4LK ENGINE

ENGINE No...................

GENERAL DIRECTIONS

for the Operation of the

GARDNER

4LK DIESEL ENGINE

Vertical Four-Cycle Compression-Ignition
Airless Fuel Injection

NORRIS HENTY & GARDNERS, LTD.
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GLASGOW OFFICE: 124 ST. VINCENT STREET C.2.

Telegrams "Glasgard, Glasgow" Telephones CENtral 0887/8

PRICE 8s. 6d. EACH

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For the Operation of the
GARDNER
4LK DIESEL ENGINE

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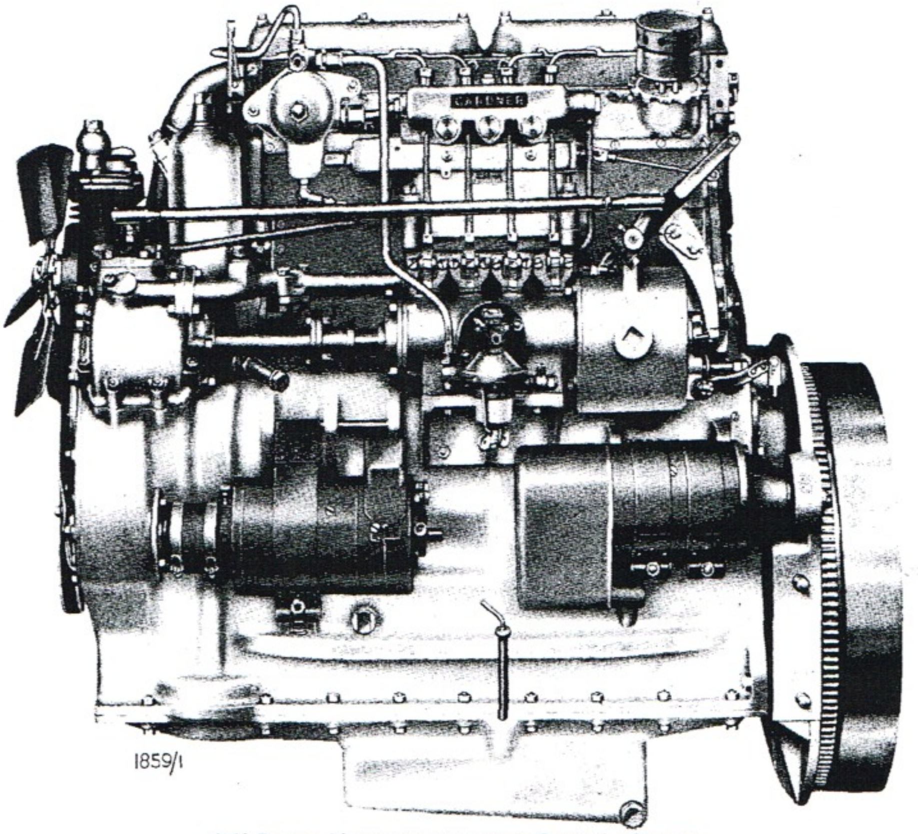

4LK Engine Near-side view with Central oil sump.

NORRIS, HENTY & GARDNERS, LTD.
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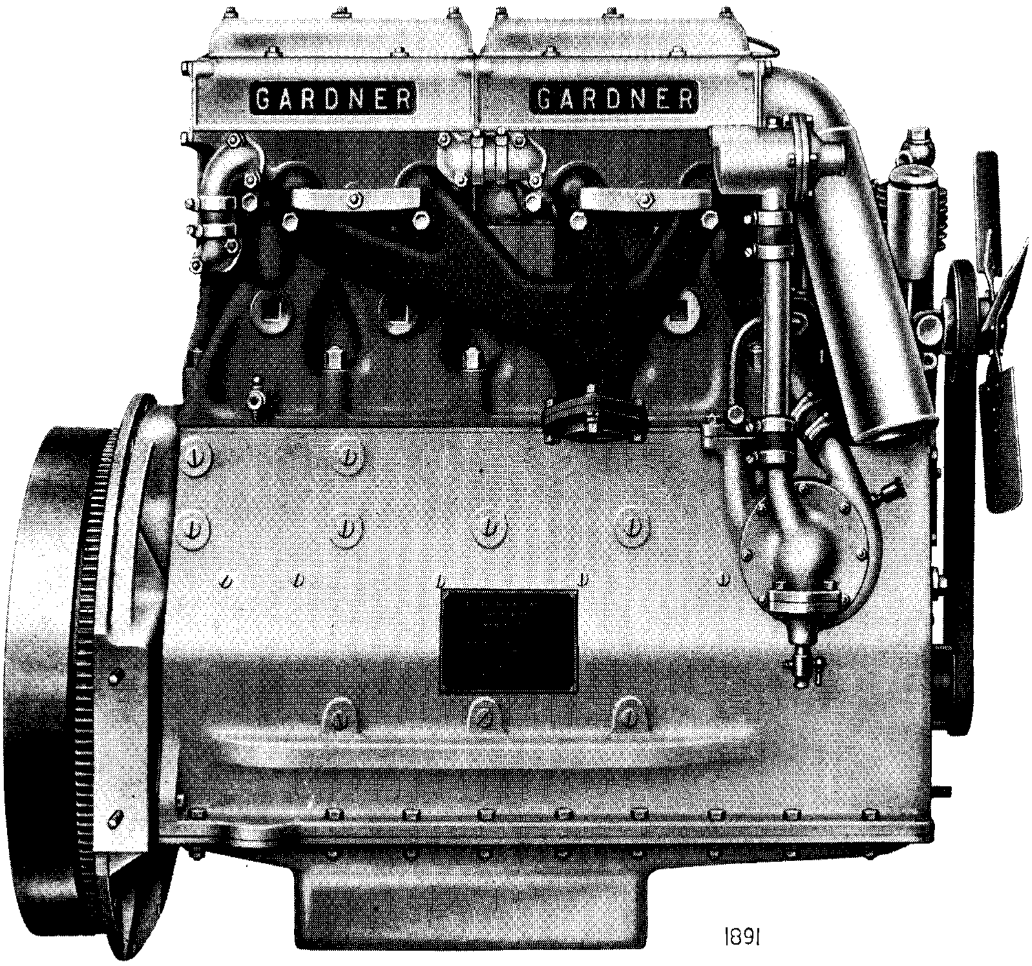
GARDNER
4LK
TYPE



4LK Engine Off-Side View with Central Oil Sump.

GARDNER

SERVICE

UNITED KINGDOM

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The following are officially appointed Service Agents or Recommended Repairers who carry Stocks of Spare Parts. At these Depots are Practical Engineers from whom users of Gardner Engines can rely upon obtaining assistance and advice regarding their Engines.

OFFICIAL SERVICE AGENTS AND DISTRICT STOCKISTS

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DEVONSHIRE ...	Autopart Engineering Co. Ltd., Haven Road, Exeter ...	Exeter 73429 ...	—	Exeter 73429

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	C.V.R. (Engineers) Ltd., 37 Virgil Street, Liverpool, 5	North 1808/9	Great Crosby 4408	North 1808/9
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	S. A. Satterthwaite, Chester Rd., Streetly, nr. Birmingham	Streetly 7290	Streetly 78333	Streetly 7290
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CAMBRIDGESHIRE	King & Harper Ltd., Hills Road, Cambridge	Cambridge 3201	—	Motors Cambridge
CORNWALL	A. & J. E. Polmear, Island Works, St. Ives. (*Marine only*)	St. Ives 131	—	Polmear Engineers St. Ives Cornwall
DORSETSHIRE	Wilkins & Wilkins Ltd., Quay Side, Hamworthy, Poole, (*Marine only*)	Poole 174	—	Poole 174
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INVERNESS-SHIRE	MacRae & Dick Ltd., Academy Street, Inverness	Inverness 1000	—	Dick Inverness
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	Normand Ltd., Cumberland Avenue, Park Royal, London, N.W.10	Elgar 7757	—	Appoint Harles London
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YORKSHIRE	Rodwell's Motors Ltd., Woodside Garage, Wombwell	Wombwell 2307 & 2308	—	Wombwell 2307 & 2308

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South Australia	Rasch Motors Pty. Ltd., 317-319 King William Street, Adelaide. Phone: LA 5371 & LA 5372.
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CANADA: British Columbia	Gardner Diesel Engines Ltd., 1729 West Georgia Street, Vancouver, 5.B.C. Phone: Mutual 3-7481.
Eastern Canada, Newfoundland and Maritime Provinces	Gardner Engines (Eastern Canada) Ltd., 6033 Hamilton Street, Montreal, 20, Que. Phone: Pontiac 6-7718.
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PORTUGAL	Conde Barao, Lda., Avenida 24 de Julho 62-64, Lisbon. Phone: 671011/8.
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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.

GARDNER
4LK
TYPE

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GARDNER 4LK TYPE

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SECTION I

ASSEMBLING AND INSTALLATION

SECTION II

GENERAL OPERATION, MAINTENANCE AND OVERHAUL

GARDNER
4LK
TYPE

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GARDNER
4LK
TYPE

INDEX—*continued.*

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 1,000 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 2,000 feet altitude with a mean annual atmospheric temperature of 75° F., from the graph, page 13, we read the following reductions:

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

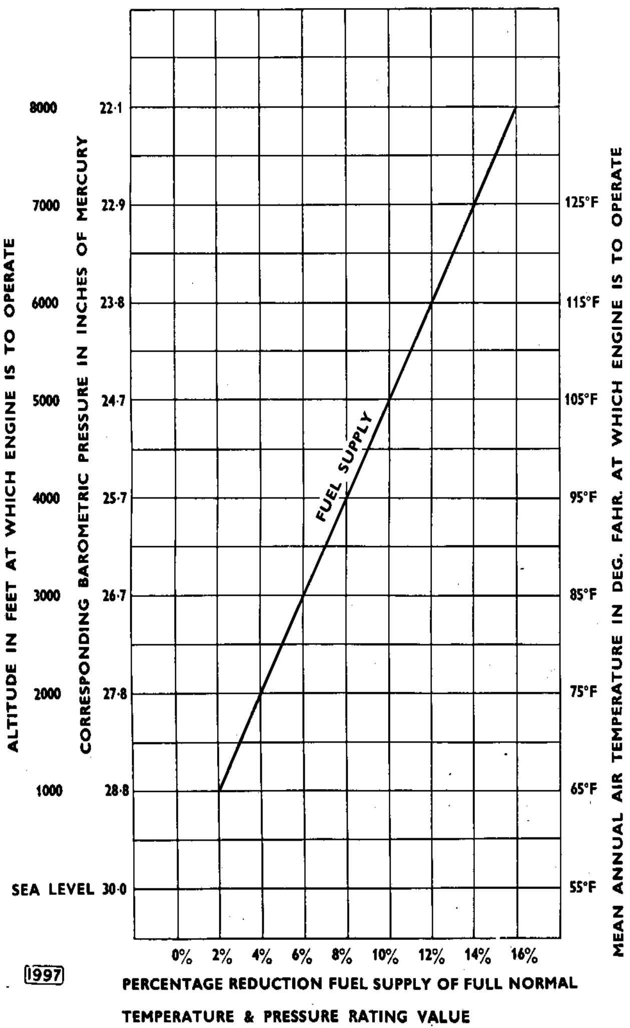
When it is intended that an engine shall operate permanently at 1,000 feet altitude or 65° F. mean annual ambient temperature, or in excess of either of these figures, it is necessary that the length of the fuel pump output control trigger be increased in order to reduce the injected fuel supply appropriately according to altitude and temperature shown on the graph on page 13.

When site operating conditions are known, new engines are appropriately set during test at the maker's works, and the setting clearly stamped on the fuel pump rating plate. When, however, it is necessary to adjust spare or reconditioned fuel pumps the work can be accomplished only by use of the Gardner fuel pump calibrating machine and by observing precisely the provisions of Instruction Book 45·3. On page 9 of Book 45·3 will be found the average delivery from each plunger in cubic centimetres and the values quoted are to be reduced according to the graph on page 13.

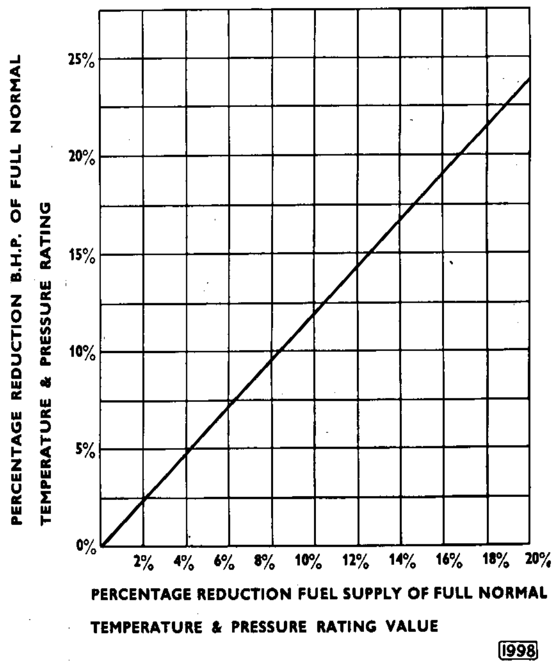
On page 13 will also be found a graph showing the approximate reduction in B.H.P. when the fuel supply is reduced under altitude and temperature conditions.

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

Altitude and Temperature Diagrams



REDUCTION IN FUEL SUPPLY FOR ALTITUDE AND TEMPERATURE CONDITIONS.



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

GARDNER
4LK
TYPE

4LK ENGINE DATA

Four Cylinders, 3¾ in. bore, 5¼ in. stroke (95·250 mm.×133·350 mm.).

Swept Volume: 3·80 litres.

Maximum Governed B.H.P. 60 at 2,100 R.P.M. (The governor controls the maximum engine speed to approximately 2,175 R.P.M. at no load.)

Maximum Torque: 162 lb. ft. at 900/1,300 R.P.M.

Weight with flywheel: Approximately 775 lb.

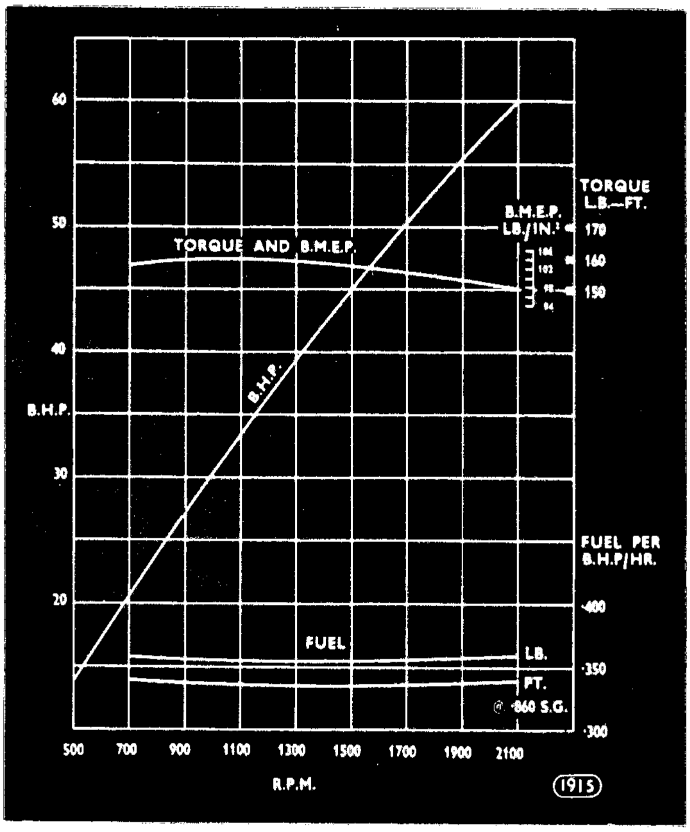
The Weight does not include electrical equipment and is approximate only. It is not necessarily the lightest specification which can be compiled on application to the works. The Power quoted is that developed at normal atmospheric temperature and pressure with recommended Exhaust Silencing and Air Induction arrangements, but without battery charging dynamo or radiator cooling fan. The latter absorbs approximately ½ B.H.P.

For adverse climatic conditions see pages 12 and 13.

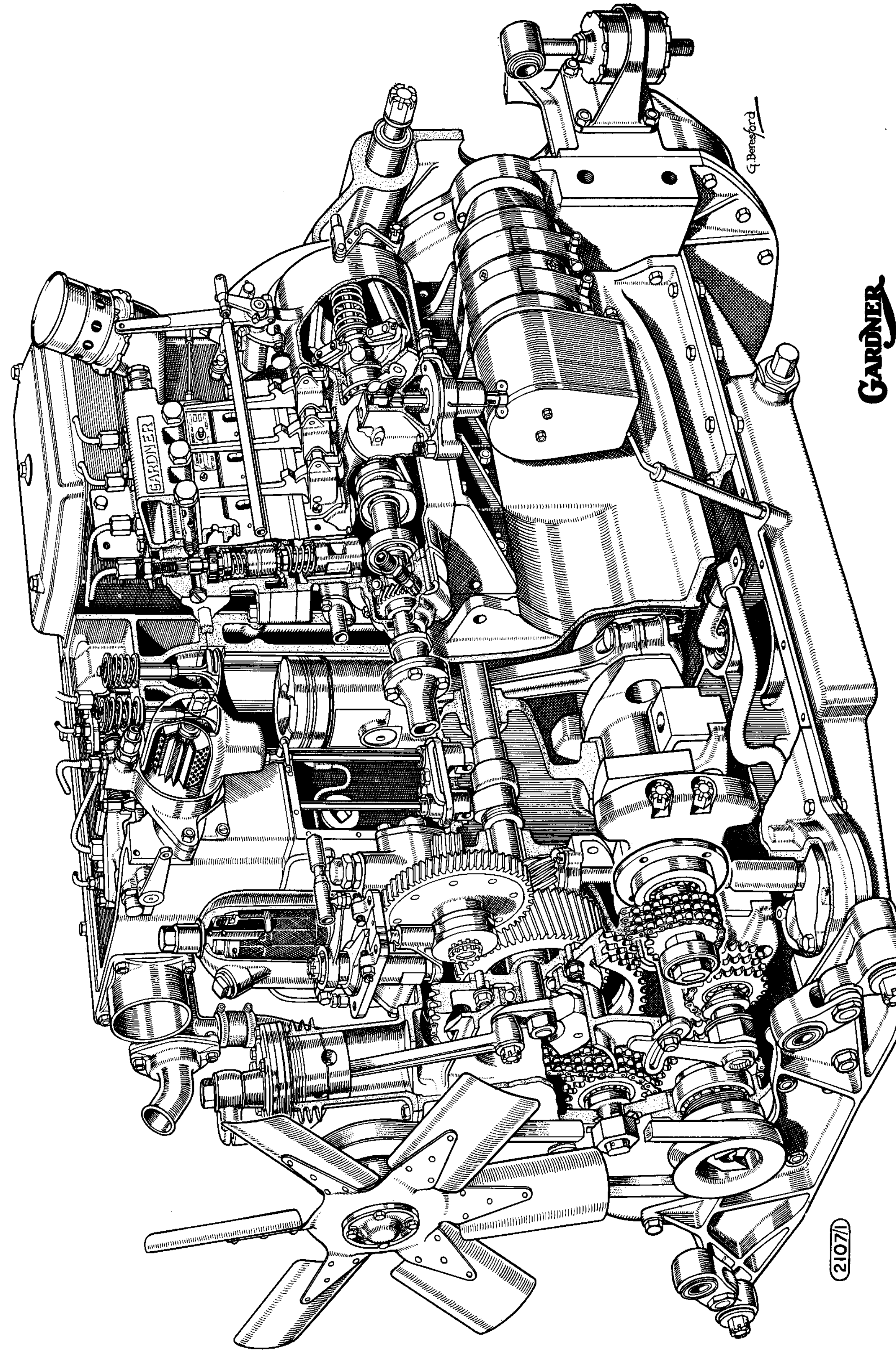
Please refer to pages 17 and 20 dealing with Cooling, Exhaust and Induction Systems.

PERFORMANCE CURVES

4LK ENGINE



This curve is produced by plotting the actual figures recorded during normal production test of these engines, and as such must not be confused with special laboratory results. Large scale prints of the performance curves are available and will be sent on application.



GARDNER 4LK AUTOMOTIVE ENGINE

INTRODUCTORY NOTES AND GENERAL DETAILS

The complete working cycle of the 4LK 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 a 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 4LK 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 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.

Section I of this Instruction Book deals with Assembly and Installation while Section II deals fully with the engine and its general operation and maintenance, etc. The arrangement should enable the user to refer to the appropriate section or paragraph with the minimum of time or trouble.

Packing.—Unless expressly ordered otherwise, engines are packed in their assembled state. Before packing, all bright parts are varnished with a rust preventive which is soluble in paraffin or fuel oil.

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

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

Lifting Eye-Bolts.—For convenience of lifting the engine it will be observed that certain cylinder head studs project considerably beyond the nuts. On to these projecting portions are lightly screwed the lifting eyes.

AIR INDUCTION SYSTEM

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, or through a remotely mounted air filter or silencer, if required. 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. 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 air. An oil bath air filter is really essential to prevent undue wear of all engine components, particularly pistons, liners and valves.

AUXILIARY UNITS AND DRIVES

Provision is made on the engine for mounting and driving a dynamo and for mounting an electric starting motor on the near side of the engine.

Exhauster.—When so ordered, a vacuum pump (exhauster) for the vacuum operated brakes is fitted on the engine, incorporated with the casing of the chain drive of the camshaft. The pump is crank driven and is positively lubricated from the main system.

The diagrammatic arrangement of vacuum Servo brake pipes is shown on Drawing No. 3387H in Book No. 55, and the sizes of pipes for use with the Gardner Ring Valve type Exhauster are as follows:—

Between Single Cylinder Exhauster and Check Valve or Vacuum Tank—$\frac{5}{8}$ in. o.d. 18 gauge copper pipe.

Between Vacuum Tank and Servo Unit—1 in. o.d. 16 gauge copper pipe.

Fan Drive.—A single V-groove fan driving pulley mounted on the crankshaft is the standard equipment on all engines.

Do not on any account attach rigidly a heavy mass to the forward end of the crankshaft.

CLUTCH

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.

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. 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 shall be fully cowled, with provision for belt adjustment.
The drive is taken off the crankshaft which is the standard arrangement.

GARDNER
4LK
TYPE

COOLING SYSTEM—*continued*

(*b*) The radiator shall have a heat dissipating capacity capable of limiting the water temperature at the engine outlet to 80° F. 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 favourable than those obtaining in the British Isles.

Constructional Details.—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 Radiator fan blades must not be less than 1¾ in. and the fan blades must be enclosed by a cowl, the diameter of which is not greater than the fan blades plus 1½ in.

(2) **Water Inlet and Outlet Connections.**—The minimum permissible bore of any portion of the connections between radiator, thermostat outlet and water pump inlet, and the bore of hose for which standard connections are arranged is as follows:—

Engine type	Min. bore	Bore of hose
4LK	1¼ in.	1½ in.

If any smaller connections are used the water circulation rate will be reduced and the system will lose efficiency.

(3) **Free entry of air to radiator.**—Any 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.

RADIATORS

For Temperate, Sub-Tropical, and Tropical Conditions

Wire-Wound Tubes

Engine	Fan Particulars (GardnerStd.)		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 in.²	Typical Dimensions		Tubes		Effective Area in.²	Typical Dimensions		Tubes		Effective Area in.²	Typical Dimensions		
	Dia. in.	Blades	No.	Rows		Width in.	Height in.	No.	Rows		Width in.	Height in.	No.	Rows		Width in.	Height in.	
4LK	18	6	41	3	450	20¾	22	44	3	515	22¼	23	47	3	600	23¾	25	

RADIATORS—*continued*

Tubes.—Brass tube ⅜ in. O.D., 20's gauge, wire wound type 1$\frac{3}{16}$ in. O.D. (Approx.).

Tube layout.—Pitch of tubes 1½ in., in rows spaced 1$\frac{5}{32}$in., alternate rows staggered.

Alternative Tubes.—The foregoing 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 a 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.

ELECTRICAL EQUIPMENT

Voltage.—The recommended voltage is 12 volts.

Dynamo.—The bores of cradle ribs on the engine crankcase can be supplied to suit dynamos of 4½ in. to 6½ in. diameter as specified in the order. The timing chain sprocket has teeth to give a dynamo speed of 1·526 times crankshaft speed.

Starter.—The standard starter mounting parts are designed to accommodate the following machines:—

4LK .. .. C.A.V. type SP512A/4M. Simms type .. .. 512 SGR56M.

Mounting parts are available for Delco-Remy and others.

Battery.—The size of battery will usually be determined by the lamp load, but for engine starting only the following capacity is recommended (of a type suitable for engine starting):—

4LK .. .. .. 100 ampere-hours at 10 hour rate.

Cable Sizes.—The minimum size of cable should not be less than as follows:—

	12 Volts
Battery to Starter (not exceeding 8 ft. long)	61/·044 in.
Dynamo to Battery	35/·012 in.
Field	14/·012 in.
Switch to Starter	14/·012 in.
Ammeter	35/·012 in.

ENGINE CONTROLS

Speed Control.—In order that the foot control be " light " when the engine is installed in the chassis 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 (on the engine) 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., is optimum.

Stopping Control.—The Amal flexible control, which is supplied when specified, is simple, reliable and easily installed.

ENGINE MOUNTING

For installations demanding the maximum insulation of vibration and noise, the engine should be carried on a fully flexible mounting arrangement. The Gardner Patented Flexible Mounting is available, in various forms, and our Technical Staff will be pleased to co-operate in its application to individual installations.

EXHAUST SYSTEM

The exhaust system should impose a back pressure at the manifold of not more than approx. 10 in. 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. If maximum silencing is required or in very long systems, two silencers should be fitted, the first being as close to the engine manifold outlet as is practicable.

Special care should be taken to avoid unnecessary bends and the overall length should not exceed 18 feet. If in excess of 18 ft. 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 the 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 details:—

4LK Engine		
System Length 18 ft. Max.	System Length 36 ft. Max.	
Single or Double Silencers	Double Silencers only	
Silencers and all pipes	1st Silencer and engine pipe	2nd Silencer Intermediate and tail pipe
$2\frac{1}{4}$ in.	$2\frac{1}{4}$ in.	$2\frac{1}{2}$ in.

FUEL SUPPLY SYSTEM

We recommend the use of the Gardner Overflow Return system, incorporating an engine operated Amal Fuel Lift Pump which is supplied with all engines. See Drawing No. 3387H, Book No. 55 for the correct installation procedure which should be strictly followed to ensure an unfailing fuel feed arrangement.

Fuel pipe sizes are important and minimum sizes should be as follows:—

	Up to 10 ft.	10 ft. to 18 ft.
Between fuel tank and intermediate strainer .. .. Between intermediate strainer and lift pump	$\frac{3}{8}$ in. od.—20G.	$\frac{7}{16}$ in. o.d.—18G.
Overflow return pipe to fuel tank	$\frac{3}{8}$ in. o.d.—18 or 20G.	

FUEL SUPPLY SYSTEM—*continued*

The overflow return pipe between the engine strainer 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 pump may become de-primed.

The suction pipe should be taken out from the top of the tank and the intermediate filter placed above maximum fuel level, but below the level of the lift pump thus avoiding the need for a stop cock. If pipes smaller than those shown in the table are used, or the suction filter becomes choked, the flexible diaphragm will receive increased load which may precipitate failure.

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.

First Fuel Filter.—This is supplementary to the filter fixed on No. 1 cylinder and it is intended to be fixed at low level in circuit with the pipe line leading from the fuel service tank to the filter on No. 1 cylinder. This supplementary fuel filter is supplied as a standard with all engines.

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.

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. Felt, rubber sheet, and sprayed-on sound deadening materials are very valuable if properly applied. 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.

SPACE REQUIRED FOR REMOVAL OF COMPONENTS

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 portions of the installation:—

(*a*) Crankcase Sump (Standard Central Type)—2½ in. Other types of sump are available and details of space required for removal will be supplied by the works upon application.

(*b*) Cylinder Blocks and Heads—7¾ in.

(*c*) Lubricating oil strainer cover—6½ in.

(*d*) Fuel oil strainer covers—4 in.

(*e*) Water pump—2½ in.

(*f*) Timing Chain Case Cover—3⅛ in.

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.

GARDNER 4LK TYPE

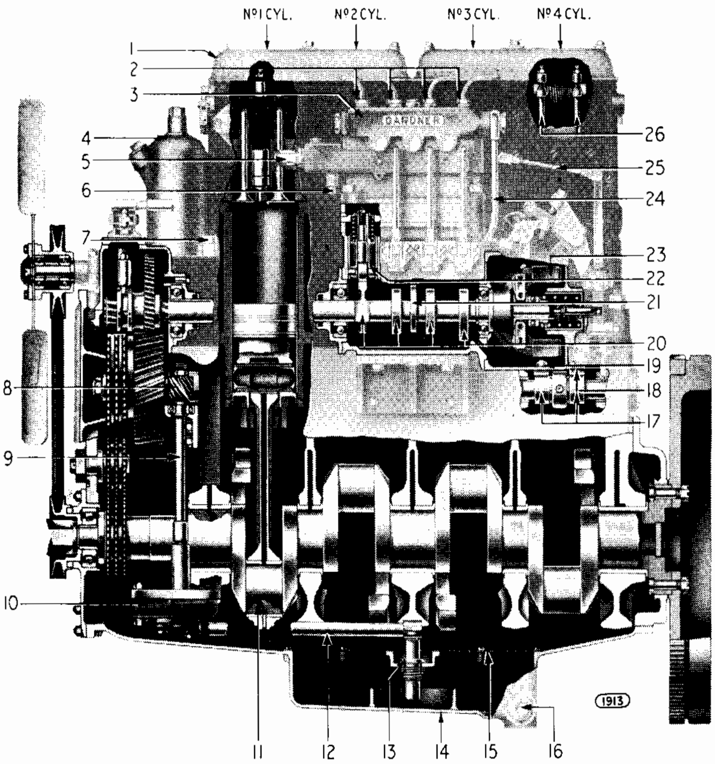


Fig. 1

1 Valve and Cylinder Head Cover
2 Sprayer Pipe Union
3 Fuel Suction Air Chamber
4 Lubricating Oil Delivery Filter
5 Governor Control Bar Buffer
6 Starting Fuel Plunger
7 Oil Pressure Regulating Valve
8 Oil Pump Driving Gear
9 Oil Pump Driving Shaft
10 Oil Pump
11 Oil Feed Tube to Crankpin
12 Oil Pump Suction Pipe
13 Oil Pump Suction Pipe Bush
14 Oil Sump
15 Primary Filter
16 Oil Sump Drain Plug
17 Valve Cam
18 Valve Tappet
19 Oil Return Passage
20 Fuel Cam
21 Fuel Lift Pump Eccentric
22 Fuel Pump Tappet
23 Governor Weights
24 Fuel Pump Inlet Pipe
25 Connecting Link—Governor to Slider Bar
26 Valve Lever Push Rod

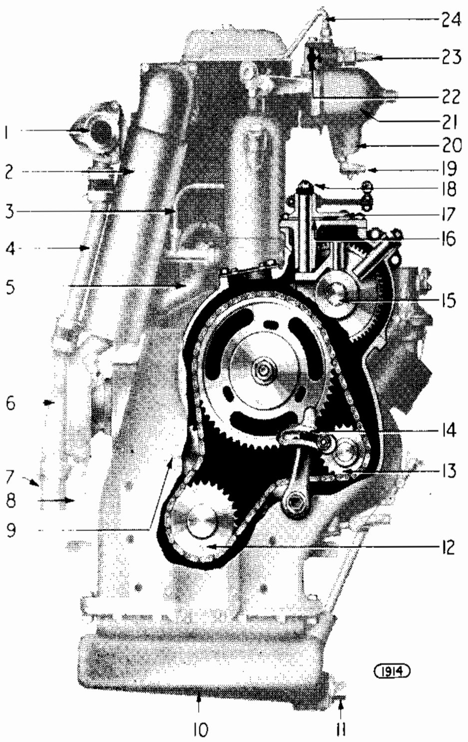


Fig. 2

1 Water Outlet
2 Air Intake Pipe
3 Valve Gear Oil Feed Pipe
4 Temperature Control By-pass Pipe
5 Cylinder Water Door
6 Water Circulating Pump
7 Water Pump Inlet
8 Water System Drain Cock
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 Friction Washer
17 Injection Timing Pointer
18 Friction Device Nut
19 Filter Sump Drain
20 Filter Sump
21 Second Fuel Filter
22 Fuel Inlet to Filter
23 Fuel Overflow Return to Tank
24 Sprayer Leak Pipe

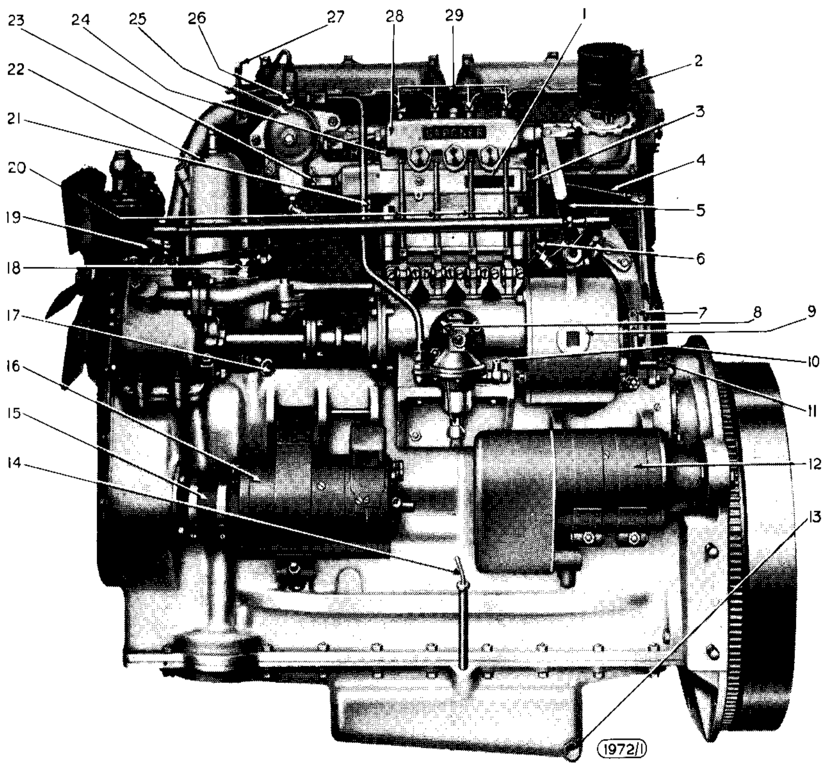


Fig. 3

Near Side Elevation

1 Engine Data Plate
2 Oil Filler and Crankcase Breather
3 Fuel Pump Slider Bar
4 Governor Lever and Connecting Link
5 Accelerator Control
6 Accelerator Idler Stop
7 Stopping Lever
8 Fuel Lift Pump Hand Priming Lever
9 Governor Casing Inspection Opening
10 Fuel Inlet
11 Idling Speed Adjusting Sleeve and Nut
12 Electric Starter
13 Lubricating Oil Sump Drain Plug
14 Oil Level Dip Rod
15 Dynamo Flexible Drive Coupling
16 Dynamo
17 Lubricating Oil Filter Drain Plug
18 Pressure Regulation Valve for Lubrication System
19 Fuel Injection Timing Lever
20 Hand Priming Levers
21 Cold Starting Fuel Plunger
22 Lubricating Oil Delivery Filter
23 Fuel Pump Slider Bar Buffer
24 Fuel Injection Pump
25 Second Fuel Filter
26 Fuel Overflow Return Outlet
27 Decompression Lever
28 Fuel Suction Air Chamber
29 Sprayer Pipe Unions

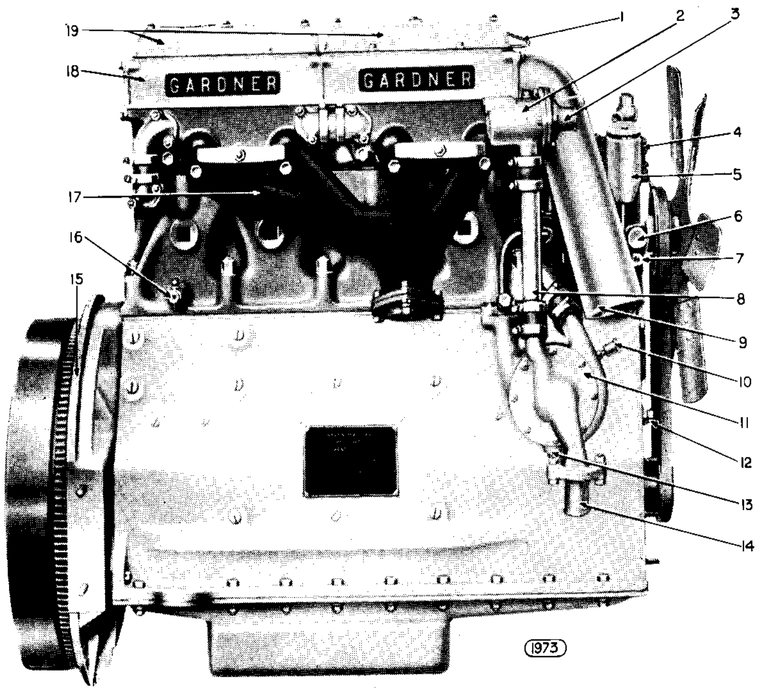


Fig. 4

Off Side Elevation

1 Sprayer Leak Pipe
2 Automatic Temperature Control (Thermostat)
3 Water Outlet
4 Exhauster for Vacuum Servo Brakes
5 Combined Oil Separator and Breather
6 Fan Bearing Greaser
7 Fan Belt Adjustment Cotter
8 Temperature Control By-Pass Pipe
9 Air Inlet Pipe
10 Water Circulating Pump Greaser
11 Water Circulating Pump
12 Timing Chain Idler (Fixed)
13 Water Pump Drain Cock
14 Water Inlet
15 Crankcase End Plate
16 Water Drain Cock
17 Exhaust Manifold
18 Air Inlet Passage Cover
19 Valve & Cylinder Head Cover

ATTENTION IN TERMS OF MILEAGE

DAILY

Lubrication System.—Check level of oil in sump and replenish if necessary. See page 44 for full details.

Cooling System.—Ensure that the radiator or cooling system is filled to maximum capacity, preferably with rain water. This is particularly important in hard water districts in order to avoid deposits which will impair cooling efficiency.

AFTER EVERY 3,000 MILES (300 Hours)

Lubricating Oil Sump.—Change contents when using straight oil when the fuel in use contains less than ·3% sulphur.

Note.—Where engines are operated under dusty conditions it is highly desirable to change sump contents very frequently. Under extreme conditions after periods of less than 1,000 miles regardless of fuel and lubricating oil quality.

Lubricating Oil Delivery Filter.—Examine and clean if necessary. See page 50 for full details.

Fuel Filters.—Examine and replace elements if necessary. See page 32 for full details.

Induction Air Filter.—The oil container and element should be removed for examination, clean if necessary and recharge with S.A.E. 30 oil when used in ambient temperatures between 40° F. and 70° F. Use S.A.E. 50 oil for higher temperatures. Do not overfill otherwise engine may suffer serious damage. In very dusty climates the filter will require more frequent attention.

AFTER EVERY 4,000 MILES (400 Hours)

Lubricating Oil Sump.—Change the contents of the lubricating oil sump when using oil to Supplement 1 Specification, when the fuel in use contains up to ·8% sulphur.

Lubricating Oil Delivery Filter.—Examine and clean if necessary. See page 50 for full details.

AFTER EVERY 6,000 MILES (600 Hours)

Lubricating Oil Sump.—Change the contents of the lubricating oil sump when using oil to Supplement 1 Specification, when the fuel in use contains less than ·3% sulphur.

Lubricating Oil Filter.—Examine and clean if necessary. See page 50 for full details.

Sprayers.—Operate fuel pump priming levers and observe by feel and sound that sprayers are functioning correctly as detailed on page 40.

AFTER THE FIRST 10,000 MILES (1,000 Hours)

Main Timing Chain.—Inspect and, if necessary, adjust for stretch. See page 61 for full details.

AFTER EVERY 10,000 MILES (1,000 Hours)

Radiator Fan.—Inject not more than one grease-cup-full of grease and adjust driving belt if necessary.

Slow Running Adjustment.—Inspect and adjust if necessary. See page 56 for full details.

Fuel Injection Pump.—Inject small quantity (about 30 c.c.) of engine lubricating oil through 2 B.A. screw hole in fuel control box.

ATTENTION IN TERMS OF MILEAGE—*continued.*

AFTER EVERY 20,000 MILES (2,000 Hours)

Valve Tappet Clearance.—Inspect and, if necessary, adjust as detailed on page 60.

Crankcase Breather Filter.—Renew paper element as detailed on page 49.

AFTER EVERY 30,000 MILES (3,000 Hours)

Decarbonising and Top Overhaul.—See page 29 for full details.

Lubricating Oil Sump.—Remove and clean as detailed on page 50.

Fuel Injection Pump.—Check maximum output and balance on calibrating machine as directed in Book No. 45.3. See also page 34 of this Instruction Book.

Main Timing Chain and Timing.—Adjust and re-time if necessary. See pages 61 and 62 for full details.

Fuel Injector Pump Slider Bar.—Inspect and, if necessary, adjust as detailed on page 46.

Advance and Retard Friction Device.—Inspect and, if necessary, adjust as detailed on page 34.

Accelerator Control.—Inspect and, if necessary, adjust as detailed on page 45.

Sprayers.—Inspect and service, if necessary, as detailed on pages 40 to 45 inclusive.

Water Pump.—Inject not more than one grease-cup full of grease as directed on page 63.

AFTER 180,000 MILES (18,000 HOURS) OR WHEN A ·006″ FEELER GAUGE CLEARANCE HAS DEVELOPED IN ANY ONE CRANKSHAFT MAIN BEARING

Effect major overhaul of engine involving re-sizing of crankshaft and the fitting of new bearing shells, etc. etc.

NOTE

The preceding summary of recommended attention is based upon average conditions of operation, including fuels, lubricants, duty, etc. etc. It is to be appreciated that heavy duty and adverse conditions and light duty and favourable conditions may respectively reduce or considerably increase the periods at which attention is advisable. For example, it is not unusual that 250,000 miles be attained or exceeded before major overhaul is effected in passenger vehicle operation. Conversely, the engine of a tractor unit should receive attention at a greatly reduced mileage. Similarly cylinders, piston rings and pistons, may have a useful life of, and run without removal, for periods from 100,000 miles to 200,000 miles or more.

BIG END AND MAIN BEARINGS

Whenever new bearing shells have to be fitted to the connecting rod or crankcase the following points must be observed:—

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

(*b*) Both the big end bearing and main bearing are so designed that when bolted up, the face of the bearing 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 bearing must be perfectly free on the crankpin or journal.

(*c*) In order to ensure that the bearing shells are tightly held in their housings the main bearing caps or connecting rod shims must be adjusted by careful filing or other method so that when the nuts are evenly tightened to the correct torque, and then one nut slackened off, the cap should spring open ·004 in. to ·006 in. which provides the correct " nip " for the bearing shells.

When main bearings are line bored the size of the bore so produced should be such as to give ·001 in. to ·0015 in. clearance between the crankshaft journal and bearing.

After line boring main bearings the crankshaft must be fitted and all nuts finally tightened, a check then being made for zones of hard or tight bearing particularly adjacent to the radii. If present, these must be removed by judicious use of the hand scraper until there remains no local high places and the shaft can be turned freely by hand pressure only applied to the coupling flange with all cap nuts fully tightened. On no account must any attempt be made to " burn in " the bearings by running an engine with inadequate bearing clearances since this will cause certain failure.

The big end bearings should be bored or hand scraped to give ·00175 in. to ·002 in. 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 so have a more accurate shape and therefore more complete contact with the crankpin than could be produced by hand scraping. As in the case of the main bearings it is essential to check that the big end bearing is free from tight places adjacent to the radii; if these do exist they must of course be relieved by light hand scraping.

Having obtained the correct clearance in this way 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 $\frac{5}{16}$ in. 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 $\frac{5}{8}$ in.

BIG END AND MAIN BEARINGS—*continued.*

The correct tightening torque for the connecting rod big end bolts is 980 lb./inches and for the main bearing cap studs 1,500 lb./inches. Always use new joints and locking plates for the lubricating oil pump suction pipe when overhauling an engine.

The diametral clearances together with the correct end clearances and correct positioning of grooves and chamfers on the big end bearings etc. are fully illustrated by diagrams given on pages 44 and 48 of Book No. 55 entitled " Workshop Tools, Equipment and Instructional Drawings." On page 55 of this book will also be found a list of the standard undersize bearing shells together with the range of undersize bearings which are available for the crankshaft journals and connecting rod big ends.

RE-METALLING OF EXISTING BEARING SHELLS IS NOT RECOMMENDED

Inserting and Extracting Main Bearing Shells (Upper).—A special tool to facilitate the extraction and refitting of main bearing shells during the bedding operation is illustrated and described in Workshop Tools Book No. 55.

Removal of Main Bearing Caps.—The main bearing caps are a very close fit and they are not easily removed by the use of standard tools. A special cap withdrawal tool has therefore been designed and full details are given in Workshop Tools Book No. 55.

Main Bearing and Connecting Rod Big End Nuts.—Special instructions for the correct tightening of the main bearing cap nuts and the connecting rod big end nuts are given in Workshop Tools Book No. 55.

CRANKSHAFT

When it is necessary to re-size or regrind the 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 truly round. The axis of the crankpins must be parallel with the journal bearings in both planes and the radii joining bearings to 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 the crankshaft and bearings may ensue. The sizes and clearances are given in detail in Workshop Tools Book No. 55. Before assembly clean thoroughly all passages and examine surfaces for abrasion; a scratch or dinge may be detected by rotating a half shell on the shaft.

Crankshaft Balance Weights.—These are stamped with the relative crankweb number, thus: 1, 4, 5 and 8 and if, for any reason, the weights are removed they should be correctly replaced according to the relative numbers. The correct tightening torque for the castle nuts is 800 lb/inches and new split pins of the correct diameter and length should always be used.

Crankshaft Sprocket Nut.—A special spanner for the removal and retightening of the large nut at the forward end of the crankshaft is illustrated in Workshop Tools Book No. 55 together with instructions for its use.

Crankshaft Sprocket Nut Locking Plate.—This locking plate should be fitted between the crankshaft chain sprocket and the nut. After finally tightening the crankshaft nut, the edge of the plate should be turned up and punched into the two spanner slots in the crankshaft nut. Finally, the edge of the plate must be punched into two of the three holes in the crankshaft chain sprocket.

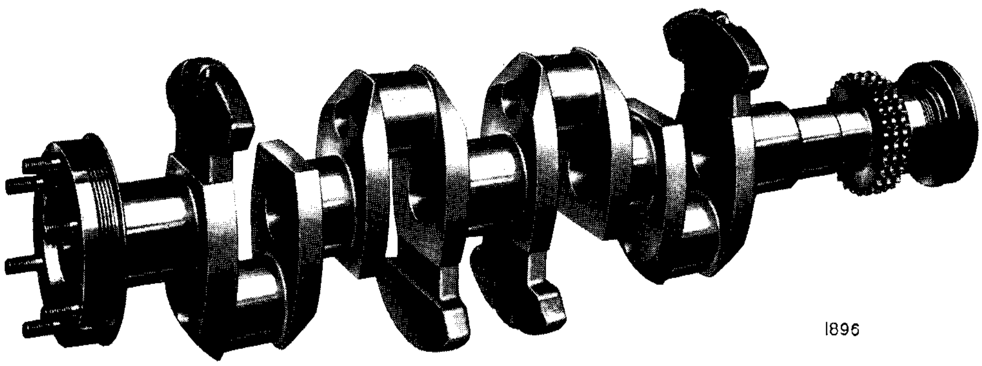


Fig. 6 CRANKSHAFT

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 $\frac{1}{32}$ in. wide band around the circumference of the holes on pins and journals and can be formed by use of a small oil stone.

GARDNER
4LK
TYPE

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 30,000 miles. This mileage is commonly exceeded, but is only 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 machines to 45° removing 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 and the minimum of metal should be removed. The valve and seat should be lapped together with fine abrasive, say 400 grit Carborundum powder. When after long use the valve heads become thin and the valve seats become enlarged the parts should be renewed in order to maintain engine efficiency. The valves and guides should both be renewed if the valve stem wear exceeds ·005 in. **Use only genuine Gardner replacement parts to ensure durability and freedom from failure which might seriously damage the engine.**

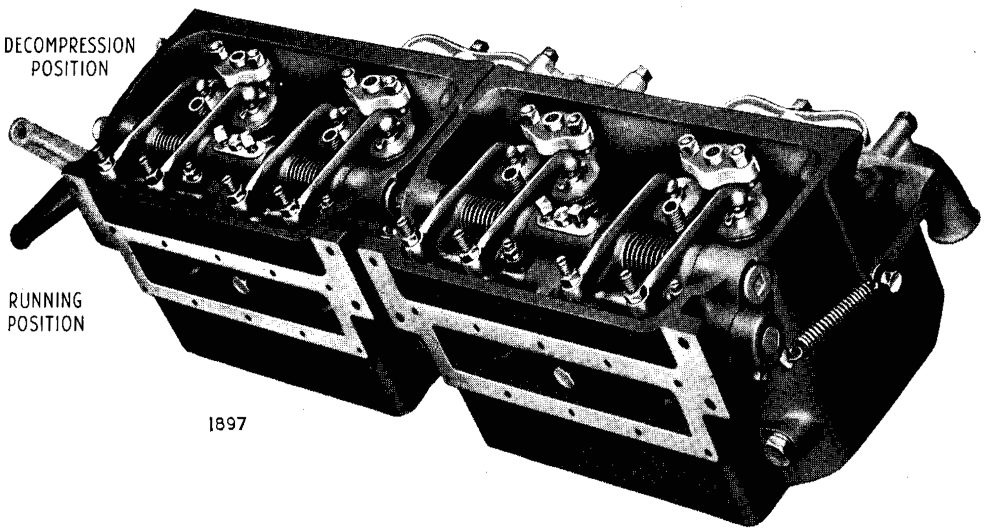


Fig. 7 CYLINDER HEAD ASSEMBLIES

Valve Seat Inserts.—Details of the valve seat insert assembly and of the special tools for the withdrawal and fitting of the inserts are given in Workshop Tools Book No. 55.

To avoid damage to the Sprayer Nozzles.—The sprayer nozzles project slightly from the flat surface of the cylinder head and it is essential that the sprayer assemblies be withdrawn before removing the heads since it is almost certain that the nozzles will be accidentally damaged if this precaution is not taken.

Details of the sprayer withdrawal tool, sprayer hole cleaning tool and sprayer seat cutter and lap, together with instructions for their use, are given in Workshop Tools Book No. 55.

Cylinder Head Water Inlet Elbows and Rubber Hoses.—These should be examined and cleaned in their bores where necessary whenever a cylinder head is removed for decarbonising, etc. The hose connections will have to be renewed where the bore has closed in—do not attempt to restore the bore by cutting the rubber. New packings should always be fitted whenever the elbows have been disturbed.

Replacing the Inlet Valves.—These valves are formed with patent deflectors and are prevented from turning around by the specially shaped valve collars and split pins. It is **essential** that the valves be replaced in their correct position, that is, with the deflectors on the opposite side to the exhaust manifold, and they must be definitely positioned by the split pin in the valve collar. To ensure this, the slot for the split pin in the collar and also the pin hole in the valve stem do not pass through the centre line of the valve stem. With this construction it is impossible for one to screw the valve into the collar and to thread in the split pin with the valve half a turn wrong. When the inlet valves 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. and should the valve stems be a closer fit than this the guides must be reamed out until the 0·00125 in. clearance is obtained.

CYLINDER HEADS—*continued.*

Replacing the Exhaust Valves.—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. and, should the valve stems be a closer fit than this, the guides must be reamed out until the 0·00275 in. clearance is obtained.

Refitting Inlet and Exhaust Valve Spring Collars.—Particular care should be taken to ensure that the spring collars are not screwed further down the valve stems than is necessary to thread the split pin, otherwise the valves may not have sufficient lift and the operating mechanism may suffer damage. Always use a new pin and ensure that it fits tightly in the hole. Before fitting, spring open the legs of the split pin in order to prevent movement in service and open equally to approximately 90° between legs after fitting.

Replacing a Cylinder Head.—The gas joint of head to cylinder is made with a thin metallic-asbestos packing which should be renewed whenever a cylinder head is removed. **Do not use any jointing compound whatever.** Apply evenly to the cylinder head nuts a tightening torque of 750 lb./inches. Do not exceed this figure and see Workshop Tools Book No. 55 for the correct procedure and order of tightening up the cylinder head nuts. **Use only genuine Gardner packings.**

Decompression Lift of Inlet Valve.—The act of turning the decompression shaft to the decompression position causes the cam shaped portion of the shaft to bear upon an adjustable screw fitted in the heel of the inlet valve rocker lever. This action lifts the heel and consequently holds open the inlet valve. The amount of opening is determined by the adjustable screw which, in case of derangement, should be adjusted so that it lifts the inlet valve ·020 in. (twenty thousandths of an inch) from its seat. Further details of the special box spanner and means to indicate the decompression lift will also be found in Workshop Tools Book No. 55.

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 and use new packings in all cases.

Cylinder Foot Packing.—In the earlier 4LK engines which are fitted with aluminium cylinder blocks it is not necessary to use a paper joint between the block and the crankcase. In the case of all later engines which are fitted with cast iron cylinder blocks it is, however, necessary to fit a standard paper joint ·004 in. thick between the cylinder foot and the crankcase. This is essential in order to obtain the correct clearance between the cylinder head and the top of the piston which is nominally ·0575 in. for the 4LK engine. See Workshop Tools Book No. 55.

Cylinder Block Holding Down Nuts.—These should be tightened with a torque not exceeding 815 lb./inches and a special cylinder foot nut spanner is available for this purpose as detailed in Workshop Tools Book No. 55.

Cylinder Liners.—Full instructions for the fitting of new cylinder liners in either aluminium or cast iron cylinder blocks are contained in Workshop Tools Book No. 55. Service cylinder blocks are also available at the works and Depots for immediate use. 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 fine carborundum on 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.

CYLINDER BLOCKS—*continued*

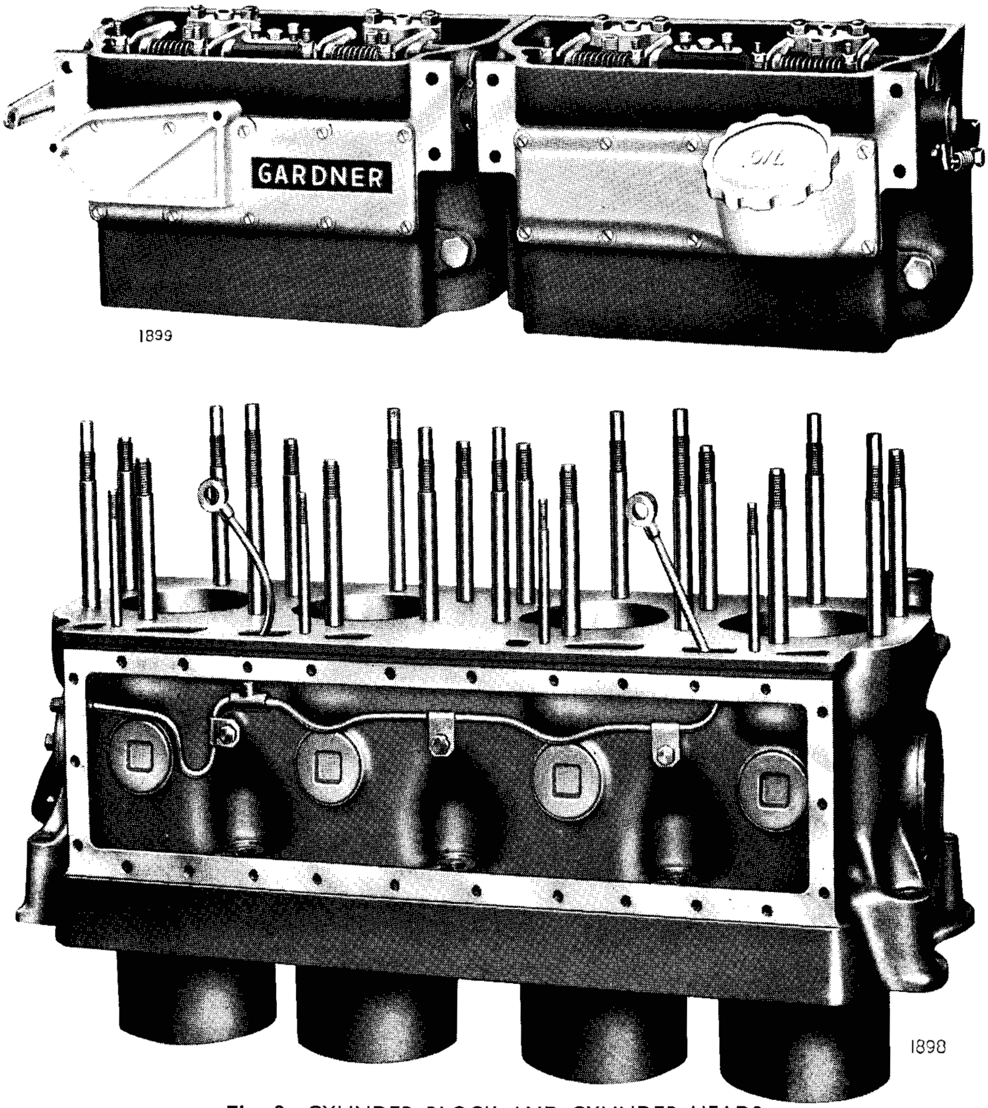


Fig. 8 CYLINDER BLOCK AND CYLINDER HEADS

DYNAMO DRIVE

The flexible rubber coupling clips must be tightened up **before** the dynamo 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 dynamo and timing case bearings. **Use only genuine Gardner replacement parts.**

EXHAUSTER

When fitted, the exhauster is of the simple reciprocating type and consists of a cylinder and piston driven through a connecting rod from a crank fitted to the forward end of the valve camshaft.

The suction and delivery valves are of the " flat " type and are fitted over the ports in the cylinder cover plates, the suction valve on the upper plate and the delivery valve on the lower plate.

If the inlet valve has to be replaced care should be taken to avoid bending the valve and to see that when clamped by its stop plate, it is in contact with the cover plate for the whole of its area. The delivery valve is not flat all over inasmuch as its extreme tip is slightly curled for the full width of the valve; this is to reduce noise of operation.

When fitted the extreme tip of the curled portion should be in contact with the cover plate for the full width of the valve.

EXHAUSTER—*continued*

The metal of the valve stop plates should be lightly punched into the screw slots to provide a locking means. The delivery valve is formed by the piston ring which has approximately ·013 in. 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 in the piston and into the exhauster crankcase. From there it passes to atmosphere through the combined oil separator and breather. On the downward stroke the piston ring is forced into the top face of the groove and automatically seals the discharge holes. Any air which is in the vacuum tank and pipes is therefore drawn into the exhauster cylinder through the suction valve.

Air Suction Filter.—The filter located inside the suction union on the cylinder head should be cleaned periodically and if in so doing a quantity of matter is disturbed, remove the cylinder head and clean thoroughly to avoid fouling the piston. The filter is capable of preventing entry into the cylinder of large particles only and is incapable of arresting fine dust or scale, etc. which may cause undue wear or piston seizure. It is therefore essential to ensure that the complete vacuum tank and pipe system be thoroughly cleaned with compressed air, steam, or other means during overhaul.

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. 55.

Cylinder Head to Piston Clearance.—The Nominal, Maximum and Minimum clearances are given in Workshop Tools Book No. 55.

FLYWHEEL

Electric Starter Ring.—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 playing the flame of a blowlamp around same until the internal diameter is increased by about $\frac{1}{16}$ in. Very little heat is required to cause this expansion, therefore care must be taken not to overheat the ring during this operation. After expanding, place the gear ring in position on the flywheel and allow it to cool slowly in the air. **It is most important that the gear ring must not be heated in a fire.** For further details in this connection and machining tolerances see Workshop Tools Book No. 55.

Coupling Bolts.—The nuts on the bolts coupling the flywheel to the crankshaft should be tightened to the correct torque of 850 lb./inches and new split pins of the correct diameter and length should always be used whenever occasion necessitates the replacement of these parts.

FUEL FILTERS

Each engine is equipped with two fuel filters of special design which are fitted in circuit with the fuel system. Both filters are similar in design. The **First Fuel Filter** is intended to be fixed on the chassis or bulkhead in circuit between the fuel tank and the **Second Fuel Filter** which is mounted permanently on the front of No. 1 cylinder head. See Fig. 9.

Fuel Filters.—These employ a special form of paper filtering elements which are inexpensive and readily replaced. 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 strainer for this purpose. On gravity feed systems a vent cock is fitted to the second strainer.

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.

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FUEL FILTERS—*continued*

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

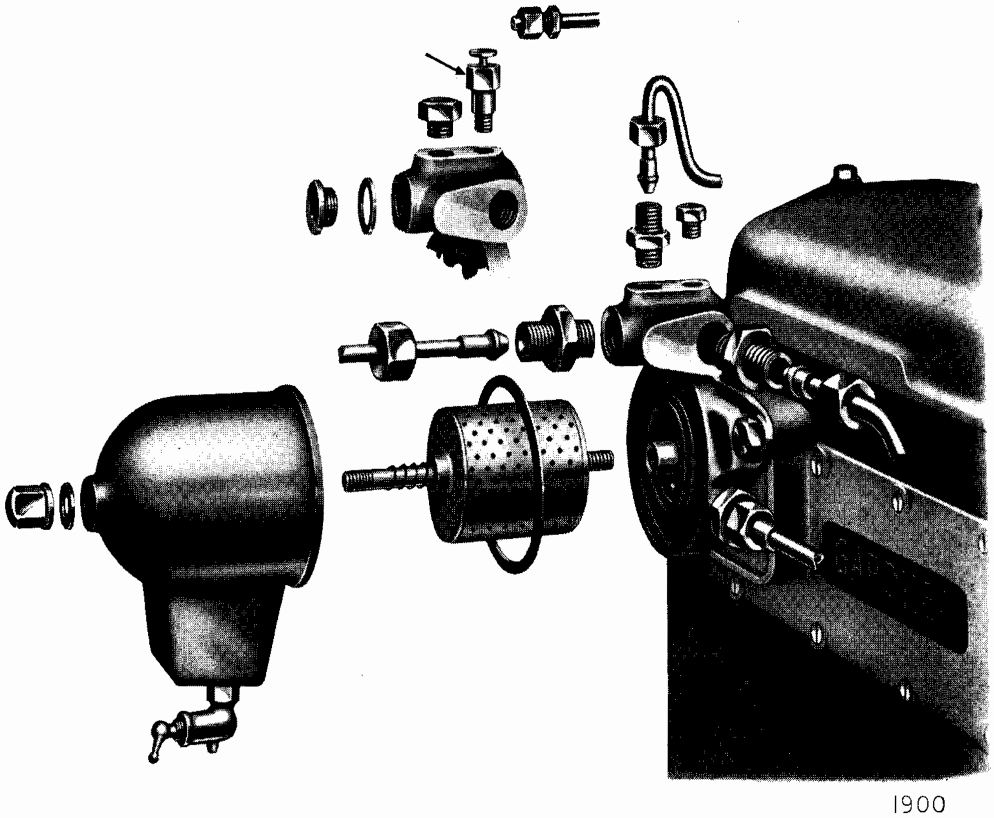


Fig. 9

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

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.

Replacement of Filter Elements.—Apart from stoppages due to the causes outlined in preceding paragraph 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 30,000 miles or 3,000 hours. Generally speaking the second filter element should have a " clean " life longer than that of the first filter element.

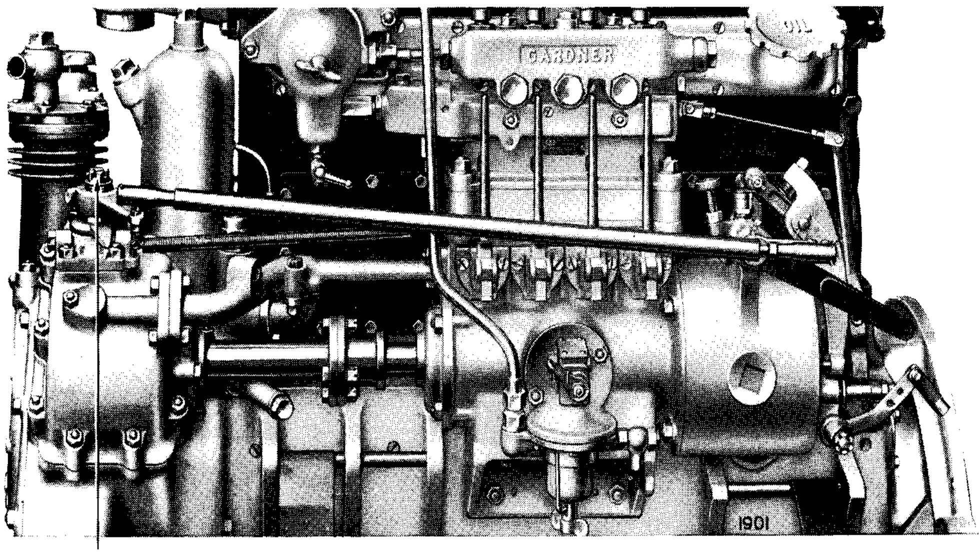
When Replacing the Filter Covers gently rotate them on their joint faces so as to minimise the chance of foreign matter causing an unsound joint. Do not use a hammer to tighten the nut on the cover. Use a new standard specification joint ring to ensure absence of leakage.

FUEL INJECTION PUMP

The fuel injection pump is built in one unit and contains four plungers and barrels (pumps) each with its delivery valve and seating, etc. Each plunger is operated by its own cam on the fuel pump camshaft assembly and, in addition, it is furnished with a hand lever and latch enabling the plungers to be worked by hand for priming the fuel injection system. The latches enable any plunger to be put into or out of action.

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 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, ball jointed, connecting rod to the lever of the advance and retard mechanism located on the fuel pump driving gear cover at the forward end of the engine. Should the mechanism become deranged it is a simple matter to readjust 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 the 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 fully depress 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.

Advance and Retard Device.—The advance and retard mechanism controls the axial position of a helical gear capable of sliding along the helically splined portion of the fuel injection pump camshaft which is coupled to the camshaft proper by a special coupling and four bolts. There is consequently a slight reaction from the cams on the mechanism which is transmitted through the helical gears and splined shaft. To provide against this



FRICTION DEVICE NUT

Fig. 10 VIEW OF ENGINE SHOWING FRICTION DEVICE NUT

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FUEL INJECTION PUMP—*continued.*

movement being transmitted to the accelerator lever and so wearing the connecting links, etc., an adjustable friction device is fitted consisting of a cork washer clamped between the control plate and the advance pointer lever and loaded by a castle nut and spring washer. See Figure 10. This should be inspected every 30,000 miles and if, while the engine is idling, the pointer lever is seen or felt to move slightly backward and forward, the castle nut should be tightened by the minimum amount required to damp out the vibration. If the friction device be over-tightened, it will make the accelerator lever stiff to move and will prevent it returning to the position of slow running. The amount of friction applied in this way may be judged by operating the accelerator lever, but if this be effected with the engine stopped, it is necessary to pull back all the priming levers on the injection pump in order to liberate the pump cams from spring load. The cork washer should be renewed at each major overhaul.

Fuel Injection Pump Output.—After every 30,000 miles the fuel injection pump complete with its insertion plate should be removed and fitted to a Gardner calibrating machine for the purpose of checking the fuel pump output. Tests should be made of the maximum fuel delivery with the slider bar in contact with the control trigger and also in the idling position as described in detail in Book No. 45.3. In course of time the 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 the fuel pump delivery valve seat assembly also adversely affects the timing and hydraulic characteristics and it is recommended that these parts be renewed at major engine overhauls.

Fuel Pump Element Testing.—Special equipment is available for testing the wear of the fuel pump elements (plungers and barrels). Such tests can be made either without dismantling the pump unit or, if necessary, by checking the elements when they are not fitted in the pump body. Details of these tools are given in Workshop Tools Book No. 55.

Fuel Pump Camshaft (also Engine b.h.p.).—Engine prior to those numbered 76707 are fitted with type 7 fuel pump camshafts and are set to develop 51 b.h.p. at a maximum speed of 2,000 r.p.m. at full load or 2,080 r.p.m. at no load with engine hot. When it is necessary to fit a spare fuel pump camshaft to any engine prior to No. 76707 it is recommended that the existing maximum fuel pump output of 74·5 c.c. in 1½ minutes at 2,000 r.p.m. crankshaft speed be retained. In this case the existing Injection Control Lever, type 1, should also be retained and the fuel injection timing set to 34° before T.D.C. at 2,000 r.p.m. The speed of an engine fitted with type 7 fuel pump camshaft must not be increased above 2,000 r.p.m. at full load.

Engines numbered 76707 and after are fitted with type 8/8 or 8/4 fuel pump camshafts and the correct maximum fuel pump output for such engines is 80·0 c.c. in 1½ minutes at 2,100 r.p.m. crankshaft speed. This output will enable an engine correctly assembled with genuine Gardner components to develop 57 b.h.p. at 2,100 r.p.m., the correct fuel injection timing being 34·8° maximum before T.D.C.

It is permissible to fit a type 8/8 or 8/4 fuel pump camshaft to engines prior to those numbered 76707 and to increase the maximum speed to 2,100 r.p.m. during a complete overhaul. In such cases, however, a type 2 Injection Control Lever must also be fitted to enable the correct fuel injection timing range to be obtained. This lever is supplied with the fuel pump camshaft type 8/8 or 8/4 in such instances. The type No. 8/8 or 8/4 is clearly stamped on the side face of No. 1 Cam and the engine speed adjustment should be effected by the Adjusting Screw

FUEL INJECTION PUMP—*continued.*

(Part No. 5/30) at the upper end of the Governor Spring Lever (Part No. 5/29) and **not** by the Accelerator Cam Stop Screw (Part No. 5/69) which should be set on all engines to provide an Accelerator Cam angle of 27°. The engine output at 2,100 r.p.m. will be 57 b.h.p. and the maximum speed at no load with the engine hot should be set to 2,175 r.p.m.

Engine numbered 123269 and all subsequent 4LK engines have been set to deliver 60 b.h.p. at 2,100 r.p.m. The Governor and all timing settings remain exactly as they are for engines set to deliver 57 b.h.p. The fuel pump output has, however, been increased so that each plunger delivers 90 c.c. in 1⅓ minutes at 2,100 r.p.m. crankshaft speed. The power setting of all older engines cannot be increased unless they are overhauled and rebuilt with genuine Gardner components of current design.

Fuel Injection Control Plate and Spindle.—In later engines two thrust washers have been introduced between the injection control spindle and plate. To convert the original injection control plate to accommodate the two thrust washers, the end face of the boss must be suitably machined and the thrust washers must be assembled with the bevel on the same side as the spindle thrust face. The tension on the spring should be made by screwing up the nut until the spring is just solid; then slack off the nut 6 flats and secure by the split pin in the nearest slot: All parts should be oiled copiously upon assembly.

Fuel Pump Tappets.—These are adjusted during engine tests and the setting should not be disturbed. Normally, they will not require any further attention, but should the adjustment be inadvertently upset, or if new parts have to be fitted due to accident or wear, they should be reset as follows:—

Remove the fuel pump and turn the flywheel until the tappet has lifted to its maximum, then turn the flywheel one more revolution when the tappet will be resting on the base of the cam. Place on top of the tappet screw a suitable disc or washer of exactly ·111 in. thickness. Re-fit the fuel pump and tighten the holding down nuts. Examination should now be made to see that the line marked on the fuel pump window coincides with the line on the spring thimble. If this condition does not obtain, remove the pump and readjust the tappet screw up or down until the lines register exactly. The tappet screw should now be firmly locked and the disc or washer removed. This operation must be carried out on each tappet in turn and the fuel pump afterwards refitted. **Important Note.**—Under no circumstances must the engine be turned whilst the ·111 in. gauge is in position on any of the tappets otherwise most serious damage will occur to the fuel pump.

Fuel Pump Cambox.—The fuel pump tappets and the cam box bores are of course liable to wear and it is desirable to re-size cambox bores when the wear is such that a new standard size tappet has ·006 in. clearance in a worn bore. A special Cambox Reamer can be supplied to re-size worn bores to receive ·010 in. oversize tappets and further details in this connection are contained on pages 34 and 35 of Book No. 55.

Fuel Pump Tappet Pins and Rollers.—If the tappet rollers have more than about ·005 in. slack on their pins the rollers and pins should be replaced, for which purpose proceed as follows:—

The pin hole in the tappet is slightly smaller at one side than the other, thus the plain unstepped pin is a shrink fit in one side only of the tappet.

FUEL INJECTION PUMP—*continued.*

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 tap 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 grooves 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 the pin will then carry the load.

Fuel Pump Slider Bar Bushes.—When these bushes are renewed it is very desirable that they should be in complete alignment otherwise governing and thereby fuel injection will be most seriously impaired. A special bush reamer and fitting key can be supplied for this important operation and further details are contained in Workshop Tools Book No. 55.

Instructions for Fitting Spare Fuel Pumps.—When fitting a spare fuel pump it is necessary to proceed as follows:—

No. 1.—Fit the pump in the normal manner after having checked, and corrected where necessary, the tappet settings as instructed on page 36.

No. 2.—Fit the eyed rod connecting the control bar to the vertical governor lever. The length of this rod may have to be adjusted to suit the new pumps. The correct setting of the control bar with relation to the governor weights is such that, when the governor weights are parted to their full extent by inserting the fingers through the inspection opening in the governor case, the length of the eyed connecting rod is so adjusted as to give the control bar a position approximately $\frac{1}{32}$ in. from its maximum stroke towards the timing case. Should it be necessary to make adjustment to this rod, great care should be exercised to see that the holes for the joint pins are parallel when the nuts are locked and that the control bar moves perfectly freely. When making this adjustment it is necessary to remove the hinge pin from the large forked governor spring lever otherwise spring load may prevent the governor weights from being parted to their maximum by finger pressure. It is also necessary to remove the buffer from the fuel pump control box.

No. 3.—When the stopping lever is in the " stop " position the control bar should still have a movement, or clearance, of $\frac{1}{32}$ in. before reaching the maximum " in " position (as in No. 2 above). To obtain this, adjust the screw in the lower end of the governor lever. This clearance is necessary in order to prevent straining of the governor lever, the eyed connecting rod and the fuel pump control bar and quadrants, etc. when the stopping lever is in the stopping position.

No. 4.—Fit the pipe-work and the control rod spring at the back of the pump and also the fuel pump steady. After fitting the spare fuel pump it will, of course, be necessary to check the timing of fuel injection and to prime the fuel system as directed on pages 54 and 45-46.

FUEL INJECTION PUMP—*continued.*

Important Note.—The fuel control box fitted to the pump must only be used on the pump to which it was fitted when delivered. The number of the pump to which a control box has been set is stamped on the box itself as is also the engine serial number. The fuel control box is only interchangeable when the fuel pump has been subject to the full calibration procedure as directed in Book No. 45.3. An engraved brass plate is now fitted to the control box. On this plate is given full particulars of the power setting.

FUEL LIFT PUMP

Description.—This pump, of which the Amal is a typical example, is mounted on the fuel pump cambox and is operated by a cam which is an integral part of the fuel pump camshaft. The pump is so arranged that it will deliver about 60 per cent. more fuel than the engine demands on maximum load. The fuel from the pump is delivered into a chamber, embodied in the fuel strainer assembly mounted on No. 1 cylinder head, at a pressure of about $1\frac{1}{2}$ lb./sq. in. See Fig. 9. Out of the chamber, fuel, and any air there may be, is allowed to overflow through a ·018 in. diameter hole back to the tank along with the leak fuel from the sprayers. By this means it is ensured that any air which finds its way into the fuel on the suction side at joints, taps, etc., is separated from the fuel which feeds the injection pump on the engine.

The Amal fuel lift pump is also provided with a lever for operating by hand in order to initially fill the pipe system and prime the fuel injection pump.

Installation.—The Amal fuel lift pump is used with the Gardner Overflow Return system which is described in Section I under the heading of Fuel Supply System. When re-fitting the pump care should be taken to see that the paper packing, or in later engines the brass packing, is not omitted.

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FUEL OIL

Specification.—The following is a laboratory specification of a typical example of the type of Fuel Oil which should be used in these engines. Whilst a selected fuel may conform to these figures, before it is finally approved it should be the subject of an actual trial in an engine.
Any fuel for this purpose should be wholly distillate.

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

Note.—Paraffin, as used in lamps and heating appliances, is an excellent fuel, having a high ignition quality, and, therefore, particularly suitable under conditions of extreme cold, but, if blended for use in spark ignition engines, is unsuitable for compression ignition engines, since it has low ignition quality.
Ignition Quality.—This is an extremely important factor. An accepted criterion of ignition quality of a Diesel Fuel is its Cetane Value expressed as a number.
A good quality fuel has a Cetane Value of not less than 57, it is desirable that the Cetane Value of the fuel used should not be less than this figure and should not in any case fall below 52.
Another unit in use is the Diesel Index Number. This is always several points higher than the Cetane Number for any given fuel. The above figures if quoted as Diesel Index Numbers are:—

Cetane 57—Diesel Index 62.
Cetane 52—Diesel Index 56.

Generally speaking, the higher the ignition quality, the better will be the startability, general maintenance and the quieter will be the operation of the engine. It should be noted that the addition of coal oil derivative to the normal petroleum fuel can result in a mixture of lowered ignition quality which gives rise to noisy operation, misfiring and objectionable exhaust fumes particularly from a cold engine. On this account it is essential that the petroleum fuel is of the highest quality and that only small amounts of coal oil are added.

Fuels corresponding to the above specification are readily obtainable from most of the fuel companies.
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

FUEL OIL—*continued.*

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, inflammability, handling, etc., of this product.

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.

FUEL SPRAYERS

Description.—The fuel sprayers are illustrated in Fig. 11 and will be seen to be a very simple and robust piece of apparatus. The sprayer is designedly made non-adjustable, meaning that when it is reassembled after taking to pieces for cleaning or examination (as distinct from overhauling), it requires no adjustment of any kind. The sprayer is one of the most vitally 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 under the heading of Fuel Filters.

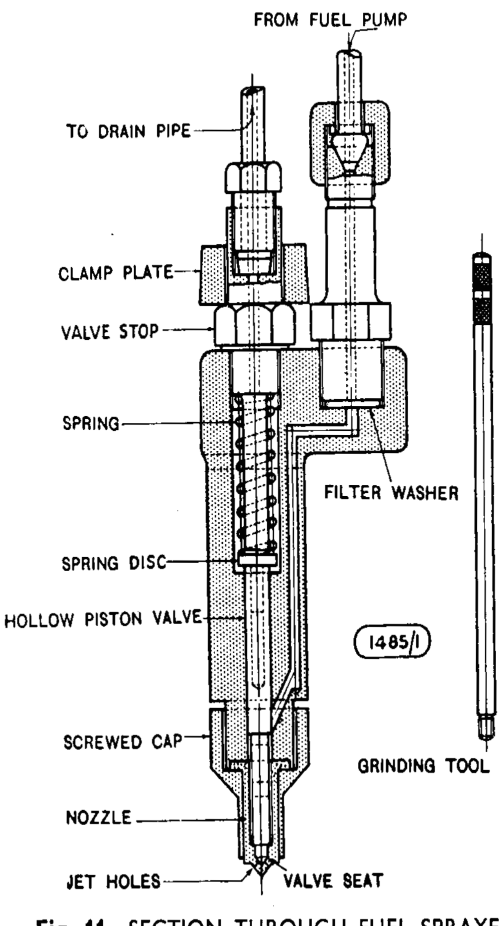

Fig. 11 SECTION THROUGH FUEL SPRAYER

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.

Fuel Sprayer Test every 3,000/6,000 miles (300/600 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 SPRAYERS—*continued.*
fuel dilution of lubricating oil, impaired fuel consumption, loss of power, burning of exhaust valves and even cracking of cylinder heads, etc. etc.

Fig. 12 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.
It should be noted that Gardner Factory-reconditioned sprayers are available from the works, Branch Offices, Service Depots, and from our official Service Agents, at a modest cost, in exchange for used sprayers.

Every 30,000 miles (3,000 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 indicated in the following appropriate paragraphs:—

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.

Defective Sprayers.—If a sprayer is known to be defective, do not run the engine longer than absolutely necessary since this will cause undue wear, smoky exhaust and other accompanying evils.

Reconditioning of Sprayers.—Fuel sprayers which have been removed from the engine at the 30,000 miles routine change should be returned to the works or Service Depots for reconditioning. 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.

If it is not possible for the sprayers to be returned to the works or a Service Depot for reconditioning, they should be inspected and serviced as indicated in the following appropriate paragraphs:—

Withdrawal of Sprayer.—After long usage it may prove difficult to remove the sprayer from the cylinder head and each engine is therefore supplied with 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 and the bar set to bridge the top faces of the cylinder head as illustrated in Workshop Tools Book No. 55. The nut should then be screwed down enabling the sprayer to be withdrawn easily.

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, as illustrated in Fig. 12 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 the spray is defective, remove the screwed cap and nozzle and prick out the holes with the standard pricker supplied with the engine. 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. See Workshop Tools Book No. 55 for further directions regarding use of the sprayer nozzle drift.

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 the seat of the nozzle using metal polish or 600 grit Carborundum powder. Then prick out the jet holes and finally wash out by forcing paraffin from outside to inside of the 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 which obtains when the engine is in operation. See Fig. 13.

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

FUEL SPRAYERS—*continued.*

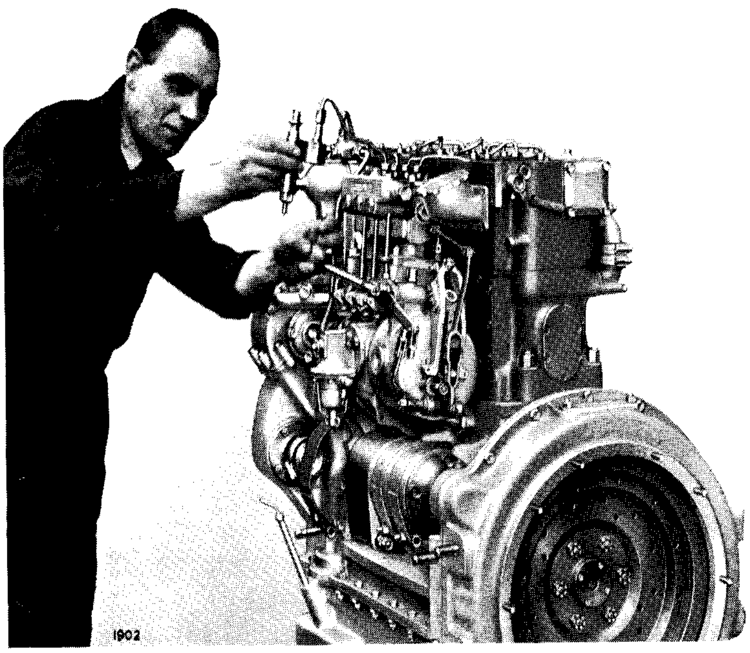

Fig. 12 TESTING A SPRAYER

having the **same diameter plunger as the engine pump.** Operate the hand priming lever and expel all air from the system; then apply force to the lever just short of that required to lift the sprayer valve from its seat—that is, operate the lever to lift the sprayer valve without forcing fuel through the sprayer nozzle. If, when making the test, fuel is seen to run down the nozzle this indicates that the valve seat is unsound. 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 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."

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 the paragraph hereunder dealing with reassembly of the sprayer. 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 only be effected as a very last resource and as seldom as ever possible.

To Lap Together Sprayer Valve and Nozzle Seat.—Remove valve stop spring, screw cap and nozzle, and mount sprayer body in vice with nozzle end to left hand side. Screw into hollow end of valve the knurled lapping tool supplied with the engine and replace valve in the 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

FUEL SPRAYERS—*continued.*

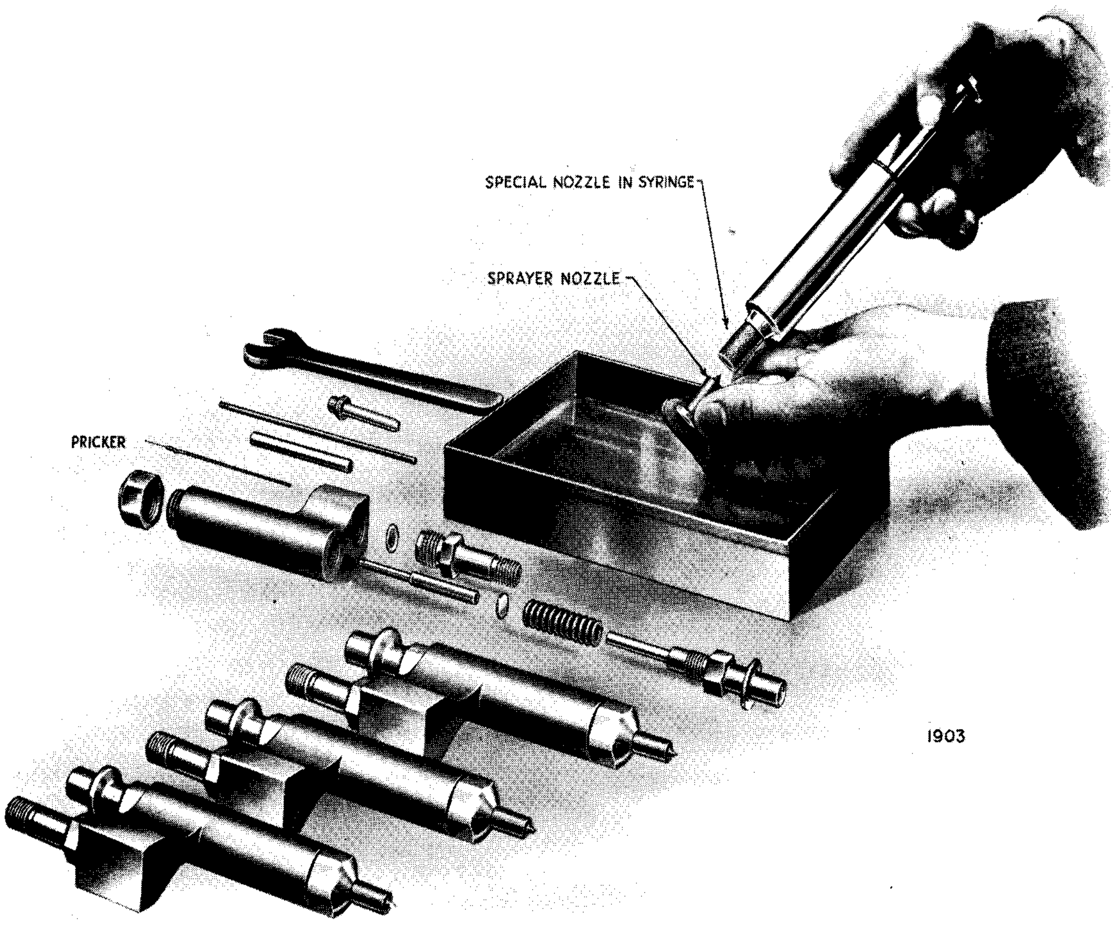

Fig. 13 CLEANING AND SERVICING FUEL SPRAYERS

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 regrinding the valve and relapping the nozzle. These operations are normally effected by the works since specialised machines are required for this purpose.

Screwed Cap and Nozzle.—Before assembling the sprayer 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 of the valve in the sprayer body as mentioned under the following paragraph dealing with Reassembly of Sprayer.

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 ·006 in. 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.

FUEL SPRAYERS—*continued.*

Sprayer Filter Washers.—These are held in position by the Delivery Union Stock and must be renewed during the reconditioning of the sprayers at the routine change every 30,000 miles.

Spring Load on Sprayer Valve.—The opening and closing pressure of the sprayer valve is determined by the load required to compress the spring a given amount. This method of determining the opening and closing pressure is a more reliable means of setting than by using a pump and hydraulic gauge. The correct spring load, which should be rigidly adhered to, is 59 lb.; for this purpose the spring should exert this load (59 lb.) when compressed to its working length of 1·320 in.

Hydraulic Opening Pressure.—Although as stated in preceding paragraph that it is preferable to determine the correct loading of the sprayer valve by measuring the load exerted by the spring when compressed to its working length of 1·320 in. and that this load should be 59 lb., the following hydraulic opening pressures are quoted as a guide for use when a spring weighing machine is not available and refer to the use of a hand operated pump operated slowly and having a plunger diameter approximately equal to that of the engine injection pump:—

(1) With sprayer valve seats in new condition a load of 59 lb. corresponds to a hydraulic opening pressure of 131 Kg. per square centimetre or 126·7 Atm. A tolerance of plus or minus $1\frac{1}{2}\%$ is regarded as permissible.

(2) When sprayer valve seats become worn after long use (80,000 to 100,000 miles) the seat width is increased and the effective seat diameter becomes smaller. A 59 lb. spring load will then give a lower hydraulic opening pressure.

If, when testing a sprayer on a hand test pump, the needle valve **vibrates satisfactorily** and **does not leak,** proceed as follows:—

(*a*) If the opening pressure has fallen to not less than 119 Kg. per square centimetre or 115 Atm. increase by shimming the spring between its upper end and the screw stop to not more than 124 Kg. per square centimetre or 120 Atm.

(*b*) If the opening pressure has fallen below 119 Kg. per square centimetre return to engine makers for complete overhaul.

(*c*) When a sprayer has been in use for a long period and consequently developed a wide valve seat, do not attempt to shim the springs to exceed an opening pressure of 124 Kg. per square centimetre or 120 Atm.

Replacement Sprayer Springs.—When fitting a replacement spring, the correct spring load on the sprayer valve, when compressed to the correct working length of 1·320 in., is obtained by the use of shims fitted between the upper end of the spring and the screwed stop. In its assembled condition two ·007 in. thick shims are normally required to obtain the correct spring load.

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

(1) Piston valve with grinding spindle attached.

(2) Nozzle and cap.

(2a) 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.

FUEL SPRAYERS—*continued.*

Replacing a Sprayer in the Cylinder Head.—The nose of the sprayer is slightly taper, whereas the hole in which it fits in the cylinder head is parallel, consequently the space thus left becomes, in the course of time, filled with carbon. 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. The sprayer hole cleaning tool is illustrated and described in Workshop Tools Book No. 55.

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 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 become distorted and its functioning impaired; in addition, the cylinder head may suffer distortion and possible cracking.

Sprayer Pipe Unions.—It is imperative that these unions do not leak, especially those in the valve gear chambers on the cylinder heads. When replacing the sprayers, therefore, take particular care to see that the sprayer fuel pipe nuts and the sprayer leak pipe nuts are properly tightened. In course of time the conical pipe ends may become reduced in bore by the action of repeated tightening of the sprayer fuel pipe nuts and the consequent pressure on the conical seats. 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 ·054 in.

GOVERNOR AND GOVERNOR CONTROL

Slow Running Adjustment.—See Figure 4 for location of the adjusting sleeve nut. Engines are set to idle at approximately 450 r.p.m. during test and this speed should be accordingly adjusted every 10,000 miles or whenever necessary, since slight wear of parts may reduce this speed and lead to unsteady idling. After starting a cold engine make use of the pedal control until engine attains normal operating temperature and ensure that the engine idling speed is suitably maintained.

Adjustment of Fuel Pump Slider Bar Buffer.—Located on the fuel control box will be seen the slider bar buffer, the purpose of which is to prevent stalling of the engine in the event of friction being generated in the fuel pump. The slider bar buffer should be adjusted according to the following procedure when the engine has reached normal operating temperature. Adjust idling speed to 450 r.p.m. by means of idling screw, gradually screw buffer towards bar until slight speed increase is experienced, withdraw buffer 10 hexagon flats and lock in position. If the buffer is set with insufficient clearance from bar, unstable idling will result. Use only light pressure to lock buffer in fuel control box.

Accelerator Control.—This should be inspected every 30,000 miles to ensure that the pedal-operating mechanism is working the control throughout the whole of its range, that is, from idling to maximum speeds. An inspection of the accelerator mechanism will reveal the limiting stops, the one for idling being the knurled " slow-running " screw, while that for maximum speed consists of two $\frac{5}{16}$ in. diameter pegs at the end of the governor spring lever. Do not under any circumstances alter or interfere with these $\frac{5}{16}$ in. pegs, or otherwise increase the maximum governed speed of the engine which is 2,100 r.p.m. crankshaft at full load and approximately 2,175 r.p.m. at no load.

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

GOVERNOR AND GOVERNOR CONTROL—*continued.*

Fuel Pump Slider Bar.—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 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. from its maximum stroke towards the timing case. Inspect that this dimension obtains every 30,000 miles 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. clearance is 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 slider bar return spring. When making adjustment to provide this $\frac{1}{32}$ in. clearance it is necessary to remove the hinge pin from the forked governor spring lever and to remove the buffer from the fuel pump control box otherwise spring load will prevent the governor weights from being parted to their utmost by finger pressure.

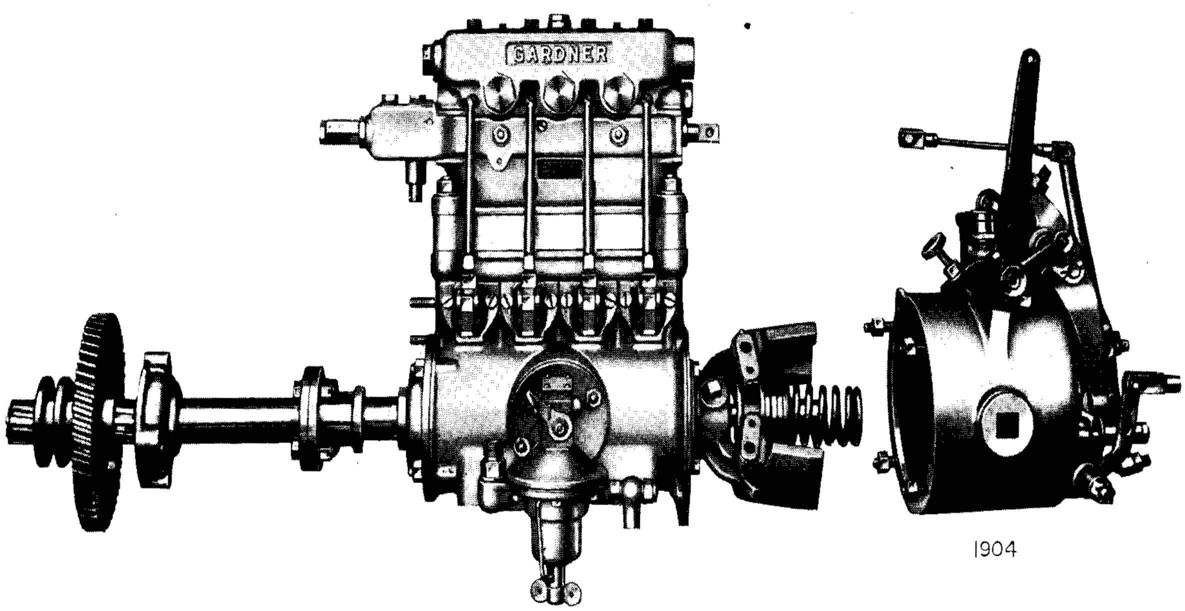

Fig. 14 FUEL PUMPS AND GOVERNOR ASSEMBLY

Governor Weight Toe Bearing.—The toes of the governor weights are fitted with rectangular spring loaded bronze blocks and the correct number of springs per toe is three. It is essential that the two trunnion blocks be assembled in each governor weight with the Zero marks coincident and pointing towards the governor spring, i.e., the Zero marks are to be on the loaded flange of the governor sleeve. If it is necessary to remove or fit springs in the trunnion blocks use new split pins on reassembly.

GOVERNOR AND GOVERNOR CONTROL—*continued.*

Governor Assembly.—For the governor to operate smoothly it is necessary that the various pins, bushes and rollers have no more than about ·004 in. diametral slack. Where exceeded it will be necessary to fit new rollers 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. Always use new split pins of the correct diameter and length and see that they are properly opened after assembly.
Later engines are fitted with trunnion blocks and springs in place of rollers and the same instructions apply. When engines which have previously been equipped with rollers are being overhauled, the rollers should be replaced by trunnion blocks and springs.
Service reconditioned bodies and weights assemblies can be obtained from the works and Service Depots in exchange for worn parts.

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. 55.

LUBRICATING OIL

Detergent Oils.—Of recent years it has become established that the sulphur content of fuel oil has a very important effect on the internal cleanliness and wear rate of an engine—in particular the question of lacquer formation on cylinders and piston rings, etc.—and accordingly the following are our recommendations:—
The use of approved detergent oil to any of the following specifications is desirable, but not essential.
(1) 2-104B Supplement 1. (U.S. Army Ordnance, see note overleaf).
(2) DEF-2101-B (British Ministry of Supply).
(3) MIL-L-2104A (U.S. Army Ordnance).
Their use is particularly desirable when one or more of the following conditions obtain:—
(1) The fuel oil in use contains more than ·3% sulphur.
(2) The engine is operating under continuous load (e.g. stationary electricity generating plant).
(3) The gross laden weight of a road vehicle in tons (2240 lb./ton), per litre of engine swept volume is in excess of 1·6 approx.
(4) High atmospheric, coolant and lubricant temperature.
(5) The engine duty is insufficient to promote rapid attainment of optimum coolant temperature (e.g. short haul road delivery vehicles, shunting locomotives, etc).
Oils to the above specifications possess a remarkable ability to combat the evils of sulphur in the fuel both from a wear (corrosion) and cleanliness point of view (lacquer), and we recommend that use be made of the high quality 2-104B Supplement 1 oil wherever possible. This oil promotes the lowest rate of wear and remarkably clean running which likewise applies even when the fuel oil has a low sulphur content. Additionally the lubricating oil consumption rate of an engine is thereby under many conditions considerably reduced. Should Supplement 1, however, not be available, oils to the other two specifications may be used and the engines are capable of sustained performance under the following approximate conditions:—

	FUEL	OIL	DRAIN PERIODS
(a)	·8% sulphur fuel of good ignition quality.	(1) Supplement 1	4000 miles (400 hrs.).
		(2) DEF-2101-B or MIL-L-2104A	3000 miles (300 hrs.).
(b)	Low sulphur fuel say less than ·3% of good ignition quality.	First class straight oil.	3000 miles (300 hrs.).
(c)	Low sulphur fuel say less than ·3% of good ignition quality.	(1) Supplement 1	6000 miles (600 hrs.).
		(2) DEF-2101-B or MIL-L-2104A	4000 miles (400 hrs.).

LUBRICATING OIL—*continued.*
From the foregoing it will be seen that not only do we advocate the use of detergent oils but also advocate a detergent oil of highest quality. We do not, however, do so to the extent of saying that their use is essential, but, nevertheless, the lowest rate of wear, the greatest cleanliness, and the best maintained engine condition are not under any conditions obtainable without them.
In addition, when considering detergent oil versus straight oil the questions of drainage period and lubricating oil consumption assume much importance in arriving at costs and we claim that the low lubricant usage rate of our engines enables a high quality lubricant to be considered and also a more frequent drainage period with beneficial results in regard to the removal of internal "wearings."
Note.—U.S. Army Ordnance Specification 2-104B Supplement 1 is officially obsolete, but oil of Supplement 1 type is still generally recognized as referring to a superior lubricant.
Special Caution.—When using a detergent for the first time in an engine which has been in service it is advisable to inspect the lubricating oil filter after a short period and pay due regard to engine oil pressure, since oils of this type free deposited carbon, and if the filter does not receive attention it may suddenly, in case of a dirty engine, become choked.
Suitable oil is supplied by any of the well-known makers.
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 upon the mean ambient temperature prevailing during the operation of the engine.

VISCOSITY REDWOOD No. 1	
Specification BS. 55°—90° F. *e.g.* British Isles June, July, Aug., Sept. **Temp.° F.** 70 Not exceeding 1600 sec. 100 ,, ,, 600 ,, 140 Not less than 160 ,, 200 ,, ,, 64 ,,	**Specification BW.** 30°—55° F. *e.g.* British Isles March, April, May, Oct., Nov., and Dec., Jan., Feb., Normal Winter. **Temp. °F.** 70 Not exceeding 1250 sec. 100 ,, ,, 420 ,, 140 Not less than 120 ,, 200 ,, ,, 54 ,, Cold Test—Not higher than 5° F.
Specification KW. 10°—30° F. *e.g.* British Isles Dec., Jan., Feb., Severe Winter. **Temp. °F.** 70 Not exceeding 780 sec. 100 ,, ,, 300 ,, 140 Not less than 112 ,, 200 ,, ,, 52 ,, Cold Test—Not higher than 5° F.	**Specification BT.** Over 90° F. **Temp. °F.** 70 Not exceeding 2500 sec. 100 ,, ,, 800 ,, 140 Not less than 220 ,, 200 ,, ,, 74 ,,

Note.—The works will be pleased to advise in any case where operating conditions are particularly arduous or where temperature conditions are not covered by the above table, as for instance severe tropical and arctic conditions where oils heavier and lighter respectively than those quoted above should be used. The use of ultra low viscosity lubricating oil is emphatically not recommended and indeed, we cannot accept responsibility for

LUBRICATING OIL—*continued.*

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 KW specification in a public service vehicle engaged on stage carriage service, provided the ambient temperature is not in excess of 70° F.

LUBRICATION SYSTEM

Description.—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 use of suitable lubricating oils has already been dealt with in the preceding paragraphs and the lubricating 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 base-chamber at the forward end of the engine.

The pump is driven by a vertical shaft from the camshaft and 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 to the delivery filter and pressure regulator. An external pipe from the delivery filter delivers the oil to an opening in the top of the crankcase from where it passes through passages formed in the crankcase to 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 by an external pipe through the governor unit, the fuel injection pump cams, the tappet mechanism and, finally, to the main timing drive of the valve camshaft. The lubricating pump is regulated to deliver oil at a pressure of 35 lb./sq. in. under conditions of normal working temperature when the engine is running at 1,000 r.p.m. and the arrangement of filters is such that all lubricating oil is filtered before delivery to the various bearings. On the external pipe which passes the oil from the delivery filter to the opening on top of the crankcase will be found a connection which is to be coupled up to the pressure gauge on the instrument panel. On the other side of the delivery filter is a spring-loaded by-pass valve for regulating the oil pressure.

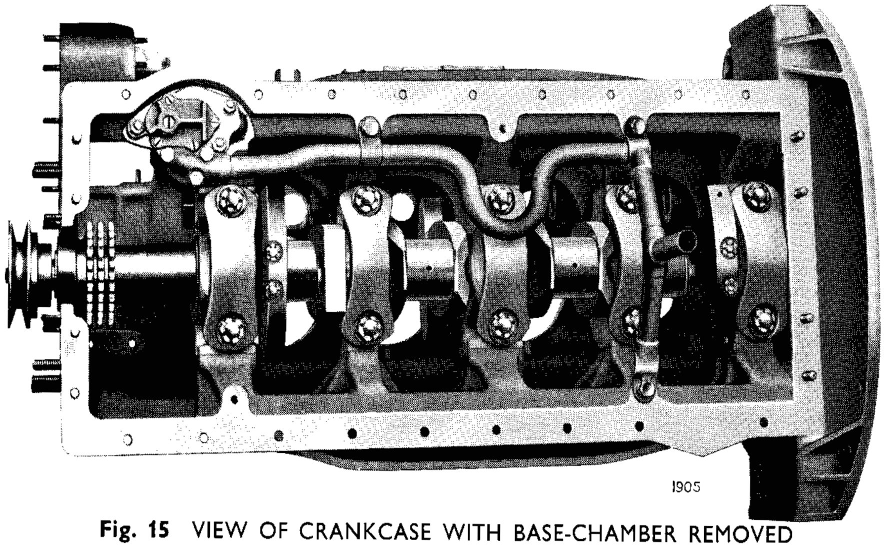

Fig. 15 VIEW OF CRANKCASE WITH BASE-CHAMBER REMOVED

Oil Level Indicator.—The oil sump is charged through the opening in the oil filter assembly which is situated on the cylinder head at the flywheel end of the engine. Some engines are fitted with the oil filler assembly mounted on the side of the head; others have the filler fitted on the cylinder head cover. Both types of filler have an aluminium cover which is clearly marked " OIL " and which can be readily removed and replaced by screwing up or down by hand.

Crankcase Breather.—Mounted on this oil filler cover is a paper element type of breather filter to provide for crankcase ventilation. This breather filter should be replaced completely every 20,000 miles.

The oil level dip rod is normally fitted in the base-chamber on the near side of the engine and **the sump should be charged until the level rises to the maximum mark on the dip rod.** To test the level correctly, with-

LUBRICATION SYSTEM—*continued.*
draw the rod and wipe perfectly dry, then re-insert and withdraw again. The approximate oil charge required for engines fitted with our standard oil sump is 2 gallons.

For engines fitted with sumps of other pattern, the charge may vary and the quantity required must be determined by the markings on the dip rod. The correct oil level 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 and this is the level to which the sump should be charged and also the level which should be maintained. In other words, the oil level in the sump should not be allowed to fall below the minimum mark on the dip rod nor should it be allowed to rise above the maximum mark.

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 a cold engine may reach 12 hours. When making accurate measurements of oil level in a road vehicle it is essential that due regard be paid to gradient and camber.

Lubrication Oil Pressure.—The pressure gauge should read not less than 35 lb./sq. in. after starting from cold and while the engine is running at 1,000 r.p.m. If this pressure is not registered, stop the engine and make careful investigation.

After starting the engine, an interval of from 10 to 15 seconds is necessary for the pipe and filter system to become filled by the lubricating pump; consequently, during this interval the gauge will not be expected to record any pressure.

Delivery Filter.—As will be seen, this unit is situated at the forward end of the engine. It is of simple yet special construction comprising a vertical cylinder in which is a special gauze element instantly detachable by removing the filter cover which is secured by a single nut. In the base of this unit is a sludge sump provided with drain pipe and plug for drawing away any foreign matter extracted by the filter element. This unit embodies a relief valve which operates and maintains lubrication in the event of filter chokage.

The whole of the lubricating oil passes through this filter before reaching the main and big end bearings and the valve gear, so that it is of the greatest importance that the filter be kept clean as described in the next paragraph.

Cleaning of Delivery Filter.—This unit **must** be thoroughly cleaned after every 3,000-6,000 miles. To this end, first remove the drain plug of the sludge sump and so drain away the contents. Next remove the filter cover, take out the gauze element and wash it thoroughly in clean paraffin or fuel oil.

After decarbonising, or otherwise disturbing the engine, an increased collection of dirt, etc., may be found on the gauze. Anticipate this by early inspection. Do not operate the engine with a damaged element; it should be fitted with a new gauze or a replacement element should be fitted.

Reassembling of Delivery Filter.—Always 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. Care should also be taken to see that the circular fibre washer is not omitted when fitting the cover nut. The correct tightening torque for the cover nut is 610 lb./in. as mentioned in Workshop Tools Book No. 55.

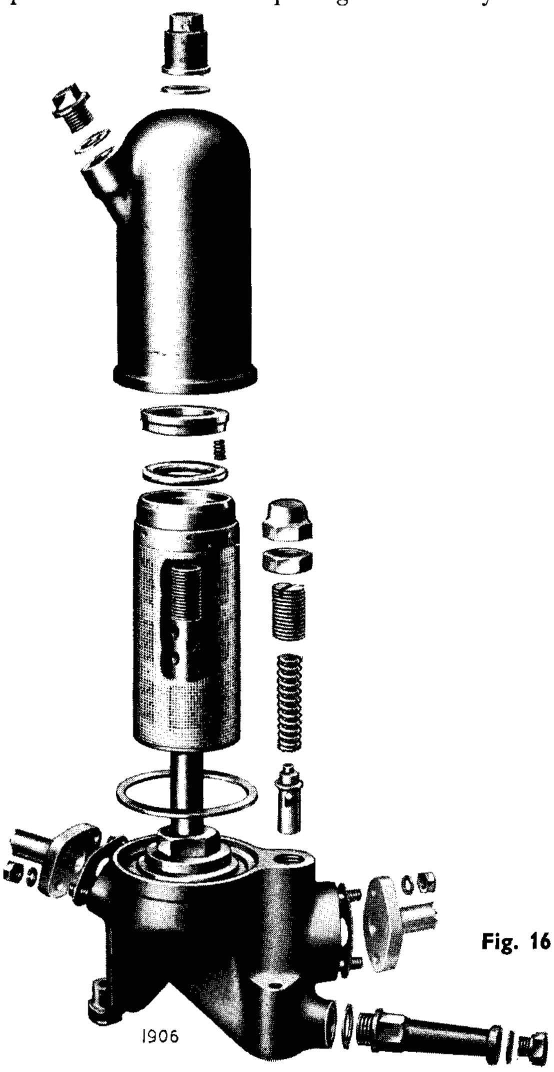

Fig. 16 LUBRICATING OIL DELIVERY FILTER & PRESSURE CIRCULATING VALVE ASSEMBLY

LUBRICATION SYSTEM—*continued.*

It is recommended that the filter be replenished with clean oil through the orifice closed by the square-headed plug at the top of the filter cover.

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 being 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, but low oil pressure must not be rectified by indiscriminate adjustment of the relief valve as this can cut off the oil supply to the fuel pump cam box, governor, tappet mechanism and main timing drive gears.

The adjusting screw is set during test to 35 lb./sq. in. at about 1,000 r.p.m. with lubricating oil at a temperature of about 130° F. At 110° F. the pressure will read approximately 37 lb./sq. in. If the regulating valve be dismantled for any reason it should be reset to give the above pressures according to the 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 stand above the hexagon lock-nut. If correctly counted, this should prove a useful aid when reassembling.

If the pressure regulating valve is correctly adjusted and, if due to wear or other causes, the pressure records approximately 30 lb./sq. in. the main bearings will receive sufficient lubricant, but all auxiliaries fed by the surplus oil pipe will receive insufficient or no lubricant.

Oil Pressure too Low—Possible Causes:—

(1) Delivery filter requires cleaning.
(2) Foreign matter under the seat of the pressure regulation valve.
(3) Fracture of the spring of the regulation valve.
(4) Sprayer pipe unions slack or pipe broken thus allowing fuel oil to reach the crankcase lubricating oil sump.
(5) The gauze filter over the sump is choked by sludge deposit.
(6) Shortage of oil in the sump.
(7) A lubricating oil 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 the delivery filter.
(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 above.
(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 3,000-6,000 miles.
(5) Remove and clean the base-chamber and also clean the delivery filter as previously described.
(6) The oil level in the sump should not be allowed to fall below the minimum mark on the dip rod as already mentioned under paragraph headed " Oil Level Indicator."

Pressure Gauge Oil Pipe.—When leading the small oil pipe from the pipe on the engine to the pressure gauge on the instrument panel it is important to secure the pipe from all vibration and consequent possible fracture. A piece of flexible connecting pipe is supplied for this purpose which insulates the solid pipe from the engine.

LUBRICATION SYSTEM—*continued.*

Base-Chamber or Sump—Renewal of Lubrication Oil.—It is recommended that the sump oil be completely drained off not less frequently than every 3,000-6,000 miles. This should be effected after a long run while the oil is warm and fluid.

The use of a " Flushing " oil or washing out the sump with paraffin is not recommended since there is always the possibility of disturbing particles which might re-enter the lubrication system.

Removal and Cleaning of Base-Chamber, Sump and Primary Filter.—It is recommended that this be effected not less frequently than every 30,000 miles.

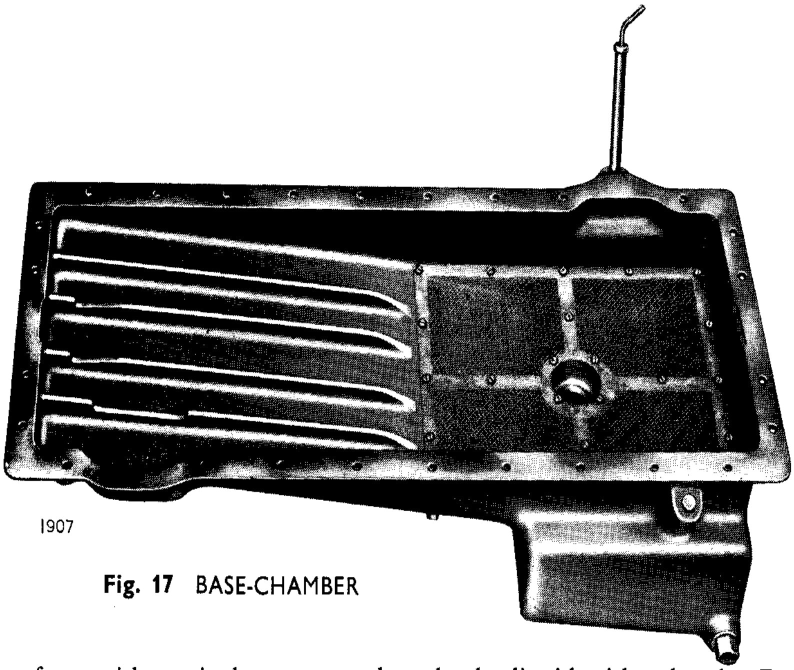

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Fig. 17 BASE-CHAMBER

Remove the primary gauze filter which is secured by a number of cheese-head screws. Wash the gauze and surfaces of the base-chamber with clean fuel oil or paraffin. Allow the washed parts to drain in preference to wiping them with a cloth which is liable to leave behind swarf, etc.

Replacement of Primary Filter.—Make sure that the securing screws are perfectly tightened. Care should also be taken to see that the suction pipe bush and spring around the connection to the lubricating oil pump are in place.

Replacement of Base-Chamber.—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.**

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.

Exhauster Lubrication.—This is effected by splash from oil which is collected via a trough in the timing case cover. Oil in the exhauster is returned through the muffle and drain pipe. No external lubrication attention is therefore required.

PISTONS AND CONNECTING RODS

Pistons.—The pistons and connecting rods can only be withdrawn by lifting the cylinder blocks. 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, duty, etc., etc. pistons will run for 70,000 to 140,000 miles with original piston rings and without dismantling, or the re-machining of the upper two grooves and the fitting of 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 be re-sized. Diametral wear mainly affects piston noise and pistons which have been re-grooved may be used for a total of 200,000 miles or more. Full details regarding the machining of the grooves for the fitting of first or second oversize width piston rings will be found in Workshop Tools Book No. 55. The foregoing 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

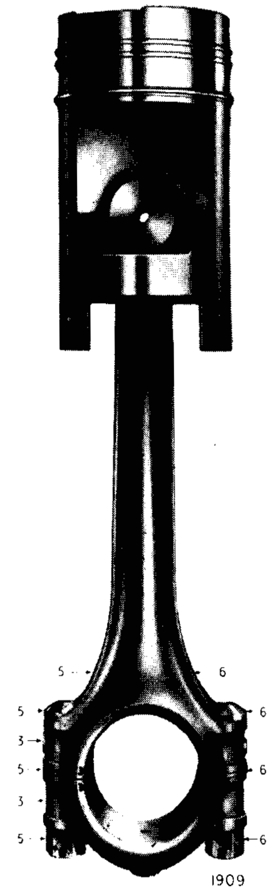
PISTONS AND CONNECTING RODS—*continued.*

conditions are known to produce unclean running do not remove pistons until cylinders require re-sleeving. When diametral cylinder bore wear exceeds ·010 in. the cylinder blocks should be re-sleeved. In many instances this figure is exceeded but power and startability may then be adversely affected.

Fitting New Piston Rings in Worn Bores.—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 fine carborundum on 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 lined bores a surface finish of 25 to 30 micro inches is desirable.

Piston Rings.—The pistons of all later engines are fitted with two pressure rings and one oil control or scraper ring. The top pressure ring is chromium plated on the sides and periphery, whilst the second pressure ring is plated on its periphery only.

Piston Pin.—The piston pin is free to move in the piston and in the connecting rod bush. The correct clearance between pin and bush is ·0015 in. and the pin should be renewed if the maximum wear exceeds this amount. Do not, however, assemble the parts with less clearance. A special tool is available for removing the piston pins from pistons where prolonged service has produced carbon which tends to fasten the pin. This tool is illustrated and described in Workshop Tools Book No. 55.



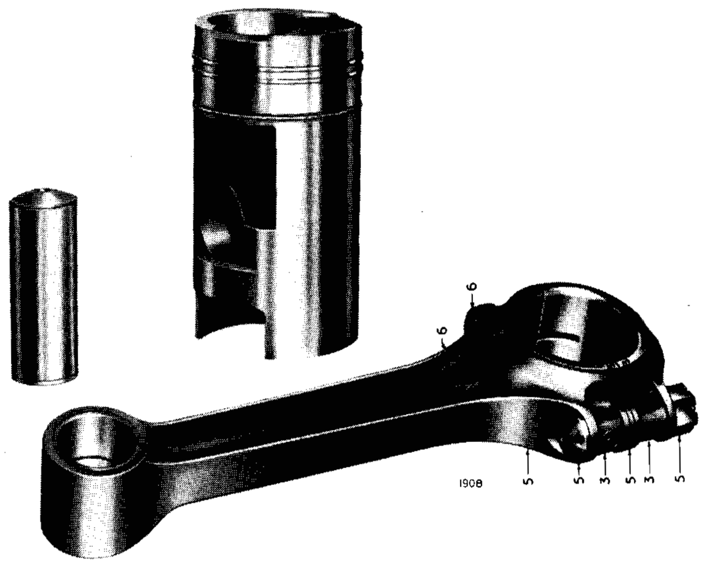


Fig. 18 CONNECTING ROD AND PISTON ASSEMBLY

Piston Entering Guide.—To facilitate entry of the pistons into the cylinder block during reassembly, a special piston entering guide is available. This is illustrated and described in Workshop Tools Book No. 55.

PISTON AND CONNECTING RODS—*continued.*

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 underneath the corresponding valves. The correct position for the piston is clearly indicated by the lettering " TAPPET SIDE " on the top of the piston.

Cylinder Head to Piston Clearance.—The Nominal, Maximum and Minimum clearances are illustrated diagramatically in Workshop Tools Book No. 55.

Connecting Rods.—The rods should be thoroughly cleaned and tested for cracks by any of the well-known methods during major overhaul. Big end bolts must be examined for stretch and renewed if necessary. Split pins for the big end bolts should be used once only; they should be the correct size for the holes and sprung to give tight fitting. Small end bushes which have ·003 in. 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 ·0025 in. to ·00175 in. Should scraping be necessary this should be confined to the upper half of the bore so that the more accurate machined surface remains untouched on the heavily loaded bottom portion. Before finally assembling the rod the oil duct through the centre should be thoroughly flushed out with paraffin or fuel oil.

After assembling a rod on its crankpin, the piston pin in the small end bush should be parallel to the crankcase top to within ·001 in. in the length of the pin.

RADIATOR FAN

Driving Belt Adjustment.—This should be inspected every 10,000 miles and one grease-cup-full of grease injected into the spindle bearing.

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 three to six. 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.

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 Spare Parts Catalogue which is Numbered 533.1 at the date of printing of this Instruction Book.

STARTING THE ENGINE

Before starting the engine it is first of all essential to check the level of the oil in the sump and to ensure that the radiator or cooling system is filled to maximum capacity as already mentioned in detail under the headings Lubricating System and Attention in Terms of Mileage. It is also necessary to carry out the following operations before it is possible to start an engine which has not previously been in service, i.e., a new engine.

To Prime the Fuel System.—First couple the Amal Pump suction union to the first fuel filter and so to the fuel supply. Before operating the hand lever on the Amal pump it will be necessary to ascertain if the engine has stopped in such position that the Amal pump driving eccentric is at maximum lift. If so, the hand lever will not operate the pump diaphragm and it will be necessary to rotate the engine about one revolution to rotate the camshaft eccentric from maximum lift position.

STARTING THE ENGINE—*continued.*

It may be necessary to fill the first filter with fuel to assist the Amal pump in its initial " pick-up." This necessity depends upon the piping layout and location of the first fuel filter.

The hand lever on the Amal pump should now be operated until the fuel injection pump with its air vessel are supplied with fuel; this will be evident by the very much reduced resistance of the Amal pump hand lever. The fuel injection pump hand priming levers should now be used until the sprayers are heard to operate. This will be indicated by vibration of the sprayer valves and is easily audible at each stroke of the fuel injection pump hand levers. Do not continue to operate the injection pump hand levers when fuel is known to have reached the sprayers by this test.

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.

Sprayer Pipe Connections.—After the preceding priming operations have been completed, 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 lubricating oil. This applies equally to the unions on the drain pipes of the sprayer. 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.

Decompression Gear.—An essential feature of the 4LK engine is that starting can be effected by a hand cranking handle when the engine is equipped with a flywheel which is suitable for this purpose. The decompression gear is also used to facilitate turning the engine when it is necessary to check the timing of the valves or fuel injection, etc. The decompression lever on the cylinder head operates a small shaft; certain parts of the shaft adjacent to the inlet valves being machined to form a slight cam, and, when the lever is turned vertically upwards, the compression is entirely relieved by the cams lifting the inlet valves from their seats. When the lever is in the vertical position the inlet valves are therefore prevented from closing during the period that the engine is being turned by means of the hand cranking handle. The lever is set in this position only when starting by hand and **it is not** to be set in the upward position when starting the engine by the electric starter motor.
When the engine is running or when it is being started by the electric starter motor, the lever must always be in the horizontal position and both positions of the lever will be clearly noted from the illustration Figure 19. To recapitulate, there are only two positions of the decompression lever, thus:—

> **Position No. 1** (Vertical).—Decompression for easy turning. In this position the inlet valves cannot close and there is no compression.
>
> **Position No. 2** (Horizontal).—Running position. The lever must be in this position at all times when the engine is running.

Starting Fuel-Plunger.—A vertical spring-loaded plunger will be found below the aluminium box on the forward end of the injection pump—see Figure 4. On being pressed up as far as it will go, the plunger allows the fuel pump slider bar to move further towards the flywheel and in which position the pumps deliver an increased charge of fuel for starting from cold. If the slider bar be sluggish to move when the plunger is pressed up, help it by lightly pressing on the governor lever. The plunger must not, however, be held up by hand since it goes out of action automatically as soon as the engine begins to work and the slider bar automatically retakes its normal working position in which the pumps cannot give an excessive charge of fuel.

The plunger must only be used when starting from cold and on no account must this device be used for any other purpose than starting, e.g., it must not be used in order to give the engine extra fuel while running since if the plunger be held or propped up while the engine is working serious trouble may occur.

Speed Control.—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.

STARTING THE ENGINE—*continued.*

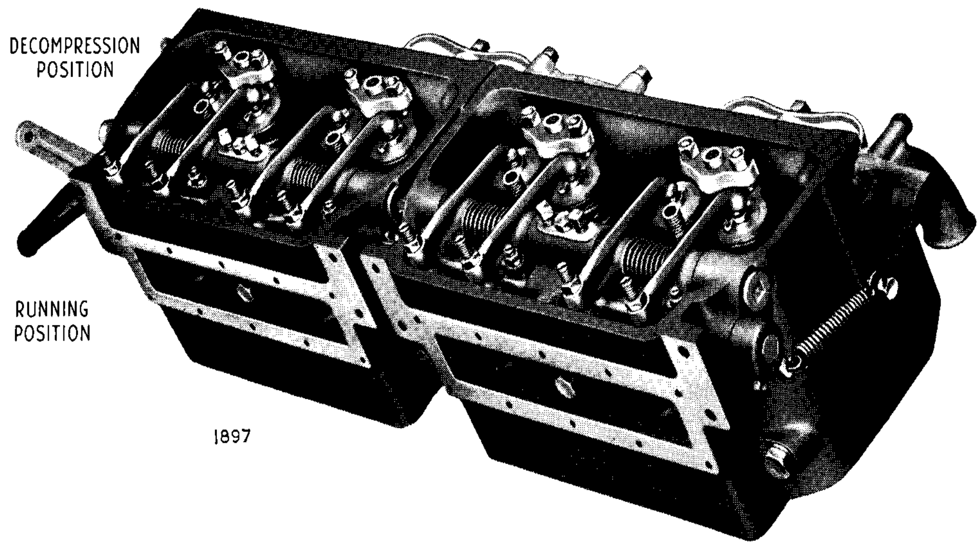


Fig. 19 CYLINDER HEADS SHOWING DECOMPRESSION LEVER POSITIONS
Position No. 1 (Decompression) Position No. 2 (Running)

Idling Speed.—On the end face of the governor case a flanged sleeve nut with locknut will be found. The flange of the sleeve nut controls the endwise position of the governor main spring guide and thus controls the idling speed of the engine. To adjust the idle speed, slack off the locknut and screw the sleeve nut **towards** the governor case to increase the r.p.m. and **away** from the governor case to reduce the idle speed. When the desired speed has been attained, tighten the locknut. If set to run at too low r.p.m., the engine idle speed will fluctuate and the fuel pump slider bar will keep floating backwards and forwards; e.g. hunting. The normal idling speed as set at the works is 450 r.p.m.

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.
(4) Set the decompression lever in position No. 1 (Decompression). Fig. 7.
(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. 7. 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.

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. 7.
(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.

STARTING THE ENGINE—*continued.*

(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.
(8) Set the decompression lever in position No. 1 (Decompression). Fig. 7.
(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. 7. 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.

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 (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 paragraph at top of this page in order to " free " the engine.

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 on page 19; 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.

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.

Electric Starter Button.—Do not keep this depressed for long periods if the engine fails to start readily. The button should also not be depressed when the engine is running otherwise damage will be caused to the starter pinion and to the gear ring on the flywheel.

After Starting.—See that the water circulating pump and the lubricating pump are operative and that the pressure gauge of the latter registers not less than 35 lb./sq. in. at about 1,000 r.p.m. If not, shut down at once and investigate. After starting, the engine is at once able and ready to take up full load, but a careful engineer will recognise that in all heat engines it is better practice to apply the load as gradually as circumstances will permit, especially after starting from cold, in order that the internal parts may become heated gradually. It is also advisable to follow this practice in order to permit the lubrication system to assume complete circulation.

Idling Running.—It is not good practice to run an engine idle for long periods.

STOPPING THE ENGINE

To Stop.—Turn the stopping lever to such a position that it moves the fuel pump slider bar towards the radiator as far as it will go. In this position the fuel injection pumps immediately cease to deliver fuel.

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

TIMING OF VALVES

Timing of Valves.—When reassembling 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 is not in accordance with the timing marks on the flywheel and the timing gears, the valves will foul the pistons and **serious consequences will result.** For this reason, it is desirable 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 whilst 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; see Figure 20.

Timing of 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 and a dot will also be observed on top of the crankcase flanged endplate 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 34·8° " registers with the zero line on the compression stroke, the timing lines on the fuel injection pump should coincide as described under paragraph headed " Timing of Fuel Injection."

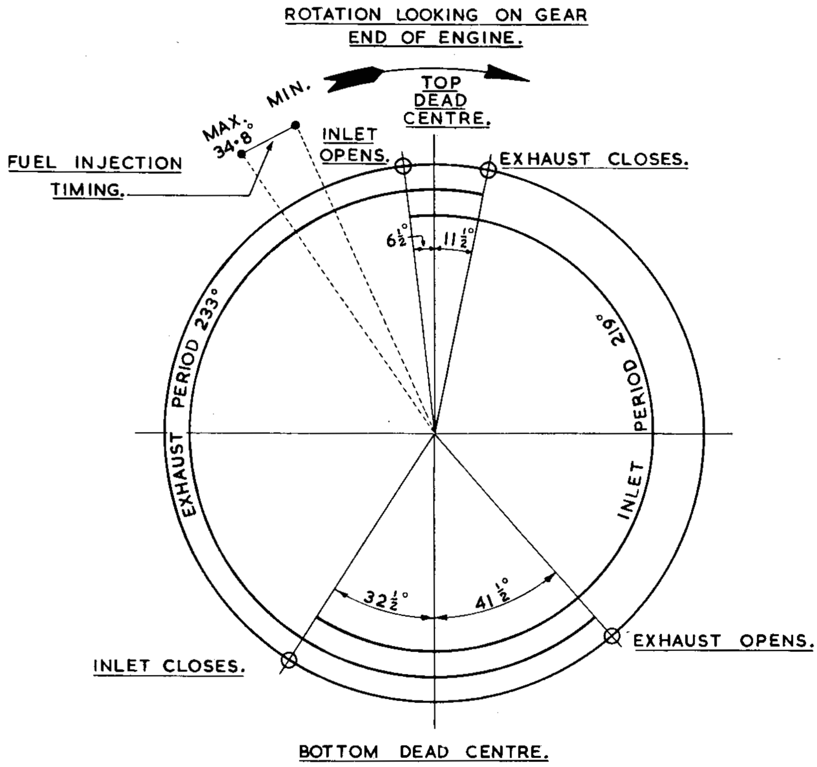


Fig. 20

VALVE OPENING & CLOSING DIAGRAM WITH ·018" CLEARANCE AT VALVE, ENGINE COLD. FOR TIMING PURPOSES ONLY

TIMING OF VALVES—*continued.*

The line marks the position of maximum advance and the number denotes the number of degrees before T.D.C. 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 the position of maximum advance.

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

Valve and Injection Timing Indicator.—Where chassis considerations make it difficult or impossible to gain access to the timing marks on the flywheel, a special tool is available for the purpose of obtaining the correct timing position of the crankshaft. This tool can be supplied at a small extra charge and it is illustrated and described in Workshop Tools Book No. 55.

Timing of Fuel Injection.—Each fuel pump is provided with a sight hole or window through which can be seen the plunger moving up and down when the crankshaft is rotated. On the sides of the window is a horizontal line and also one on the plunger. When these two lines coincide, the corresponding injection line on the flywheel should register with the zero line as described above. When so checking the timing, be careful not to be misled by turning the flywheel in the wrong direction. On the fuel pump tappet are locked screws which should never be disturbed. See page 36 for the correct adjustment of these tappets in the event of them having been inadvertently disturbed.

Fuel Pump Driving Shaft.—This shaft is coupled to the Fuel Pump Camshaft by flanged couplings, the camshaft coupling boss being provided with flats to take a spanner. The holes in the camshaft coupling flange are also slightly elongated so that when the four coupling bolts are slackened, the timing of fuel injection can be adjusted independently of the Valve and Valve camshaft timings. When the timing of valves and fuel injection is set at the works, a line is cut on the flanges of the Fuel Pump Driving Shaft and Camshaft and also marked by two centre punches to indicate the correct timing of fuel injection.

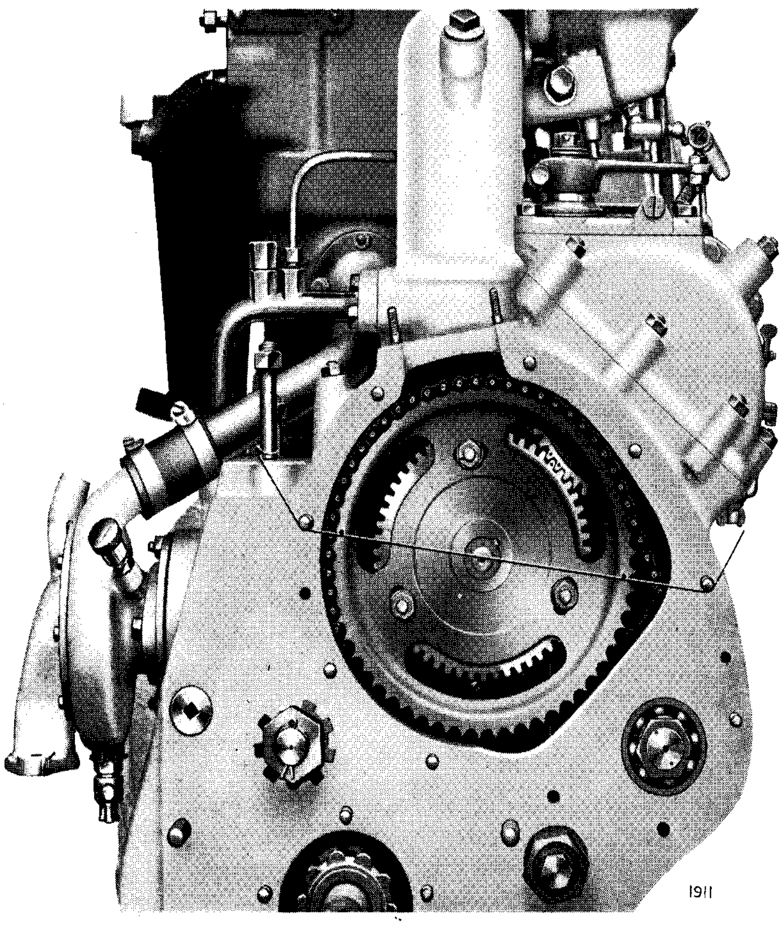


Fig. 21 VALVE CAMSHAFT CHAIN WHEEL AND FUEL INJECTION PUMP GEARS

Timing of Camshaft, Marking of Valves and Injection Pump.—The Valve Camshaft Chain Wheel and the Fuel Pump Camshaft Driving Gear with Gear Adapter are bolted together, face to face, by three studs. The stud holes in the Valve Camshaft Chain Wheel are slightly elongated to permit a certain small amount of rotation relative to the Fuel Pump Camshaft Driving Gear for the purpose of accurate timing. When the timing is correct, the relative position of the Valve Camshaft Chain Wheel and the Fuel Pump Camshaft Driving Gear with Gear Adapter is marked by a straight line and four dots; i.e., two dots on the Chain Wheel and two dots on the

TIMING OF VALVES—*continued.*

Gear Adapter. When the cover of the chain case is removed, and the flywheel is set with No. 1 crank at T.D.C. after the compression stroke as directed on page 58, if all be correctly timed, the following events will take place. See Fig. 21.

(1) The dots 1 and 2 on the crankcase and the dots 3 and 4 on the periphery of the Valve Camshaft Chain Wheel will all lie on a straight line as indicated by the stretched cord in Fig. 21.

(2) Through the opening in the Valve Camshaft Chain Wheel will also 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) It will also be seen that the four dots on the Camshaft Chain Wheel and Gear Adapter all lie on the straight line which is marked on these parts by means of a light chisel cut. Should the Chain Wheel and Gear Adapter be incorrectly bolted together, this defect will, of course, be immediately visible.

(4) The line cut on the flanges of the Fuel Pump Driving Shaft and Camshaft, as mentioned above, will also show correct registration.

(5) One spline on the hub of the Fuel Pump Driven Gear is also marked and this will correspond with the particular spline marked in a similar manner on the end of the Fuel Pump Driving Shaft.

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

WORKSHOP TOOLS, INSTRUCTIONAL DRAWINGS AND SPECIAL EQUIPMENT

Book No. 55, which is mentioned from time to time in this Instruction Manual, is an illustrated list of special tools to facilitate major servicing of the 4LK engine; it contains instructional drawings and brief operational instructions, etc., and is available at a small charge upon application to the works.

VALVES—TAPPET CLEARANCE

Tappet Clearance.—After every 20,000 miles adjust, if necessary, the clearance between the end of the valve and the toe of the valve lever. The correct clearances are given in the table which follows and, when tightening the locknuts, 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 that the pump tappet is in the lifted position.

It is essential that for satisfactory operation of the engine the correct tappet clearance shall be provided. The correct clearance for the following combinations of Cylinder Block and Cylinder Head material is as follows and it is desirable to ensure that the appropriate clearance is stamped on the valve covers. If the existing stamping is incorrect for the combination in use, erase and re-stamp according to the following table.

	Inlet	Exhaust
Cast Iron Head and Cast Iron Cylinder Blocks	·008 in.	·012 in.
Cast Iron Head and Aluminium Cylinder Blocks	·003 in.	·006 in.

VALVE CAMSHAFT

Valve Cams, Camshaft and Tappets.—When assembling these components 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 a less rise than the inlet cam, but is of longer period. Ensure that the binding screws are thoroughly tightened home. A special square box key is supplied with the engine for this purpose. See relative pages in Workshop Tools Book No. 55.

GARDNER
4LK
TYPE

VALVE CAMSHAFT—*continued.*

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.

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. Bushes are a light drive fit in the crankcase and are located by means of cheese head screws.

VACUUM TANK

With certain vacuum fuel feed systems it is possible, if the system becomes deranged, for liquid fuel to be drawn into the vacuum tank and into the engine crankcase. Check for this contingency by inspecting the vacuum tank drain plug occasionally for any collection.

TIMING CHAIN

Timing Chain Adjustment.—After the first 10,000 miles and every 30,000 miles inspect and adjust if necessary by means of the manual chain adjuster shown in Fig. 2. The chain is correctly adjusted when it is possible to move the middle of the nearly vertical run through approximately a distance of $\frac{1}{4}$ in. on either side of the main position. Do not run the 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 the chain tension be relieved.

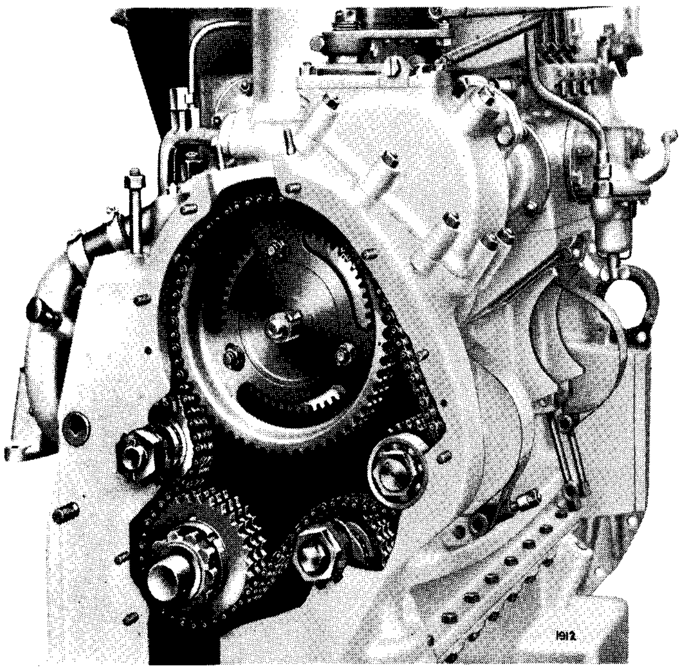


Fig. 22 TIMING CHAIN ARRANGEMENT

Correction for Stretch or Wear of Timing Chain.—In the course of time the chain wears and, consequently, increases in length which causes the timing of the valves and fuel injection to become slightly retarded, therefore make correction every 30,000 miles by the following procedure:—

Inspect the fuel injection timing as indicated on page 59. If it be retarded, slacken the three hexagon nuts securing the Valve Camshaft Chain Wheel to the Fuel Pump Camshaft Driving Gear with Gear Adaptor. See Fig. 21. Rotate valve camshaft (which also rotates fuel camshaft) until lines on the fuel pump window coincide, then re-tighten the three nuts.

Later engines are equipped with a lever type adjuster. To tighten chain this lever must be moved in a clockwise direction; this automatically corrects any error in timing.

Wear of a chain is accelerated by lack of adjustment and undue slackness may promote noise and unsteady governing.

With reasonable maintenance a chain should not require renewal until the engine is completely overhauled but if, as in older engines, the chain is joined by means of the detachable type link and spring clip this link assembly should be renewed once during the life of a chain.

Further details in respect of the permissible chain stretch will be found in Workshop Tools Book No. 55.

TIMING CHAIN—*continued.*

Riveted Joint Link.—On engines subsequent to serial number 112100 this type of link superseded the spring clip type. The riveted type does not require replacement until the timing chain is renewed. This link may be recognised by the small indent in the two studs.

To remove the chain it is preferable to part this link; for this purpose the sump and splash door must be removed and the engine rotated until this riveted link lies on the crankshaft sprocket in which position the two studs can be driven through the link plate using a pin punch and hammer. Do not attempt this operation with the link located on the camshaft chain wheel.

Special workshop tools are available for pressing on the outer plate and for indenting the studs when re-assembling. See Workshop Tools Book No. 55. These tools greatly facilitate assembly but the work can 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.

Timing Chain Sprockets.—These will only require renewal if the teeth have become " hooked " to such an extent that they are liable to interfere with the smooth driving of the chain. If any new sprockets are fitted care must be taken to ensure that they are in perfect alignment one with the other. This may necessitate the fitting of shims or removal of metal at the rear side of the camshaft sprocket.

If a new chain will not wrap smoothly around a worn sprocket, i.e., if slight impact can be felt at the engagement of each tooth, a replacement is indicated.

WATER CIRCULATION SYSTEM

Description.—Water circulation is effected by a centrifugal pump of special design, with self-adjusting gland which is readily accessible. The pump is positively driven by the camshaft at crankshaft speed. Temperature is controlled by thermostat.

Thermostat Control.—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.). 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 should be maintained at a higher figure. See also our recommendations as regards lubricating oil on pages 47 to 49.

It is not normally necessary to fit shutters or blanking plates to the radiator, since the thermostatically controlled valve, 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. A suitable tapped boss is provided in the thermostat housing or water outlet pipe to receive the bulb of the usual automotive type thermometer.

For various duties and climatic conditions the approximate thermostatic valve opening temperatures and respective thermostat unit code numbers are as below:—

153° F. .... X 43517/20.

For passenger carrying road vehicles, locomotives, cranes and short haul road vehicles under temperate climatic conditions.

137° F. .... X 43517/21.

For passenger carrying road vehicles, locomotives, cranes, short haul road vehicles under sub-tropical and tropical conditions. For goods carrying vehicles, earth moving machinery, welding compressor sets, stationary units, marine propulsion and marine auxiliary units under all climatic conditions.

126° F .... X 43517/22.

For rail cars under all climatic conditions.

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WATER CIRCULATION SYSTEM—*continued.*

Thermostat Air Release Hole.—Owing to the construction of the Automatic Temperature Control Valve, it is necessary to inspect the water level a few minutes after filling the water system. This precaution is necessary since there is of necessity only a small air release hole in the thermostatic valve. The diameter of this hole is ·052 in. If due regard is paid to the water level when filling the system, the air release hole may with advantage be reduced to ·040 in. diameter in order to more readily attain optimum temperature in low duty engine applications.

Water Circulation.—Inspection should be made regularly in order to ascertain if circulation be taking place, especially if there has been any possibility of damage to the impeller due to frost.
It must be remembered that circulation does not take place until the temperature rises sufficiently to open the thermostat valve to the radiator. Above 160° F. or 71° C. it should always be possible to observe this circulation. The operation of the thermostat unit can be readily observed by removing it from its case and raising its temperature when immersed in water. In the event of the thermostat bellows becoming damaged the valve should assume a full open position, so that dangerously high temperatures should not occur through this cause.

Extractor for Thermostat Unit.—A special extractor is available for removing the thermostat unit from its aluminium housing and full details in this respect will be found in Workshop Tools Book No. 55.

Water Pump Gland and Greaser.—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 of slight malalignment between the pump and its driving member. The only attention which the pump requires is the lubrication of the ball bearing. This should be carried out by injecting not more than one grease-cup-full of grease per 30,000 miles. **Do not fit grease gun nipple in order to use a grease gun. Grease is detrimental to the carbon gland.**

Water Pump Service.—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. clear of the internal face of the pump body it should be renewed, at the same time any score marks in the matting face of the impeller spindle should be removed by skimming in a lathe.

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. Care must also be taken to ensure that the face of the carbon and impeller spindle are completely free of all grease or oil when finally assembled.

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 parts should be washed in petrol before assembling.

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. 55 which contains drawings and instructions for 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.

ATER CIRCULATION SYSTEM—*continued.*

.nen reassembling the pump care must be taken to refit the synthetic rubber washer on the impeller spindle; his washer is located in the water and grease drain slot.

/ater Pipes and Hoses.—These should all be examined and cleaned where necessary in their bores. The hose connections will have to be renewed where the bore has closed in—do not attempt to restore their bore by cutting he rubber.

erating Under Conditions of Extreme Cold

sed Circuit Fresh Water Cooling Systems.—Under these conditions 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 since, even whilst the engine is running, radiators and water pipes can become frozen.

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-freeze formulation with another.

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 minimised 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 radiator tubes to approach freezing point, drain away the water from the cooling system as soon as possible after stopping the engine and leave all cocks open until the system is to be refilled. Hang a suitable label on the radiator or take other precaution 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.

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 dispensors, 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.*

A number of approved corrosion inhibitors are available and the Works will be pleased to further advise in this matter. One example is "Aqua-Clear", the Sole U.K. Concessionaires for which are Messrs. Kinnis and Brown Ltd., 54/62 New Broad Street, London, E.C.2.

Draining of Cooling System and Effect of Frozen Water Pump.—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.

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. The standard Gardner packing can, however, be used in any position without fear of blanking up this hole. If the engine installation is such that the engine is inclined rearwards, the cylinders should also be drained by means of the cock fitted at the base of No. 4 cylinder; i.e., the cylinder nearest to the flywheel end of the engine. 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 suitable implement, into the hole provided for this purpose in the centre of the square. A piece of wire or a wood screw may also be used for this purpose.

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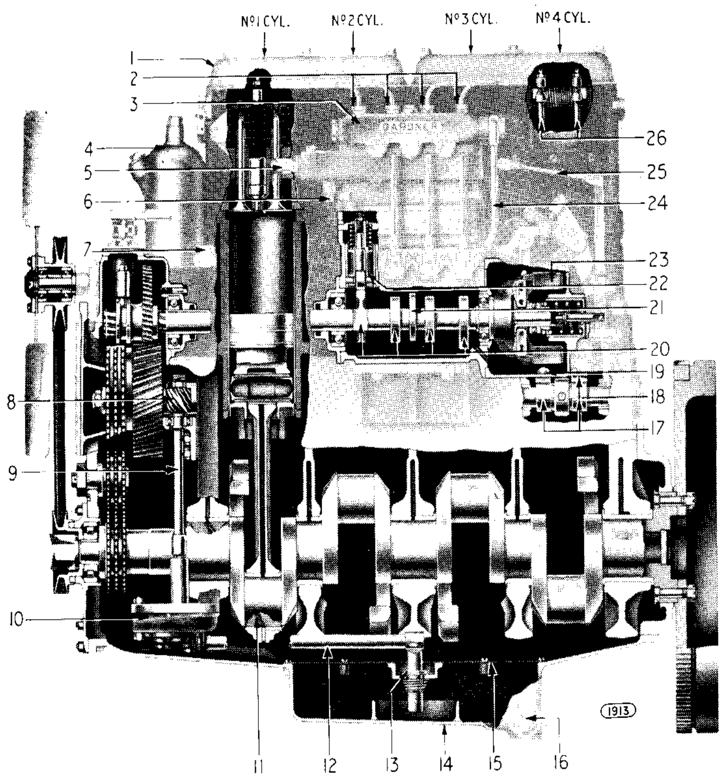

Fig. 23

1. Valve and Cylinder Head Cover
2. Sprayer Pipe Union
3. Fuel Suction Air Chamber
4. Lubricating Oil Delivery Filter
5. Governor Control Bar Buffer
6. Starting Fuel Plunger
7. Oil Pressure Regulating Valve
8. Oil Pump Driving Gear
9. Oil Pump Driving Shaft
10. Oil Pump
11. Oil Feed Tube to Crankpin
12. Oil Pump Suction Pipe
13. Oil Pump Suction Pipe Bush
14. Oil Sump
15. Primary Filter
16. Oil Sump Drain Plug
17. Valve Cam
18. Valve Tappet
19. Oil Return Passage
20. Fuel Cam
21. Fuel Lift Pump Eccentric
22. Fuel Pump Tappet
23. Governor Weights
24. Fuel Pump Inlet Pipe
25. Connecting Link—Governor to Slider Bar
26. Valve Lever Push Rod

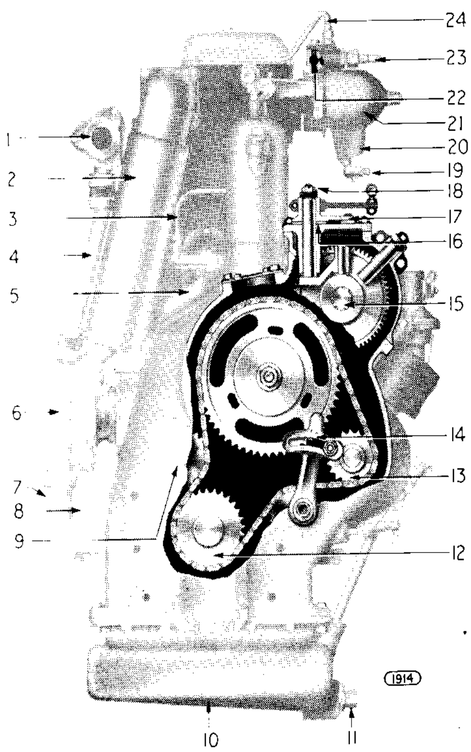

Fig. 24

1. Water Outlet
2. Air Intake Pipe
3. Valve Gear Oil Feed Pipe
4. Temperature Control By-pass Pipe
5. Cylinder Water Door
6. Water Circulating Pump
7. Water Pump Inlet
8. Water System Drain Cock
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. Friction Washer
17. Injection Timing Pointer
18. Friction Device Nut
19. Filter Sump Drain
20. Filter Sump
21. Second Fuel Filter
22. Fuel Inlet to Filter
23. Fuel Overflow Return to Tank
24. Sprayer Leak Pipe

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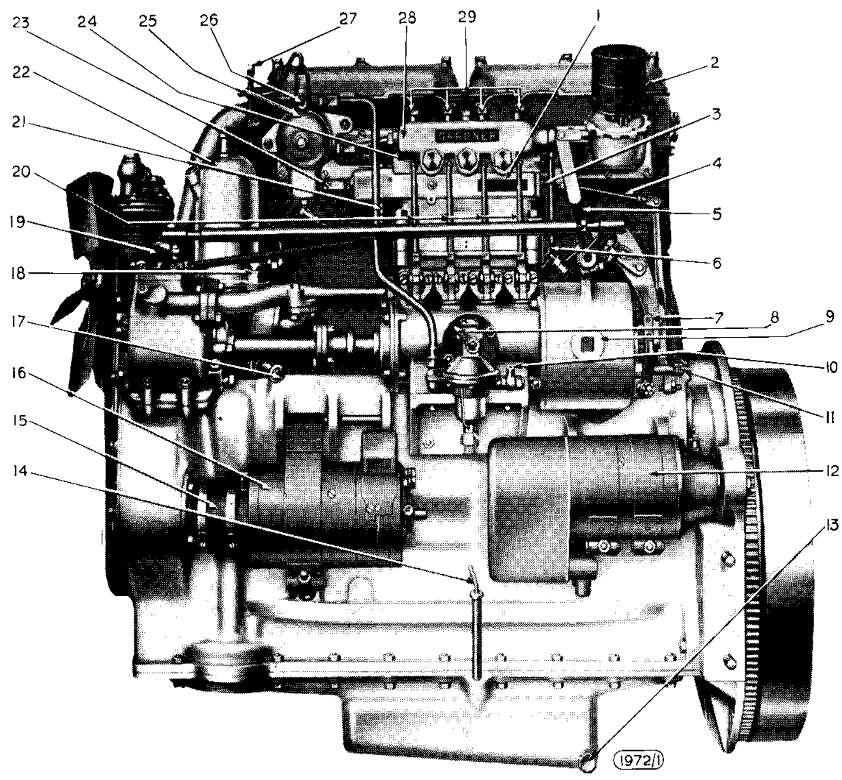

Fig. 25

Near Side Elevation

1 Engine Data Plate
2 Oil Filler and Crankcase Breather
3 Fuel Pump Slider Bar
4 Governor Lever and Connecting Link
5 Accelerator Control
6 Accelerator Idler Stop
7 Stopping Lever
8 Fuel Lift Pump Hand Priming Lever
9 Governor Casing Inspection Opening
10 Fuel Inlet
11 Idling Speed Adjusting Sleeve and Nut
12 Electric Starter
13 Lubricating Oil Sump Drain Plug
14 Oil Level Dip Rod
15 Dynamo Flexible Drive Coupling
16 Dynamo
17 Lubricating Oil Filter Drain Plug
18 Pressure Regulation Valve for Lubrication System
19 Fuel Injection Timing Lever
20 Hand Priming Levers
21 Cold Starting Fuel Plunger
22 Lubricating Oil Delivery Filter
23 Fuel Pump Slider Bar Buffer
24 Fuel Injection Pump
25 Second Fuel Filter
26 Fuel Overflow Return Outlet
27 Decompression Lever
28 Fuel Suction Air Chamber
29 Sprayer Pipe Unions

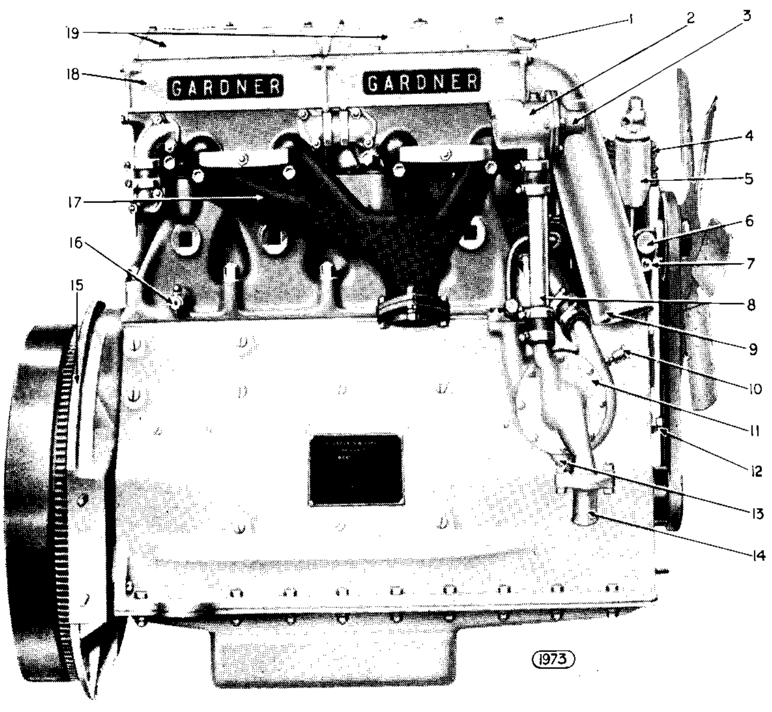

Fig. 26

Off Side Elevation

1 Sprayer Leak Pipe
2 Automatic Temperature Control (Thermostat)
3 Water Outlet
4 Exhauster for Vacuum Servo Brakes
5 Combined Oil Separator and Breather
6 Fan Bearing Greaser
7 Fan Belt Adjustment Cotter
8 Temperature Control By-Pass Pipe
9 Air Inlet Pipe
10 Water Circulating Pump Greaser
11 Water Circulating Pump
12 Timing Chain Idler (Fixed)
13 Water Pump Drain Cock
14 Water Inlet
15 Crankcase End Plate
16 Water Drain Cock
17 Exhaust Manifold
18 Air Inlet Passage Cover
19 Valve & Cylinder Head Cover