subject and is in common use. A typical example as applied to the LW engine is shown in Figs. 41 and 42.
The forward end of the engine is supported by means of two rubber bushed "swing links" as shown in Fig. 42. The upper end of each link is bolted to some member integral with the chassis frame.
At the rear end the engine is carried by the bracket, cross bolt and large rubber bush as shown in part section in Fig. 41. The flat upper face of this bracket is bolted to one of the frame cross members. Combined with this bracket is an extended portion carrying a large circular upper and lower rubber collar. Torque reaction of the engine unit is contained by these rubber collars via the adjustable steel collars, stud and bracket attached to the side facing on the engine flanged end plate. The steel torque reaction stop collars should be adjusted as follows:—

Screw each collar up by hand only until they come into definite contact with the rubber collars and lock in this position. Overtightening of these stop collars will defeat the whole object of the flexible mounting arrangement.

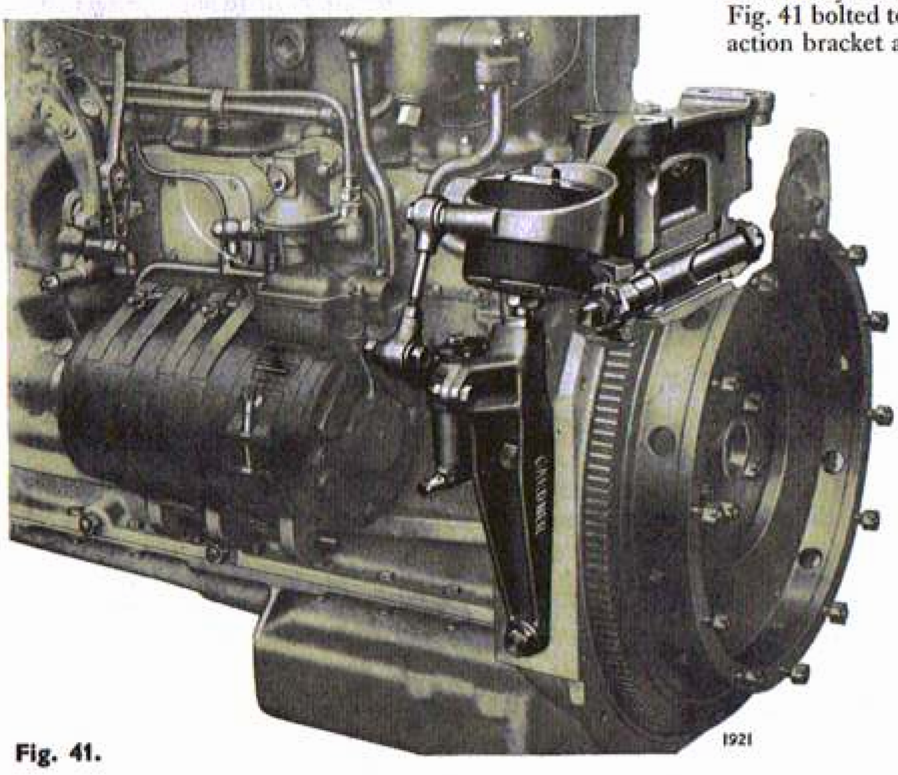


Fig. 41.

A small hydraulic damper will be seen in Fig. 41 bolted to the side of the torque reaction bracket and coupled by means of a rubber bushed link, to the frame bracket. The purpose of this damper is to avoid the build up of minor synchronous vibrations in the vehicle. After installation it is desirable to check that the damper is fully primed by disconnecting the link and moving the damper lever two or three times through its full travel. Beneath the damper body will be found a small cap nut which, when removed, will reveal a lock nut and adjusting screw. When delivered these dampers are adjusted to suit average requirements but for optimum results final adjustment must be carried out in individual installations.

INSTALLATION INSTRUCTIONS AND RECOMMENDATIONS

EXHAUST SYSTEM

162. **The Exhaust System** should impose a back pressure at the manifold of not more than approx. 10 in. (254 mm.) water gauge at full power. Any form of baffle type silencer will create pressure in excess of this figure. Maximum power economy and durability will not be available if the back pressure is in excess of this figure. Any of the well-known "straight through" absorption type silencers are recommended. These can be used singly or, for long systems, in pairs. Where maximum silencing is required the Works will be pleased to offer an alternative arrangement of silencer and resonator.

The overall length of the system should be as short as possible; with a minimum number of bends. If in excess of 18 ft. (5,486 mm.) the double silencer arrangement is recommended.

Tail pipes should have a length of 10–15 pipe diameters for maximum silencing efficiency.

The silencer should be mounted in a position from which heat cannot be radiated to the engine and under no circumstances placed beneath the crankcase sump, unless effectively heat insulated.

Any portion of the exhaust pipe in proximity to the crankcase and sump should be lagged.

The bore of silencers and pipes should be in accordance with the following sizes:—

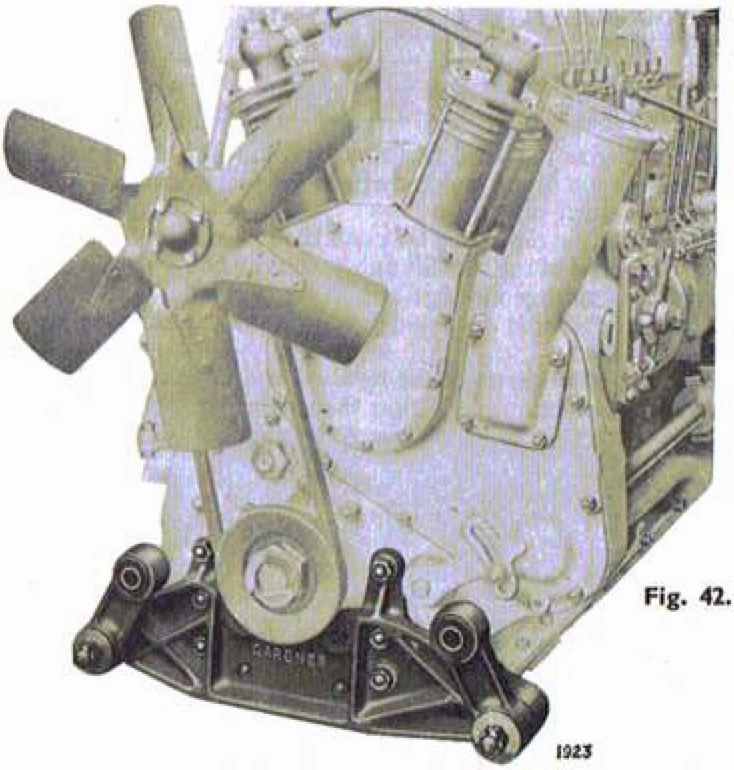


Fig. 42.

Engine	System Length 18 ft. Max. (5486 mm.)		System Length 36 ft. Max. (10973 mm.)			
	Single or Double Silencers		Double Silencers only			
	Silencers and all pipes		1st Silencer and engine pipe		2nd Silencer Intermediate and tail pipe	
	in.	mm.	in.	mm.	in.	mm.
2–3LW	2½	63·5	2½	63·5	2½	63·5
4LW and 4HLW ..	2½	63·5	2½	63·5	3	76·2
5LW, 5HLW and 5LW20	2⅝	66·7	2⅝	66·7	3	76·2
6LW, 6HLW and 6LW20	3	76·2	3	76·2	3½	88·9

GARDNER

INSTALLATION INSTRUCTIONS AND RECOMMENDATIONS

FUEL FEED SYSTEM

163. We recommend the use of Gardner Overflow Return system, incorporating an engine operated Amal Fuel Lift Pump, as shown on Drawing No. 3387H. It is very important that the provisions of this instructional drawing be strictly followed, to ensure an unfailing fuel feed arrangement.
Fuel pipe sizes are important and minimum sizes should be as follows:—

Pipework	Up to 10 ft. (3048 mm.)	10 ft. to 18 ft. (3048 mm. to 5486 mm.)
Between fuel tank and intermediate strainer Between intermediate strainer and lift pump	⅜ in. o.d. — 18G (9·5 mm.)	7/16 in. o.d. — 18G (11·1 mm.)
Overflow return pipe to fuel tank	⅜ in. o.d. — 18 or 20G (9·5 mm.)	

The overflow return pipe between the engine mounted fuel filter and the fuel tank must be arranged to have a continuous fall and to feed into the top of the tank, otherwise the fuel injection pumps may become de-primed due to syphon effect of the return pipe.
The suction pipe should be taken out from the top of the tank and the intermediate ("First") filter placed above maximum fuel level but below the level of the fuel lift pump, thus avoiding the need for a stop cock.
It is advantageous and highly desirable to arrange a sludge trap in the main fuel tank with suitable drain plug, so placed in relation to the suction pipe that only sludge-free fuel is drawn into the system.

164. **Flywheel.**—It is recommended that the total inertia of the flywheel and clutch should be as small as is practicable. In general, the lightest assembly obtainable is more than sufficient to reduce cyclic irregularity to a satisfactory minimum and the advantages to be gained are very important.

165. **Gear Ratios.**—The Works Technical Staff are always ready to offer advice upon the selection of gear box and axle ratios to provide optimum performance with minimum fuel consumption.

166. **Sound Insulation.**—We recommend that the bonnet and engine side of the bulkhead should be lined with one of the highly efficient materials specially developed for this purpose.
The effectiveness of sound insulation is greatly enhanced by a fully flexible engine mounting and the advantages, in the case of automotive installations, amply justify additional costs.
Alternatively, felt, rubber sheet, and sprayed-on sound deadening materials are very valuable, if properly applied.

SPACE REQUIRED FOR REMOVAL OF COMPONENTS

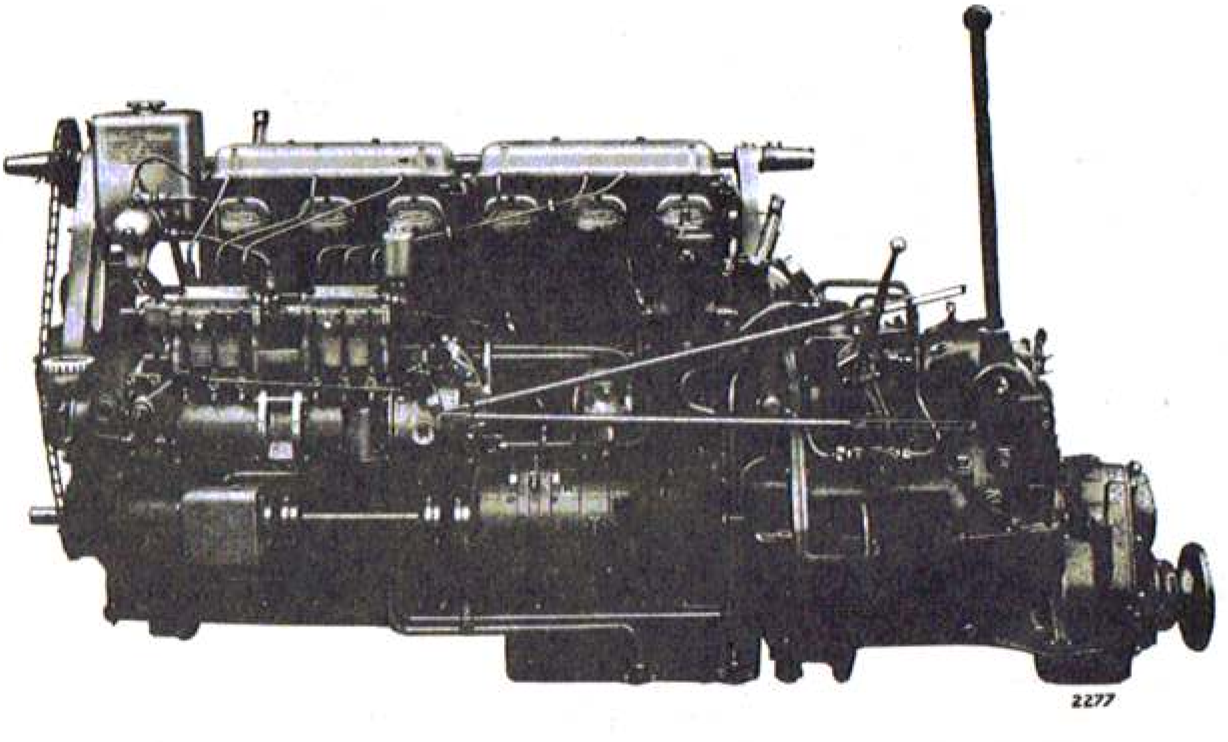
167. To facilitate routine maintenance work and the removal and replacement of major components, the following clear space should be provided between points on the engine and fixed portion of the installation:—

(*a*) Crankcase Sump (Standard: Type 11) Vertical Engines .. .. .. 4½ in. (114 mm.)
Space required for removal of non-standard types of sumps will be supplied upon request.
(*b*) Crankcase Sump (Horizontal Engines) Main Oil Reservoir .. .. .. 1¼ in. (32 mm.)
(*c*) Crankcase Sump (Horizontal Engines) Base Chamber .. .. 11⅛ in. (283 mm.)
(*d*) Cylinder Heads .. .. 5⅛ in. (203 mm.)
(*e*) Cylinder Block (with pistons *in situ*) .. .. 10 in. (254 mm.)
(*f*) Lubricating Oil Delivery Filter Element .. .. 8 in. (203 mm.)
(*g*) Fuel Filter Cover (on cylinder head) .. .. 4 in. (102 mm.)
(*h*) Centrifugal Water Circulating Pump .. .. 2 in. (51 mm.)
(*i*) Chain Case Cover .. .. 2⅞ in. (73 mm.)

168. **Access to Timing Marks on Flywheel.**—Free access should be provided to the timing lines on the periphery of the flywheel at a point directly above the crankshaft, with a view of the zero line at the base of the cylinder block or on the flywheel housing. Alternatively, if this position cannot be made accessible, there is provided in the flange of the crankcase endplate, a port through which can be seen radial lines on the forward face of the flywheel for No. 1 cylinder T.D.C. and injection timing.

GARDNER

LW TYPE
MARINE DIESEL ENGINES



2277

6LW Marine Propulsion Unit fitted with Gardner Single Lever Control for engine speed and reverse gear operation.

SUPPLEMENTARY INSTRUCTIONS FOR THE OPERATION OF MARINE ENGINES TO BE USED IN CONJUNCTION WITH LW TYPE INSTRUCTION BOOK NO. 56·6 (or later issue) AND NO. 2 U.C. REVERSING AND REDUCING GEAR INSTRUCTION BOOK NO. 44·3 (or later issue).

GARDNER

DESIGNATION

LW denotes the mark of the engine, the numeral denotes the number of cylinders. 4LW, for example, denotes the LW series engine of four cylinders. Standard Engines have an anti-clockwise rotation looking from aft suitable for a left-hand propeller. When either a 2 : 1 or 3 : 1 reducing gear is fitted the tail shaft rotation is reversed, requiring a right-hand propeller.

Engines can be offered having opposite rotation, as in the case of twin screw installations or other special applications, but this must be clearly specified and for which there is a small extra charge.

GENERAL DATA AND POWER OUTPUT

FOR HEAVY DUTY COMMERCIAL AND SIMILAR CRAFT
Cast Iron or Aluminium Construction Engine, Reverse Gear and Reducing Gear

Engine	Swept Volume		B.H.P.	R.P.M.	Approximate Weights (lb.)						Drawing No.
					Direct Drive		2 : 1 Reducing Gear		3 : 1 Reducing Gear		
	Litre	in.³			Aluminium	Cast Iron	Aluminium	Cast Iron	Aluminium	Cast Iron	
2LW	2·8	170	28	1300	—	1,792	—	1,988	—	2,044	12800
3LW	4·2	255	42	1300	1,736	2,100	1,876	2,296	1,916	2,352	12801
4LW	5·6	340	56	1300	1,848	2,240	1,988	2,436	2,028	2,492	12802
5LW	7·0	426	70	1300	2,044	2,464	2,184	2,660	2,224	2,716	12803
6LW	8·4	511	84	1300	2,240	2,688	2,380	2,884	2,420	2,940	12804

FOR YACHTS, CRUISERS, AUXILIARY VESSELS and other MARINE use as distinct from commercial craft, which may operate continuously at maximum hours per annum.
Cast Iron or Aluminium Construction Engine, Reverse Gear and Reducing Gear

Engine	Swept Volume		B.H.P.	R.P.M.	Approximate Weights (lb.)						Drawing No.
					Direct Drive		2 : 1 Reducing Gear		3 : 1 Reducing Gear		
	Litre	in.³			Aluminium	Cast Iron	Aluminium	Cast Iron	Aluminium	Cast Iron	
2LW	2·8	170	31	1500	—	1,792	—	1,988	—	2,044	12800
3LW	4·2	255	47	1500	1,736	2,100	1,876	2,296	1,916	2,352	12801
4LW	5·6	340	62	1500	1,848	2,240	1,988	2,436	2,028	2,492	12802
5LW	7·0	426	78	1500	2,044	2,464	2,184	2,660	2,224	2,716	12803
6LW	8·4	511	94	1500	2,240	2,688	2,380	2,884	2,420	2,940	12804

FOR HIGH SPEED CRAFT
Aluminium Construction Engine, Reverse Gear and Reducing Gear

Engine	Swept Volume		B.H.P.	R.P.M.	Approximate Weights (lb.)			Drawing No.
	Litre	in.³			Direct Drive	2 : 1 Reducing Gear	3 : 1 Reducing Gear	
4LW	5·6	340	71	1700	1,736	1,876	1,916	12802
5LW	7·0	426	89	1700	1,932	2,072	2,112	12803
6LW	8·4	511	107	1700	2,128	2,268	2,308	12804

The above tables give the powers developed at **normal atmospheric temperature and pressure.** They are net values and represent installed performance except for deductions on account of any auxiliaries or inadequate induction or exhaust systems.

For adverse climatic conditions, engines are de-rated in accordance with the engine Instruction Manual.

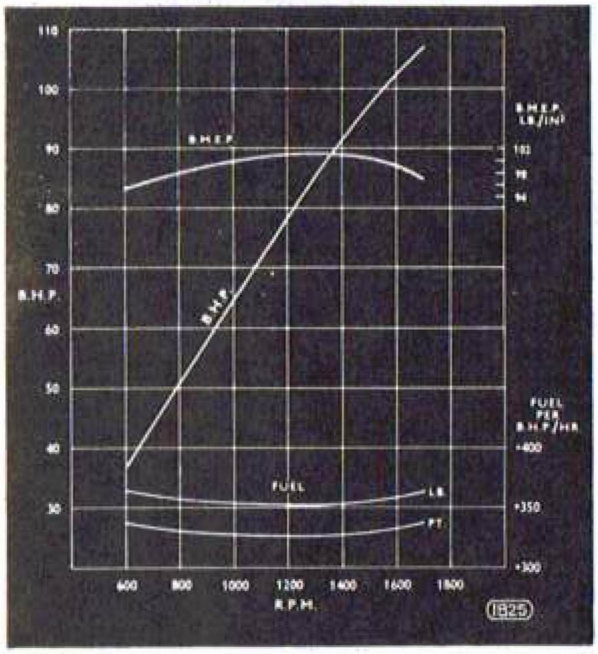
The weights quoted include:
1300 and 1500 r.p.m. units: Hand Starting equipment only and heavy design flywheel.
1700 r.p.m. units: Electric Starting equipment only and light design flywheel.

GARDNER

LW

MARINE DIESEL ENGINES

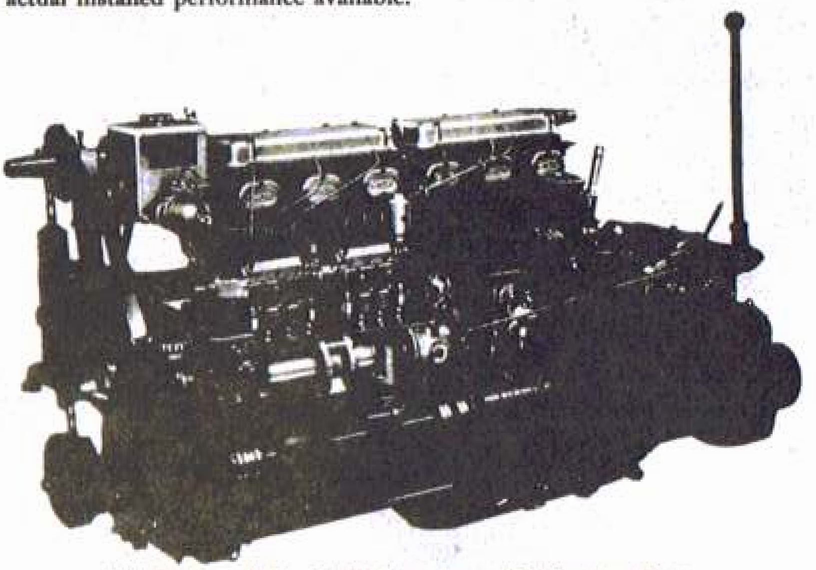
PERFORMANCE CURVES



1,700 R.P.M.

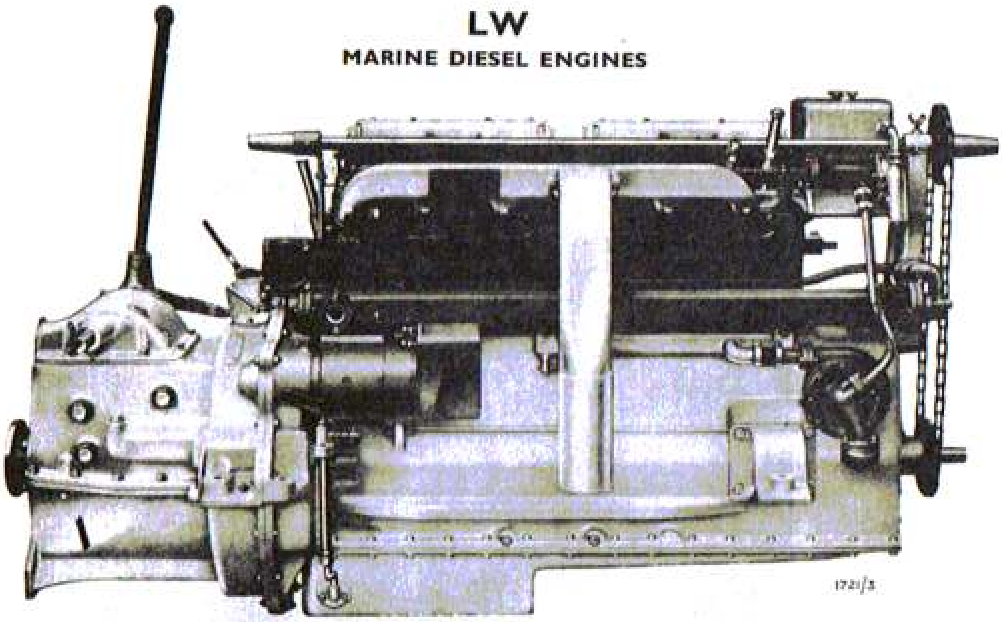
The above are the performance curves of the six-cylinder LW engine at 1,700 R.P.M. The power and torque of the other sizes of engines are approximately as above but proportionate to the number of cylinders and the R.P.M. The fuel consumption and mean effective pressure remains sensibly constant for all numbers of cylinders.

These curves are made from figures regularly observed during normal production tests of the engines, and represent the actual installed performance available.

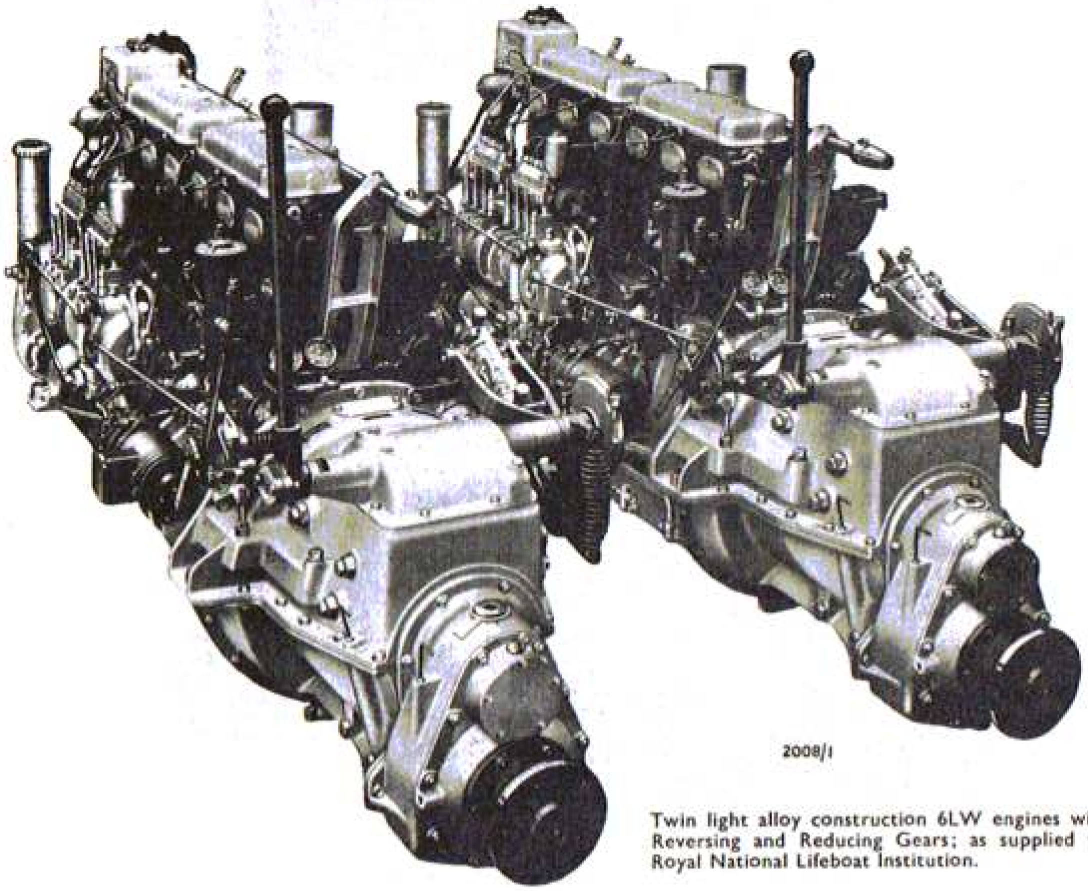


6LW Engine with No. 2 U.C. Reversing and 2:1 Reducing Gears.

LW
MARINE DIESEL ENGINES

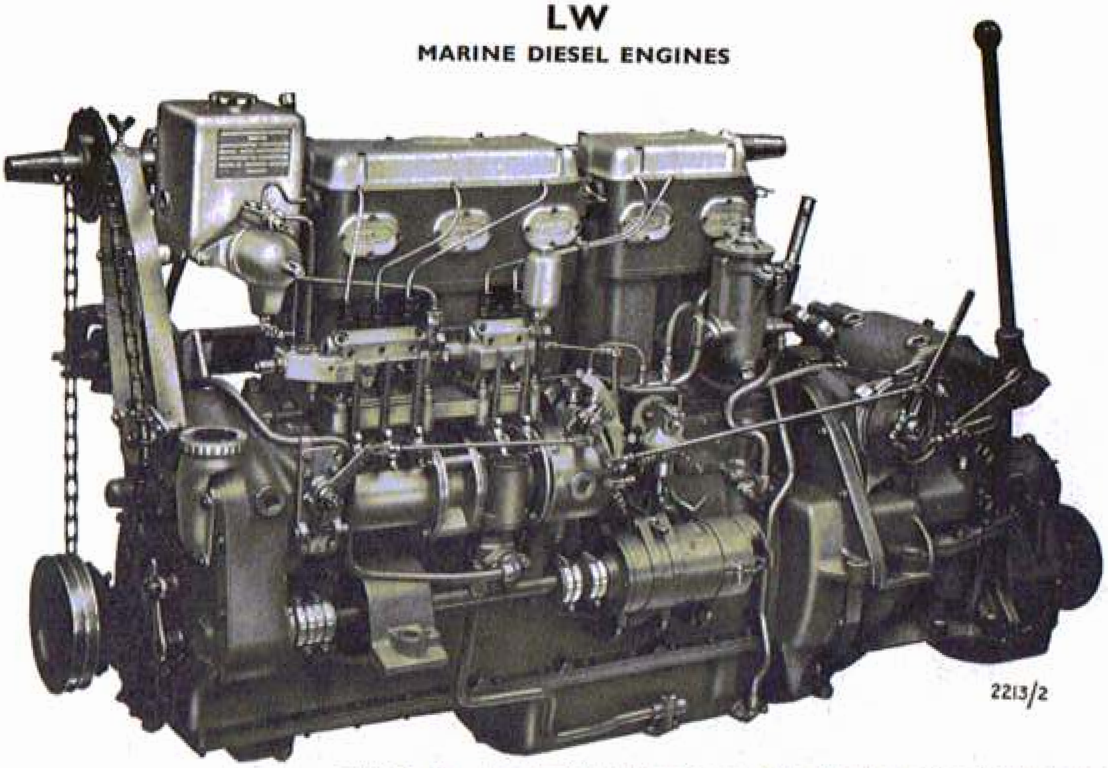


Light alloy construction 6LW Engine and Reverse Gear Unit arranged for direct drive to propeller shafting.



Twin light alloy construction 6LW engines with 2:1 Reversing and Reducing Gears; as supplied to the Royal National Lifeboat Institution.

LW
MARINE DIESEL ENGINES



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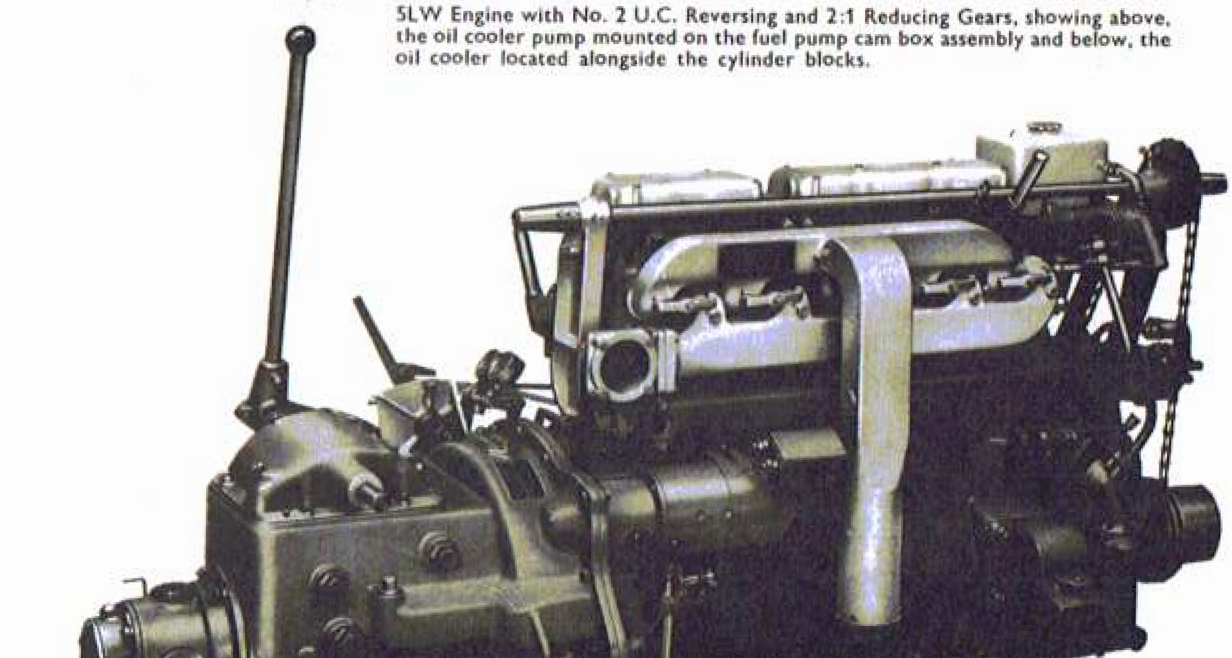
5LW Engine with No. 2 U.C. Reversing and 2:1 Reducing Gears, showing above, the oil cooler pump mounted on the fuel pump cam box assembly and below, the oil cooler located alongside the cylinder blocks.



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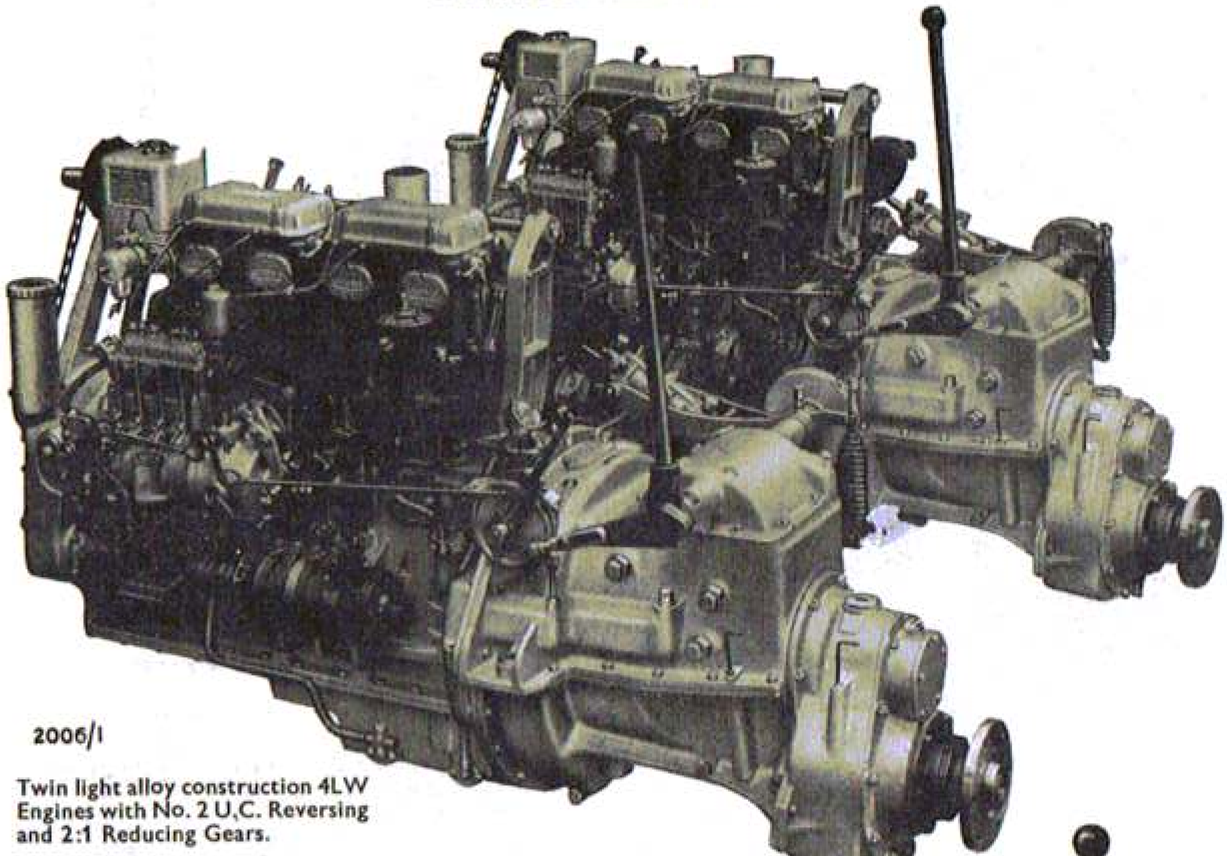
GARDNER

LW

MARINE DIESEL ENGINES



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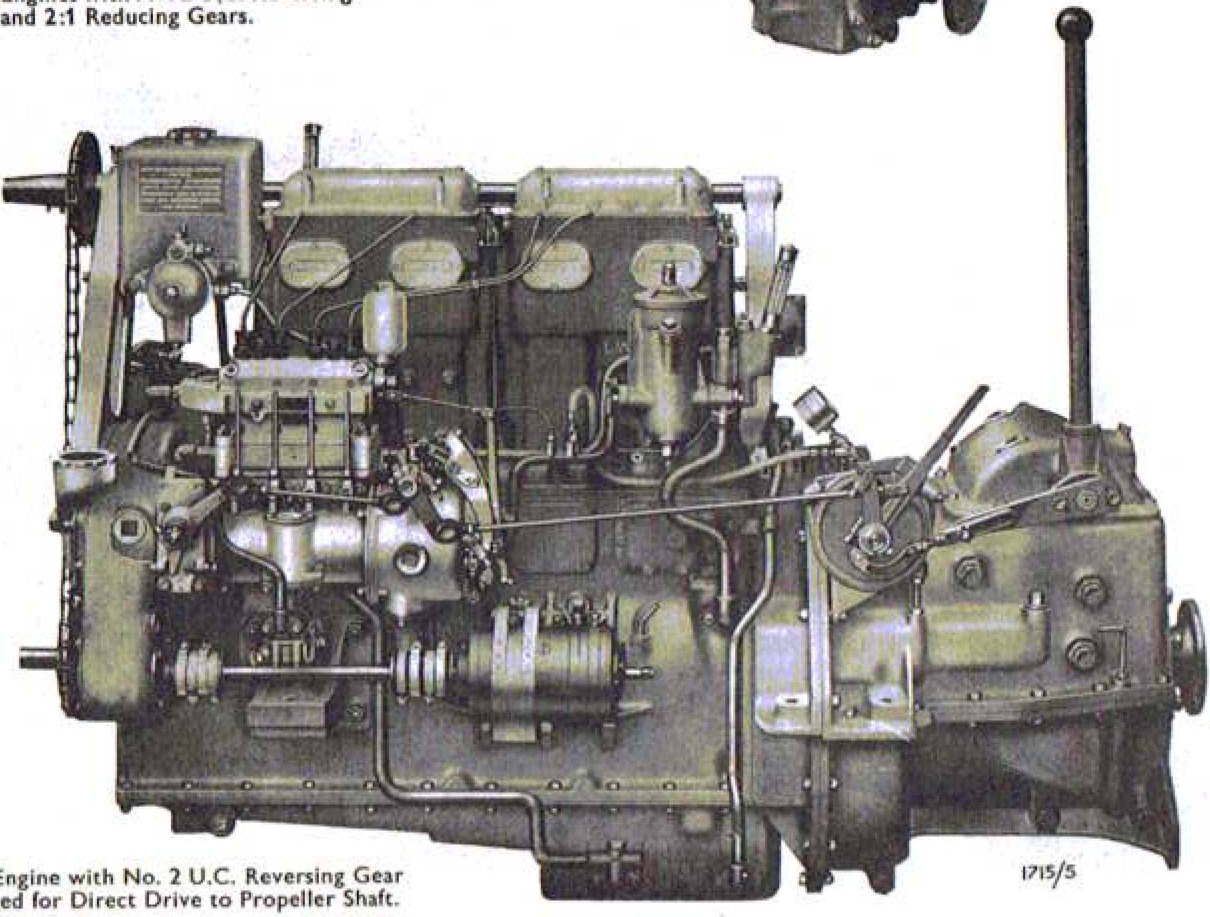
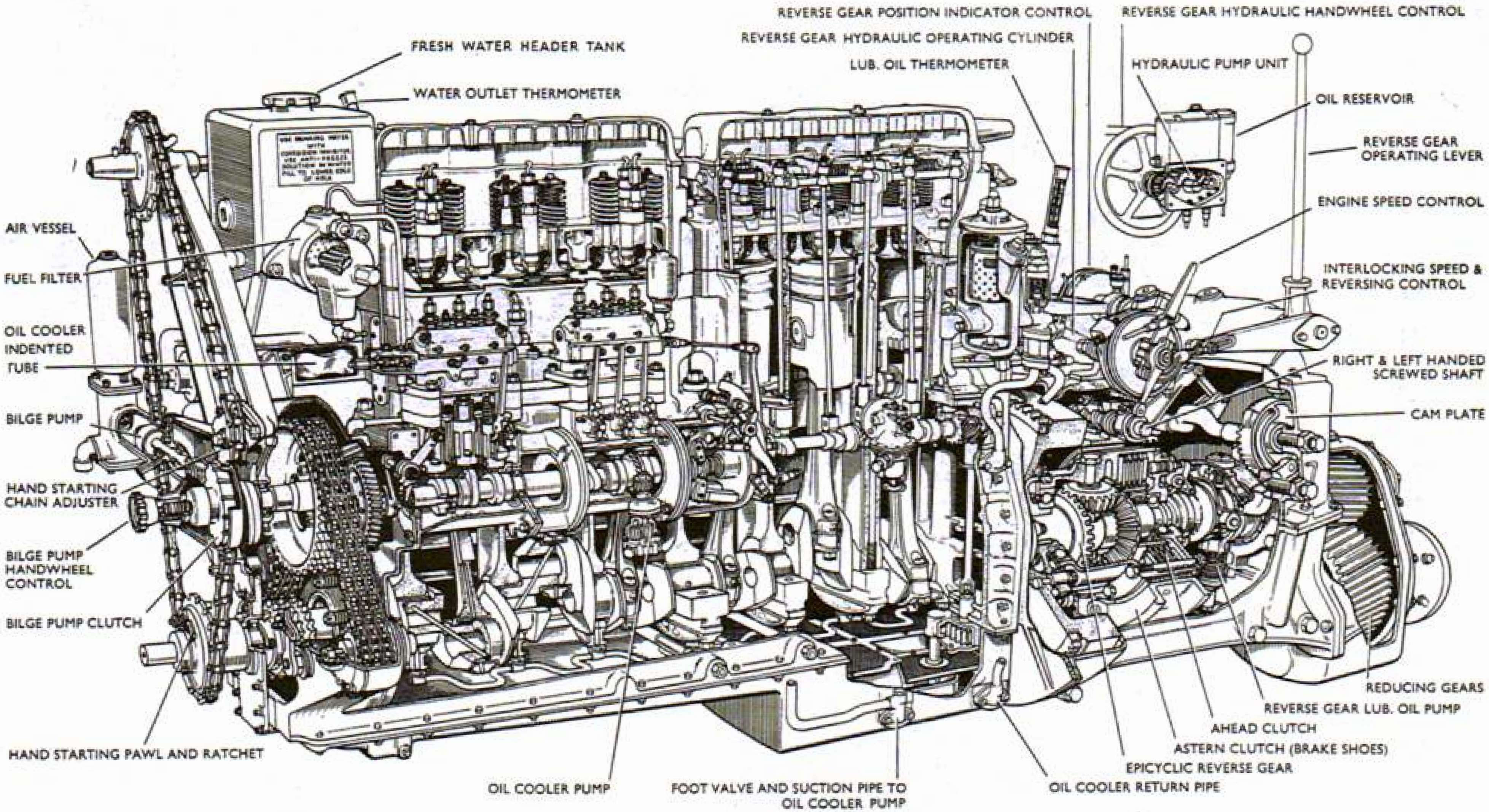
Twin light alloy construction 4LW Engines with No. 2 U.C. Reversing and 2:1 Reducing Gears.



4LW Engine with No. 2 U.C. Reversing Gear arranged for Direct Drive to Propeller Shaft.

1715/5



GARDNER

6 LW MARINE ENGINE WITH REVERSING AND REDUCING GEAR

2073 A/2

GARDNER

LW

MARINE DIESEL ENGINES

INDEX

The numbers refer to paragraphs only

GARDNER

LW

MARINE DIESEL ENGINES

INTRODUCTION

The following information deals with certain items which are special to LW Marine type engines and the information now given is supplementary to standard Instruction Book No. 56·6 (or later issue) for LW engines. Detailed instructions in respect of the No. 2 U.C. Reversing and Reversing-Reducing Gear fitted to LW Marine engines are contained in Instruction Book No. 44·3 (or later issue).

1. **Engine Lifting Eye Nuts.**—The following information regarding correct procedure for fitting of these nuts is given in view of a recent case where a cylinder head stud was bent during installation of the engine and the stud consequently loosened due to incorrect slinging procedure. These eye nuts have always carried a label recommending the use of a spreader.

   From investigations we have made on the effect of cylinder head nut tightness after the eye nuts have been screwed down tightly on to the cylinder head nuts by means of a bar or lever, it has been found that Cylinder Head Nut tightness can be (*a*) unaffected, (*b*) partially affected, (*c*) considerably loosened or (*d*) the stud withdrawn. Accordingly, it has been considered desirable to issue instructions to the effect that this practice is incorrect and that the eye nuts should be screwed fully home *by fingers only* in order to avoid risk of reducing the correct tightness of the nuts.

   The label (No. A.I.180) attached to all eye bolts, reads as follows when applied to LW engines:—

   > Incorrect slinging or applications of eye nuts can result in damaging or loosening the cylinder head holding down studs by either (*a*) bending the studs due to sideways pull caused by lack of use of spreader, or by sideways pull caused by heavy component attached to end of engine causing unbalance or, (*b*) by screwing up eye nuts tightly with bar or lever causing stud to be withdrawn or slackened on removal.
   >
   > In order to avoid (*a*), it is essential that a spreader be used — see diagram — between the slings in order to secure a straight pull on the eye nuts and to arrange the apex of the sling midway between these points.
   >
   > In order to avoid (*b*), screw eye nuts fully home to cylinder head nut . . . with fingers only: do not use bar or lever. Slacken eye nut a portion of one turn if required to engage sling or hook . . .
   >
   > Replace brass cap after removing lifting eye nuts on marine engines.

   The correct tightening torque for all LW engine Cylinder Head Nuts is 1,000 lb./in.

2. **Alignment of Engine and Propeller Shafting.**—Full information regarding Dimensions, Location, Quantity and combination of shims of varying thicknesses which are available for insertion between engine unit supporting feet and engine bearers to obtain accurate alignment of engine and propeller shafting are detailed in the following tables.

   This information is also listed in LW and HLW Workshop Tools Book No. 48·2 (or subsequent issue).

To obtain alignment within ·003 in. and to obtain a total thickness of shims between ·003 in. and $\frac{1}{16}$ in. with steps not greater than ·003 in., it is necessary to have available shims of the following thickness and quantity for each individual foot on the Engine Reverse Gear Unit.

4 off shims ·003 in. thick
3 ,, ,, ·007 in. ,,
2 ,, ,, ·032 in. ,,

With these shims it is possible to obtain a total thickness as per the table below.

Total Thickness of Shims	QUANTITY OF SHIMS TO BE USED			Total Thickness of Shims	QUANTITY OF SHIMS TO BE USED		
	·003"	·007"	·032"		·003"	·007"	·032"
·003"	1	–	–	·035"	1	–	1
·006"	2	–	–	·038"	2	–	1
·007"	–	1	–	·039"	–	1	1
·009"	3	–	–	·041"	3	–	1
·010"	1	1	–	·042"	1	1	1
·012"	4	–	–	·044"	4	–	1
·013"	2	1	–	·045"	2	1	1
·014"	–	2	–	·046"	–	2	1
·016"	3	1	–	·048"	3	1	1
·017"	1	2	–	·049"	1	2	1
·019"	4	1	–	·051"	4	1	1
·020"	2	2	–	·052"	2	2	1
·021"	–	3	–	·053"	–	3	1
·023"	3	2	–	·055"	3	2	1
·024"	1	3	–	·056"	1	3	1
·026"	4	2	–	·058"	4	2	1
·027"	2	3	–	·059"	2	3	1
·030"	3	3	–	·062"	3	3	1
·032"	–	–	1	·064"	–	–	2
·033"	4	3	–				

Location of Shims	Dimensions of Shim	Drawing No.	Number of Supporting Feet	Total number of Shims to be supplied per each Engine Reverse Gear Unit				
				2LW	3LW	4LW	5LW	6LW
Eng. Side Supporting Feet	4" × 2⅛" × ·003" 4" × 2⅛" × ·007" 4" × 2⅛" × ·032"	J7253 J7254 J7255	2	– – –	– – –	8 6 4	8 6 4	8 6 4
	3¼" × 2¼" × ·003" 3¼" × 2¼" × ·007" 3¼" × 2¼" × ·032"	J7259 J7260 J7261	2	8 6 4	8 6 4	– – –	– – –	– – –
Reversing Gear Supporting Feet	5⅞" × 2" × ·003" 5⅞" × 2" × ·007" 5⅞" × 2" × ·032"	J7256 J7257 J7258	2	8 6 4	8 6 4	8 6 4	8 6 4	8 6 4

It is of prime importance that the engine and reverse gear or the engine with reverse and reduction gears be carefully and accurately aligned with the propeller shafting when initially installed. This alignment should also be very fully checked periodically and corrected as necessary by the fitting of suitable thickness packings (i.e. shims as above mentioned) between the engine unit and engine bearers. Serious damage can occur in the reverse gear or reduction gear if correct alignment is not maintained and to facilitate adjustment of alignment all supporting feet on 2LW to 6LW marine engines are tapped to receive $\frac{7}{16}$" B.S.F. jacking screws.

Alignment of the shafting is made in the usual manner by splitting the engine half-coupling from the shafting half-coupling and testing by feeler gauge to ensure that both faces meet solidly and spigot diameters enter freely when drawn together by hand, also that no gap is evident by testing with feeler gauge irrespective of position of shafting couplings, when rotated separately to any position through one or more complete turns.

When adjusting the shim packings beneath the engine and reverse gear supporting feet it is most important that all feet are carrying their proper proportion of the total weight. When checking the shaft alignment the craft should, of course, be afloat and on an even keel.

3. **Sterngear: Shaft and Propeller Sizes.**—To conform to Lloyd's Rules (1953), intermediate and tail shaft diameters are to be not less than the dimensions quoted in the following table. The sizes quoted are for shafts not fitted with continuous liners and made from ordinary mild steel, having an ultimate tensile strength of 28 to 32 tons per sq. in.

STEEL SHAFT SIZES TO CONFORM TO LLOYD'S RULES (1953)

Engine	B.H.P.	DIRECT DRIVE			2:1 REDUCING GEAR			3:1 REDUCING GEAR		
		R.P.M.	Intermediate Shaft	Tail Shaft	R.P.M.	Intermediate Shaft	Tail Shaft	R.P.M.	Intermediate Shaft	Tail Shaft
2LW	28	1,300	1·121"	1·354"	663	1·404"	1·715"	439	1·610"	1·985"
3LW	42	1,300	1·283"	1·548"	663	1·606"	1·955"	439	1·843"	2·280"
4LW	56	1,300	1·413"	1·705"	663	1·768"	2·155"	439	2·029"	2·500"
5LW	70	1,300	1·495"	1·810"	663	1·872"	2·290"	439	2·147"	2·675"
6LW	84	1,300	1·566"	1·892"	663	1·959"	2·383"	439	2·248"	2·780"
2LW	31	1,500	1·106"	1·331"	756	1·353"	1·651"	507	1·588"	1·958"
3LW	47	1,500	1·271"	1·524"	756	1·590"	1·939"	507	1·824"	2·247"
4LW	62	1,500	1·393"	1·672"	756	1·744"	2·120"	507	2·000"	2·460"
5LW	78	1,500	1·478"	1·770"	756	1·855"	2·252"	507	2·121"	2·617"
6LW	94	1,500	1·549"	1·856"	756	1·939"	2·355"	507	2·224"	2·750"
4LW	71	1,700	1·398"	1·668"	866	1·711"	2·077"	574	2·006"	2·460"
5LW	89	1,700	1·481"	1·768"	866	1·855"	2·248"	574	2·126"	2·610"
6LW	107	1,700	1·552"	1·852"	866	1·943"	2·350"	574	2·227"	2·740"

Intermediate shafts having lengths in excess of 6 ft. should be supported by a plummer block. The plummer block should be positioned not less than 4 ft. from the reducing or reversing gear intermediate shaft half-coupling.

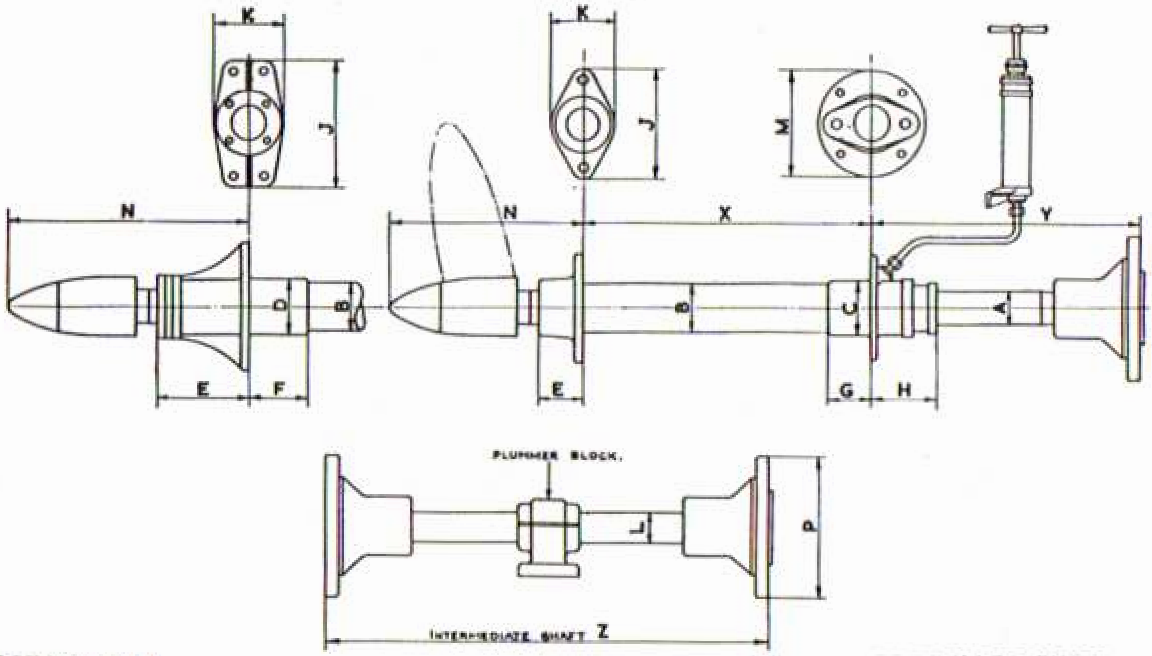
Reduction gears referred to as 2:1 and 3:1 are actually 1·962:1 and 2·960:1, respectively.

GARDNER

LW

MARINE DIESEL ENGINES

The following are the approximate dimensions of bronze Sterngear with white metal bearings for wooden vessels. Confirmation and precise dimensions must be obtained from the Works before installation.



STERNGEAR SIZES

ENGINE	DESCRIPTION	A Tail Shaft	B	C	D	E	F	G	H	J	K	L	M	N	P
2LW	DIRECT DRIVE	1⅝" Dia.	2⅝"	2½"	—	2¼"	—	2⅝"	3"	5⅛"	3"	1½"	4½"	9"	6½"
	2:1 RED. GEAR	1⅞" ..	2½"	2⅞"	—	2½"	—	2⅞"	3⅞"	5⅞"	3½"	1½"	5"	9⅞"	8½"
	3:1	2⅛" ..	3"	3⅜"	3⅜"	6"	4⅜"	3⅝"	4⅝"	7⅜"	4½"	1¾"	7¼"	16"	8½"
3LW	DIRECT DRIVE	1⅞" Dia.	2⅞"	2¾"	—	2½"	—	2⅞"	3"	5¼"	3⅜"	1⅞"	5"	9⅝"	6½"
	2:1 RED. GEAR	2" ..	2¾"	3¼"	3¼"	5¾"	4¼"	3⅛"	3⅞"	7⅞"	5"	1⅞"	6¼"	14⅛"	8½"
	3:1	2⅜" ..	3⅜"	3⅞"	3⅞"	5½"	6¼"	4"	4"	7"	4⅝"	2"	7⅝"	15½"	8½"
4LW	DIRECT DRIVE	1¾" Dia.	2½"	2¾"	—	2½"	—	2⅞"	3⅜"	5⅝"	3½"	1½"	5"	9⅝"	6½"
	2:1 RED. GEAR	2¼" ..	3"	3½"	3½"	5½"	5½"	3¾"	4⅝"	7½"	4⅝"	1¾"	7"	14⅛"	8½"
	3:1	2⅜" ..	3½"	4"	4"	6½"	6⅜"	5¼"	5"	9"	5"	2½"	7¼"	17¼"	8½"
5LW	DIRECT DRIVE	1⅞" Dia.	2⅞"	3"	—	2⅞"	—	2⅞"	3⅞"	6¼"	3½"	1⅞"	6¼"	10⅞"	6½"
	2:1 RED. GEAR	2⅜" ..	3⅜"	3⅞"	3⅞"	5½"	6¼"	4"	4"	7"	4⅝"	1⅞"	7⅝"	15½"	8½"
	3:1	2¾" ..	3½"	3⅝"	3⅝"	6½"	6⅞"	5¼"	5"	8¾"	5"	2¾"	7⅞"	17½"	8½"
6LW	DIRECT DRIVE	2" Dia.	2¾"	3¼"	3¼"	5¾"	4½"	3⅛"	3⅞"	7⅞"	5"	1⅞"	6¼"	14⅛"	6½"
	2:1 RED. GEAR	2½" ..	3⅜"	3¾"	3¾"	6¼"	6"	4⅜"	4⅝"	8½"	5"	2"	7¾"	16½"	8½"
	3:1	2⅞" ..	3¾"	4¼"	4¼"	7"	7"	5¼"	4⅞"	8"	5½"	2½"	8½"	18¾"	8½"

PROPELLER SIZES

ENGINE	ENGINE SPEED r.p.m.	3 BLADE PROP. DIAM. (in.) Direct	2 : 1	3 : 1
2LW	1300	17·5	24	29·5
	1500	17	23	29
	—	—	—	—
3LW	1300	20	27	34
	1500	19	27	33
	—	—	—	—
4LW	1300	22	30	37
	1500	21	29	36
	1700	20	28	35
5LW	1300	24	32	40
	1500	22	31	39
	1700	21	30	38
6LW	1300	25	33	42
	1500	23	32	41
	1700	22	31	40

Dimensions X and Y must be supplied by clients when ordering sterngear, also dimension Z if intermediate shaft is required. Propeller sizes are approximate and may vary according to the lines of the vessel. Four blade propellers can be supplied but are not recommended for shaft speeds above 700/800 r.p.m. Direct Drive Engines require L.H. propellers, engines with Reducing Gears require R.H. propellers.

4. **Ventilation of Engine Room—Marine Installations.**—In many boats it has been observed that the engine-room ventilation is inadequate. It is of importance that provision be made to permit hot air to pass out and cool air to pass into the engine-room thus assisting in general cooling and ventilation; also allowing the required quantity of air to enter the engine compartments.
Inlet and outlet cowls and trunks creating natural draft accomplish this in some vessels. In others, electrically-driven extractor fans will change the engine-room air some 30 to 35 times per hour.
In fishing vessels and similar craft some degree of ventilation can be provided by a simple and inexpensive arrangement of placing the silencer inside a funnel which can be fitted either inside or outside the deck-house. In addition to the engine exhaust gases creating a suction effect within the funnel and thus extracting hot air from the engine room, the convection currents around the silencer assist in reducing the engine-room temperature.

Installation drawings are also available upon request from the Works, and we shall be pleased to give any further advice that may be required in this connection. It must be remembered that adequate engine-room ventilation is also vital for the well-being of the hull.

5. **Closed Circuit Fresh Water Cooling Systems.**—In order that corrosion scale and silt formation, etc., within the cooling system of marine propelling and marine auxiliary type engines shall be held to a minimum, it has long been our established practice to recommend a closed circuit fresh water system in preference to the circulation and discharge overboard of sea water.
Such a system may comprise:—
    1. A heat exchanger system with engine-driven sea water pump.
    2. A keel cooler system.
    3. An air-cooled radiator with engine-driven fan.

6. **Heat Exchanger Systems.**—An inboard mounted heat exchanger system with engine-driven sea water circulating pump, strainer, valves, etc., have been widely used and represents sound practice. In addition, it remains the only reasonably practicable closed circuit fresh water system for the cooling of engines in marine craft which have to operate at full power with the vessel at rest, except for an air cooled radiator system which is advantageous for certain applications only.
Diagrammatic arrangement drawings of fresh water cooling systems comprising Heat Exchanger, engine-driven Centrifugal Sea Water Pump and engine-mounted Fresh Water Header Tank, etc., for LW marine engines are shown on pages 24 and 25. These drawings show arrangements for engines having a dry exhaust system, and for engine installations with a quenched (water cooled) exhaust system.

7. **Keel Cooler Systems.**—On page 26 will be found diagrammatic arrangement drawings of the closed circuit fresh water cooling system employing a Keel Cooler. It consists of a series of pipes of selected length and diameter mounted externally and running fore and aft on the hull of the vessel through which is passed the engine (fresh) cooling water by means of the inbuilt engine circulating pump.
Accordingly there has been established a range of complete Gardner keel cooling equipment matching the complete range of Gardner marine propulsion engine units for temperate and tropical conditions possessing the following advantages:—
    1. The provision of a fresh water system at minimum expense, of minimum weight, minimum bulk and maximum simplicity.
    2. The provision of a system free from silting and corrosion.
    3. The provision of a system of maximum reliability independent of sea water circulation by separate pump and strainer equipment, etc.

The pipes, respective skin fittings and support bracket, which are of suitable material in order to avoid so far as be possible electrolytic or corrosive action, may be protected from grounding, etc., by hull features.

The inside diameter and total length of pipe is dependent on the size of the

engine to be used and also on the prevailing climatic conditions and sea water temperature. Air mean ambient, sea water temperature, frame spaces and width of frames, should be stated at time of ordering.
The length "X" as shown on this drawing is the total length of exposed pipe which is divided in four equal parts, and which should be shaped to follow the hull design as closely as possible before final assembly.
The standard lengths and bores of pipes established are based on a minimum full power boat speed of 5 knots. For vessels having a design speed of less than 5 knots and for other engine duty, special consideration is required and such application should be referred to our Technical Department.

8. **Air-cooled Radiator Systems.**—For the cooling of engines for example in barges, etc., used in inland waterways on which it may be impracticable to use an externally mounted keel cooler system, a Gardner combined radiator and oil cooler with engine-driven fan, is desirable equipment. Such a system is, however, dependent upon the practicability of providing such ducting as will permit of an unrestricted flow of air at external atmospheric temperature to the radiator and the free exit of heated air from the engine room.

9. **Centrifugal Type Pump.**—Where engines are cooled by fresh water through the medium of a keel cooler, an air cooled radiator or sea water cooled heat exchanger, centrifugal type circulating water pumps are fitted.
These centrifugal type pumps are mounted on the manifold side of the engine and driven by helical gears from the valve camshaft. The gears are arranged to drive the pump at crankshaft speed.
The impeller spindle is spring loaded in an endwise direction on to a spherical faced carbon gland to form the water seal. This type of water pump and its maintenance is described in the Instruction Book No. 56·6, paragraph 73 to 76.

10. **Water Temperature Control: Closed Circuit Systems.**—The centrifugal type pump permits the use of automatic temperature control which is performed by a thermostatically controlled valve fitted to the water outlet pipe on the engine.
Until a temperature of 137°F. is exceeded all the circulating water is diverted through the by-pass on the engine, thus there is no circulation through the keel cooler, heat exchanger or radiator so giving a rapid "warm-up".
As the temperature increases the thermostatically controlled valve gradually opens, so closing the by-pass port and opening the main valve, to permit a progressively increasing volume of water to flow through the keel cooler or heat exchanger, etc.
When a temperature of 172° F. is reached the by-pass port is finally closed and all the circulating water is pumped through the keel cooler or heat exchanger.
Water outlet temperature, under normal running conditions, should be 142°F.

11. **Cooling Water Additives.**—While it is generally known that cooling by a closed circuit fresh water system reduces engine water jacket corrosion to minimum proportions, it should, nevertheless be mentioned that a small addition of "Aqua Clear" to such cooling water still further reduces the remaining slight corrosive action, and of course reduces discolouration of the water.
Where engines have to be cooled by circulation of "raw" sea or contaminated fresh water, it is recommended that an "Aqua Clear" dispenser is interposed in the water pump suction pipe.

12. **Direct "Raw" Sea Water Cooling.**—Where engines are cooled by an "open" circuit (direct sea water cooling) system, an engine mounted plunger (ram) type pump is employed to circulate the raw water through the cylinder water jackets and oil cooler, etc. The pump is driven through an eccentric and clip from the valve camshaft and is accessible, silent in operation and so constructed that water cannot enter the engine crankcase. It is equipped with an air vessel, drain tube, snifting valve and safety valve.
When marine engines leave the works the Snifting Valve, Safety Valve and Drain Plug are removed from the water circulating and bilge pumps and are securely attached to the pumps by wire.
This precaution is taken to avoid damage in transit and to drain off any water that may accumulate before the engine is put into use again.
Warning labels are attached to the parts and stress the importance of the Snifting Valve, Safety Valve and Drain Plug being replaced before attempting to run the engine.

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MARINE DIESEL ENGINES

The Snifting Valve is fitted on the outward end of the pump body. It consists of a bronze ball resting on a seat and limited in lift by a knurled headed screw. The purpose of this valve is to admit a small amount of air together 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 by hand as far as it will go; 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, resulting in high discharge water temperatures.

13. **Ram Type Pump Valves and Cup Washers.**—The pump valves are disc-like in form and are made of a special oil-resisting material. 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 which are 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 on the ram.
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 metal to metal on the brass washers. If the nut was tightened only on to the rubber cup washers they could be seriously distorted and the nut would not remain tight.
Inspection should be made regularly to see that the wick feed lubricators fitted to the body of the pump are kept filled with lubricating oil.

14. **Water Temperature Control: Open Circuit Systems.**—Marine engines fitted with ram type pumps have a manually operated 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 through the engine and oil cooler. It will be readily understood that the by-pass valve serves as a means of controlling, within limits, the temperature of the water in the cylinder jackets and at the point of discharge. This is of special utility when the engine is running at light loads during which the temperature of the discharge 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. A direct reading thermometer for the water outlet temperature is incorporated in the water temperature control unit.
Note.—When starting the engine or idling it is important that the control valve be closed, otherwise air may get into the circulation pump and interfere with its operation.

15. **Water Flow Indicator.**—On engines fitted with ram type water circulating pumps a Gardner water flow indicator is fitted in the outlet pipe from the engine and a test cock is also provided for observing the continuity of the water supply through the engine. The test cock is also of use to eliminate air locks when priming the water system.

16. **Water Outlet Pipe—Chokes.**—When ram type water circulating pumps are fitted, all LW marine engine water outlet pipes are equipped with gun metal cadmium plated chokes and it is imperative, when fitting a new pipe, to see that it is equipped with the same number of chokes of the correct bore as those already fitted to the water pipe which is being replaced.
If new chokes are being fitted to an existing water pipe, it is also imperative that the bore of the chokes are of the same size as the existing chokes. **It is not necessary to fit chokes to the water pipes of 2LW to 6LW engines fitted with centrifugal type water circulating pumps.** The following table shows the correct sizes of the bore of the chokes for LW marine engines with ram type water circulating pumps:—

2LW	$\frac{7}{32}$ in.
3LW	$\frac{5}{16}$ in.
4LW	$\frac{7}{32}$ in.
5LW	$\frac{17}{64}$ in.
6LW	$\frac{17}{64}$ in.

17. **Cylinder Water Jackets.**—With "open" circulating systems, after lengthy periods of use, the water jackets will accumulate a certain amount of sediment. The amount and time taken for this to accumulate, varies considerably according to where the craft is operating; i.e. whether in muddy rivers or harbours or sandy estuaries.
In marine engines there is always a likelihood of sand or mud accumulating in the water jackets except in cases where a "closed" system incorporating a water-cooled heat exchanger is fitted. On account of this sediment it is always advisable to observe from time to time that it has not accumulated sufficiently to impede the flow of water through the jackets.
Whenever necessary, therefore, and certainly at each major overhaul, the cylinder block water jacket spaces must be thoroughly cleared by flushing through with clean water. The cylinder doors and all inspection and core plugs should be removed to facilitate this operation. New packings should be used when replacing the cylinder doors, inspection plugs and core plugs.

18. **Bilge Pump.**—This is a ram type pump built into the engine. It is driven through the intermediary of a friction clutch so that it may be started and stopped at will. It is incorporated in the main timing chain cover and is driven by an eccentric from the valve camshaft. The pump is a counterpart of the plunger type water circulating pump except, of course, for the friction clutch and many of the parts are interchangeable with the engine circulating pump.
Engines are not supplied with bilge pumps unless specially ordered; they are then the subject of an extra charge.

19. **Bilge Pump Friction Clutch (when fitted).**—Outside the gearcase of the pump is the operating hand-wheel with a central locking screw. The hand-wheel is attached to a sleeve which screws in and out of the gear case cover.
The designed loading on the clutch spring is such that, when the hand-wheel is in the fully engaged position, a pressure of 20 lb./sq. in. (1·406 kg./sq. cm.) is recorded on the output side of the pump.
If, after long use, it becomes necessary to restore the designed spring loading of the clutch, this can be effected by fitting thin shims between the brass thrust pad in the hand-wheel and the outer end of the screwed sleeve thus permitting additional inward movement of the hand-wheel and sleeve to increase the spring pressure on the clutch cones. From the commencement of clutch engagement to full load engagement requires between half and one complete turn of the hand-wheel. This must not be appreciably exceeded, otherwise excessive load will be imposed on the camshaft end bearing resulting in undue wear of the bearing thrust face.

20. **Duplex Fuel Filter—Type No. 5.**—All LW marine propelling engines are now supplied with this type filter as part of the standard equipment. It is illustrated on page 18 and is fitted in circuit between the fuel supply or "day tank" and the second fuel filter mounted on No. 1 cylinder head of the engine. When installing the Duplex fuel filter care must be taken as regards its accessibility for cleaning and for removal of the sump and filtering element. A minimum of 2·38 in. is required for this purpose as shown in the outline drawing on page 18.
The Duplex filter employs a special form of paper filtering elements which are inexpensive and readily replaced. The securing plug which holds the sumps and filtering elements in place will, when loosened, permit the sump to be drained prior to removal. The change-over valve and the two vent screws in the Duplex Filter head also permits cleaning and replacement of a new element, and also the clearing of air and re-filling of the dismounted unit, whilst the other unit is still in operation. This applies to either of the two units and is of great value when used for marine propulsion installations.
One method of testing paper filtering elements for obstruction after they have been removed from the assembly is by holding the element in a vertical position and closing the lower end by holding it down on a flat surface. Fuel should then be poured into the open upper end and, if it collects and does not run away through the filtering media almost as quickly as it is poured in, then the filter is probably sufficiently choked to cause erratic engine running and the element should be replaced.
Under average conditions, when using a clean fuel supply and a good fuel system, the filtering elements should not require replacement before they have been in use for at least 2,400 hours.
Replacement elements are readily available from the Works, Branch Office Service Depots and from

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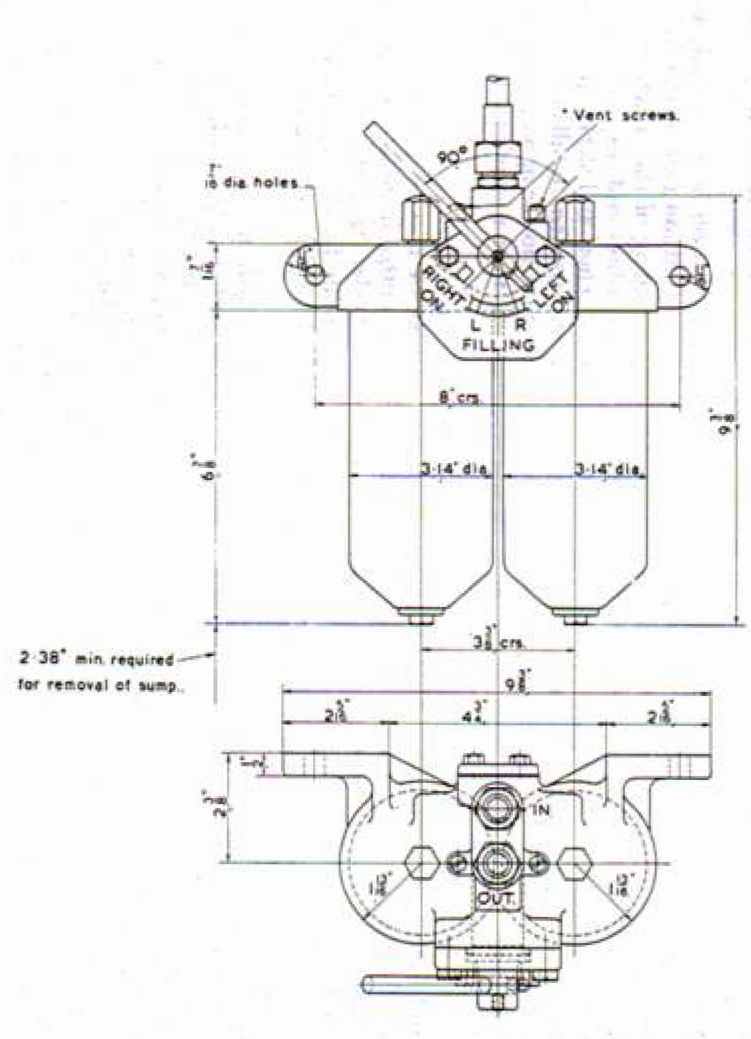

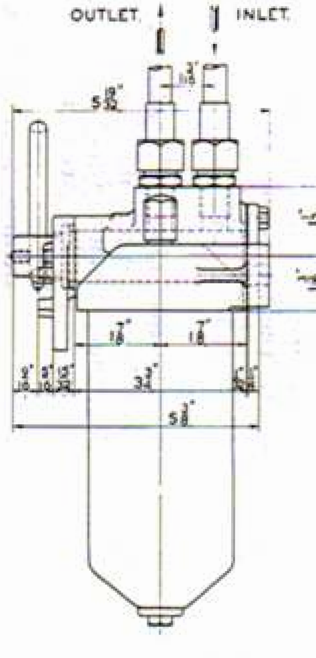

ENGINE	PIPE SIZES (O.D. COPPER.)			
	WITH FEED PUMP		WITHOUT FEED PUMP	
	INLET.	OUTLET.	INLET.	OUTLET.
L.K.	5/16" *	3/8" *	1/2"	1/2"
LK & HLK, LW & HLW	5/16" *	3/8" *	1/2"	1/2"
3-BL3	3/8"	3/8"	3/8"	3/8"
1L2.	–	–	1/2"	1/2"
6&8L3B	3/8"	3/8"	3/8"	3/8"

COPPER PIPE SIZES.

1/2 & 7/16 od. pipes to be 16's gauge
5/16 & 3/8 od. pipe to be 18's gauge

* This size of pipe correct for up to 10 ft. total length of pipework from tank to pump. For 10-18 ft. total length of pipework use 7/16 od pipe for total length of pipework over 18 ft. please consult the works.

R.D. 297.

DWG. Nº 13640	L. GARDNER & SONS. Ltd. PATRICROFT, Nr MANCHESTER.	TYPE "L" TYPE ENGINES DESCRIPTION DUPLEX FUEL FILTER TYPE Nº 5. SCALE FULL SIZE.

DATE 12/3/36. DRAWN BY J.A. TRACED BY … CHECKED BY J.A.

DWG. Nº 13640

Service Agents and Recommended Repairers in the United Kingdom and also from our Overseas Agents and Representatives in various parts of the world. A list of these is contained in Instruction Book No. 56·6 or later issue.

21. **Timing of Valves and Fuel Injection.**—With the exception of the **Fuel Injection Timing,** the valve timing diagram on page 56 of LW Instruction Book No. 56·6 is correct for all marine engines.
The correct timing of Fuel Injection at maximum speed for all LW marine engines is given in the following table:—

For Engines set to Maximum Speed of:	All Engines Bearing Serial Nos. up to and including 83848	All Engines Bearing Serial Nos. after 83848
1,200 r.p.m.	26° 24′ before T.D.C.	25° 24′ before T.D.C.
1,300 r.p.m.	—	25° 48′ ,, ,,
1,500 r.p.m.	27° 48′ before T.D.C.	26° 48′ ,, ,,
1,700 r.p.m.	29° ,, ,,	28° ,, ,,

If there is any doubt as regards the timing of fuel injection it is always advisable to refer to the figures stamped on the Injection Control Plate. Please also refer to paragraph 104 of Instruction Book No. 56·6 for further details.

22. **Hand and Rotation of Engines.**—We can offer Handed Rotation LW Marine Propulsion Engines to all clients who may require a twin set of 4LW, 5LW or 6LW engines with rotation to suit left hand and right hand propellers.
In a single screw installation, the LW marine engine crankshaft rotates in an **anti-clockwise** direction when viewed from the flywheel end and, if specially ordered, the 4LW to 6LW marine engines can be supplied for twin screw installations with the twin engine having a **clockwise crankshaft** rotation when viewed from the flywheel end.
The external form of LW marine engines with Handed Rotation has not changed in any way, both engines appearing identical, and an example of such engines is shown on pages 4 and 6 of this book. It will be observed that these engines, as supplied to the Royal National Life-Boat Institution, are fitted with reducing gears and the propellers will, of course, therefore revolve in the opposite direction to the crankshaft.
It should be mentioned in passing that the special nature of the component parts required to embody non-standard rotation compels us to increase the cost of any engines so arranged. Prices in this respect may be readily obtained from our Head Office and Branch Offices.

23. **Lubricating Oil Coolers.**—All Gardner marine engines are fitted with means to cool the lubricating oil. With heat exchanger or keel cooler systems, the oil is passed through an indented cupro-nickel tube encased in a gun-metal jacket through which the cooling water passes. Thus heat passes from the oil into the water so controlling oil temperature to a figure not exceeding 155° F. approx.
In the oil cooler jacket is fitted a ferrous wasting strip, consisting of a full length longitudinal ribbon of sheet steel, the function of which is to provide corrosion protection for the non-ferrous components.
In time, dependent on the varying water quality, the ferrous wasting strip will corrode away and it is recommended that renewal be effected every twelve months or at more frequent intervals under adverse conditions.
When the oil cooler is dismantled for inspection, the water jacket and indented oil cooler pipe should be thoroughly cleaned of any silt and scale which has accumulated, in order to ensure maximum conduction of heat from the oil. It will be noted that one end of the indented tube is brazed into a circular flange plate whilst at the other end, the water joint is made by a rubber ring to permit endwise movement created by expansion.
The oil flow through the cooler is provided by one of the following arrangements:—

All 2LW and 3LW engines The engine pressure pump draws its oil from the sump and delivers via the oil cooler to the engine system.

4LW, 5LW and 6LW engines with ram type water pumps — Oil circulated as described above but with the addition of a spring-loaded relief valve to by-pass oil around the cooler at low temperature when, due to higher oil viscosity, cooler resistance is high.

4LW, 5LW and 6LW engines with centrifugal type water pumps — A second oil pump is fitted to the fuel pump cam box. This pump draws oil from and returns via the oil cooler direct to the sump. A valve is incorporated in this oil pump cover thus allowing oil to re-circulate in the pump when cooler resistance is high as mentioned above.

24. **Cooling of Lubricating Oil.**—On engines equipped with a heat exchanger for water cooling, the raw water is piped through the engine oil cooler before reaching the heat exchanger.
In a keel cooler system, however, a small auxiliary engine-mounted pump or separate inboard mounted belt-driven pump, provides a circulation of raw water through the engine oil cooler.
Where the engine water is cooled by means of a radiator and engine-driven fan, the oil is cooled by passing it from the oil cooler pump through a small auxiliary radiator, mounted in front of the main radiator and returning it to the engine sump.

25. **Interlocking Speed and Reversing Control.**—A manual speed control is mounted on all marine engine units and consists of a permanently loaded cork-lined friction disc which will remain in any selected speed position.
This control can be connected to one or more control stations and does not require any additional locking device. The speed control can thus be effected from either the engine room or from a remote station such as the bridge or wheel house.
To prevent engagement of the Reverse Gear Ahead and Astern clutches at high engine speed, the engine speed and reverse gear controls are suitably interconnected. This allows maximum engine revolutions only when the reverse gear lever is in the position Ahead or Astern and the return of the gear lever to Neutral position automatically reduces the engine speed.
The idling speed adjusting screw is fitted to the Speed Control Plate and the interlocking speed control is so arranged that, when changing from Ahead to Astern or vice versa, the engine speed is automatically reduced to 770 r.p.m. when the gear lever is returned to the Neutral position.
In the event of the adjustment between the Speed Control Interconnection Forked Eye and Interconnecting Link being disturbed it must be re-set so that the speed in the Neutral position is limited to 770 r.p.m. There is, however, no reason to interfere with this setting which is interconnected with other intimate engine speed adjustments. Where necessary, certain adjustments are permanently set and suitably sealed before the engine is passed off test.

26. **Hydraulic Remote Control System for Engine Speed.**—This equipment can be fitted to new engines or to existing engines already in service and installation drawings will be supplied upon request. Very little servicing is necessary as there are practically no working parts which are subject to wear.
The speed control arrangement comprises a hand-lever-operated master hydraulic unit connected by copper piping to a "slave" unit bolted to a support bracket mounted on the reverse gear casing. The "slave" unit is connected by rod and lever to the standard friction disc speed control. Any movement of the hand-lever is therefore instantaneously transmitted to the "slave" unit which is connected to the engine speed control.
The hydraulic system must be initially primed by a priming unit consisting of a small hand-operated plunger type pump complete with hydraulic fluid tank of one gallon capacity. No further attention is required after the initial priming unless, of course, the piping, etc. has been dismantled for any reason.
It is not anticipated that it will be necessary for the priming pump, etc., to be supplied with each set of speed control equipment. If a number of vessels belonging to one owner are operating from one port, it would only be necessary to utilise one priming pump and the question of the number of priming units required in other cases would have to be considered on their merits. We shall be glad to advise in this matter whenever necessary.

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LW, HLW, LW20, HLW20
INSTRUCTION BOOK NO. 56.7
SERVICE DATA

ADDENDUM No. 1
January, 1970

TIMING CHAIN ADJUSTMENT

Superseding Para. 88, Page 51

The timing chain is correctly adjusted when the middle of the near vertical run has a movement of ⅛ in. (3·2 mm.) either side of the mean position, i.e. ¼ in. (6·35 mm.) maximum overall deflection with finger pressure.

VALVE TAPPET ADJUSTMENT

Superseding Para. 91, Page 53, also the Schedule on Page 55

Tappet clearances should be checked and if necessary adjusted every 12,000 miles (1,200 hours). It is essential in the interest of durability and efficiency that correct clearance is maintained between the end of the valve stem and the toe of the valve lever.

Frequency of adjustment will vary according to engine duty and lubricant etc., for example an engine operating continuously at high speed with heavy load in hilly country will require more frequent adjustment than one on lighter duty.

Excessive clearance increases stresses and noise in the valve and valve gear and reduces the efficiency of the engine. The importance, therefore, of regular inspection cannot be over emphasized.
The correct clearances and method of adjustment are as described in Para. 91.

SPRAYER DELIVERY STOCK AND FILTER WASHER

Ref.: Para. 59, Page 42 Sprayer Re-assembly

When reconditioning the sprayer at routine change every 48,000 miles (4,800 hours) renew the filter washer located under the delivery stock (Fig. 10, Page 39). Sprayers embodying the filter washer are identified by a plain hexagon or by a groove and drilled dimple on the hexagon of the delivery stock.

Sprayer assemblies with the groove alone and without a dimple are fitted with a plain steel washer instead of the filter washer. These sprayers must *not* be fitted with a filter washer unless assembled in conjunction with a new or modified delivery stock. All new and Gardner serviced sprayers now incorporate the filter washer.

The correct tightening torque for the delivery stock, with either plain washer or filter washer, is 625 lb. in. (7·2 Kg.m.).

FUEL INJECTION TIMING — LW20 ENGINES

Ref.: Para 131, Page 79

The correct fuel injection timing for LW20 engines is 31° B.T.D.C. with the pointer of the advance and retard device in the position of maximum advance. The injection timing mark for No. 1 cylinder is inscribed on the flywheel accordingly.

ADDENDUM No. 1 *continued*

FUEL INJECTION PUMP MAXIMUM POWER "SETTING"

Ref.: Para. 74, Page 46

When the engine is "set" to the required full rated power under normal temperature and pressure (N.T.P.) conditions, the average quantity of fuel delivered from each fuel pump plunger, with slider bar in the maximum position against the fuel limiting trigger, should be as given in the following table. The quantities quoted are an absolute maximum.

They are the correct quantities when the fuel oil conforms to the Specification given on this Addendum and with atmospheric temperature and pressure at 60°F. (15½°C.) and 30·0 in. Hg. 762 mm. Hg.), respectively.

Under no circumstances must these quantities be exceeded.

LW & HLW ENGINES—"K" Type Sprayers						
Duty	Crankshaft r.p.m.	B.M.E.P. lb./in.²	B.M.E.P. kg./cm.²	Fuel Pump Camshaft r.p.m.	Time in Seconds	Average Delivery for each Plunger cm.³
Road Vehicles	1,700	102·0	7·171	850	60	63·6
Rail Traction and High Speed Marine ..	1,700	97·6	6·862	850	60	60·7
Yachts, Cruisers, etc. ..	1,500	97·5	6·855	750	90	78·5
Other Marine Use ..	1,500	93·0	6·539	750	90	74·2
Heavy Marine Duty Commercial Craft, etc. ..	1,300	100·0	7·031	650	90	70·5
Industrial and Marine Auxiliary Gen. Sets, etc...	1,200	93·0	6·539	600	90	59·4
LW20 & HLW20 ENGINES—"LW20" Type Sprayers						
Duty	Crankshaft r.p.m.	B.M.E.P. lb./in.²	B.M.E.P. kg./cm.²	Fuel Pump Camshaft r.p.m.	Time in Seconds	Average Delivery for each Plunger cm.³
Road Vehicle and Rail Traction Duties ..	1,700	109·5	7·699	850	60	66·7

NOTE: When taking final readings it is desirable always to interchange sprayers on individual pumps in order to establish whether an abnormal reading is due to an imperfect sprayer or to some defect or maladjustment in the pump.

In addition to the possibility of sprayers accumulating foreign matter they may, after long service, suffer wear of the actual injection holes in the nozzle, in which event calibration may be impaired and accurate setting of maximum output cannot be effected. It is advantageous, therefore, to use sprayers known to be in optimum condition when calibrating injection pumps.

ADDENDUM No. 1 *continued*

FUEL INJECTION PUMP MAXIMUM POWER "SETTING"

Ref.: Para. 74, Page 46

When the engine is "set" to the required full rated power under normal temperature and pressure (N.T.P.) conditions, the average quantity of fuel delivered from each fuel pump plunger, with slider bar in the maximum position against the fuel limiting trigger, should be as given in the following table. The quantities quoted are an absolute maximum.

They are the correct quantities when the fuel oil conforms to the Specification given on this Addendum and with atmospheric temperature and pressure at 60°F. (15½°C.) and 30·0 in. Hg. 762 mm. Hg.), respectively.

Under no circumstances must these quantities be exceeded.

LW & HLW ENGINES—"K" Type Sprayers						
Duty	Crankshaft r.p.m.	B.M.E.P.		Fuel Pump Camshaft r.p.m.	Time in Seconds	Average Delivery for each Plunger cm.³
		lb./in.²	kg./cm.²			
Road Vehicles	1,700	102·0	7·171	850	60	63·6
Rail Traction and High Speed Marine ..	1,700	97·6	6·862	850	60	60·7
Yachts, Cruisers, etc. ..	1,500	97·5	6·855	750	90	78·5
Other Marine Use ..	1,500	93·0	6·539	750	90	74·2
Heavy Marine Duty Commercial Craft, etc. ..	1,300	100·0	7·031	650	90	70·5
Industrial and Marine Auxiliary Gen. Sets, etc...	1,200	93·0	6·539	600	90	59·4

LW20 & HLW20 ENGINES—"LW20" Type Sprayers						
Duty	Crankshaft r.p.m.	B.M.E.P.		Fuel Pump Camshaft r.p.m.	Time in Seconds	Average Delivery for each Plunger cm.³
		lb./in.²	kg./cm.²			
Road Vehicle and Rail Traction Duties ..	1,700	109·5	7·699	850	60	66·7

NOTE: When taking final readings it is desirable always to interchange sprayers on individual pumps in order to establish whether an abnormal reading is due to an imperfect sprayer or to some defect or maladjustment in the pump.

In addition to the possibility of sprayers accumulating foreign matter they may, after long service, suffer wear of the actual injection holes in the nozzle, in which event calibration may be impaired and accurate setting of maximum output cannot be effected. It is advantageous, therefore, to use sprayers known to be in optimum condition when calibrating injection pumps.

ADDENDUM No. 1 *continued*

74·1 **Power Reduction by Lengthening of Fuel Limiting Trigger:** Should it be desired to reduce the maximum power rating for special installations or to suit certain site conditions as prescribed on Page 14, the trigger length must be increased as described in Workshop Tools Book No. 48·2, or preferably a new trigger substituted of the correct length.

The accompanying table shows the percentage of full power available and approximate percentage of full power fuel supply when the trigger is lengthened by increments of ·010 in. (·254 mm.).

For example on the LW engine if the trigger length is increased by ·060 in. (1·524 mm.) to derate to 86·1% of its normal full power, with camshaft running at 850 r.p.m. (1,700 crankshaft), the maximum fuel delivered in 60 seconds will be 86·1% of 63·6 cm.³ = 54·8 cm.³.

Trigger length increase		Percentage of Full Power available	
in.	mm.	LW & HLW	LW20 & HLW20
0·010	0·254	97·6	98·7
0·020	0·508	95·3	97·0
0·030	0·762	92·7	95·1
0·040	1·016	89·6	93·0
0·050	1·270	88·7	90·6
0·060	1·524	86·1	88·2
0·070	1·778	83·3	85·5
0·080	2·032	81·3	82·7
0·090	2·286	78·0	79·8
0·100	2·540	76·3	76·5

FUEL OIL SPECIFICATION

Superseding Para. 7, Page 19

Liquid Fuels.—The following Laboratory Specification is an example of the type of fuel oil recommended for use in Gardner engines:—

Specific Gravity at 60°F. (16°C.)	Not exceeding	·845
Initial Boiling Point	,, ,, ...	·356°F. (180°C.)
Distillation Test	Not less than 90% at	675°F. (357°C.)
Flash Point (Pensky-Martin)	,, ,, ,, ...	170°F. (77°C.)
Viscosity at 100°F. (37·8°C.)		
Redwood No. 1	Not exceeding	40 secs.
Kinematic	,, ,, ...	5·5 cs.
Sulphur	,, ,, ...	0·4%
Cloud Point	,, ,, Winter ..	14°F. (—10°C.)
	Summer ..	28°F. (—2°C.)
Ash	,, ,, ...	0·01%
Water	To be free from visible water.	
Calorific Value	.. ..	19,400 Btu/lb. (10,800 Kcal/kg.)
Ignition Quality	.. ..	See below

An accepted criterion of the ignition quality of a Diesel Fuel is its Cetane value expressed as a number.

A good quality fuel may have a Cetane value as high as 57.

It is desirable that the fuel used approaches this figure and should not in any case fall below 52.

The Diesel Index Number is usually several points higher than the Cetane number and the corresponding values are as given in Para. 7·1, Page 20.